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Közgazdaság- és Regionális Tudományi Kutatóközpont
KÖZGAZDASÁG-TUDOMÁNYI INTÉZET

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Comparative analysis of the evolution of the CE4 countries' national innovation systems and their innovation performance in 2000–2020

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KRTK-KTI WP – 2023/38
December 2023

INSTITUTE OF ECONOMICS, CENTRE FOR ECONOMIC AND REGIONAL STUDIES
HUNGARIAN RESEARCH NETWORK (HUN-REN)
BUDAPEST

ABSTRACT
This paper compares the evolution of CE4 countries' (Czechia, Hungary, Poland, and Slovakia) national innovation systems, as well as their innovation performance. Its analytical framework draws on evolutionary (and institutional) economics of innovation.

Given the structural features and the level of socio-economic development in the CE4 countries, as well as the dominant way of thinking since the cold war, Western politicians, business people, analysts and journalists tend to share a 'block' view of these countries. Further, there is a noticeable – and certainly understandable – 'drive' also from the academic community to produce findings that can be generalised across the new EU member states, but at least for the CE4 countries, that is, to focus on identifying shared or similar features. Yet a closer look at the structure of the national innovation systems in these countries, as well as at their innovation performance, points to a different direction. While the structural composition of the research sub-systems of the CE4 countries showed a great diversity already in 2000, fairly significant changes have occurred since then almost in all countries, adding more colours to the observed diversity. Neither a similar structural composition of the research sub-system can be observed, nor a move towards a similar structure. Their innovation performance is also diverse.

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. The CE4 countries, 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 reasonable or disappointing performance.

JEL codes: B52, O30, O38, O39
Keywords: Models of innovation; Economics paradigms; National innovation systems; STI policy rationales; Measurement of innovation; Composite indicators; Scoreboards and league tables; Czechia; Hungary; Poland; Slovakia

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Négy közép-európai ország nemzeti innovációs rendszerének és innovációs teljesítményének összehasonlító elemzése: 2000–2020

HAVAS ATTILA

ÖSSZEFOGLALÓ

A tanulmány a „visegrádi négyek” (Csehország, Magyarország, Lengyelország és Szlovákia; V4 országok) nemzeti innovációs rendszerének szerkezeti változásait, valamint innovációs teljesítményét hasonlítja össze, az innováció evolúciós (és intézményi) közgazdaságtana elemzési keretére támaszkodva.

A hidegháború óta uralkodó gondolkodásmódot elfogadva sok nyugati politikus, üzletember, elemző és újságíró hajlamos arra, hogy egy "tömbként" lássa ezeket az országokat. A tudományos közösség részéről is érzékelhető bizonyos – könnyen érthető – "nyomás”, hogy az új EU-tagállamokra, de legalábbis a V4 országokra érvényes, általánosítható megállapításokat tegyenek, azaz a közös vagy hasonló jellemzők azonosítására összpontosítsanak. Ám ha közelebbről megvizsgáljuk ezen országok nemzeti innovációs rendszerének szerkezetét, valamint innovációs teljesítményét, más kép rajzolódik ki. A kutatási alrendszerek szerkezeti összetétele már 2000-ben is nagy változatosságot mutatott a V4 országokban, és azóta jelentős változások történtek, amelyek tovább színesítik a megfigyelt változatosságot. Sem a kutatási alrendszerek szerkezeti összetétele nem hasonló, sem hasonló struktúra felé való elmozdulás nem látszik. A négy ország innovációs teljesítménye is eltérően alakult 2000 óta.

Tekintettel az innovációs rendszerek sokféleségére, nagyon óvatosnak kell lennünk, amikor szakpolitikai tanulságokat próbálunk levonni az innovációs rangsorokban elért helyezésekből. A V4 országoknak is el kell kerülniük azt a csapdát, hogy túl nagy figyelmet fordítanak a leegyszerűsítő módszerek használatával készített rangsorokra. Ehelyett részletes, alapos összehasonlító elemzéseket kell elvégezniük, hogy megtalálják az elfogadható vagy kiábrándító teljesítmény okait, és azok ismeretében tervezzék az innovációpolitikájukat.

