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# Measurement of innovation:

# the use and misuse of indicators and scoreboards

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# Measurement of innovation: the use and misuse of indicators and scoreboards

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Abstract

The choice of indicators to measure innovation processes and assess performance is of vital significance. This paper argues that those economic theories give a more accurate, more reliable account of innovation activities that follow a broad approach of innovation, that is, consider all knowledge-intensive activities leading to new products (goods or services), processes, business models, as well as new organisational and managerial solutions, and thus take into account various types, forms and sources of knowledge exploited for innovation by all sorts of actors in all economic sectors. In contrast, the narrow approach to innovation focuses on the so-called high-tech goods and sectors. The broad approach is needed to collect data and other types of information, on which sound theories can be built and reliable and comprehensive analyses of innovation activities can be offered to decision-makers to underpin public policies and company strategies.

Keywords: Schools of economics; Mainstream economics; Evolutionary economics of innovation; Measurement of innovation; Composite indicators; Scoreboards, league tables

JEL codes: B52, C80, O31, O38, Y10

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# Az üzleti innovációk mérése: a rangsorok haszna és csapdája

Attila Havas


## Összefoglaló

Az üzleti innovációk a gazdasági teljesítmény javításában meghatározó szerepet játszanak. Ezért a folyamatok jobb megértéséhez, azaz a gazdaságot magyarázó elméletek fejlesztéséhez, a vállalati versenyképességi és innovációs stratégiák, valamint a szakpolitikai intézkedések megalapozásához is szükséges az innovációs folyamatok megbízható mérése. Az Európai Innovációs Eredménytábla (European Innovation Scoreboard, EIS) összeállításához használt mérőszámok többsége a K+F alapú innovációs folyamatokat méri. A gyakorlati tudásra támaszkodó innovációk legalább ilyen fontosak a vállalatok számára, ezért az EIS csak részleges képet ad az innovációs teljesítményről. A Globális Innovációs Index kiszámításához használt mutatószámokat is hasonlóan választották ki, ezért ugyanaz a fő hiányossága. Az innovációs folyamatok megbízhatóbb, teljesebb képet adó méréséhez tehát új mutatószámok kidolgozására lenne szükség. Ez komoly módszertani és elméleti tudást, valamint széles körű nemzetközi együttműködést igénylő feladat. A számított (kompozit) mutatók (pl. a Summary Innovation Index és a Globális Innovációs Index) csak korlátozottan alkalmasak az egymástól jelentősen eltérő innovációs rendszerek teljesítményének elemzésére: egy ilyen mutató alacsony szintje nem elégséges annak megállapítására, hogy az innováció melyik alrendszerben és milyen típusú szakpolitikai intézkedés szükséges. A számított mutatók alapján összeállított rangsorok alkalmasak lehetnek a döntéshozók „riasztására", de hiba lenne pusztán ezek alapján szakpolitikai eszközökkel beavatkozni. Az elégtelen teljesítmény okait és a kilábalás lehetőségeit csak alapos nemzetközi összehasonlító elemzésekkel lehet feltárni.



Tárgyszavak: közgazdasági iskolák; klasszikus, neoklasszikus és főáramlatú közgazdaságtan; az innováció evolúciós közgazdaságtana; az üzleti innovációk mérése; számított (kompozit) mutatók; innovációs eredménytáblák és rangsorok

JEL: B52, C80, O31, O38, Y10

## Köszönetnyilvánítás

A tanulmány az "Innovation and Economic Performance in Central European Countries: Theoretical underpinnings of innovation policies, policy practices, and impacts" c. kutatási projekt keretében készült. A kutatást az NKFIH támogatta (NKFIH Alap, Az innováció lendülete, szerződésszám: K 124858).

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## 1 INTRODUCTION

In an ideal world, data are collected to characterise the state of a given system at a certain point in time, analyse its dynamics and assess its performance over time. By the same token, policies aimed at influencing a given system, can only be evaluated by drawing on appropriate indicators. Evaluation, in turn, assists policy learning and help designing more effective policies. Data collection for both empirical and policy analyses (conducted either for academic or practical purposes) need to be theoretically guided, based on meaningful definitions and a thorough understanding of relevant phenomena. From time to time, however, empirical observations necessitate the reconsideration of various building blocks of theories and point to new policy challenges or opportunities. Some of these new policy needs also raise theoretical questions. In sum, measurement, theory building and policy-making are closely interrelated, and thus social scientists need to consider all these elements in their interactions practically on all fields. Research, technological development and innovation (RTDI) activities and science, technology and innovation (STI) policies are no exception. This paper, therefore, assesses the relevance of two sets of widely used innovation indicators, that is, those that are used for compiling the Innovation Union Scoreboard and the Global Innovation Index. The main question is as follows: to what extent are these relevant from the point of view of assessing innovation performance, advancing theory development, and assisting policy formation?

Significant progress has been achieved in measuring RTDI activities since the 1960s (Gault (ed.), 2013; Gault, 2016; Grupp, 1998; Grupp and Schubert, 2010; Smith, 2005) with the intention to provide comparable data sets as a solid basis for assessing RTDI performance and thereby guiding policy-makers in devising appropriate policies.[1] Although there have been widely used guidelines to collect data on R&D and innovation for decades – that is, the Frascati and Oslo Manuals (their most recent editions are OECD, 2015 and OECD/ Eurostat, 2018, respectively) –, it is not straightforward to find the most appropriate way to assess R&D and innovation performance. To start with, R&D is such a complex, multifaceted process that it cannot be sufficiently characterised by just two or three indicators, and that applies to innovation *a fortiori*. Hence, there is always a need to select a certain set of indicators to depict innovation activities, and especially to analyse and assess innovation performance. The choice of indicators is, therefore, an important decision reflecting the mindset of those decision-makers who have chosen them. These figures are 'subjective' in that respect, but as they are expressed in numbers, most people perceive indicators as being 'objective' by definition.

For this reason – besides several others – it is important to review how business innovation – henceforth innovation – is understood in particular models of innovations and how it is analysed by various schools of economics. (Sections 2 and 3) Based on this, two major measurement endeavours, namely the European Innovation Scoreboard and the Global Innovation Index are assessed in detail. (Sections 4 and 5) The paper argues that these indicators mainly capture the so-called S&T mode of innovation activities – that is, those based on R&D results – and thus eclipse innovations based on learning by doing, using and interacting (called DUI mode of innovation by Jensen *et al.*, 2007). In other words, these indicators are mainly relevant for underpinning STI policies aimed at fostering the S&T (science

[1] "The Innovation Union Scoreboard 2013 gives a comparative assessment of the innovation performance of the EU27 Member States and the relative strengths and weaknesses of their research and innovation systems." (EC, 2013a: 4)

and technology) mode of innovation at the expense of the DUI mode of innovation. Further, they are in line with the market failure rationale for STI policies, but far less relevant for the systems approach to innovation and the concomitant systemic failures policy rationale. Theoretical and policy implications are summarised in Section 6.

## 2 LINEAR, NETWORKED AND INTERACTIVE LEARNING MODELS OF INNOVATION

Besides Schumpeter, only a few economists had perceived innovation as a relevant research theme in the first half of the 20th century.[2] At that time, however, natural scientists, managers of firms' R&D labs, and policy advisors had formulated the first models of innovations – stressing the importance of scientific research –, and these ideas are still highly influential.[3] Since the late 1950s, more and more economists have shown interest in studying innovation, leading to new models of innovation, as well as an explicit mention of innovation in various economics paradigms. The role of innovation in economic development, however, is analysed by various schools of economics in diametrically different ways.[4] The underlying assumptions and key notions of these paradigms lead to diverse policy implications.

### 2.1 Linear models of innovation

The first models of innovation had been devised by natural scientists and practitioners before economists showed a serious interest in these issues.[5] The idea that basic research is the main source of innovation had already been proposed at the beginning of the 20th century, gradually leading to what is known today as the science-push model of innovation, forcefully advocated by Bush (1945).

> It is worth recalling some of the main building blocks of Bush's reasoning:
>
> "We will not get ahead in international trade unless we offer new and more attractive and cheaper products. Where will these new products come from? How will we find ways to make better products at lower cost? The answer is clear. There must be a stream of new scientific knowledge to turn the wheels of private and public enterprise. There must be plenty of men and women trained in science and technology for upon them depend both the creation of new knowledge and its application to practical purposes. (…)

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[2] Classical economists, in contrast, had pursued dynamic analyses, that is, been interested in technological, organisational, and institutional changes, as well as in the opening up of new markets. (see section 3.1)

[3] For further details, see, e.g., Fagerberg *et al.* (2011: 898) and Godin (2008: 64–66).

[4] The ensuing overview can only be brief, and thus somewhat simplified. More detailed and nuanced accounts, major achievements and synthesising pieces of work include Baumol (2002); Baumol *et al.* (2007); Castellacci (2008a); Dodgson and Rothwell (eds) (1994); Dodgson *et al.* (eds) (2014); Dosi (1988a), (1988b); Dosi *et al.* (eds) (1988); Edquist (ed.) (1997); Ergas (1986), (1987); Fagerberg *et al.* (eds) (2005); Fagerberg *et al.* (2012); Freeman (1994); Freeman and Soete (1997); Grupp (1998); Hall and Rosenberg (eds) (2010); Klevorick *et al.* (1995); Laestadious *et al.* (2005); Lazonick (2013); Lundvall (ed.) (1992); Lundvall and Borrás (1999); Martin (2012); Metcalfe (1998); Mowery and Nelson (1999); Nelson (ed.) (1993); Nelson (1995); OECD (1992), (1998); Pavitt (1999); Smith (2000); and von Tunzelman (1995).

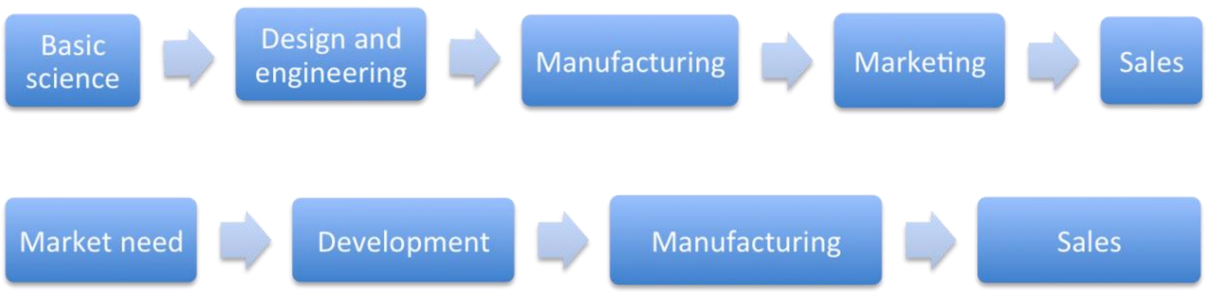
[5] This brief account can only list the most influential models. Balconi *et al.* (2010); Caraça *et al.* (2009); Dodgson and Rothwell (1994); and Godin (2006) offer detailed discussions on their emergence, properties and use for analytical and policy-making purposes.

> New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science.
>
> Today, it is truer than ever that basic research is the pacemaker of technological progress. In the nineteenth century, Yankee mechanical ingenuity, building largely upon the basic discoveries of European scientists, could greatly advance the technical arts. Now the situation is different.
>
> A nation which depends upon others for its new basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade, regardless of its mechanical skill." (Bush, 1945: chapter 3)

By the second half of the 1960s the so-called market-pull model contested that reasoning, portraying demand as *the* driving force of innovation. Then a long-lasting and detailed discussion started to establish which of these two types of models is correct, that is, whether R&D results or market demand are the most important information sources of innovations.[6]

Both the science-push and the market-pull models portray innovation processes as linear ones. (Figure 1) In other words, these models assume that (a) there is an 'ideal type' of an innovation process, (b) there are distinct, clearly separable stages in this process, and (c) these stages follow each other in a certain, somewhat predetermined sequence. Their aim is to describe and characterise innovation processes. These models also identify causal links by pinpointing the starting stage and the order, in which the other ones succeed each other.

**Figure 1: Linear models of innovation**



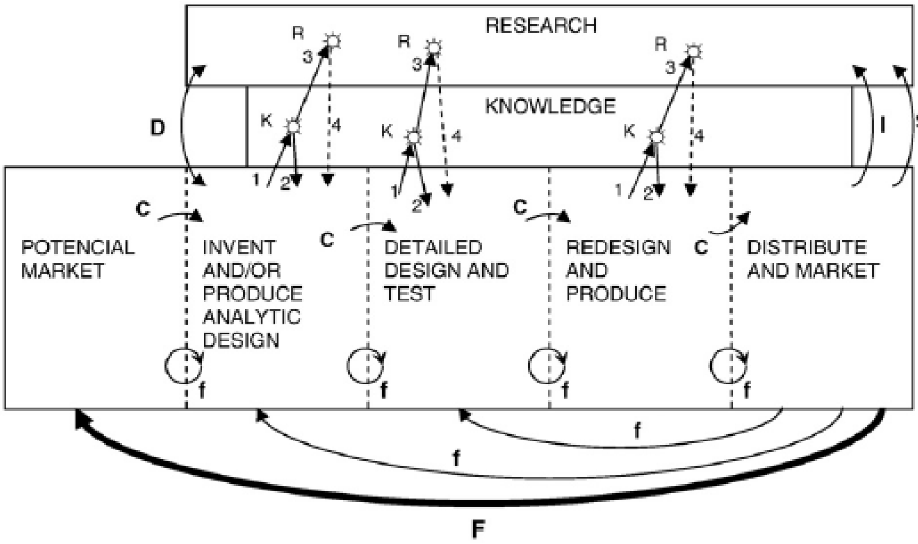

*Source*: Dodgson and Rothwell (eds) (1994), Figures 4.3 and 4.4 (p. 41)

### 2.2 Networked and interactive learning models of innovation

Kline and Rosenberg (1986) rejected the idea that an innovation process can be characterised by a clear sequence of activities (or stages). They suggested the chain-linked model of innovation, stressing the non-linear properties of innovation processes, the variety of information sources, as well as the importance of various feedback loops. (Figure 2)

[6] It is telling that a recent review of this discussion by Di Stefano *et al.* (2012) draws on one hundred papers.

**Figure 2: The chain-linked model of innovation**




Chain-linked model showing flow paths of information and cooperation.
Symbols on arrows: C = central-chain-of-innovation; f = feedback loops; F = particularly important feedback.

**K-R**: Links through knowledge to research and return paths. If problems solved at node K, link 3 to R not activated. Return from research (link 4) is problematic - therefore dashed line.

**D**: Direct link to and from research from problems in invention and design.

**I**: Support of scientific research by instruments, machines, tools, and procedures of technology.

**S**: Support of research in sciences underlying product area to gain information directly and by monitoring outside work. The information obtained may apply anywhere along the chain.

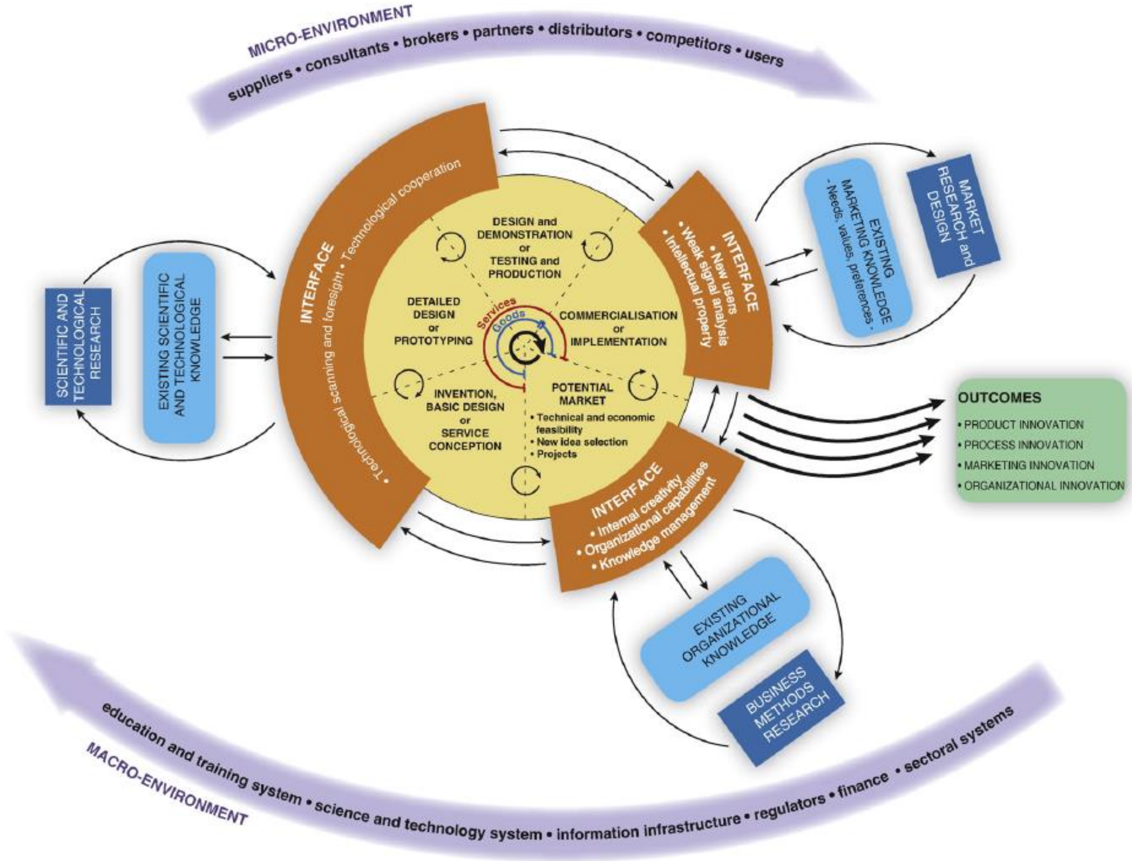
*Source*: Kline and Rosenberg (1986)

Smith (2002a) went further in rejecting the main assumptions of the linear models of innovation. Indeed, in his bold claim he questions if an 'ideal type' of innovation process can be constituted at all. In his view it is not even a worthwhile effort to devise any model of innovation: "There is no single model of the innovation process: enterprises can differ very significantly in their approaches to innovation." (p. 102)

The networked model of innovation rests on this observation. Its recent, refined version is called the multi-channel interactive learning model. (Caraça *et al.*, 2009) (Figure 3) This model

> "has representational purposes and not representative ones, i.e. it does not assume that all factors have to be in place for innovation to be realised and successful. Rather, it tries to provide a stylised representation of the main classes of variables, and their interrelationships, which are involved in the innovation process taking place in a wide array of industries. (...)
>
> Thus, the model is an analytical grid that describes and contextualises elements, but it also provides a set of flexible generalisations upon which to base our thinking when trying to explain the sources and stages of the innovation process. It points to the ubiquitous experience-based learning processes taking place within firms, as well as at the interfaces with users, suppliers and competitors." (Caraça *et al.*, 2009: 864–866; emphasis added – AH; footnotes are removed from the original)

**Figure 3: The multi-channel interactive learning model of innovation**




*Source*: Caraça *et al.* (2009)

Just as the notion of the national innovation system, it is a focussing device, a lens that helps thoroughly analysing a subject (Lundvall, 2007: 98–99). In other words, this model is not a model in a strict sense. Rather, it aims at identifying the major (potential) actors and highlighting their roles, activities, and interactions, and thus ways and channels of (co-)producing, disseminating and exploiting knowledge in innovation processes. The model is emphasising various sources, types and forms of knowledge, and hence not only the S&T mode of innovation can be analysed by using this lens. The importance of the micro and macro environment is also stressed. Finally, as opposed to the linear models of innovation, this one does not aspire to describe or characterise a 'typical', 'schematic' innovation process.

# 3 THEORETICAL APPROACHES TO INNOVATION

## 3.1 Classical economics: a strong emphasis on changes

Although classical economics cannot be regarded as a paradigm – in terms of having shared axioms, basic notions, research questions, methods, postulates or main theses – it can be safely generalised that major classical economists put a strong emphasis on technological, organisational, institutional, and managerial changes as well as the opening up of new markets when analysing "*the Nature and Causes of the Wealth of Nations*", the "*Principles of Political Economy*", or "*the Principles of Political Economy and Taxation*" (Smith, 1776/1904; Mill, 1848/1909, and Ricardo, 1817/1821, respectively). More generally, these authors paid attention to historical developments (long-term issues) and thus to the dynamic nature of the economy and considered it embedded in political and social structures.

As a few selected quotes illustrate in Appendix 1, major representatives of this school shared an important intention: they were interested in explaining various types of changes, taking into account complex relationships, including the co-evolution of technologies (in a broad sense, that is, both products and processes), organisations, markets and various societal features – without using the term innovation. They also paid attention to the diversity of contexts, in which changes took place. Just to mention an obvious, and fundamental, difference among these scholars, the main concern for Marx was not (only) to explain socio-economic phenomena, but to change the socio-economic structures.[7]

To conclude this brief characterisation of classical economics from the angle of their approach to change processes, it is worth stressing that classical economists did not pay a particular attention to the allocation of scarce resources. Following Kaldor (1972), two functions of decentralised markets are identified by Dosi and Orsenigo (1988: 14): allocation of resources and transmission of impulses to change. To generalise, classical economists had inclined to focus on the latter one.

> "Fundamental dynamic properties such as the relationship between expansion of markets, division of labour, and productivity growth in Smith, or the 'increasing organic composition of capital' in Marx, are examples of a class of propositions argued on the grounds of the irreversible transformations originated by processes of what we could call 'dynamic competition'. Moreover, their neglect of explicit microfoundations was justified on the grounds of what we may term a 'holistic' or 'macroinstitutional' assumption about behaviour: it seemed obvious to them that, for example, given an opportunity, capitalists were ready to seize it, or that their 'institutional' function was to invest and accumulate the surplus." (*ibid.*, emphasis in the original)

Yet, in that period measurement of change processes was not an issue, and thus no implications were derived as to what to be measured and how.

### 3.2 Neo-classical economics: focus on static allocative efficiency

In contrast, *neo-classical economics* had a strictly defined, unifying theoretical framework. A fundamental postulate is that economic actors, who can be characterised by a representative agent, have perfect information, and thus can rationally calculate when making decisions. This school, in a sharp contrast with classical economics, essentially abandoned research questions concerned with dynamics, and instead focused on static allocative efficiency. Optimisation was the key issue for this paradigm, assuming homogenous products, diminishing returns to scale, technologies accessible to all producers at zero cost, perfectly informed economic, rational agents, perfect competition, and thus zero profit. Technological changes were treated as exogenous to the economic system, while other types of innovations were not considered at all. Hence, measurement of change processes was a non-issue for neo-classical economists.

[7] Marx explicitly distanced himself from classical economics: it is not by accident that his major book is entitled „Capital: A critique of political economy".

### 3.3 Mainstream economics

Given the empirical findings and theoretical work on firm behaviour and the operation of markets, mainstream industrial economics and organisational theory has relaxed the most unrealistic assumptions, especially perfect information, deterministic environments, perfect competition, and constant or diminishing returns. Yet, "this literature has not addressed institutional issues, it has a very narrow concept of uncertainty, it has no adequate theory of the creation of technological knowledge and technological interdependence amongst firms, and it has no real analysis of the role of government." (Smith, 2000: 75)

Mainstream economics considers R&D as a main source of innovation, and thus pays attention to measuring R&D-based technological innovations.

### 3.4 Evolutionary economics of innovation

Evolutionary economics of innovation rests on radically different postulates compared to mainstream economics.[8] The latter assumes rational agents, who can optimise by calculating *risks* and taking appropriate actions, while the former stresses that "innovation involves a fundamental element of *uncertainty*, which is not simply the lack of all the relevant information about the occurrence of known events, but more fundamentally, entails also (a) the existence of techno-economic problems whose solution procedures are unknown, and (b) the impossibility of precisely tracing consequences to actions". (Dosi, 1988a: 222 – emphasis added) Thus, *optimisation* is impossible on theoretical grounds.[9]

Availability of *information* (symmetry vs. asymmetry among agents in this respect) has been the central issue in mainstream economics until recently. Evolutionary economics, in contrast, has stressed since its beginnings that the success of firms depends on their accumulated *knowledge* – both codified and tacit – , *skills*, as well as *learning capabilities*. Information can be purchased (e.g. as a manual, blueprint, or licence), and hence can be accommodated in mainstream economics as a special good relatively easily and comfortably. Yet, knowledge – and *a fortiori,* the types of knowledge required for innovation, e.g. tacit knowledge, skills, and competence in pulling together and exploiting available pieces of information – cannot be bought and used instantaneously. A learning process cannot be spared if one is to acquire knowledge and skills, and it is not only time-consuming, but the costs of *trial and error* need to be incurred as well.[10] Thus, the uncertain, cumulative and path-dependent nature of innovation is reinforced.

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[8] The so-called new or endogenous growth theory is not discussed here separately because its major implicit assumptions on knowledge are very similar to those of mainstream economics. (Lazonick, 2013; Smith, 2000) Moreover, knowledge in new growth models is reduced to codified scientific knowledge, in sharp contrast to the much richer understanding of knowledge in evolutionary economics of innovation. When summarising the "evolution of science policy and innovation studies" (SPIS), Martin (2012: 1230) also considers this school as part of mainstream economics: "Endogenous growth theory is perhaps better seen not so much as a contribution to SPIS but rather as a response by mainstream economists to the challenge posed by evolutionary economics."

[9] On the nature of innovation, and how it is treated in economics, see also Dosi (1988b), (2013); Dosi and Grazzi (2010); Dosi and Nelson (2010); Dosi *et al.* (eds) (1988); Metcalfe (1998), (2010); as well as Salter and Alexy (2014).

[10] Arrow (1962) was already discussing „The Economic Implications of Learning by Doing", and Rosenberg (1982) stressed the importance of learning by using (ch. 6). Recently, learning has become a more regular subject in mainstream economics, most notably in game theory. For instance, while „learning" only appeared twice in the title of NBER working papers in 1996, it occurred 5 times in

Cumulativeness, path-dependence and learning lead to *heterogeneity* among firms, as well as other organisations. On top of that, sectors also differ in terms of major properties and patterns of their innovation processes. (Castellacci, 2008b; Malerba, 2002; Pavitt, 1984; Peneder, 2010)

Innovators are not lonely champions of new ideas. While talented individuals may develop radically new, brilliant scientific or technological concepts, successful innovations require various types and forms of knowledge, rarely possessed by a single organisation. Close collaboration among firms, universities, public and private research organisations, and specialised service-providers is, therefore, a prerequisite for major innovations, and can take various forms, from informal communications to highly sophisticated R&D contracts, alliances, and joint ventures. (Freeman, 1991, 1994, 1995; Lundvall and Borrás, 1999; OECD, 2001; Smith, 2000, 2002b; Tidd *et al.*, 1997) In other words, 'open innovation' is not a new phenomenon at all. (Mowery, 2009)

### 3.5 Policy rationales derived from contemporary economics paradigms

Different policy rationales can be drawn from competing schools of economic thought. Mainstream economics is primarily concerned with market failures: the unpredictability of knowledge outputs from inputs, the inappropriability of full economic benefits of private investment in knowledge creation, and the indivisibility in knowledge production lead to a 'suboptimal' level of business R&D efforts. Policy interventions, therefore, are justified if they aim at (a) creating incentives to boost private R&D expenditures by ways of subsidies and protection of intellectual property rights, or (b) funding for public R&D activities.

Evolutionary economics of innovation investigates the role of knowledge creation and exploitation in economic processes; that is, it does not focus exclusively on R&D. This school considers various types and forms of knowledge, including practical or experience-based knowledge acquired via learning by doing, using and interacting. As these are *all* relevant to innovation, scientific knowledge is far from being the only type of knowledge required for a successful introduction of new products, processes or services, let alone non-technological innovations. R&D is undoubtedly among the vital sources of knowledge. Besides in-house R&D projects, however, results of other R&D projects are also widely utilised during the innovation process: extramural projects conducted in the same or other sectors, at public or private research establishments, home or abroad. More importantly, there are a number of other sources of knowledge, also essential for innovations, such as design, scaling up, testing, tooling-up, trouble-shooting, and other engineering activities, ideas from

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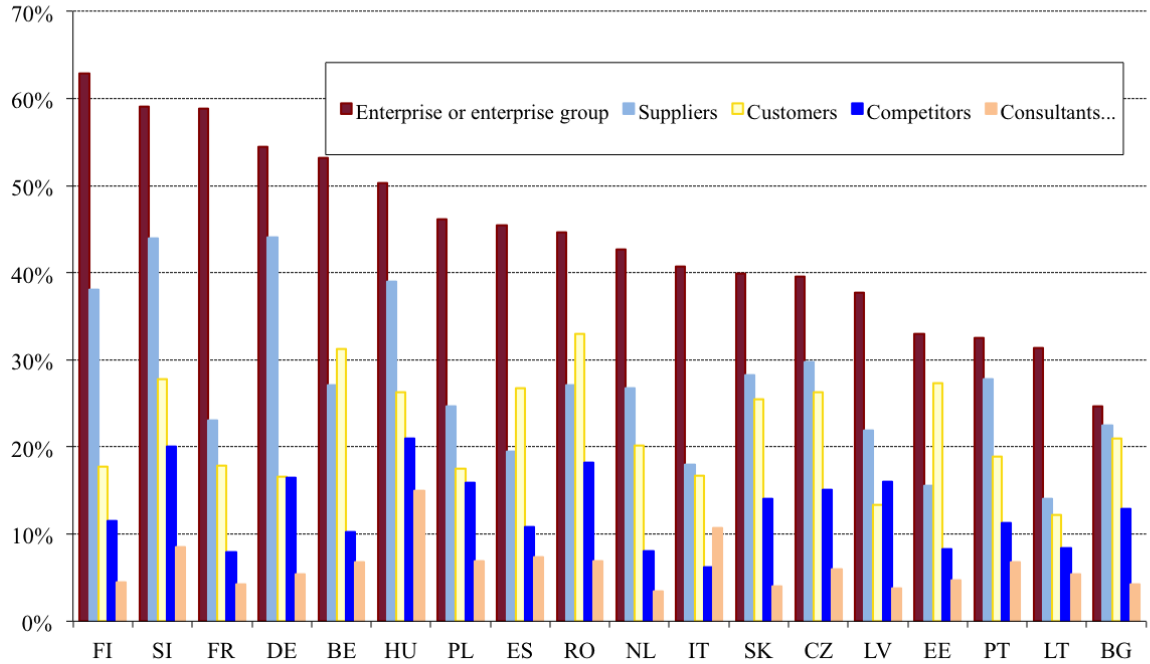
1999, 6 times in 2002, 13 times in 2008, 10 times in 2013, and 12 times in 2014, among others in the forms of „learning by doing", „learning from experience", and „learning from exporting" – but also „learning from state longitudinal data systems" and „learning millennial-style". (It should be added that at least 15-20 NBER working papers are published a week.) Taking the titles and abstracts of articles published in the American Economic Review, „learning" occurred first in 1999, then 2-3 times a year in 2002-2006; 4 times in 2008, 2011, and 2012; 5 times in 2013; 6 times in 2007, 2010, and 2014; and 7 times in 2009. These articles discuss a wide variety of research themes – e.g. behaviour of firms and other organisations, business cycles, stock exchange transactions, forecasting of economic growth, mortgage, art auctions, game theory, behavioural economics, energy, health, labour market – and modes of learning. Thus, not all these articles are relevant from the point of analysing innovation processes (e.g. „learning [one's] HIV status" is not part of an innovation process). Further, in several cases knowledge is narrowed down to patents, which is clearly a misconception. Yet, a detailed analysis of the substance of these articles is beyond the scope of this paper.

suppliers and users, inventors' concepts and practical experiments (Hirsch-Kreinsen *et al.* (eds), 2005; Klevorick *et al.*, 1995; Lundvall (ed.), 1992; Lundvall and Borrás, 1999; Rosenberg, 1996, 1998; von Hippel, 1988), as well as collaboration among engineers, designers, artists, and other creative 'geeks'. Further, innovative firms also utilise knowledge embodied in advanced materials and other inputs, equipment, and software.

The Community Innovation Survey (CIS) defines its own set of categories as highly important sources of information for product and process innovation: the enterprise or the enterprise group; suppliers of equipment, materials, components or software; clients or customers; competitors or other enterprises from the same sector; consultants, commercial labs or private R&D institutes; universities or other higher education institutes; government or public research institutes; conferences, trade fairs, exhibitions; scientific journals and trade/ technical publications; and professional and industry associations. All rounds of CIS clearly and consistently show that firms regard a wide variety of sources of information as highly important ones for innovation. Given space limits, data are only presented here for two periods, namely for 2006–2008, and 2014–2016, respectively, in Figures 4–7.[11]

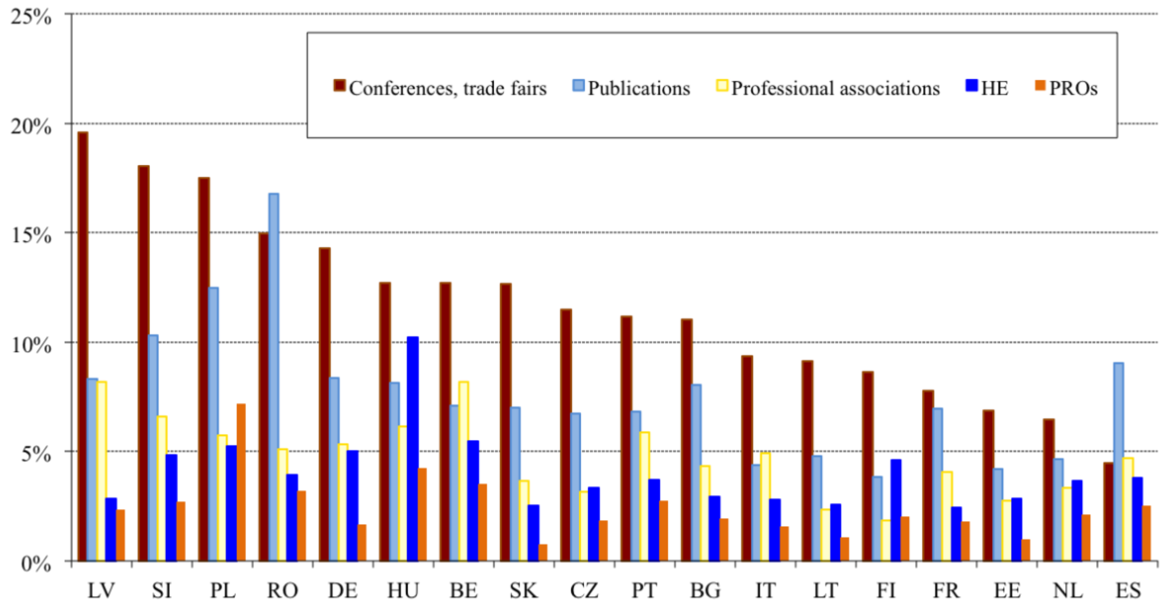
**Figure 4: Highly important 'business' sources of information for product and process innovation, selected EU members, 2006–2008**




*Source*: Eurostat, CIS2008

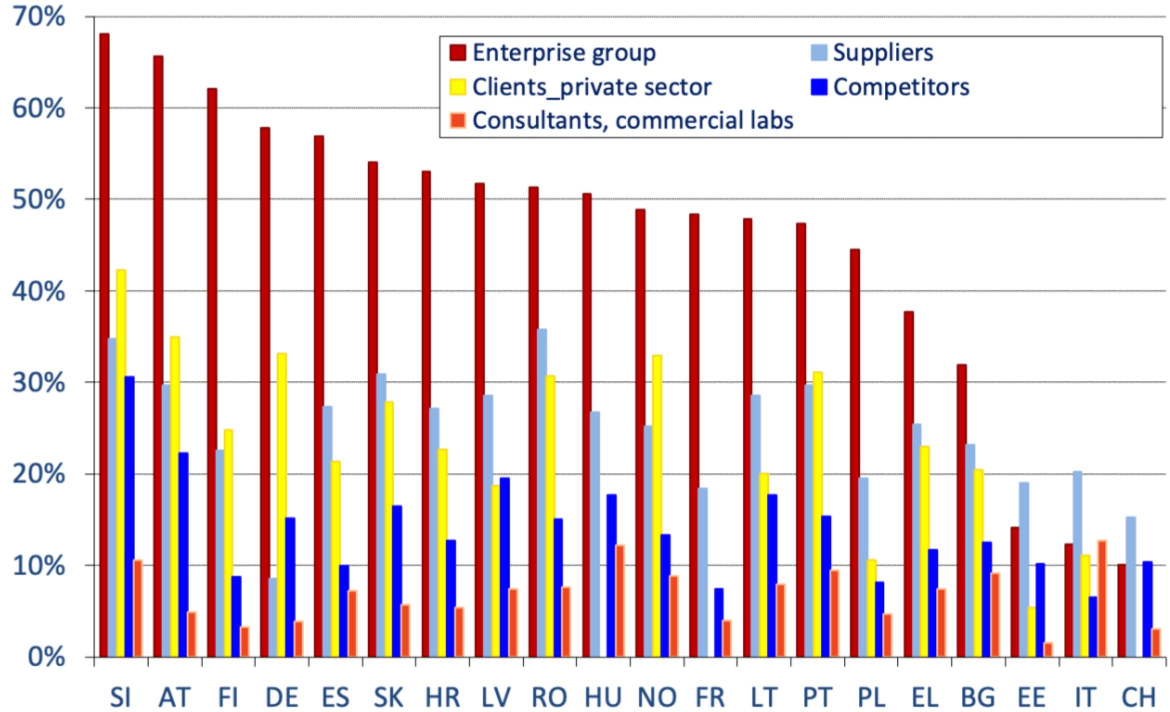
[11] CIS2018 results, covering the period of 2016-2018, are not published yet by the Eurostat. Data for 2008–2010 and 2010–2012 are presented in the Appendix (Figures A1–A4).