JEL: B52, O30, O38, O39

Kulcsszavak: Innovációs modellek; Közgazdasági iskolák; Nemzeti innovációs rendszerek; Tudomány-, technológia- és innovációpolitikai alapelvek; Az innováció mérése; Összetett (kompozit vagy szintetikus) mutatószámok; Rangsorok és eredménytáblák; Csehország; Magyarország; Lengyelország; Szlovákia

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1 INTRODUCTION[1]

This paper compares the innovation performance and the evolution of their national innovation system of four Central European countries, namely the Czechia, Hungary, Poland, and Slovakia (henceforth: CE4 countries). Hence, several – otherwise relevant – questions are *not* analysed here: (i) the impacts of science, technology, and innovation (STI) policies on innovation performance (whether the policy goals and tools have been appropriate, whether their implementation has been effective and efficient); (ii) the impacts of various other factors on innovation performance (in brief, the so-called framework conditions for innovation, which include, among others, macroeconomic conditions and stability, regulations concerning competition, the nature and intensity of competition, non-STI policies influencing innovation processes, entrepreneurial attitudes and behaviour, conditions for doing business); (iii) the contribution of innovation performance to economic performance and quality of life (e.g. via enhanced productivity and improved competitiveness concerning the former, and better products and services, reduced environmental burden, concerning the latter); and (iv) the impacts of economic performance, and quality of life on innovation performance (e.g. via availability of resources generated by a healthy economy for research, technological development, and innovation (RTDI) activities and creativity thanks to a tolerant, vibrant, supportive society, given high quality of life). Any attempt to address just one of these questions would require four detailed country case studies, and that has been clearly beyond the means and scope of this project. Yet, what is presented in this paper still might be a relevant contribution when these broader questions are tackled.

The paper is organised as follows. The analytical framework is presented briefly in Section 2 by summarising the various models of innovation and juxtaposing major economics paradigms focussing on their approach to innovation. The theoretical framework pursued in this project is the evolutionary (and institutional) economics of innovation.[2]

Then the structure of, and changes in, the national innovation systems (NIS) of these countries are described, namely the main actors in the R&D performing sectors. (Section 3)

Innovation performance is characterised in Section 4, using some basic indicators, as well as two composite indicators. There are several further complex interrelations, in which innovation performance is an important element. These include: the impacts of economic performance on innovation performance, and the other way around; what STI policy needs and opportunities are perceived, given the economic and innovation performance; and what financial resources are available for supporting research, technological development and innovation (RTDI) activities via direct and indirect policy tools (e.g., subsidies and tax incentives). Again, most of these aspects are beyond the scope of this paper.

The frequency and quality of business-academia collaborations are among the major factors influencing innovation performance. Thus, various aspects of these collaborations are depicted by exploiting the available statistical data sets on R&D and innovation in Section 5. These findings also shed light on the nature of innovation processes (what information sources and what co-operation methods for innovation are used by what proportion of firms, and how these sources and methods are assessed by them).

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[1] Financial support from the National Research, Development, and Innovation Fund, Hungary (grant no. 124858) is gratefully acknowledged.

[2] More specific strands of the literature are highlighted in the relevant sections, and in more detail in Havas (2015b).

The theoretical and policy relevance of the findings are discussed in the concluding section, where several policy recommendations are also presented.

2 Analytical framework

Various economics schools analyse innovation processes in rather dissenting ways: they rely on dissimilar postulates and assumptions, ask different research questions, and often use their own specific analytical tool and techniques. Moreover, these different schools of thought offer contrasting policy advice. Given the decisive economic and societal impacts of innovation performance, it is of paramount importance how innovation is understood (defined), how it is measured and analysed by researchers, what types of goals are set and what tools are used by policy-makers. In brief, theory building, measurement and policy-making can interact either in a virtuous or a vicious circle.

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 (gods or services), processes, business models, as well as new organisational and managerial solutions and techniques, and thus take into account various types, forms and sources of knowledge exploited for innovation by all types of actors in all economic sectors. In contrast, the narrow approach focuses on the so-called high-tech goods and sectors. The choice of indicators to measure innovation processes and assess performance is of vital significance, too: the broad approach is needed to collect data and other types of information, on which sound theories can be built and a reliable and comprehensive description of innovation activities can be offered to decision-makers. Finally, STI policies could be more effective – contribute more to enhancing competitiveness and improving quality of life – when their goals are set, and tools selected, following the broad approach of innovation.[3]

2.1 Linear, networked, and interactive learning 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.[4] The idea that basic research is the main source of innovation had already been proposed in 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).