**Figure 5: Highly important 'scientific' sources of information for product and process innovation, selected EU members, 2006–2008**



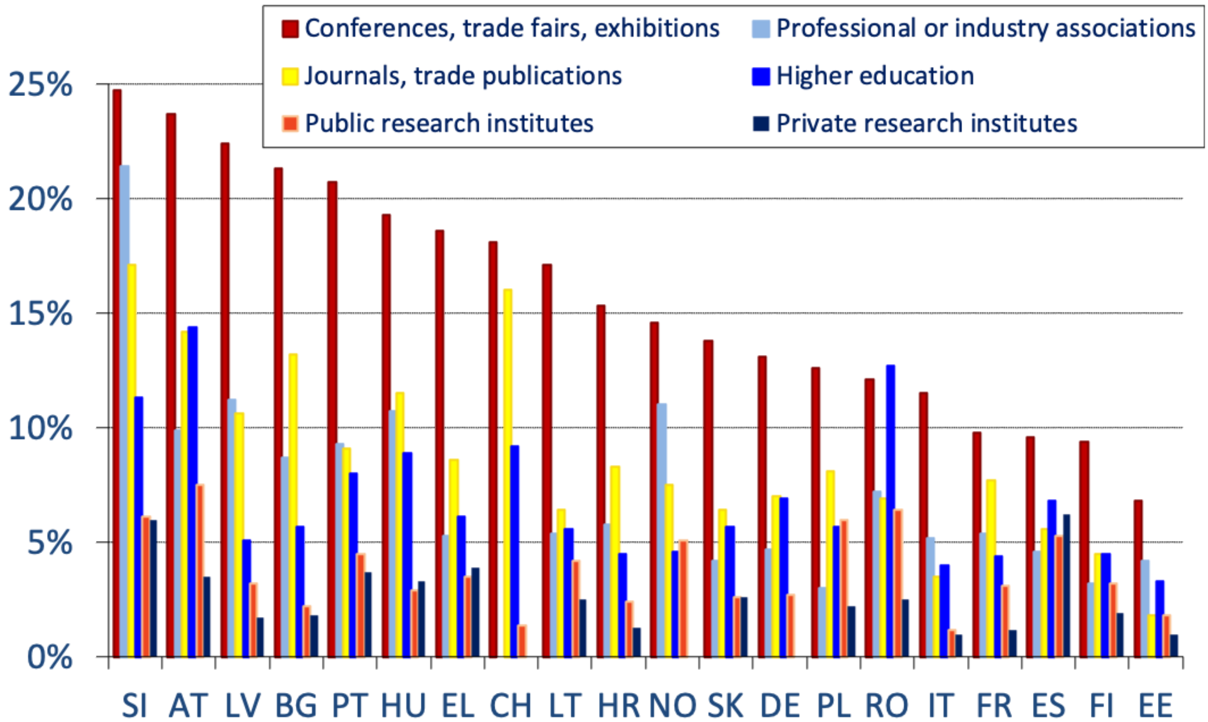

*Source*: Eurostat, CIS2008

**Figure 6: Highly important 'business' sources of information for product and process innovation, selected EU members, 2014–2016**




*Source*: Eurostat, CIS2016

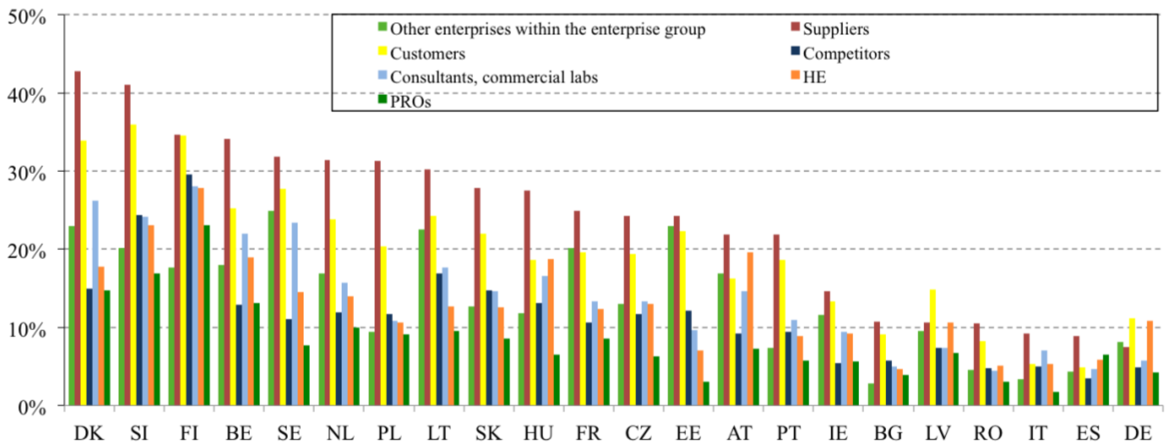
**Figure 7: Highly important 'scientific' sources of information for product and process innovation, selected EU members, 2014–2016**




*Source*: Eurostat, CIS2016

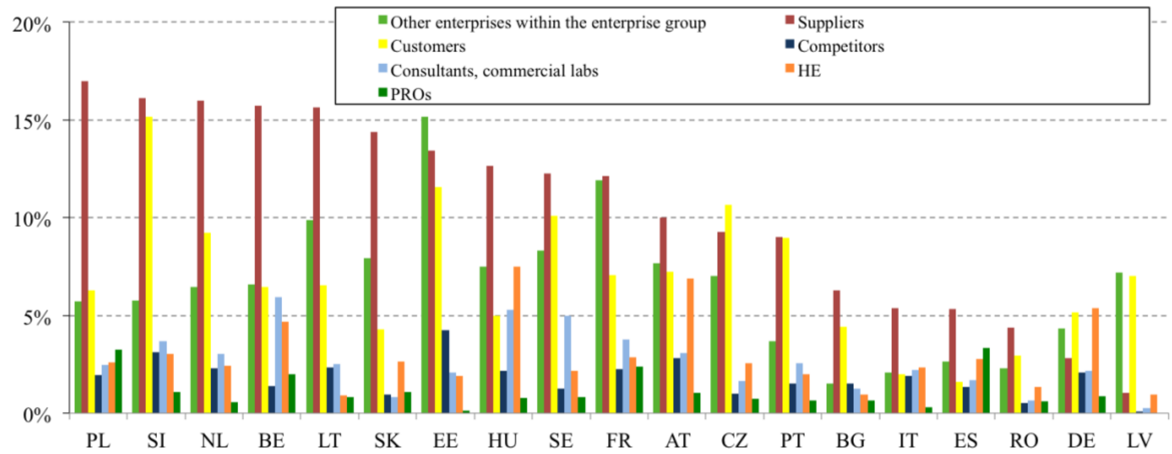
From a different angle, CIS data also confirm that a much larger share of firms are engaged in innovation co-operation with business partners than with academic partners. (Figures 8–11 and Figures A5–A8 in Appendix 2) Of course, many of those business partners might have their own internal R&D units, these data still indicate rather strongly that besides codified knowledge, stemming from formalised R&D activities, several other types of knowledge, accumulated via learning by doing, using and interacting, are also of crucial importance. To put it simple, firms can and want to learn more frequently from each other than from academic partners.

**Figure 8: Types of innovation co-operation partners, 2006–2008**



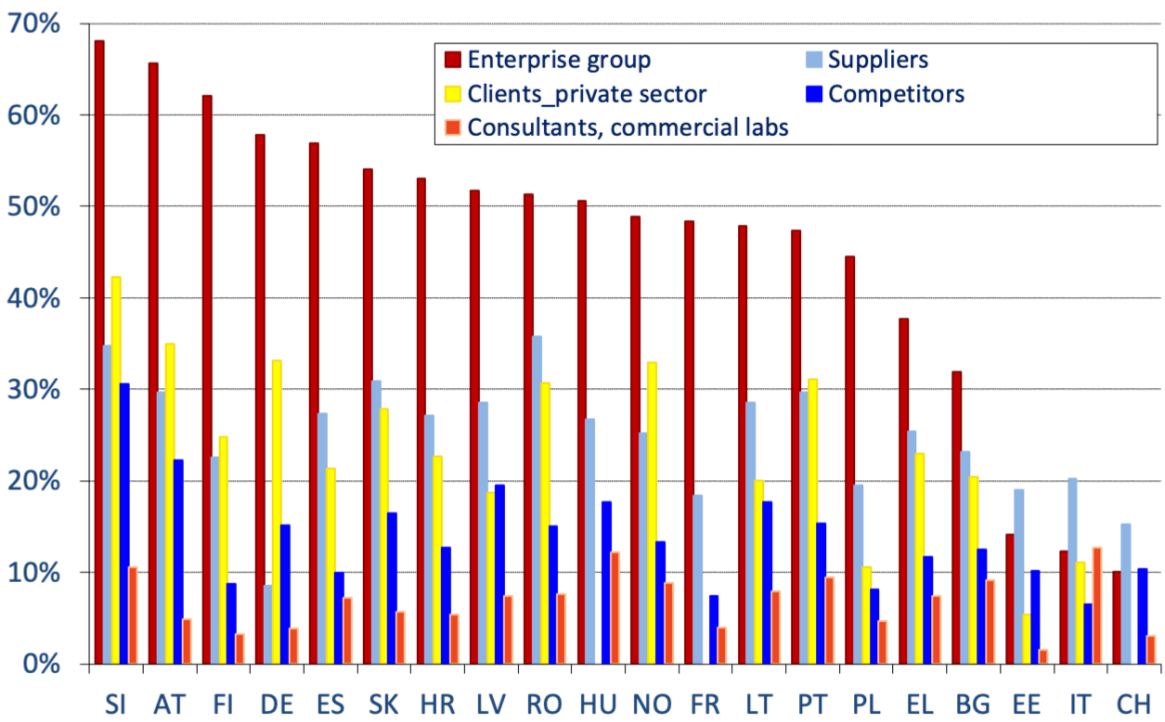

*Source*: Eurostat, CIS2008

**Figure 9: Most valuable methods of innovation co-operation, 2006–2008**



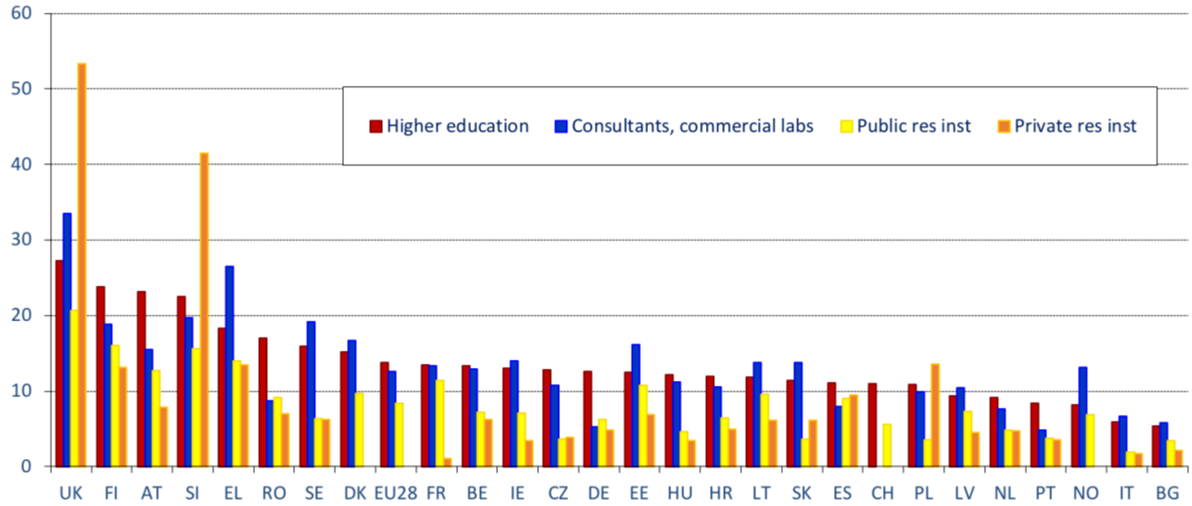

*Source*: Eurostat, CIS2008

**Figure 10: Innovation co-operation with business partners, 2014–2016**




*Source*: Eurostat, CIS2016

**Figure 11: Innovation co-operation with scientific partners, 2014–2016 (%)**




*Source*: Eurostat, CIS2016

The wide variety of knowledge drawn on in innovation processes is a crucial point to bear in mind as the OECD classification of industries only takes into account expenditures on formal R&D activities, carried out within the boundaries of a given sector.[12] In other words, a number of highly successful, innovative firms, exploiting advanced knowledge created externally in distributed knowledge bases (Smith, 2002b) and internally by non-R&D processes, are classified as medium-low-tech or low-tech, just because their R&D expenditures are below the threshold set by the OECD.

Evolutionary economics has also noticed the *highly uneven speed of progress*, that is, performance improvement, in various fields, e.g., rather fast development in space exploration, drugs, medical imaging and telecommunications, on the one hand, and hardly any change in improving education, on the other. One of the major reasons explaining these differences is that these fields have different underlying knowledge bases and the types of knowledge required for advancing progress can be developed at a different pace. (Nelson, 1977, 2011)

Without trying to capture all the major building blocks of this thorough analysis of learning processes, a few key features are highlighted here. First, this evolutionary account of learning stresses that „the ability to learn from variation, from experiments natural or deliberate" is a key to achieve progress. (Nelson, 2011: 684) Clearly, experimentation is a completely different 'ballgame' when the 'subjects' are human beings: ethical, societal and political considerations become vital (as opposed to a number of technological experiments, notwithstanding the significance of these issues in some of those fields). Second, progress is a rather vague notion; it should be translated (observed) as a better performance. Measuring performance, however, is far from being a trivial task, even when it comes to technological or economic performance (in a somewhat narrow sense). Progress can only be measured in an appropriate, context-specific way even in these realms. But to compare performance,

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[12] The so-called indirect R&D intensity has been also calculated as R&D expenditures embodied in intermediates and capital goods purchased on the domestic market or imported. Yet, it has been concluded that indirect R&D intensities would not influence the classification of sectors. (Hatzichronoglou, 1997: 5)

and thus being able to learn (what directions of search seem to be promising, i.e., what efforts should be redoubled, and what doesn't work, and thus should be abandoned) one needs a reliable yardstick: „the criteria for better performance must be clear and relatively stable, and competing practices must differ non-trivially in efficacy under those criteria. Further, the evidence of efficacy must be relatively sharp, and available in timely fashion." (ibid: 684) That seems to be a tall order even for a relatively 'simple' technological innovation, let alone more far-reaching ones, e.g., the so-called generic purpose technologies.

*In sum*, evolutionary economics of innovation posits that the success of firms is largely determined by their abilities to exploit various types of knowledge, generated by both R&D and non-R&D activities. Knowledge generation and exploitation takes place in, and is fostered by, various forms of internal and external interactions. The quality and frequency of the latter is largely determined by the properties of a given innovation system, in which these interactions take place. STI policies, therefore, should aim at strengthening the respective innovation system and improving its performance by tackling *systemic failures* (Table 1) hampering the generation, diffusion, and utilisation of any type of knowledge required for successful innovation.[13] (Edquist, 2011; Foray (ed.), 2009; Freeman, 1994; Lundvall and Borrás, 1999; OECD, 1998; Smith, 2000) From a different angle, *conscious, co-ordinated policy efforts are needed to promote knowledge-intensive activities in all sectors.*

**Table 1: Types of systemic failures in innovation systems**

*Evolutionary failures*
- generation of technological opportunities
- learning by firms (accumulation of capabilities)
- lock-in in inferior technology (competence trap), trade-offs
  - exploration vs. exploitation (current vs. future profits)
  - variety generation vs. selection
  - tight IPR vs. exploration of new approaches/ diverse competence base

*System failures (problems)*
- missing or weak elements of the system ('nodes', actors)
- missing, weak, or inappropriate connections among the actors
- transition to a substantially different system (system dynamics)

*Policy failures*
- weak learning (e.g., from previous practice, interactions with other actors, and good practices)
- inflexibility in policy implementation
- lack of understanding of sectoral characteristics
- poor (or no) vision-building
- ineffective co-ordination of policies

*Source:* Malerba (2009)

[13] In an attempt to systematically compare the market and systemic failure policy rationales, Bleda and del Río (2013) introduce the notion of evolutionary market failures and reinterpret „the neoclassic market failures" as particular cases of evolutionary market failures, relying on the crucial distinction between knowledge and information.

### 3.6 Implications for measuring innovation activities

As already mentioned, mainstream economics mainly considers R&D-based technological innovations and puts a considerable emphasis on protecting intellectual property rights. Therefore, following this paradigm, measurement should focus on R&D inputs and outputs, as well as on patenting activities (which can be regarded as a throughput of R&D efforts). These are the required types of information for validating and refining theories, on the one hand, and underpinning policy proposals, on the other.

This focus on technological innovations, however, leads to a sectoral bias: attention is paid to the so-called high-tech sectors, with the highest share of internal R&D intensity. From a different angle, knowledge content of actual activities of a given firm, as well as intra-sectoral differences are neglected. For example, a firm statistically belonging to a high-tech sector, but in practice performing activities with low knowledge intensity – for instance, assembling technologically advanced products developed by the central R&D unit of its parent company, based in another country, or by its buyer – is regarded similar to another firm in the same sector, but performing knowledge-intensive activities. This occurs rather frequently in numerous countries and sectors. Yet, this phenomenon is overlooked by those analysts who disregard these qualitative features, that is, mechanistically equate the knowledge content of goods with knowledge intensity of activities and that of sectors. This oversight can easily lead to unsubstantiated theoretical observations and deceiving policy advice.

Evolutionary economics of economics, following a systems approach to innovation, in contrast posits that various types (both S&T and practical) and forms of knowledge (both codified and tacit) are needed for successful innovation activities. That requires interactions among the actors, as required types and pieces of knowledge are practically never possessed by a single actor. These interactions facilitate flow of knowledge, especially that of tacit knowledge, but codified one as well. Further, learning and competence building processes at all levels (individual, intra- and inter-organisational) are of crucial importance. As new knowledge is often co-produced by various actors, with different previous knowledge, experience and mindsets, interactions among these actors not only facilitate knowledge flows, but at least as importantly the production of new knowledge as well. For these reasons, evolutionary economics of innovation considers both R&D-based and non-R&D-based innovations, and hence does not suffer from a sectoral bias.

As for measurement, both technological and non-technological innovations should be covered, on the one hand, and both the S&T and DUI modes of innovations should be observed, on the other, for distilling valid theoretical conclusions and deriving reliable, relevant policy implications.

# 4 THE EUROPEAN INNOVATION SCOREBOARD

This section first offers an overview of changing set of indicators used to compile of the various editions of the European Innovation Scoreboard. Then it recalls two other EC initiatives to rank the EU member states by their innovation activities.

## 4.1 Indicators in the various editions of the European Innovation Scoreboard

As shown in section 3, firms exploit various types of knowledge for their innovation activities. Applying this general observation to the Danish case, and relying on the DISKO survey, Jensen *et al.* (2007) made an elementary distinction between two modes of innovation: (a) one based on the production and use of codified scientific and technical knowledge (in brief, the S&T mode), and (b) another one relying on informal processes of learning and experience-based know-how (called DUI: learning by doing, using and interacting).

Following this distinction, the indicators used in the various editions of the Innovation Union Scoreboard[14] are characterised below, using a rudimentary classification. An indicator can be relevant to reflect:

- only R&D-based innovations
- mainly R&D-based innovations
- only non-R&D-based innovations
- mainly non-R&D-based innovations
- both types of innovations.

This rudimentary classification reveals a bias towards R&D-based innovations in the first edition of the EIS: 10 indicators were only relevant for R&D-based innovations; 8 could be relevant for both types of innovations; and none focused on non-R&D-based innovations.[15] (Table 2)

[14] The European Innovation Scoreboard (EIS) was introduced in 2002. The indicators used for the EIS have been revised several times. The scoreboard was renamed as Innovation Union Scoreboard (IUS) in 2010. Since 2016 it is called EIS again

[15] A fairly detailed, partly technical, partly substantive discussion would be needed to refine this simple classification. Another important question could be as follows: to what extent are non-R&D-based innovation activities needed for successful R&D-based innovations?

**Table 2: The 2002 European Innovation Scoreboard indicators**

| | Relevance for R&D-based innovation | Relevance for non-R&D-based innovation |
|---|---|---|
| **1 Human resources** | | |
| New S&E graduates (ISCED 5a and above) per 1000 population aged 20-29 | X | |
| Population with tertiary education (% of 25–64 years age class) | b | b |
| Participation in life-long learning (% of 25–64 years age class) | b | b |
| Employment in medium-high and high-tech manufacturing (% of total workforce) | X | |
| Employment in high-tech services (% of total workforce) | X | |
| **2 Knowledge creation** | | |
| Public R&D expenditures (GERD – BERD) (% of GDP) | X | |
| Business expenditures on R&D (BERD) (% of GDP) | X | |
| EPO high-tech patent applications (per million population) | X | |
| USPTO high-tech patent applications (per million population) | X | |
| **3 Transmission and application of knowledge** | | |
| SMEs innovating in-house (% of manufacturing SMEs) | b | b |
| SMEs involved in innovation co-operation (% of manufacturing SMEs) | b | b |
| Innovation expenditures (% of all turnover in manufacturing) | b | b |
| **4 Innovation finance, output and markets** | | |
| High technology venture capital investment (% of GDP) | X | |
| Capital raised on parallel markets plus by new firms on main markets (% of GDP)[i] | X | |
| Sales of 'new to market' products (% of all turnover in manufacturing) | b | b |
| Home internet access (% of all households) | b | b |
| ICT expenditures (% of GDP) | b | b |
| Share of manufacturing value-added in high-tech | X | |

*Legend:*
X: only relevant
b: relevant for both types
*Source*: own compilation, drawing on the detailed definition of indicators, EC (2002).
*Notes*: Public R&D expenditures do not equal to GERD – BERD; rather, it should be the sum of government-funded parts of BERD, GOVERD, and HERD
Three indicators, namely EPO patent applications (per million population), Home internet access (per 100 population), and Inward FDI stock (% of GDP) were only used for candidate countries.
[i] "Parallel stock exchanges focus on high technology sectors." (EC, 2002: 31)

Jumping ahead, the 2017–2019 editions of the EIS used 27 indicators, grouped by 8 headings. (EC, 2017, 2018, 2019) Repeating the same exercise shows that the bias towards R&D-based innovations has been slightly eased: 8 of the most recent EIS indicators are *only* relevant for, and a further 6 *mainly* capture, R&D-based innovations; 11 could be relevant for both types of innovations; and a mere 2 focus on non-R&D-based innovations. (Table 3)

**Table 3: The 2017-2019 European Innovation Scoreboard indicators**

| | Relevance for R&D-based innovation | Relevance for non-R&D-based innovation |
|---|---|---|
| **Human resources** | | |
| New doctorate graduates (ISCED 6) per 1000 population aged 25-34 | X | |
| Percentage population aged 30-34 having completed tertiary education | b | b |
| Lifelong learning | b | b |
| **Attractive research systems** | | |
| International scientific co-publications per million population | X | |
| Scientific publications among the top 10% most cited publications worldwide as % of total scientific publications of the country | X | |
| Foreign doctorate students as a % of all doctorate students | X | |
| **Innovation-friendly environment** | | |
| Broadband penetration | b | b |
| Opportunity-driven entrepreneurship | b | b |
| **Finance and support** | | |
| R&D expenditure in the public sector as % of GDP | X | |
| Venture capital investment as % of GDP | x | |
| **Firm investments** | | |
| R&D expenditure in the business sector as % of GDP | X | |
| Non-R&D innovation expenditures as % of turnover | | X |
| Enterprises providing training to develop or upgrade ICT skills of their personnel | x | |
| **Innovators** | | |
| SMEs introducing product or process innovations as % of SMEs | b | b |
| SMEs introducing marketing or organisational innovations as % of SMEs | | X |
| SMEs innovating in-house as % of SMEs | b | b |
| **Linkages** | | |
| Innovative SMEs collaborating with others as % of SMEs | b | b |
| Public-private co-publications per million population | X | |
| Private co-funding of public R&D expenditures as % GDP | X | |
| **Intellectual assets** | | |
| PCT patents applications per billion GDP (in PPS€) | x | |
| Trademarks applications per billion GDP (in PPS€) | b | b |
| Designs applications per billion GDP (in PPS€) | b | b |
| **Employment impacts** | | |
| Employment in knowledge-intensive activities as % of total employment | x | |
| Employment in fast-growing enterprises in innovative sectors as % of total employment | b | b |
| **Sales impacts** | | |
| Exports of medium and high-technology products as a share of total product exports | x | |
| Knowledge-intensive services exports as % total service exports | x | |
| Sales of new to market and new to firm innovations as % of turnover | b | b |

*Legend:*
X: only relevant
x: mainly relevant
b: relevant for both types
*Source*: own compilation

As already mentioned, a fairly detailed, partly technical, partly substantive discussion would be needed to refine this simple classification, especially concerning the following issues: to what extent upper secondary education, venture capital, employment in knowledge-intensive activities, and knowledge-intensive services exports are relevant indicators to capture non-R&D-based innovations; and to what extent non-R&D-based innovation activities are needed for successful R&D-based innovations?

To provide an overview of the evolution of the EIS and IUS indicators,[16] results are summarised in Table 4. In sum, the bias towards R&D-based innovations has been rather persistent, although there has been some fluctuation.

While the number and definitions of indicators used to compile the various editions of EIS and IUS have changed to a non-negligible extent since 2002, these indicators consistently focus on measuring R&D activities (inputs and outputs) and R&D-based innovation activities. In other words, they can be relevant in settings characterised predominantly by the so-called S&T mode of innovation, but significantly less useful in other settings, characterised by other types of innovation activities. In other words, using the EIS or IUS indicators would not help establishing if a certain system is characterised by a low level of innovation activities altogether – or a low level of R&D-based innovation activities. Yet, that is a fairly important distinction both from an analytical and a practical (policy) point of view: these two systems (settings) are fundamentally different.

Several analysts and policy-makers tend to believe that (a) advanced economies can be sufficiently characterised by focussing on the S&T mode of innovation, and (b) less advanced economies should also attempt to change the sectoral composition of their economy by increasing the weight of the so-called high-tech (HT) sectors. These views, however, cannot be corroborated by empirical evidence.

[16] The indicators of the 2003–2016 editions of the EIS/ IUS are presented in Appendix 3.

**Table 4: The evolution of the EIS and IUS indicators, 2002–2019**

| | EIS 2002 | EIS 2003 | EIS 2004 | EIS 2005 and 2006 | EIS 2007 | EIS 2008 | EIS 2009 | IUS 2010 – IUS 2013 | IUS 2014 – IUS 2016 | IUS 2017 – IUS 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Indicators reflecting** | | | | | | | | | | |
| only R&D-based innovations | 10 | 9 | 9 | 8 | 7 | 8 | 8 | 10 | 10 | 8 |
| mainly R&D-based innovations | - | 3 | 3 | 5 | 5 | 4 | 4 | 4 | 4 | 6 |
| both types | 8 | 9 | 9 | 12 | 12 | 15 | 16 | 6 | 7 | 11 |
| only non-R&D-based innovations | - | - | - | - | - | 1 | 1 | 4 | 4 | 2 |
| mainly non-R&D-based innovations | - | - | 1 | 1 | 1 | 1 | 1 | - | - | - |
| Number of indicators | 18 | 21 | 22 | 26 | 25 | 29 | 30 | 24 | 25 | 27 |

*Source*: own compilation

Any simple statistical analysis reveals that the so-called high-tech sectors – supposed to be drivers of economic development, due their intense S&T mode innovation activities – have a fairly low weight either in output or employment. Innovation studies have shown that technological innovations can hardly be introduced without organisational and managerial innovations. Moreover, the latter ones – together with marketing innovations – are vital for the success of the former ones.[17] (Pavitt, 1999; Tidd *et al.*, 1997) Further, those companies are the most successful ones, which consciously combine the ST and DUI modes of innovation. (Jensen *et al.*, 2007)

Yet, the high-tech myth is so powerful that even those researchers who base their work on thorough analysis of facts are taken by surprise when the facts are at odds with the widespread obsession with high-tech. A telling example is Peneder's excellent study on the 'Austrian paradox':

> "On the one hand, macroeconomic indicators on productivity, growth, employment and foreign direct investment indicate that overall performance is stable and highly competitive. On the other hand, an international comparison of industrial structures reveals a severe gap in the most technologically advanced branches of manufacturing, suggesting that Austria is having problems establishing a foothold in the dynamic markets of the future." (Peneder, 1999: 239)

In contrast, evolutionary economics of innovation claims that any firm – belonging to either a low- and medium-technology (LMT) or a HT sector – can become competitive in 'the dynamic markets of the future' if it is successful in combining its own, firm-specific innovative capabilities with 'extra-mural' knowledge available in distributed knowledge bases. In other words, Austrian policy-makers need not be concerned with the observed 'paradox' as long as they help Austrian firms sustain their learning capabilities, and thereby maintain their innovativeness. That would lead to good economic performance – irrespective of the share of LMT industries in the economy.

From a different angle, while the bulk of innovation activities in the LMT sectors are not based on intramural R&D efforts, these sectors also improve their performance by various types of innovations. These firms are usually engaged in the DUI mode of innovation, but they also draw on advanced S&T results available through the so-called distributed knowledge bases (Robertson and Smith, 2008; Smith, 2002a, 2002b), as well as advanced materials, production equipment, software and various other inputs (e.g. electronics components and sub-systems) supplied by HT industries. (Bender *et al.* (eds), 2005; Hirsch-Kreinsen *et al.* (eds), 2005; Hirsch-Kreinsen and Jacobson (eds), 2008; Hirsch-Kreinsen and Schwinge (eds) 2014; Jensen *et al.*, 2007; Kaloudis *et al.*, 2005; Mendonça, 2009; Sandven *et al.*, 2005; von Tunzelmann and Acha, 2005) Thus, demand by the LMT sectors constitutes major market opportunities for HT firms, and also provides strong incentives – and ideas – for their RTDI activities. (Robertson *et al.*, 2009)

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[17] Although it goes without saying that not all technological innovations are based on R&D results, people tend to forget this basic fact. Certain organisational, managerial, marketing and financial innovations, in turn, draw on R&D results (but usually not stemming from R&D activities conducted or financed by firms). For these two reasons it would be a mistake to equate technological innovations with R&D-based innovations.

It is worth recalling that the 2003 EIS report also stressed the importance of the LMT sectors, as well as the significance of their innovation activities:

> „The EIS has been designed with a strong focus on innovation in high-tech sectors. Although these sectors are very important engines of technological innovation, they are only a relatively small part of the economy as measured in their contribution to GDP and total employment. The larger share of low and medium-tech sectors in the economy and the fact that these sectors are important users of new technologies merits a closer look at their innovation performance. This could help national policy makers with focusing their innovation strategies on existing strength and overcome areas of weakness." (EC, 2003a: 20)

Since then, however, these ideas have been given less prominence. No doubt, it would be an interesting research question why this is the case, but this paper cannot address this issue. More recently, another EC document, namely the 2013 EU Competitiveness Report is sending 'mixed' messages on these issues. At certain points it reinforces these adverse effects:

> „the EU has comparative advantages in most manufacturing sectors (15 out of 23) accounting for about three quarters of EU manufacturing output. (…) Of the 15 sectors with comparative advantages mentioned above, about two-thirds are in the low-tech and medium-low tech manufacturing groups. On a positive note though, even in those sectors EU competitiveness is based on high-end innovative products." (EC, 2013b: 3–4, emphasis added – AH)

Is it a negative phenomenon, then, that around 10 EU LMT sectors are internationally competitive?!? Then a more balanced view is also offered:

> "… the policy priority attached to key enabling technologies which lead to new materials and products in all manufacturing sectors has a strong potential to upgrade EU competitiveness not only in the high-tech sectors but also in the traditional industries." (*ibid*: 5)

### 4.2 A league table of research and innovation performance of EU member states

The EC Directorate-General for Research and Innovation is publishing country profiles aimed at "providing policy makers and stakeholders with concise, holistic and comparative overviews of research and innovation (R&I) in individual countries." (EC, 2013c: 2) The 2011 edition of this series identified nine groups of countries and then Hungary – together with the Czech Republic, Italy, Slovakia, and Slovenia – belonged to group 8, characterised by "medium-low knowledge capacity with an important industry base." (EC, 2011b: 436)

A new feature in the 2013 edition was a synthesis table on member states' research and innovation performance with some striking observations: Ireland had the highest level of knowledge-intensity, and Hungary came ninth, ahead of Germany, Austria and the EU average, for example, and just behind Denmark and Finland. Yet, Malta was ahead of Finland. (Table 5)

**Table 5: Overview of research and innovation performance in the EU countries, 2010–2011**

| | R&D intensity (2011) | Excellence in S&T (2010) | Index of economic impact of innovation (2010-2011) | Knowledge-intensity of economy (2010) | HT & MT contribution to trade balance (2011) |
|---|---|---|---|---|---|
| **Ireland** | 1.72 | 38.11 | 0.690 | 65.43 | 2.57 |
| **Luxembourg** | 1.43 | 19.84 | 0.589 | 64.75 | -3.35 |
| **Sweden** | 3.37 | 77.20 | 0.652 | 64.60 | 2.02 |
| **United Kingdom** | 1.77 | 56.08 | 0.621 | 59.24 | 3.13 |
| **Belgium** | 2.04 | 59.92 | 0.599 | 58.88 | 2.37 |
| **France** | 2.25 | 48.24 | 0.628 | 57.01 | 4.65 |
| **Netherlands** | 2.04 | 78.86 | 0.565 | 56.22 | 1.68 |
| **Denmark** | 3.09 | 77.65 | 0.713 | 54.95 | -2.77 |
| **Malta** | 0.73 | 17.53 | 0.350 | 54.45 | 0.92 |
| **Finland** | 3.78 | 62.91 | 0.698 | 52.17 | 1.69 |
| **Hungary** | 1.21 | 31.88 | 0.527 | 50.23 | 5.84 |
| **European Union** | 2.03 | 47.86 | 0.612 | 48.75 | 4.20 |
| **Estonia** | 2.38 | 25.85 | 0.450 | 46.48 | -2.70 |
| **Slovenia** | 2.47 | 27.47 | 0.521 | 45.90 | 6.05 |
| **Germany** | 2.84 | 62.78 | 0.813 | 44.94 | 8.54 |
| **Cyprus** | 0.48 | 27.77 | 0.558 | 44.11 | 1.72 |
| **Austria** | 2.75 | 50.46 | 0.556 | 42.40 | 3.18 |
| **Portugal** | 1.50 | 26.45 | 0.387 | 41.04 | -1.20 |
| **Czech Republic** | 1.84 | 29.90 | 0.497 | 39.58 | 3.82 |
| **Spain** | 1.33 | 36.63 | 0.530 | 36.76 | 3.05 |
| **Italy** | 1.25 | 43.12 | 0.556 | 35.43 | 4.96 |
| **Lithuania** | 0.92 | 13.92 | 0.223 | 35.28 | -1.27 |
| **Latvia** | 0.70 | 11.49 | 0.248 | 34.38 | -5.42 |
| **Greece** | 0.60 | 35.27 | 0.345 | 32.53 | -5.69 |
| **Poland** | 0.77 | 20.47 | 0.313 | 31.78 | 0.88 |
| **Slovakia** | 0.68 | 17.73 | 0.479 | 31.64 | 4.35 |
| **Bulgaria** | 0.57 | 24.65 | 0.234 | 29.45 | -4.78 |
| **Romania** | 0.48 | 17.84 | 0.384 | 28.35 | 0.38 |
| **Croatia** | 0.75 | 12.25 | 0.353 | n.a. | 2.98 |

*Source:* EC (2013c): 5
*Note:* Countries are ranked by the composite index called "knowledge-intensity of economy".