By the second half of the 1960s the so-called market-pull model contested that reasoning, portraying demand as the main driving force of innovation. Then a long-lasting and detailed discussion have started to establish which of these two types of models are correct, that is, whether R&D results or market demands are the most important information sources of innovations.[5]

Both the science-push and the market-pull models portray innovation processes as linear ones. This common feature has somewhat eclipsed the differences among these models when Kline and Rosenberg (1986) suggested the chain-linked model of innovation, stressing the

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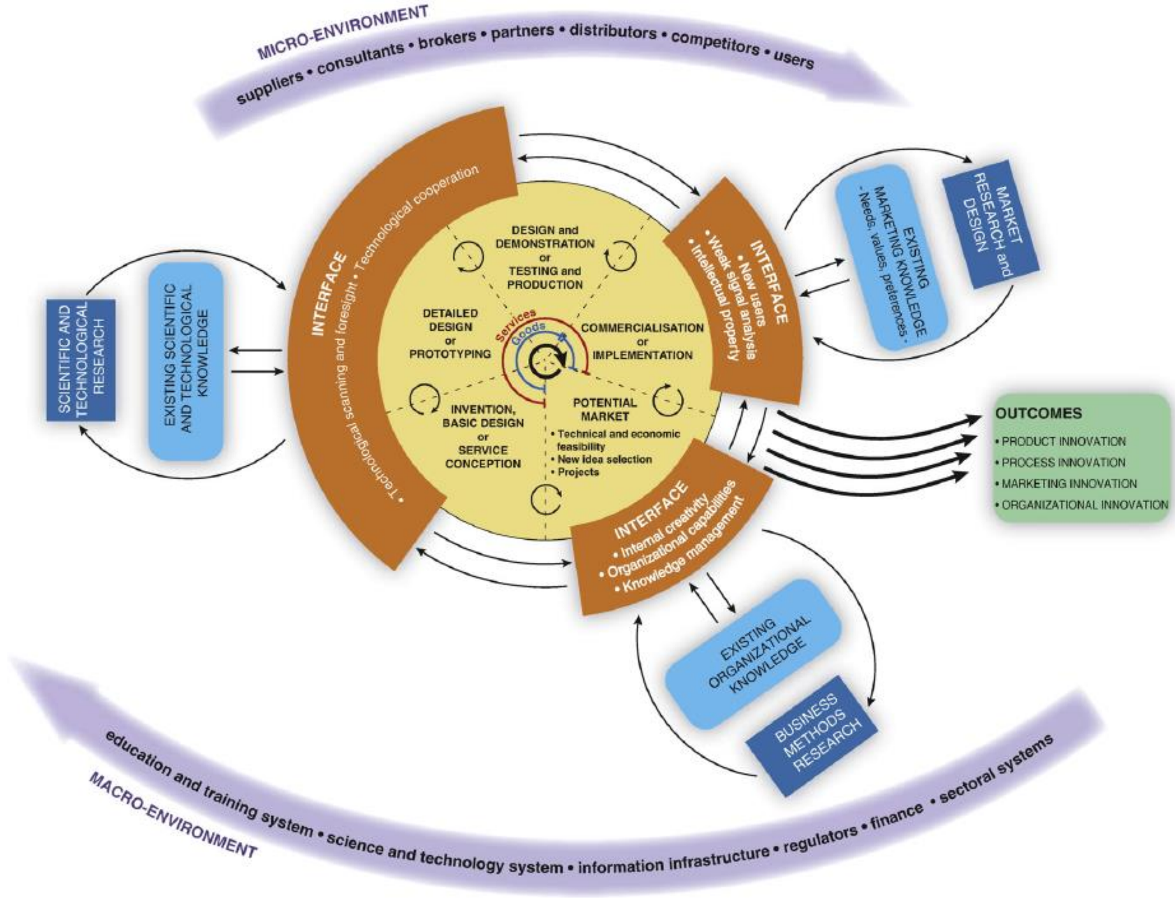
[3] Further details on measurement issues are presented in Section 4.

[4] 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.