The table was reproduced in the 2014 edition of the Innovation Union progress report (EC, 2014b: 19) with updated data. Ireland kept her top position, just a Hungary her rank of No. 11, still ahead of Germany and Austria, while Malta was overtaken by Finland.[18] These implausible results certainly demand an explanation.

[18] This overview was discontinued in the 2015 edition of the Innovation Union progress report.

The 'knowledge-intensity of the economy' is defined as follows: "Eight compositional structural change indicators have been identified and organized into five dimensions:

- The R&D dimension measures the size of business R&D (as a % of GDP) and the size of the R&D services sector in the economy (…);
- The skills dimension measures changing skills and occupation in terms of the share of persons employed in knowledge intensive activities;
- The sectoral specialization dimension captures the relative share of knowledge intensive activities;
- The international specialization dimension captures the share of knowledge economy through technological (patents) and export specialization (revealed technological and competitive advantage);
- The internationalization dimension refers to the changing international competitiveness of a country in terms of attracting and diffusing foreign direct investment (inward and outward foreign direct investments).

(…) The five pillars have also been aggregated to a single composite indicator of structural change (…)." (EC, 2013c: 321–322)

Knowledge is understood in these reports in a narrow sense: only higher education and R&D activities are supposed to create it and thus all other types of knowledge are disregarded. The name of this indicator is, therefore, misleading. The inclusion of high-tech exports and foreign direct investment in this composite indicator explains the unexpectedly high ranking of Ireland and Hungary: in both countries (i) high-tech goods account for an extremely large share in exports (Table 6) and (ii) high-tech sectors are dominated by foreign-owned firms.

These 'twinned' characteristics warrant further remarks from the point of view of knowledge-intensity. The bulk of the exported high-tech goods are developed outside Ireland or Hungary;[19] the main activity of most foreign subsidiaries is the assembly of high-tech goods by semi-skilled workers, and thus the local knowledge content is rather low. These features cannot be reflected in this indicator, and thus it does not necessarily express knowledge-intensity in the case of countries with similar structural characteristics. Hence, it may only be used with a rather big pinch of salt to compare countries' performance or devise policy measures.

[19] BERD in the 'Manufacture of computer, electronic and optical products (C26)' sector was €152–155m in Ireland, €53–56m in Hungary, while €527m in Austria in 2009–2010. (Eurostat) Austria has been chosen for comparison given her similar size (in terms of population) and lower ranking by knowledge-intensity of economy in Table 5. BERD in pharmaceuticals is not considered here given the sector's small share in Hungarian high-tech exports (around 10% of the electronics exports [sector C26]).

**Table 6: Share of high-tech goods in industrial exports, 2001–2009 (%)**

| | 2001 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|
| **Ireland** | 58.0 | 52.1 | 48.9 | 46.6 | 48.9 | 52.2 |
| **Hungary** | 28.3 | 31.7 | 30.8 | 29.9 | 30.6 | 35.5 |
| **Netherlands** | 29.6 | 30.1 | 28.7 | 27.4 | 25.2 | 29.1 |
| **United Kingdom** | 35.8 | 27.7 | 27.4 | 26.1 | 25.1 | n.a. |
| **France** | 25.2 | 22.8 | 23.7 | 22.5 | 23.0 | n.a. |
| **Finland** | 24.3 | 25.3 | 21.9 | 20.0 | 19.7 | 17.1 |
| **Slovak Republic** | 6.0 | 11.3 | 14.4 | 16.9 | 19.4 | n.a. |
| **Sweden** | 23.1 | 21.3 | 21.4 | 18.9 | 18.6 | 21.9 |
| **Czech Republic** | 11.8 | 15.0 | 16.8 | 17.5 | 17.9 | 18.8 |
| **Belgium** | 14.4 | 17.8 | 16.8 | 17.7 | 17.4 | 22.0 |
| **Germany** | 20.3 | 19.7 | 19.5 | 17.7 | 17.2 | 19.5 |
| **Denmark** | 19.6 | 20.1 | 18.1 | 17.3 | 15.6 | 17.9 |
| **Slovenia** | 10.8 | 10.7 | 11.5 | 11.6 | 13.0 | 15.0 |
| **Austria** | 15.4 | 13.3 | 12.9 | 12.8 | 12.4 | 14.0 |
| **Greece** | 8.7 | 12.9 | 11.5 | 10.7 | 11.8 | 14.8 |
| **Spain** | 10.2 | 11.1 | 10.6 | 10.3 | 10.1 | 11.3 |
| **Poland** | 6.5 | 6.3 | 7.4 | 8.1 | 9.8 | n.a. |
| **Italy** | 11.8 | 10.7 | 10.1 | 9.3 | 9.1 | 10.8 |
| **Estonia** | 25.5 | 21.5 | 16.4 | 9.5 | 8.9 | 8.0 |
| **Luxembourg** | 15.7 | 10.1 | 10.0 | 8.6 | 6.8 | 10.4 |
| **Portugal** | 11.3 | 11.5 | 11.4 | n.a. | n.a. | n.a. |

*Source:* own calculation based on OECD.Stat data
n.a.: not available

In more detail, two major policy lessons can be drawn from this attempt. First, policies aimed at promoting innovation and hence competitiveness should consider the actual activities of firms, rather than the OECD classification of sectors. Four units of analysis should be distinguished: activities, products, firms and sectors. Firms belonging to the same statistical sector might possess quite different innovation, production, management, and marketing capabilities. Furthermore, they are unlikely to produce identical goods, in terms of e.g., skills and investment required, level of quality or market and profit opportunities. Finally, they perform different activities, especially regarding their knowledge-intensity. These dissimilarities are likely to be even more pronounced when we consider sectors, firms, products and activities across different countries. In short, policies that neglect the intra-sectoral diversity of firms cannot be effective.

Second, various types of foreign direct investment activities have different longer-term impacts on economic development. Globalisation either poses threats to, or offers opportunities for, economic development, depending on the capabilities and investment promotion policies of the host country. To use an elementary dichotomy of foreign direct investment, one type can be called *'foot-loose'*. These companies conduct activities with low level of local knowledge content, and thus pay low wages. They are ready to leave at any time for cheaper locations.[20] The other types of

[20] Radosevic (2002) offers a thorough survey of the electronics industry in Central and Eastern European countries, Scotland and Wales. His analysis of plant closures and downsizing is a good illustration of the behaviour of 'foot-loose' investors.

investors, in contrast, are *'anchored'* into a national system of innovation and production: they perform knowledge-intensive activities, create higher-pay jobs, build close contacts with domestic R&D units and universities and develop a strong local supplier base.[21] In brief, co-ordinated, mindful investment promotion, STI, human resource and regional development policies are required to embed foreign investors. In this way, skills can be upgraded, local suppliers' innovation capabilities can be improved to boost their competitiveness and intense, mutually beneficial business-academia collaboration can be nurtured. Otherwise, most of the investment 'sweeteners' are wasted if foreign firms only use a given region or country as a cheap, temporary production site.

### 4.3 The EU 2020 Innovation Indicator

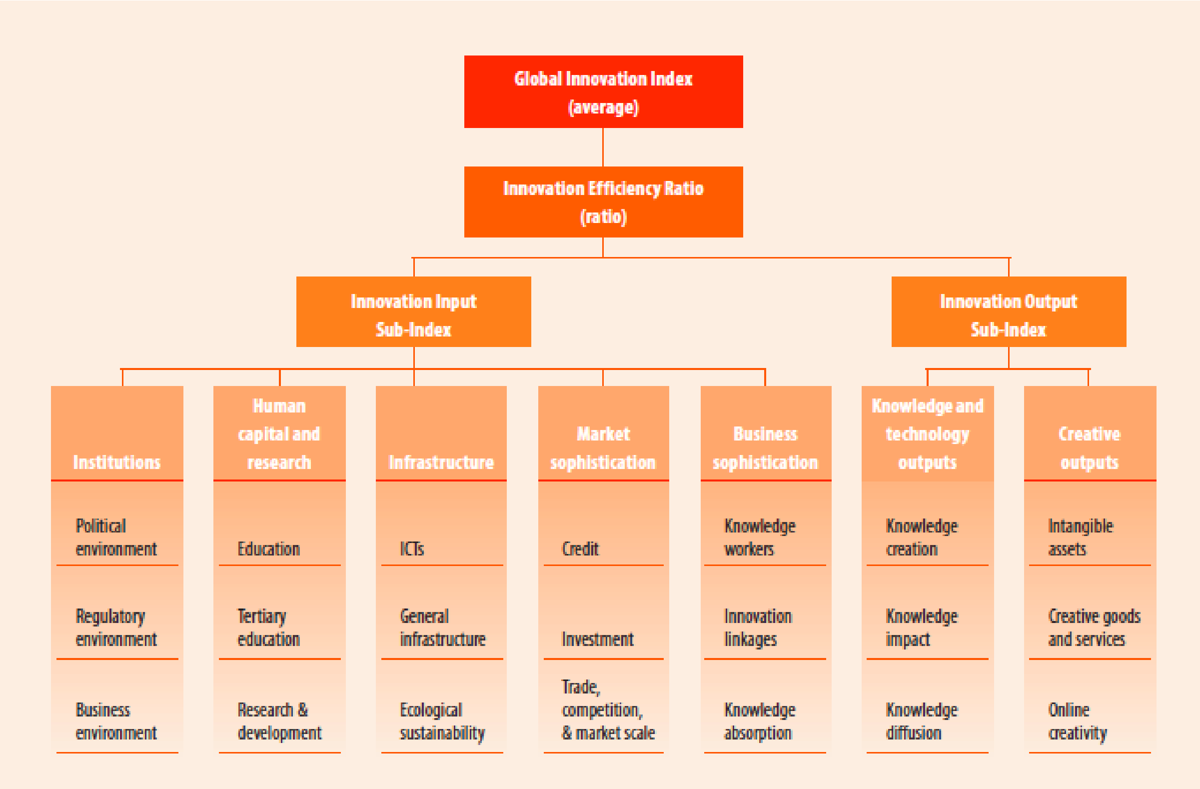
The European Commission introduced the so-called EU 2020 Innovation Indicator in October 2013 to measure progress in achieving the goals of the Europe 2020 Strategy and complement its former headline R&D intensity indicator. Yet, this new indicator is composed of four individual indicators from the EIS/ IUS: patent applications economic significance of knowledge-intensive sectors, trade performance of knowledge-intensive goods and services, and significance of fast-growing firms in innovative sectors. Thus, this apparently new composite indicator 'inherits' and further strengthens the bias of the EIS/ IUS towards the S&T mode innovation. (Janger *et al.*, 2017)

## 5 THE GLOBAL INNOVATION INDEX

Compared to the IUS, the Global Innovation Index (GII) has a significantly broader coverage in two respects: it covers well over 100 countries, and considers 80 indicators, arranged in 7 "pillars". The seven pillars used in the 2016–2019 editions of the GII include: Institutions (7 indicators), Human capital and research (12), Infrastructure (10), Market sophistication (9), Business sophistication (15), Knowledge and technology outputs (14), and Creative outputs (13). The themes considered by each pillar are summarised in Figure 12.

[21] There are important differences among the 'anchored' firms, too. This simple dichotomy is meant just to highlight some elementary policy implications, not as a basis for sound policy recommendations.

**Figure 12: Framework of the Global Innovation Index 2016–2019**




*Source*: Global Innovation Index editions in 2016–2019

To assess the relevance of these 80 indicators, and especially the 'match' between the themes (or headings) captured by the 7 pillars would require a fairly lengthy paper. In other words, the GII indicators are characterised in a somewhat simplified way here.[22] It should be stressed that most elements are indices themselves, that is, not 'stand-alone' indicators. In other words, several methodological weaknesses are likely to remain hidden.

**Pillar 1: Institutions**

Pillar 1 is composed of 3 sub-pillars. The political environment sub-pillar incorporates two indices with the intention to reflect the following aspects: "perceptions of the likelihood that a government might be destabilized" and "the quality of public and civil services, policy formulation, and implementation".

The second sub-pillar, called regulatory environment, is comprised of two indices to capture "perceptions on the ability of the government to formulate and implement cohesive policies that promote the development of the private sector and at evaluating the extent to which the rule of law prevails (in aspects such as contract enforcement, property rights, the police, and the courts)". A third indicator is meant to evaluate "the cost of redundancy dismissal as the sum, in salary weeks, of the cost of advance notice requirements added to severance payments due when terminating a redundant worker".

The third sub-pillar – business environment – is aimed at summarising three aspects directly affecting private entrepreneurial endeavours. It uses the World Bank indices "on the ease of starting a business; the ease of resolving insolvency (based on

[22] For some more detailed comments the GII indicators, see Appendix 4.

the recovery rate recorded as the cents on the dollar recouped by creditors through reorganization, liquidation, or debt enforcement/foreclosure proceedings); and the ease of paying taxes". (Cornell University *et al.*, 2016: 51–52)

*Not all the above elements are institutions ("rules of the game"), and not all are directly related to innovation processes and performance*. It can be argued, though, that the aspects (attempted to be) captured by these indices are relevant to characterise the political, regulatory and business environment for innovation. Among the important missing elements, one should mention legislation on competition,[23] as well as the entrepreneurial culture in a given country.

**Pillar 2: Human capital and research**

Pillar 2 is also comprised of 3 sub-pillars. Sub-pillar 2.1 is composed of several of indicators with the intention to capture achievements at the first two levels of education, namely elementary and secondary education. Education expenditure and school life expectancy are taken as "good proxies for coverage". Government expenditure per pupil at secondary level is meant to indicate "the level of priority given to secondary education by the state". The quality of education is measured via (a) PISA (OECD Programme for International Student Assessment) results indicating 15-year-old students' performances in reading, mathematics, and science, as well as (b) the pupil-teacher ratio.

Sub-pillar 2.2 on tertiary education is designed to measure coverage at this level of education. "(…) priority is given to the sectors traditionally associated with innovation (with a series on the percentage of tertiary graduates in science and engineering, manufacturing, and construction); and the inbound mobility of tertiary students, which plays a crucial role in the exchange of ideas and skills necessary for innovation."

Sub-pillar 2.3 on R&D is meant to capture the level and quality of R&D activities by using the number of researchers (FTE/ million of population), gross expenditures on R&D as percentage of GDP, the R&D expenditures of top global R&D spenders, and the quality of scientific and research organisations proxied by the average score of the top three universities in the QS World University Ranking as of 2015. "These indicators are not aimed at assessing the average level of all institutions within a particular economy." (Cornell University *et al.*, 2016: 52)

Formal education is a crucial factor determining the quality of human capital, no doubt, but life-long learning and other, informal modes of learning are also important. Research is conducted outside universities, too, both by other publicly financed research organisations and businesses. Moreover, the quality of research conducted by these latter types of organisations is not necessarily lower than that at universities. Moreover, university rankings themselves suffer from several major methodological weaknesses. Thus, *the name of this pillar is more 'ambitious' than its actual content*.

**Pillar 3: Infrastructure**

Three sub-pillars form the third pillar of infrastructure: information and communication technologies (ICT), general infrastructure, and ecological sustainability. Sub-pillar 3.1 on ICT is computed by using four indices developed by

[23] The intensity of competition is included in Pillar 4.

international organisations on ICT access, ICT use, on-line service by governments, and on-line participation of citizens. Sub-pillar 3.2 on general infrastructure is composed of "the average of electricity output in kWh per capita; a composite indicator on logistics performance; and gross capital formation, which consists of outlays on additions to the fixed assets and net inventories of the economy, including land improvements (fences, ditches, drains); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings". Sub-pillar 3.3 on ecological sustainability is constructed by using three indicators: "GDP per unit of energy use (a measure of efficiency in the use of energy), the Environmental Performance Index of Yale and Columbia Universities, and the number of certificates of conformity with standard ISO 14001 on environmental management systems issued". (Cornell University *et al.*, 2016: 53)

Ecological sustainability is certainly an important issue, but it is difficult to grasp why it is part of the "Infrastructure" pillar, especially when it is measured by the above three components. These are more relevant to reflect those environmental challenges that require innovation efforts – or the outcome of previous eco-innovation efforts. In other words, *there is a certain mismatch between the name of this pillar and its actual content*.

**Pillar 4: Market sophistication**

The fourth pillar on market sophistication integrates three sub-pillars "structured around market conditions and the total level of transactions". Sub-pillar 4.1 on credit intends to reflect "the ease of getting credit aimed at measuring the degree to which collateral and bankruptcy laws facilitate lending by protecting the rights of borrowers and lenders, as well as the rules and practices affecting the coverage, scope, and accessibility of credit information". Transactions are measured by the total value of domestic credit to the private sector (as a percentage of GDP) as well as by the gross loan portfolio of microfinance institutions (as a percentage of GDP) with the intention to make the method applicable to emerging markets, too.

Sub-pillar 4.2 on investment is composed of the ease of protecting investors index and three indicators on the level of transactions. Besides stock market capitalisation, the total value of shares traded (as percentage of GDP) is also taken into account to show if market size is matched by market dynamism. Data on venture capital deals (a total of 13,703 deals in 95 countries in 2015) are also exploited.

Sub-pillar 4.3 considers trade, competition, and market scale. The market conditions for trade are measured by two indicators: the average tariff rate weighted by import shares and a metric on non-agricultural market access conditions to foreign markets (five major export markets weighted actual applied tariffs for non-agricultural exports). The last indicator is a result from a survey: the intensity of competition in local markets. "Efforts made at finding hard data on competition have so far proved unsuccessful." (Cornell University *et al.*, 2014: 53) Domestic market scale has been added to GII as new indicator to reflect the impact that the size of an economy has on its capacity to introduce and test innovations in the market place. It is measured by an economy's GDP.

**Pillar 5: Business sophistication**

The fifth pillar is intended to capture the level of business sophistication to assess "how conducive firms are to innovation activity". Sub-pillar 5.1 on knowledge workers is built by five indicators: employment in knowledge-intensive services; the availability of formal training at the firm level; R&D performed by business enterprise (BERD) as a percentage of GDP; the percentage of gross expenditures of R&D (GERD) financed by businesses, and the percentage of females employed with advanced degrees.

Sub-pillar 5.2 on innovation linkages exploits data on business-university R&D collaborations, "the prevalence of well-developed and deep clusters", the ratio of GERD financed from abroad, and "the number of deals on joint ventures and strategic alliances. The latter covers a total of 1,512 deals announced in 2015, with firms headquartered in 92 participating economies. In addition, the total number of Patent Cooperation Treaty (PCT) and national office published patent family applications filed by residents in at least two offices proxies for international linkages."

"The rationale behind sub-pillars 5.3 on knowledge absorption (an enabler) and 6.3 on knowledge diffusion (a result) — two sub-pillars designed to be mirror images of each other — is precisely that together they will reveal how good economies are at absorbing and diffusing knowledge. Sub-pillar 5.3 includes five metrics that are linked to sectors with high-tech content or are key to innovation: royalty and license fees payments as a percentage of total trade; high-tech imports (net of re-imports) as a percentage of total imports; imports of communication, computer and information services as a percentage of total trade; and net inflows of foreign direct investment (FDI) as a percentage of GDP. (...) the percentage of research talent in business was added this year to provide a measurement of professionals engaged in the conception or creation of new knowledge, products, processes, methods, and systems, including business management." (Cornell University *et al.*, 2016: 53–54; some obvious mistakes are corrected – A.H.)

The name of this pillar is not explained, although it does not seem to be self-explanatory. It is not clear, either, why firms should be conducive to innovation activity. Usually analyses have a different logic: market and regulatory conditions, that is, factors external to the firms, are assessed if they are conducive for – or hamper – innovation activities performed by businesses. The name of sub-pillar 5.2 (innovation linkages) only partially matches its components, of which two concern R&D activities, and a third one (on patents) is also more relevant to characterise R&D activities than reflect innovation activities. Data on high-tech imports can only partially reflect knowledge absorption.

**Pillar 6: Knowledge and technology outputs**

The sixth pillar is also composed of 3 sub-pillars. Sub-pillar 6.1 on knowledge creation "includes five indicators that are the result of inventive and innovative activities: patent applications filed by residents both at the national patent office and at the international level through the PCT; utility model applications filed by residents at the national office; scientific and technical published articles in peer-reviewed journals; and an economy's number of articles (H) that have received at least H citations".

Sub-pillar 6.2 on knowledge impact is composed of five indicators: increases in labour productivity, the entry density of new firms, spending on computer software, the number of certificates of conformity with standard ISO 9001 on quality management systems issued, and the ratio of high- and medium-high-tech industrial output in total manufacturing output.

Sub-pillar 6.3 on knowledge diffusion "includes four statistics (…) linked to sectors with high-tech content or that are key to innovation: royalty and license fees receipts as a percentage of total trade; high-tech exports (net of re-exports) as a percentage of total exports (net of re-exports); exports of ICT services as a percentage of total trade; and net outflows of FDI as a percentage of GDP." (Cornell University *et al*., 2014: 54–55)

The first sub-pillar is meant to be composed of indicators on "the result of inventive and innovative activities". Yet, *most of these indicators are relevant to characterise R&D (and not innovation) activities*. *As for the knowledge impact sub-pillar, only two of the five components is related to knowledge impacts*. *As for knowledge diffusion*, all the four components of that sub-pillar can indicate knowledge diffusion outside a given country (with certain limitations), and thus *none of these seems to be relevant to characterise knowledge diffusion inside a given country*.

**Pillar 7: Creative outputs**

Sub-pillar on intangible assets includes data on trademark applications by residents at the national office; industrial designs included in applications at a regional or national office; and results obtained via two survey questions on the use of ICTs by businesses in business and organisational models.

Sub-pillar 7.2 on creative goods and services is aimed to capture creativity and the creative outputs of an economy by using five indicators: cultural and creative services exports, including information services, advertising, market research and public opinion polling, and other personal, cultural, and recreational services (as a percentage of total trade); national feature films produced in a given country (per million population); global entertainment and media output (per thousand population); printing and publishing output (as a percentage of total manufacturing output); and creative goods exports (as a percentage of total trade).

Sub-pillar 7.3 on online creativity is composed of four indicators, all by population aged 15–69 years: generic (biz, info, org, net, and com) and country-code top level domains, average monthly edits to Wikipedia, and video uploads on YouTube. "Attempts made to strengthen this sub-pillar with indicators in areas such as Internet and machine learning, blog posting, online gaming, and the development of applications have so far proved unsuccessful." (Cornell University *et al*., 2014: 55–56)

It is not clear why "the use of ICTs in business and organizational models" is an output indicator. Only a small fraction of printing and publishing output is a creative output, with the bulk being revenues to cover printing costs (paper, other raw materials and labour). It would be rather costly to establish what portion of video uploads on YouTube constitutes creative output.

In sum, *the GII is a remarkable effort both in terms of its geographic and thematic coverage, but it suffers from severe weaknesses concerning business innovation activities*. In several cases there is a *non-negligible mismatch between the 'headline' notions (pillars and their sub-pillars) and the actual components (indices or indicators) selected*. Just as in the case of the EIS and IUS indicators, there is *a bias towards R&D-based (S&T mode) innovations, and thus the DUI mode is eclipsed*. It is even worse when *R&D and innovation are conflated*.

## 6 SUMMARY AND CONCLUSIONS

This paper has reviewed innovation indicators from theoretical and policy perspectives. The main findings can be summarised as follows. Various economics paradigms treat innovation (if not neglect it altogether) in diametrically different ways: they consider different notions as crucial ones (e.g. risk vs. uncertainty, information vs. various forms, types and sources of knowledge, skills and learning capabilities and processes); offer diverse justifications (policy rationales) for government interventions; interpret the significance of various types of inputs, efforts, and results differently, and thus – implicitly – identify different 'targets' for measurement, monitoring and analytical purposes (what phenomena, inputs, capacities, processes, outcomes and impacts are to be measured and assessed).

The science-push model of innovation, reinforced by the sophisticated – and thus appealing and compelling – models of mainstream economics emphasises the economic impacts of R&D-based innovation efforts, advances the market failure argument and the concomitant set of policy advice. Hence it focuses the attention of decision-makers and analysts to the so-called S&T mode of innovation. Measurement and monitoring systems influenced by this way of thinking – the European Innovation Scoreboard of the European Commission, as well as the Global Innovation Index – tend to pay attention mainly to the S&T mode of innovation, at the expense of the so-called DUI mode of innovation. It is a major concern, however, as the latter one is equally important from the point of view of enhancing productivity, creating jobs and improving competitiveness.

In contrast, evolutionary economics of innovation – in line with the networked model of innovation – stresses the systemic nature of innovation and thus advocates rectifying any systemic failure that hinders the generation, circulation and exploitation of any type of knowledge required for successful innovation processes. This way of thinking has influenced the measurement and monitoring practices of the European Commission to a significantly lesser extent than mainstream economics.

The EIS/ IUS indicators in principle could be useful in settings where the dominant mode of innovation is the S&T mode. In practice, however, both the ST and DUI modes of innovation are fairly important. (Jensen *et al.*, 2007) Moreover, the so-called Summary Innovation Index – calculated from the IUS indicators – does not provide sufficient information to assess a given innovation system: its low value could reflect either a low level of innovation activities altogether or a low level of R&D-based innovation activities (while other types of innovations are abundant). Yet, that is a fairly important distinction both from an analytical and a practical (policy) point of view: these two innovation systems are fundamentally different, necessitating bespoke policy actions. Analysts and policy-makers dealing with innovation, therefore, should pay attention to both R&D-based (S&T) and non-R&D-based (DUI) innovations. In other words, new indicators that better reflect the evolutionary processes of learning and innovation would be needed to support STI policy-making. Developing, piloting and then widely collecting these new indicators would be a major, demanding and time-consuming project, necessitating extensive international co-operation.

There is a fairly strong – sometimes implicit, at other times rather explicit – pressure to devise so-called composite indicators to compress information into a single figure in order to compile eye-catching, easy-to-digest scoreboards. A major source of complication is choosing an appropriate weight to be assigned to each component. By conducting sensitivity analyses of the 2005 European Innovation Scoreboard (EIS), Grupp and Schubert (2010: 72) have shown how unstable the rank configuration is when the weights are changed. Besides assigning weights, three other ranking methods are also widely used, namely: unweighted averages, Benefit of the Doubt (BoD) and principal component analysis. Comparing these ranking methods, the authors conclude: "Not only utilizing the rankings highly sensitive to weighting (…), but even using accepted approaches like BoD or factor analysis may result in drastically changing rankings." (ibid: 74) Hence, they propose using multidimensional representations, e.g. spider charts to reflect the multidimensional character of innovation processes and performance. That would enable analysts and policy-makers to identify strengths and weaknesses, thus pinpoint more precise targets for policy actions. (ibid: 77)

Other researchers also emphasise the need for a sufficiently detailed characterisation of innovation processes. For example, a family of five indicators – R&D, design, technological, skill, and innovation intensities – offers a more diversified picture on innovativeness than the Summary Innovation Index of the EIS. (Laestadius *et al.*, 2005) Using Norwegian data, they demonstrate that the suggested method can capture variety in knowledge formation and innovativeness both within and between sectors. It thus supports a more accurate understanding of creativity and innovativeness inside and across various sectors, directs policy-makers' attention to this diversity (suppressed by the OECD classification of sectors), and thus can better serve policy needs.

In other words, given the diversity among innovation systems, one should be very careful when trying to draw policy lessons from the 'rank' of a country as 'measured' by a composite indicator. A scoreboard can only be constructed by using the same set of indicators across all countries, and by applying an identical method to calculate the composite index. Yet, it is important to realise that poor performance signalled by a composite indicator, leading to a low rank on a certain scoreboard, does not automatically identify the area(s) necessitating the most urgent policy actions.

In contrast, a high rank on a scoreboard, such as Sweden's top position in the 2015 Innovation Union Scoreboard – achieved in several other years, too –, does not necessarily reflect a satisfactory performance. By taking into account the input and output nature of various IUS indicators Edquist *et al.* (2018) calculated the productivity of national innovation systems covered by the IUS and using this assessment – which is, no doubt, highly relevant from a policy point of view – Sweden ranks a mere 23.

The most recent edition of the Oslo Manual also highlights several disadvantages of composite indicators. These include the frequently limited theoretical basis of the composite indicators, which can easily lead to "problematic combinations of indicators, such as indicators for inputs and outputs". Weighting of different indicators – as already stressed by Grupp and Schubert (2010) is also an issue, as it "is often dependent on the subjective views of those constructing the composite index. Factors that are minor contributors to innovation can be given as much weight as major ones." Further, "structural differences between countries are seldom taken into account when calculating composite performance indexes. Aggregation results in a loss of detail, which can hide potential weaknesses and increase the difficulty in identifying remedial action." (OECD/ Eurostat, 2018: 220)

Analysts and policy-makers*, therefore, need to avoid the trap of paying too much attention to simplifying ranking exercises*. Instead, it is of utmost importance to conduct detailed, thorough comparative analyses, identifying the reasons for a disappointing performance, as well as the sources of – opportunities for – balanced, and sustainable, socio-economic development.

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## APPENDIX 1: CLASSICAL ECONOMISTS ON CHANGE PROCESSES

A fundamental notion in *Adam Smith*'s theory is the division of labour, that is, an organisational innovation, using modern terminology. In developing his arguments, further aspects of innovations are also explained – such as learning, introduction of machinery, better organisation of production processes – and various sources of innovations are mentioned.

> "This great increase of the quantity of work which, in consequence of the division of labour, the same number of people are capable of performing, is owing to three different circumstances; first to the increase of dexterity in every particular workman; secondly, to the saving of the time which is commonly lost in passing from one species of work to another; and lastly, to the invention of a great number of machines which facilitate and abridge labour, and enable one man to do the work of many. (…)
>
> (…) the invention of all those machines by which labour is so much facilitated and abridged, seems to have been originally owing to the division of labour. Men are much more likely to discover easier and readier methods of attaining any object, when the whole attention of their minds is directed towards that single object, than when it is dissipated among a great variety of things. But in consequence of the division of labour, the whole of every man's attention comes naturally to be directed towards some one very simple object. (…) A great part of the machines made use of in those manufactures in which labour is most subdivided, were originally the inventions of common workmen, who, being each of them employed in some very simple operation, naturally turned their thoughts towards finding out easier and readier methods of performing it. Whoever has been much accustomed to visit such manufactures, must frequently have been shewn very pretty machines, which were the inventions of such workmen, in order to facilitate and quicken their own particular part of the work. (…)
>
> All the improvements in machinery, however, have by no means been the inventions of those who had occasion to use the machines. Many improvements have been made by the ingenuity of the makers of the machines, when to make them became the business of a peculiar trade; and some by that of those who are called philosophers or men of speculation, whose trade it is not to do any thing, but to observe every thing; and who, upon that account, are often capable of combining together the powers of the most distant and dissimilar objects." (Smith, 1776/1904: sections 1.1.5; 1.1.8; 1.1.9)
>
> Just to mention another 'modern' issue, Smith (1776) also devoted a chapter to describe the co-evolution of transport technologies, markets, and division of labour, leading to economic development. His examples stretch from the case of ancient Egypt to his contemporary Holland in time and cover Africa, Asia and Europe in space. (Book I, Ch. III)

*John Stuart Mill* also identifies various types of innovations – technical, managerial, organisational, and financial –, and distinguishes invention from innovation (practical use) and incremental innovations during diffusion. Using modern terms, he also speaks of product and process innovations. Finally, he stresses the importance of diffusing new knowledge.

> "§4. The third element which determines the productiveness of the labour of a community, is the skill and knowledge therein existing; whether it be the skill and knowledge of the labourers themselves, or of those who direct their labour. No illustration is requisite to show how the efficacy of industry is promoted by the

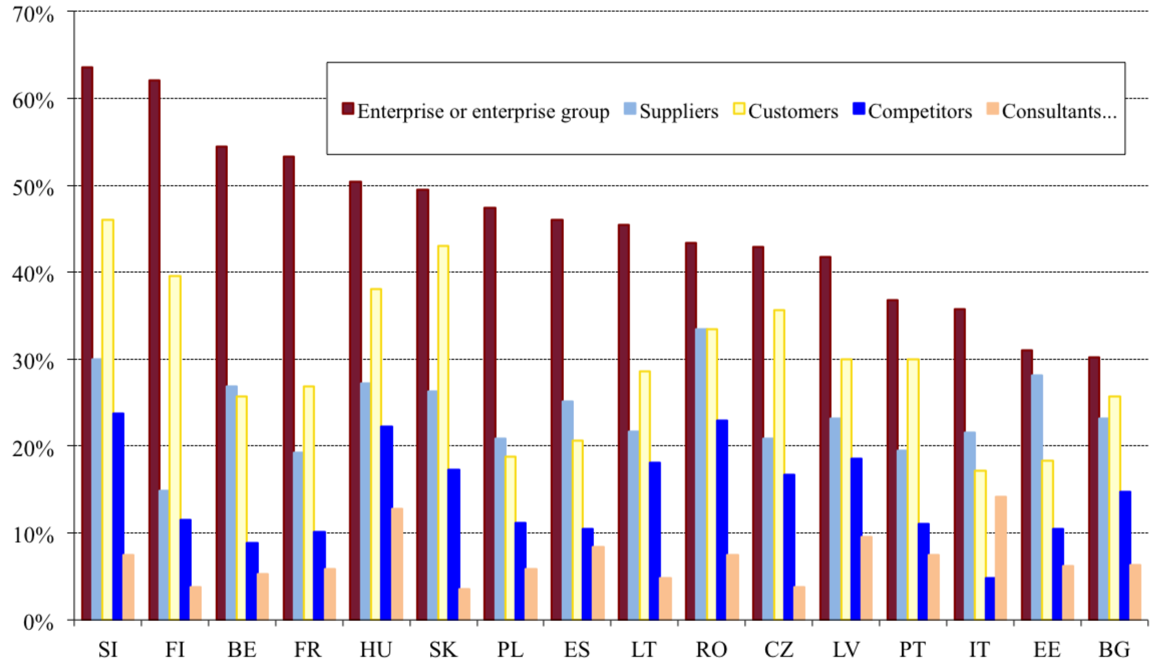
> manual dexterity of those who perform mere routine processes; by the intelligence of those engaged in operations in which the mind has a considerable part; and by the amount of knowledge of natural powers and of the properties of objects, which is turned to the purposes of industry. That the productiveness of the labour of a people is limited by their knowledge of the arts of life, is self-evident; and that any progress in those arts, any improved application of the objects or powers of nature to industrial uses, enables the same quantity and intensity of labour to raise a greater produce.
>
> One principal department of these improvements consists in the invention and use of tools and machinery. (...)
>
> The use of machinery is far from being the only mode in which the effects of knowledge in aiding production are exemplified. In agriculture and horticulture, machinery is only now [1852] beginning to show that it can do anything of importance, beyond the invention and progressive improvement of the plough and a few other simple instruments. The greatest agricultural inventions have consisted in the direct application of more judicious processes to the land itself, and to the plants growing on it (...). In manufactures and commerce, some of the most important improvements consist in economizing time; in making the return follow more speedily upon the labour and outlay. There are others of which the advantage consists in economy of material.
>
> §5. But the effects of the increased knowledge of a community in increasing its wealth, need the less illustration as they have become familiar to the most uneducated, from such conspicuous instances as railways and steam-ships. A thing not yet so well understood and recognised, is the economical value of the general diffusion of intelligence among the people." (Mill, 1848/1909: Book I, paragraphs 1.7.9–1.7.12)

In his major book, Ricardo has also analysed major marketing and technological changes, for example "Sudden Changes in the Channels of Trade", "the influence of machinery on the interests of the different classes of society", on output, trade, profit, and employment. (Ricardo, 1817/1821: chapters 19 and 31)

The way, in which Karl Marx has addressed technological changes and economic development is analysed in detail by many authors, most notably by Schumpeter (1942) [cf. Rosenberg, 2011], as well as by contemporary scholars of economics of innovation (e.g., Clark and Juma, 1988; Mazzolini and Nelson, 2013), and thus there is no need to stress here that Marx had also paid attention to novel solutions.