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

non-linear property of innovation processes, the variety of sources of information, as well as the importance of various feedback loops. This latter one has then been extended into the networked model of innovation, a recent, highly sophisticated version of which is called the multi-channel interactive learning model. (Caraça et al., 2009)

Figure 1: The multi-channel interactive learning model of innovation



Source: Figure 3 in Caraça et al. (2009)

Various types of links with foreign partners – privatisation and setting up new firms by foreign investors, supplier relationships with foreign-owned firms in a host country, learning via exporting to foreign markets, as well as importing advanced technologies, materials, equipment and software – are crucial sources for learning and innovation for most domestic firms in the CE4 countries.[6] Existing technological, organisational (business methods) and marketing knowledge – highlighted in the multi-channel interactive learning model – are absorbed to a large extent via these channels, and when adapted to the local context, and improved upon by own engineering and other development activities, these lead to improved productivity and enhanced competitiveness. In other words, incremental product, process,

[6] The body of literature is so huge on these issues that only a few references could be mentioned here, in a somewhat arbitrary way: Dyker (1997), (1999), (2004); Dyker (ed.) (1997); Ernst and Kim (2002); Estrin et al. (1997); Estrin and Uvalic (2014); Giroud et al. (2012); Havas (2000a), (2000b), (2007); Hirschhausen and Bitzer (eds) (2000); Inzelt (1994); Iwasaki et al. (2011), (2012); Jindra et al. (2009); Kokko and Kravtsova (2008); Lorentzen and Roostgaard (eds) (1997); Lorentzen et al. (eds) (1999); Lorentzen et al. (2003); Narula and Zanfei (2005); Pavlínek et al. (2009); Pavlínek and Zenka (2011); Piech and Radošević (eds) (2006); Radošević and Sadowski (eds) (2004); Radošević and Yoruk (2015); Saliola and Zanfei (2009); Sass and Szalavetz (2014); Soós et al. (2014); Stephan (ed.) (2005); Stephan (2013); Szalavetz (2012); and Szanyi (2012).

organisational, managerial, and marketing innovations, as well as improvements in production capabilities are at least as important sources for better economic performance than radical product innovations drawing on sophisticated R&D activities.

2.2 Innovation in various schools of thought in economics

Technological, organisational, and institutional changes – using modern terminology: different types of innovation – had been in the centre of analysis in several major works in classical economics. Then neo-classical economics essentially abandoned research questions concerned with dynamics, and instead focused on optimisation, assuming homogenous products, diminishing returns to scale, technologies accessible to all producers at zero cost, perfectly informed economic 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. Given abundant empirical findings and theoretical work on firm behaviour and the operation of markets, mainstream industrial economics and organisational theory have relaxed the most unrealistic assumptions of neo-classical economics, especially perfect information, deterministic environments, perfect competition, and constant or diminishing returns. Yet several major shortcomings have remained: (i) institutional issues are not addressed to a satisfactory extent in these branches of economics either; (ii) a very narrow concept of uncertainty is used; (iii) no adequate theory is offered on the creation of knowledge used in innovation activities and technological interdependence amongst firms; and (iv) the role of government is not analysed in a way that would provide a sound and constructive guidance to policy-makers. (Fagerberg et al. (eds), 2005; Foray (ed.), 2009; Lazonick, 2013; Lundvall and Borrás, 1999; Smith, 2000)

Evolutionary economics of innovation rests on radically different postulates compared to mainstream economics.[7] The latter assumes rational agents, who can optimise via calculating *risks* and taking appropriate actions, while the former stresses that innovation entails *uncertainty*. Thus, *optimisation* is impossible on theoretical grounds.

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 proficiency 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. Thus, the uncertain, cumulative, and path-dependent nature of innovation is reinforced.

[7] 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."

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, 2008; Malerba, 2002; Pavitt, 1984; Peneder, 2010)

Innovators are not lonely champions of new ideas. While talented individuals may develop radically new scientific or technological concepts, successful innovations require various types and forms and knowledge, rarely possessed by a single organisation. A close collaboration among firms, universities, public and private research organisations, and specialised service-providers is, therefore, a prerequisite of major innovations. (Freeman 1991, 1994, 1995; Lundvall and Borrás, 1999; OECD, 2001; Smith, 2000, 2002; Tidd et al., 1997) In other words, 'open innovation' is not a new phenomenon at all. (Mowery, 2009)

Given this analytical framework first the structural composition of the CE4 countries' NIS is described, including their dynamics, followed by the characterisation of their innovation performance, and a detailed account of the collaboration among the various NIS actors.

3 STRUCTURAL CHANGES IN THE CE4 COUNTRIES' NATIONAL INNOVATION SYSTEMS

3.1 Main research performers

The business sector is the most important research performer at an aggregate level in the EU27 both in terms of its share in GERD and employment, followed by the higher education and the government sectors, respectively. (Table 1) The share of the private non-profit sector is around 1% by either measure, and thus it is not reported here.

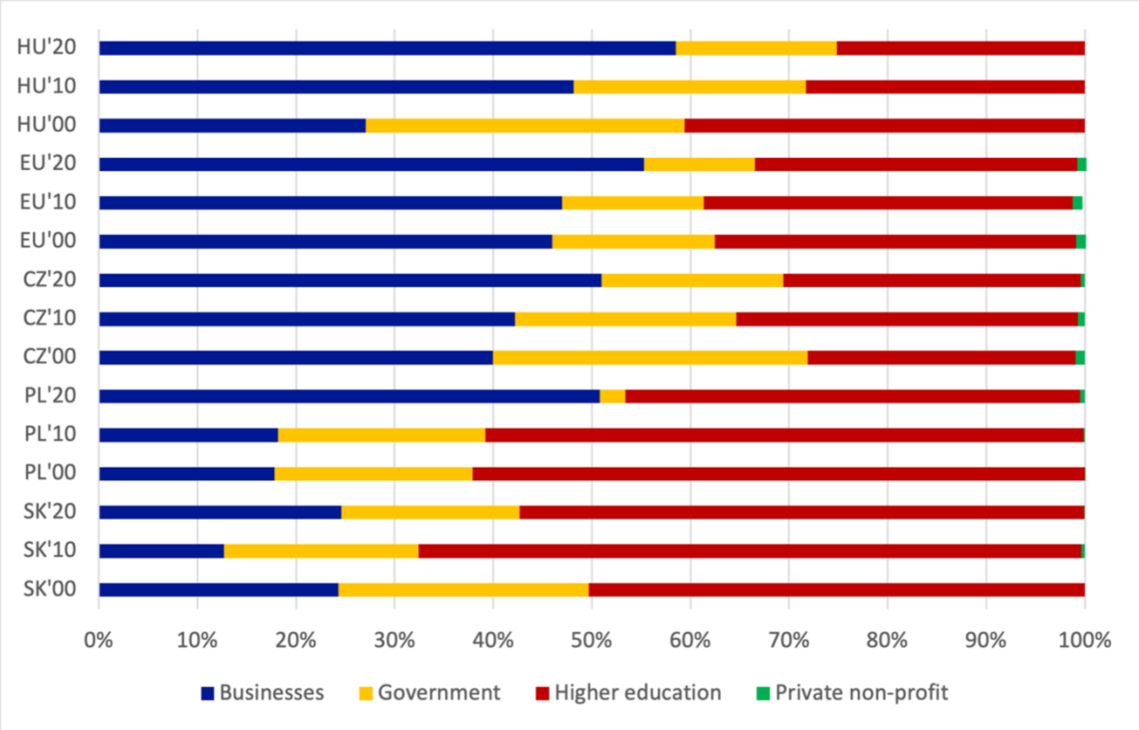
Table 1: R&D inputs and the weight of R&D performing sectors, EU, 2000, 2010, and 2020 (%)

	2000	2010	2020
GERD/GDP	1.81	1.97	2.30
Share of researchers (FTE) in total employment	0.50	0.66	0.92
Business sector			
BERD/GERD	63.36	61.24	65.41
Share of business researchers (FTE)	46.04	47.21	55.27
Higher education sector			
HERD/GERD	21.43	23.92	22.22
Share of HE researchers (FTE)	36.59	37.39	32.70
Government sector			
GOVERD/GERD	14.60	13.99	11.72
Share of government researchers (FTE)	16.50	14.36	11.27

Source: Eurostat and own calculation based on Eurostat data

This pattern was markedly different in the CE4 countries in 2000: the higher education sector was the largest employer of (FTE) researchers in 3 countries, while the business sector took the lead in Czechia. Then major changes occurred: the share of business enterprise researchers reached 58.5% in Hungary in 2020, overtaking the EU average of 55.3%. That share varied widely, that is, between 24.3% (SK) and 51.0% (CZ) in the other three CE4 countries in 2020. (Figure 2)