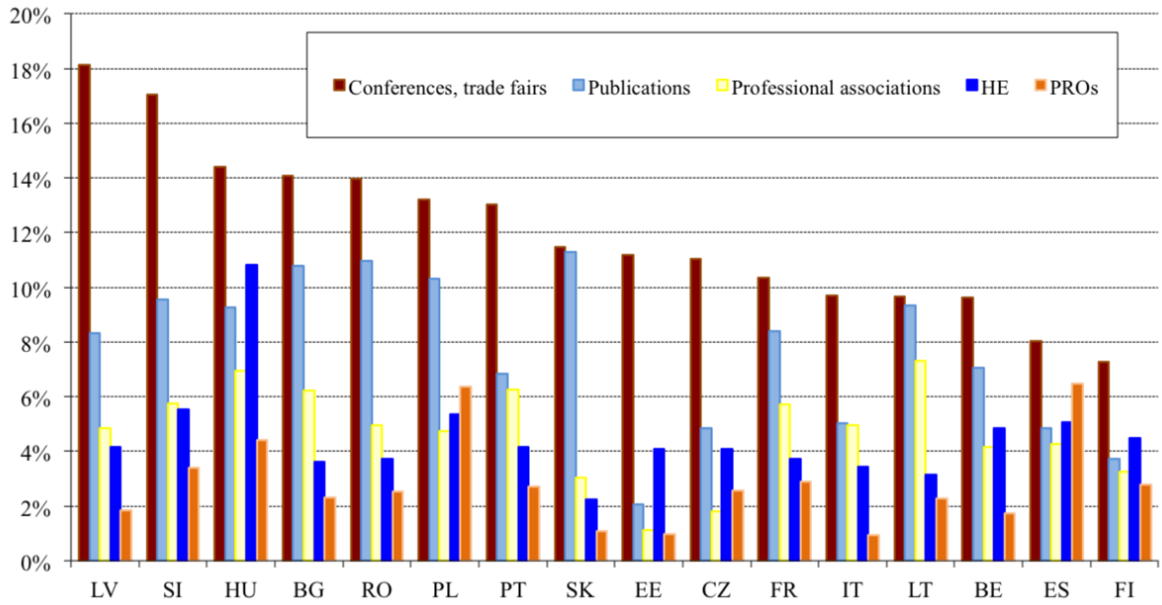
## Appendix 2: Sources of information for innovation and types of innovation co-operation partners

**Figure A1: Highly important 'business' sources of information for product and process innovation, selected EU members, 2008–2010**



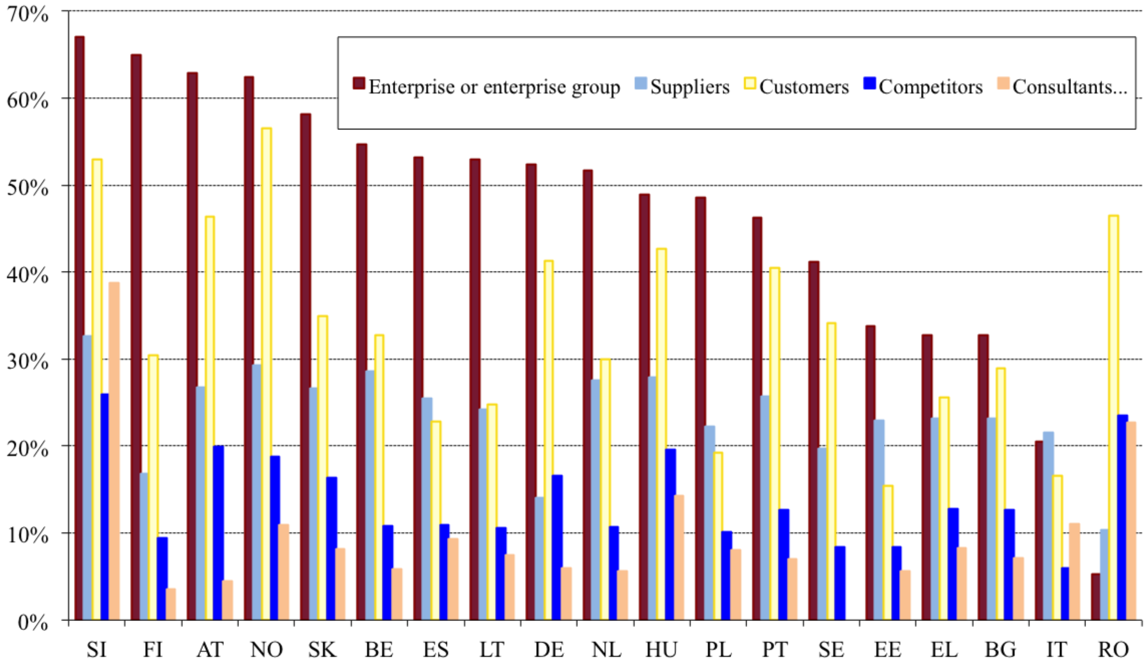

*Source*: Eurostat, CIS2010

**Figure A2: Highly important 'scientific' sources of information for product and process innovation, selected EU members, 2008–2010**



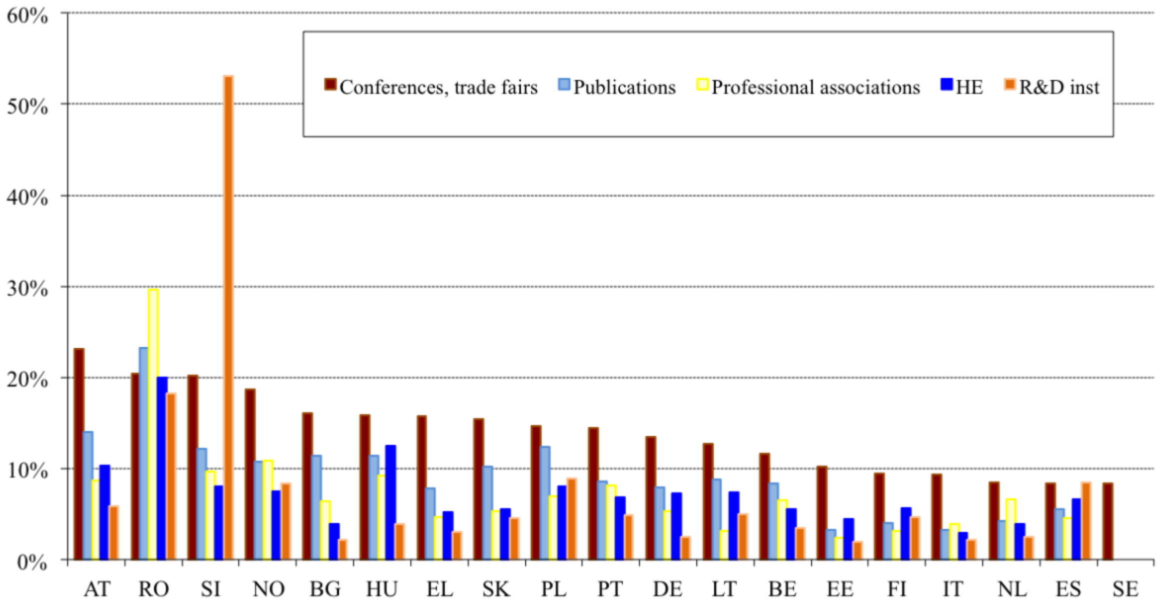

*Source*: Eurostat, CIS2010

**Figure A3: Highly important 'business' sources of information for product and process innovation, selected EU members, 2010–2012**



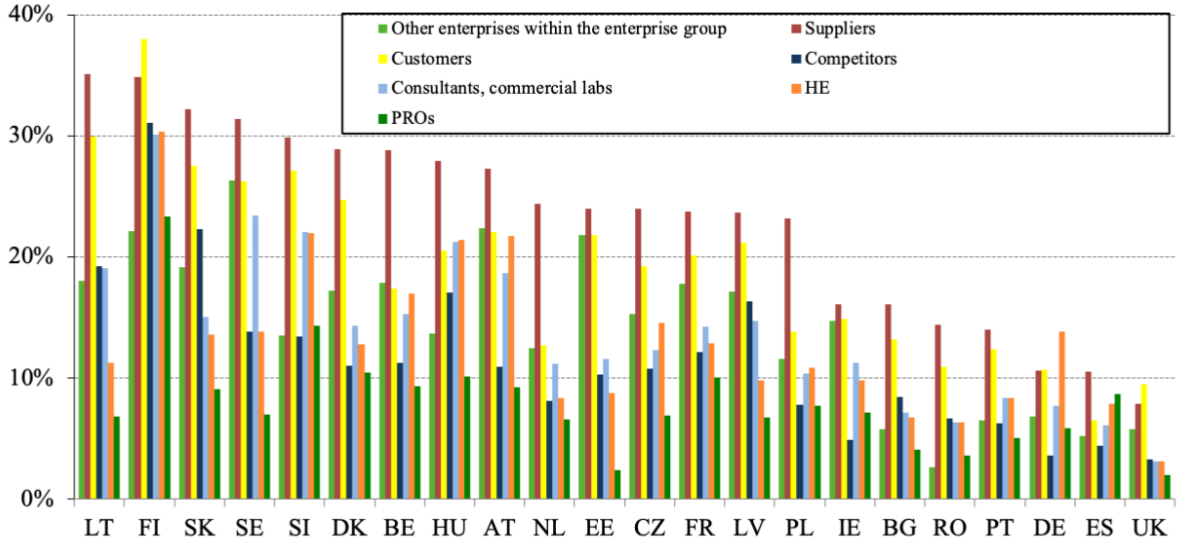

*Source*: Eurostat, CIS2012

**Figure A4: Highly important 'scientific' sources of information for product and process innovation, selected EU members, 2010–2012**



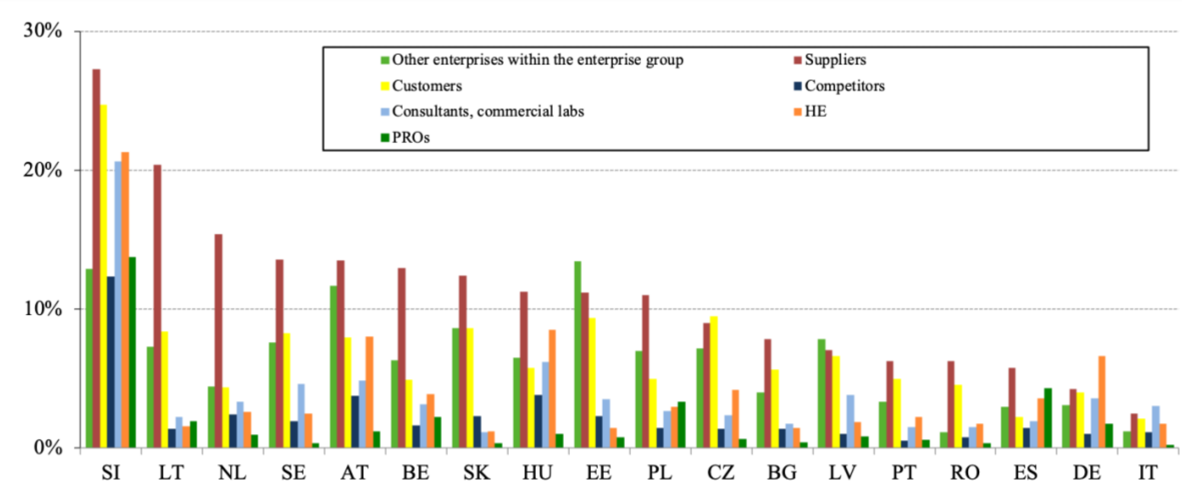

*Source*: Eurostat, CIS2012

**Figure A5: Types of innovation co-operation partners, 2008–2010**



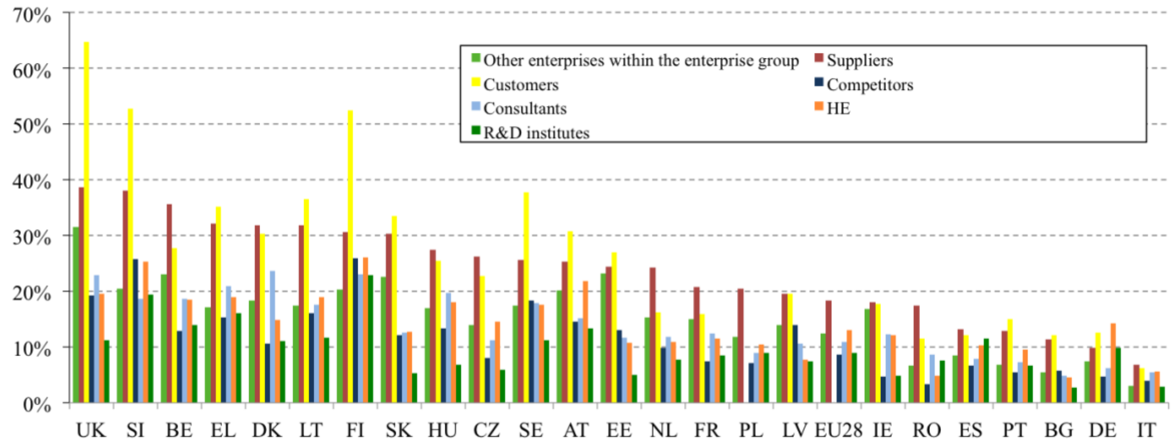

*Source*: Eurostat, CIS2010

**Figure A6: Most valuable methods of innovation co-operation, 2008–2010**



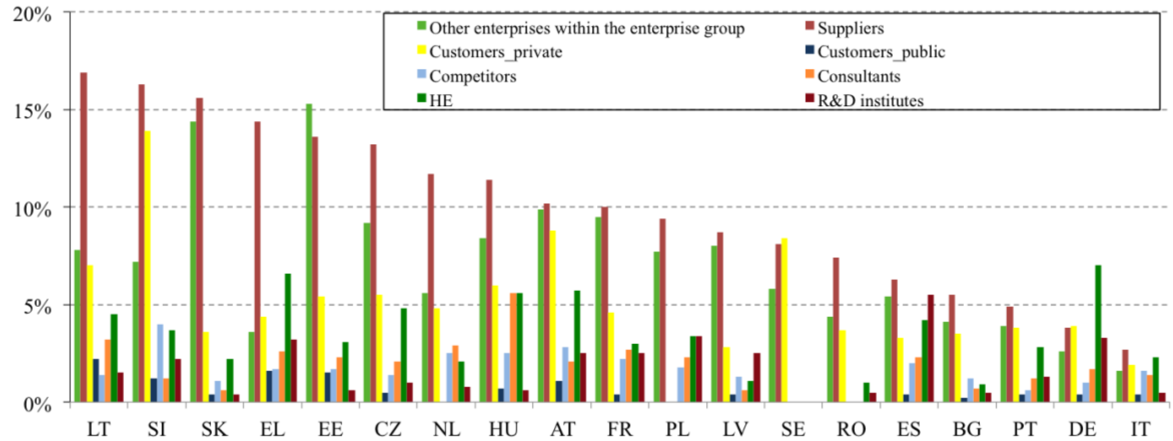

*Source*: Eurostat, CIS2010

## Figure A7: Types of innovation co-operation partners, 2010–2012




*Source*: Eurostat, CIS2012

## Figure A8: Most valuable methods of innovation co-operation, 2010–2012




*Source*: Eurostat, CIS2012

## APPENDIX 3: THE EIS AND IUS INDICATORS

The indicators used in particular editions of the EIS and IUS are presented and assessed in this Appendix, except for the first (2002) and last (2017–2019) editions, which are presented in the main body of this paper.

The indicators used in 2006 and 2007 were identical, and thus are presented in a single table (Table A4). Further, the indicators used for the 2010, 2011 and 2013 editions of the Innovation Union Scoreboard were also identical, and thus these are presented in Table A7.[24]

There was only a slight change introduced in 2015: the indicator called "Contribution of medium and high-tech product exports to the trade balance" was replaced by "Exports of medium and high-technology products as a share of total product exports". This change had no effect on the nature of the indicators, and thus the 2014–2016 editions of the IUS/ EIS is presented together in Table A8.

[24] The numbering convention was changed in 2013: in that year IUS 2013 was published, while following the previous convention it would have been called IUS 2012.

**Table A1: The 2003 European Innovation Scoreboard indicators**

| | Relevance for R&D-based innovation | Relevance for non-R&D-based innovation |
|---|---|---|
| **1 Human resources** | | |
| S&E graduates (ISCED 5a and above) per 1000 population aged 20-29 | X | |
| Population with tertiary education (% of 25–64 years age class) | b | b |
| Participation in life-long learning (% of 25–64 years age class) | b | b |
| Employment in medium-high and high-tech manufacturing (% of total workforce) | X | |
| Employment in high-tech services (% of total workforce) | X | |
| **2 Knowledge creation** | | |
| Public R&D expenditures (GERD – BERD) (% of GDP) | X | |
| Business expenditures on R&D (BERD) (% of GDP) | X | |
| EPO high-tech patent applications (per million population) | X | |
| USPTO high-tech patent applications (per million population) | X | |
| EPO patent applications (per million population) | x | |
| USPTO patents granted (per million population) | x | |
| **3 Transmission and application of knowledge** | | |
| SMEs innovating in-house (% of manufacturing and % of services SMEs) | b | b |
| SMEs involved in innovation co-operation (% of manufacturing and % of services SMEs) | b | b |
| Innovation expenditures (% of all turnover in manufacturing and % of all turnover in services) | b | b |
| **4 Innovation finance, output and markets** | | |
| Share of high-tech venture capital investment | X | |
| Share of early stage venture capital in GDP | x | |
| Sales of 'new to market' products (% of all turnover in manufacturing and % of all turnover in services) | b | b |
| Sales of 'new to the firm but not new to the market' products (% of all turnover in manufacturing and % of all turnover in services) | b | b |
| Internet access/ use (composite of home internet access and the share of SMEs with own website) | b | b |
| ICT expenditures (% of GDP) | b | b |
| Share of manufacturing value-added in high-tech | X | |

*Legend:*
X: only relevant
x: mainly relevant
b: relevant for both types
*Source*: own compilation, drawing on the detailed definition of indicators, EC (2003b)
*Notes*: Public R&D expenditures do not equal to GERD – BERD; rather, it should be the sum of government-funded parts of BERD, GOVERD, and HERD

**Table A2: The 2004 European Innovation Scoreboard indicators**

| | Relevance for R&D-based innovation | Relevance for non-R&D-based innovation |
|---|---|---|
| **1 Human resources** | | |
| S&E graduates (ISCED 5a and above) per 1000 population aged 20-29 | X | |
| Population with tertiary education (% of 25–64 years age class) | b | b |
| Participation in life-long learning (% of 25–64 years age class) | b | b |
| Employment in medium-high and high-tech manufacturing (% of total workforce) | X | |
| Employment in high-tech services (% of total workforce) | X | |
| **2 Knowledge creation** | | |
| Public R&D expenditures (GERD – BERD) (% of GDP) | X | |
| Business expenditures on R&D (BERD) (% of GDP) | X | |
| EPO high-tech patent applications (per million population) | X | |
| USPTO high-tech patents granted (per million population) | X | |
| EPO patent applications (per million population) | x | |
| USPTO patents granted (per million population) | x | |
| **3 Transmission and application of knowledge** | | |
| SMEs innovating in-house (% of all SMEs) | b | b |
| SMEs involved in innovation co-operation (% of all SMEs) | b | b |
| Innovation expenditures (% of all turnover) | b | b |
| Share of SMEs that use non-technical change (% of all SMEs) | | x |
| **4 Innovation finance, output and markets** | | |
| Share of high-tech venture capital investment | X | |
| Share of early stage venture capital in GDP | x | |
| Sales of 'new to market' products (% of all turnover) | b | b |
| Sales of 'new to the firm but not new to the market' products (% of all turnover) | b | b |
| Internet access/ use (composite of home and firms' internet access) | b | b |
| ICT expenditures (% of GDP) | b | b |
| Share of manufacturing value-added in high-tech | X | |

*Legend:*
X: only relevant
x: mainly relevant
b: relevant for both types
*Source*: own compilation, drawing on the detailed definition of indicators, EC (2004)
*Notes*: Public R&D expenditures do not equal to GERD – BERD; rather, it should be the sum of government-funded parts of BERD, GOVERD, and HERD

**Table A3: The 2005 European Innovation Scoreboard indicators**

| | Relevance for R&D-based innovation | Relevance for non-R&D-based innovation |
|---|---|---|
| **1 Innovation drivers** | | |
| New S&E graduates (ISCED 5a and above) per 1000 population aged 20-29 | X | |
| Population with tertiary education (% of 25–64 years age class) | b | b |
| Broadband penetration rate (number of broadband lines per 100 population) | b | b |
| Participation in life-long learning (% of 25–64 years age class) | b | b |
| Youth education attainment level (% of population aged 20-24 having completed at least upper secondary education) | b | b |
| **2 Knowledge creation** | | |
| Public R&D expenditures (GERD – BERD) (% of GDP) | X | |
| Business expenditures on R&D (BERD) (% of GDP) | X | |
| Share of medium-high-tech and high-tech R&D (% of manufacturing R&D expenditures) | X | |
| Share of enterprises receiving public funding for innovation | x | |
| Share of university R&D expenditures financed by business sector | X | |
| **3 Innovation & entrepreneurship** | | |
| SMEs innovating in-house (% of all SMEs) | b | b |
| Innovative SMEs co-operating with others (% of SMEs) | b | b |
| Innovation expenditures (% of all turnover) | b | b |
| Early stage venture capital (% of GDP) | x | |
| ICT expenditures (% of GDP) | b | b |
| SMEs using non-technical change (% of all SMEs) | | x |
| **4 Application** | | |
| Employment in high-tech services (% of total workforce) | X | |
| Exports of high technology products as a share of total exports | X | |
| Sales of 'new to market' products (% of all turnover) | b | b |
| Sales of 'new to the firm but not new to the market' products (% of all turnover) | b | b |
| Employment in medium-high and high-tech manufacturing (% of total workforce) | X | |
| **5 Intellectual property** | | |
| EPO patents per million population | x | |
| USPTO patents per million population | x | |
| Triadic patent families per million population | x | |
| New community trademarks per million population | b | b |
| New community industrial designs per million population | b | b |

*Legend:*
X: only relevant
x: mainly relevant
b: relevant for both types
*Source*: own compilation, drawing on the detailed definition of indicators, EC (2005)
*Notes*: Public R&D expenditures do not equal to GERD – BERD; rather, it should be the sum of government-funded parts of BERD, GOVERD, and HERD

**Table A4: The 2006 and 2007 European Innovation Scoreboard indicators**

| | Relevance for R&D-based innovation | Relevance for non-R&D-based innovation |
|---|---|---|
| **1 Innovation drivers** | | |
| New S&E graduates (ISCED 5a and above) per 1000 population aged 20-29 | X | |
| Population with tertiary education (% of 25–64 years age class) | b | b |
| Broadband penetration rate (number of broadband lines per 100 population) | b | b |
| Participation in life-long learning (% of 25–64 years age class) | b | b |
| Youth education attainment level (% of population aged 20-24 having completed at least upper secondary education) | b | b |
| **2 Knowledge creation** | | |
| Public R&D expenditures (GERD – BERD) (% of GDP) | X | |
| Business expenditures on R&D (BERD) (% of GDP) | X | |
| Share of medium-high-tech and high-tech R&D (% of manufacturing R&D expenditures) | X | |
| Share of enterprises receiving public funding for innovation | x | |
| **3 Innovation & entrepreneurship** | | |
| SMEs innovating in-house (% of all SMEs) | b | b |
| Innovative SMEs co-operating with others (% of SMEs) | b | b |
| Innovation expenditures (% of all turnover) | b | b |
| Early stage venture capital (% of GDP) | x | |
| ICT expenditures (% of GDP) | b | b |
| SMEs using non-technical change (% of all SMEs) | | x |
| **4 Application** | | |
| Employment in high-tech services (% of total workforce) | X | |
| Exports of high technology products as a share of total exports | X | |
| Sales of 'new to market' products (% of all turnover) | b | b |
| Sales of 'new to the firm but not new to the market' products (% of all turnover) | b | b |
| Employment in medium-high and high-tech manufacturing (% of total workforce) | X | |
| **5 Intellectual property** | | |
| EPO patents per million population | x | |
| USPTO patents per million population | x | |
| Triadic patent families per million population | x | |
| New community trademarks per million population | b | b |
| New community industrial designs per million population | b | b |

*Legend:*
X: only relevant
x: mainly relevant
b: relevant for both types
*Source*: own compilation, drawing on the list of indicators, MERIT and EC JRC (2006)
*Notes*: Public R&D expenditures do not equal to GERD – BERD; rather, it should be the sum of government-funded parts of BERD, GOVERD, and HERD

**Table A5: The 2008 European Innovation Scoreboard indicators**

| | Relevance for R&D-based innovation | Relevance for non-R&D-based innovation |
|---|---|---|
| **1.1 Human resources** | | |
| S&E and SSH graduates per 1000 population aged 20-29 (first stage of tertiary education) | x | |
| S&E and SSH doctorate graduates per 1000 population aged 20-29 (second stage of tertiary education) | x | |
| Population with tertiary education (% of 25–64 years age class) | b | b |
| Participation in life-long learning (% of 25–64 years age class) | b | b |
| Youth education attainment level (% of population aged 20-24 having completed at least upper secondary education) | b | b |
| **1.2 Finance and support** | | |
| Public R&D expenditures (GERD – BERD) (% of GDP) | X | |
| Venture capital (% of GDP) | x | |
| Private credit (relative to GDP) | b | b |
| Broadband access by firms (% of firms) | b | b |
| **2.1 Firm investments** | | |
| Business expenditures on R&D (BERD) (% of GDP) | X | |
| IT expenditures (% of GDP) | b | b |
| Non-R&D innovation expenditures (% of turnover) | | x |
| **2.2 Linkages & entrepreneurship** | | |
| SMEs innovating in-house (% of all SMEs) | b | b |
| Innovative SMEs collaborating with others (% of SMEs) | b | b |
| Firm renewal (SME entries plus exits) (% of SMEs) | b | b |
| Public-private co-publications per million population | X | |
| **2.3 Throughputs** | | |
| EPO patents per million population | x | |
| Community trademarks per million population | b | b |
| Community designs per million population | b | b |
| Technology Balance of Payments flows (% of GDP) | X | |
| **3.1 Innovators** | | |
| SMEs introducing product or process innovations (% of SMEs) | b | b |
| SMEs introducing marketing or organisational innovations (% of SMEs) | | X |
| Resource efficiency innovators [unweighted average of: Share of innovators where innovation has significantly reduced labour costs (% of firms) and Share of innovators where innovation has significantly reduced the use of materials and energy (% of firms)] | b | b |
| **3.2 Economic effects** | | |
| Employment in medium-high and high-tech manufacturing (% of total workforce) | X | |
| Employment in knowledge-intensive services (% of total workforce) | X | |
| Medium and high-tech manufacturing exports (% of total exports | X | |
| Knowledge-intensive services exports (% of total services exports) | X | |
| New-to-market sales (% of turnover) | b | b |
| New-to-firm sales (% of turnover) | b | b |

*Legend:*
X: only relevant
x: mainly relevant
b: relevant for both types
*Source*: own compilation, drawing on the list of indicators, EC (2009a)
*Notes*: Public R&D expenditures do not equal to GERD – BERD; rather, it should be the sum of government-funded parts of BERD, GOVERD, and HERD

**Table A6: The 2009 European Innovation Scoreboard indicators**

| | Relevance for R&D-based innovation | Relevance for non-R&D-based innovation |
|---|---|---|
| **1.1 Human resources** | | |
| S&E and SSH graduates per 1000 population aged 20-29 (first stage of tertiary education) | x | |
| S&E and SSH doctorate graduates per 1000 population aged 20-29 (second stage of tertiary education) | x | |
| Population with tertiary education (% of 25–64 years age class) | b | b |
| Participation in life-long learning (% of 25–64 years age class) | b | b |
| Youth education attainment level (% of population aged 20-24 having completed at least upper secondary education) | b | b |
| **1.2 Finance and support** | | |
| Public R&D expenditures (GERD – BERD) (% of GDP) | X | |
| Venture capital (% of GDP) | x | |
| Private credit (relative to GDP) | b | b |
| Broadband access by firms (% of firms) | b | b |
| **2.1 Firm investments** | | |
| Business expenditures on R&D (BERD) (% of GDP) | X | |
| IT expenditures (% of GDP) | b | b |
| Non-R&D innovation expenditures (% of turnover) | | x |
| **2.2 Linkages & entrepreneurship** | | |
| SMEs innovating in-house (% of all SMEs) | b | b |
| Innovative SMEs collaborating with others (% of SMEs) | b | b |
| Firm renewal (SME entries plus exits) (% of SMEs) | b | b |
| Public-private co-publications per million population | X | |
| **2.3 Throughputs** | | |
| EPO patents per million population | x | |
| Community trademarks per million population | b | b |
| Community designs per million population | b | b |
| Technology Balance of Payments flows (% of GDP) | X | |
| **3.1 Innovators** | | |
| SMEs introducing product or process innovations (% of SMEs) | b | b |
| SMEs introducing marketing or organisational innovations (% of SMEs) | | X |
| Share of innovators where innovation has significantly reduced labour costs (% of firms) | b | b |
| Share of innovators where innovation has significantly reduced the use of materials and energy (% of firms) | b | b |
| **3.2 Economic effects** | | |
| Employment in medium-high and high-tech manufacturing (% of total workforce) | X | |
| Employment in knowledge-intensive services (% of total workforce) | X | |
| Medium and high-tech manufacturing exports (% of total exports | X | |
| Knowledge-intensive services exports (% of total services exports) | X | |
| New-to-market sales (% of turnover) | b | b |
| New-to-firm sales (% of turnover) | b | b |

*Legend:*
X: only relevant
x: mainly relevant
b: relevant for both types
*Source*: own compilation, drawing on the list of indicators, EC (2010a)
*Notes*: Public R&D expenditures do not equal to GERD – BERD; rather, it should be the sum of government-funded parts of BERD, GOVERD, and HERD

**Table A7: The 2010, 2011, and 2013 Innovation Union Scoreboard indicators**

| | Relevance for R&D-based innovation | Relevance for non-R&D-based innovation |
|---|---|---|
| **1.1 Human resources** | | |
| New doctorate graduates (ISCED 6) per 1000 population aged 25-34 | X | |
| Percentage population aged 30-34 having completed tertiary education | b | b |
| Percentage youth aged 20-24 having attained at least upper secondary level education | b | b |
| **1.2 Open, excellent and attractive research systems** | | |
| International scientific co-publications per million population | X | |
| Scientific publications among the top 10% most cited publications worldwide as % of total scientific publications of the country | X | |
| Non-EU doctorate students[i] as a % of all doctorate students | X | |
| **1.3 Finance and support** | | |
| R&D expenditure in the public sector as % of GDP | X | |
| Venture capital investment as % of GDP | x | |
| **2.1 Firm investments** | | |
| R&D expenditure in the business sector as % of GDP | X | |
| Non-R&D innovation expenditures as % of turnover | | X |
| **2.2 Linkages & entrepreneurship** | | |
| SMEs innovating in-house as % of SMEs | b | b |
| Innovative SMEs collaborating with others as % of SMEs | b | b |
| Public-private co-publications per million population | X | |
| **2.3 Intellectual assets** | | |
| PCT patents applications per billion GDP (in PPS€) | X | |
| PCT patent applications in societal challenges per billion GDP (in PPS€) (environment-related technologies; health) | X | |
| Community trademarks per billion GDP (in PPS€) | | X |
| Community designs per billion GDP (in PPS€) | | X |
| **3.1 Innovators** | | |
| SMEs introducing product or process innovations as % of SMEs | b | b |
| SMEs introducing marketing or organisational innovations as % of SMEs | | X |
| **3.2 Economic effects** | | |
| Employment in knowledge-intensive activities (manufacturing and services) as % of total employment | x | |
| Contribution of medium and high-tech product exports to the trade balance | x | |
| Knowledge-intensive services exports as % total service exports | x | |
| Sales of new to market and new to firm innovations as % of turnover | b | b |
| License and patent revenues from abroad as % of GDP | X | |

*Legend:*
X: only relevant
x: mainly relevant
b: relevant for both types
*Source*: own compilation, drawing on the detailed definition of indicators, Hollanders and Tarantola (2011)
[i] It is a somewhat strict definition of openness, which only takes into account non-EU doctorate students.

**Table A8: The 2014–2016 IUS/ EIS indicators***

| | Relevance for R&D-based innovation | Relevance for non-R&D-based innovation |
|---|---|---|
| **Human resources** | | |
| New doctorate graduates (ISCED 6) per 1000 population aged 25-34 | X | |
| Percentage population aged 30-34 having completed tertiary education | b | b |
| Percentage youth aged 20-24 having attained at least upper secondary level education | b | b |
| **Open, excellent and attractive research systems** | | |
| International scientific co-publications per million population | X | |
| Scientific publications among the top 10% most cited publications worldwide as % of total scientific publications of the country | X | |
| Non-EU doctorate students[i] as a % of all doctorate students | X | |
| **Finance and support** | | |
| R&D expenditure in the public sector as % of GDP | X | |
| Venture capital investment as % of GDP | x | |
| **Firm investments** | | |
| R&D expenditure in the business sector as % of GDP | X | |
| Non-R&D innovation expenditures as % of turnover | | X |
| **Linkages & entrepreneurship** | | |
| SMEs innovating in-house as % of SMEs | b | b |
| Innovative SMEs collaborating with others as % of SMEs | b | b |
| Public-private co-publications per million population | X | |
| **Intellectual assets** | | |
| PCT patents applications per billion GDP (in PPS€) | X | |
| PCT patent applications in societal challenges per billion GDP (in PPS€) (environment-related technologies; health) | X | |
| Community trademarks per billion GDP (in PPS€) | | X |
| Community designs per billion GDP (in PPS€) | | X |
| **Innovators** | | |
| SMEs introducing product or process innovations as % of SMEs | b | b |
| SMEs introducing marketing or organisational innovations as % of SMEs | | X |
| Employment in fast-growing enterprises in innovative sectors (% of total employment) | b | b |
| **Economic effects** | | |
| Employment in knowledge-intensive activities (manufacturing and services) as % of total employment | x | |
| Exports of medium and high-technology products as a share of total product exports | x | |
| Knowledge-intensive services exports as % total service exports | x | |
| Sales of new to market and new to firm innovations as % of turnover | b | b |
| License and patent revenues from abroad as % of GDP | X | |

*Legend:*
X: only relevant
x: mainly relevant
b: relevant for both types
*Source*: own compilation

[i] It is a somewhat strict definition of openness, which only takes into account non-EU doctorate students.

* There was only a slight change introduced in 2015: the indicator called “Contribution of medium and high-tech product exports to the trade balance” was replaced by “Exports of medium and high-technology products as a share of total product exports”. This change had no effect on the nature of the indicators, and thus the 2014 edition of the IUS is not presented here separately.

## Appendix 4: The Global Innovation Index indicators

The first, 2007 edition of the GII was composed of the following indicators, grouped into eight "pillars", of which 5 meant to represent inputs, while 3 were to reflect on outputs:

### INPUTS

*Institutions and Policies*
Independence of judiciary
Demanding regulatory standards
Prevalence of laws relating to ICT
Quality of IPR
Soundness of banks
Quality of scientific research institutions
The quality of organisations is not an institution ("rule of the game"); A.H.]
Quality of management/business schools
[Same as above; A.H.]
Legal obstacles to foreign labour
Time required to start a business
Time required to obtain licenses
Rigidity of employment index
Investor protection index
ICT priority for government

*Human Capacity*
Brain drain
Quality of human resource approach
Quality of maths and science education
Graduates in engineering
Graduates in science
Population 15-64
Urban population
Schools connected to the internet
[At best indirectly – and vaguely – related to human capacity; A.H.]]

*General and ICT Infrastructure*
Quality of general infrastructure
Quality of national transport network
Quality of air transport
Fixed line penetration
Mobile penetration
Internet penetration
International bandwidth
ICT expenditure
Personal computer penetration
Mobile price basket
[This is access to infrastructure; A.H.]

*Business, Markets and Capital Flows*
Access to loans
Sophistication of financial markets
Issuing shares in local share market
Corporate governance
Buyer sophistication
Customer orientation of firms
Domestic credit to private sector
FDI net inflows
Gross private capital flows
Gross capital formation

Extent of clusters
Commercial services imports
Manufactured imports
Private investment in ICT [Why among these indicators? A.H.]
Informal economy estimate

*Technology and Process Sophistication*
Country's level of technology
E-Participation index
E-Government index
Government procurement of advanced technology
Internet use by businesses
Competition among ISP providers [Why among these indicators? A.H.]
Company technology absorption
Telecom revenue [Why among these indicators? A.H.]
Secure internet servers per 1,000 people
Spending on R&D
Royalty and license fee payments
Business/university R&D collaboration

**OUTPUTS**

*Knowledge*
Local specialised research and training [Not output; A.H.]
Nature of competitive advantage [Not output; A.H.]
Quality of production process technology [Not output; A.H.]
High-tech exports
Manufactured exports
ICT exports
Insurance and financial services
Patents registered (domestic and non-domestic) [Not output; A.H.]
Royalty and license fee receipts

*Competitiveness*
Growth of exports to neighbouring countries
Intensity of local competition
Reach of exporting in international markets
Commercial services export
Merchandise exports
Goods exported
Service exports
Listed domestic companies [Why among these indicators? A.H.]

*Wealth*
Final consumption expenditure
GDP per capita, PPP
GDP growth rate
Industry, value added
Manufacturer, value added
Services, value added
International migration stock
Value of stocks traded
FDI net outflows

**Figure A9: Framework of the Global Innovation Index 2014**