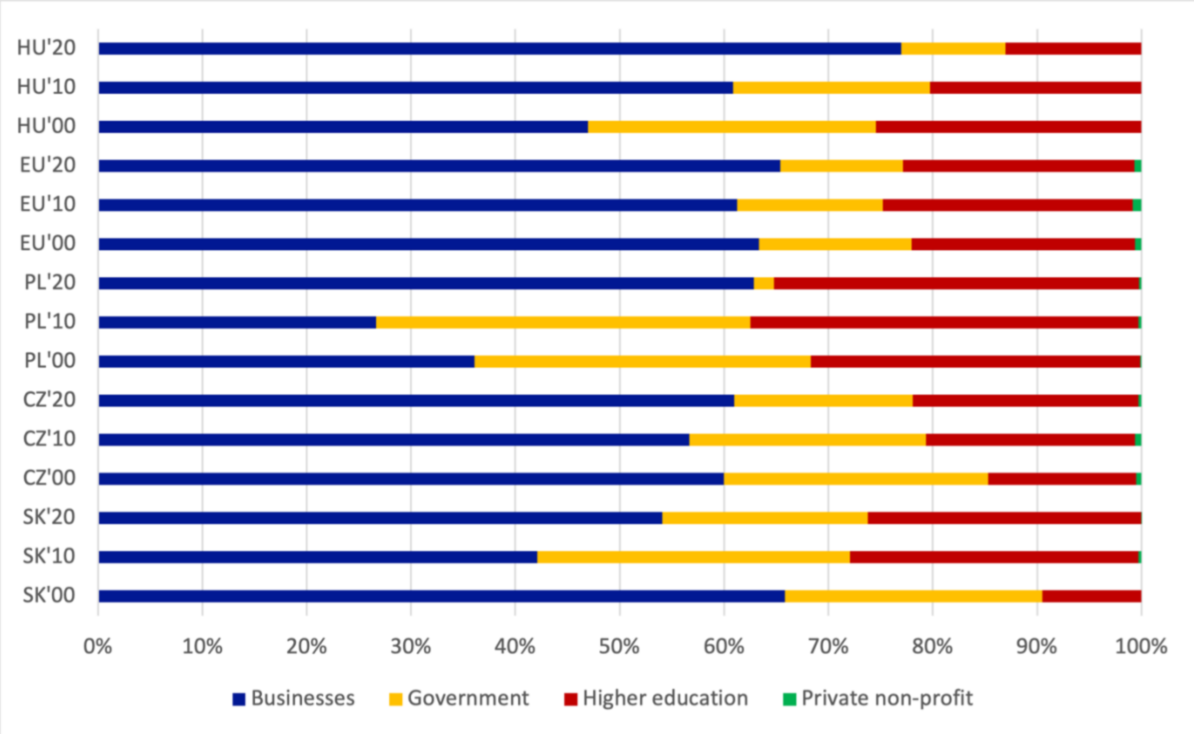
Figure 2: Share of research performing sectors in employing FTE researchers, EU and CE4 countries, 2000, 2010, and 2020



Source: own compilation by using Eurostat data
Notes:
HU'00, HU'10, and HU'20 denotes Hungary 2000, 2010, and 2020, respectively. The same applies to the other abbreviations.
Countries are ranked by the weight of their business sector in 2020.

The share of GERD performed by the business enterprise sector was 63.4% and 65.4% at the EU level in 2000 and 2020, respectively. In the CE4 countries this ratio was ranging between 36.1% (PL) and 65.8% (SK) in 2000, then 54.1% (SK) and 76.5% (HU) in 2020. (Figure 3) Thus, Slovakia, the frontrunner in 2000 became the 'underdog' in 2020.

Figure 3: Share of research performing sectors in performing GERD, EU and CE4 countries, 2000, 2010, 2020



Source: compiled by using Eurostat data
Notes:
HU'00, HU'10, and HU'17 denotes Hungary 2000, 2010, and 2020, respectively. The same applies to the other abbreviations.
Countries are ranked by the weight of their business sector in 2020.

Higher education (HE) organisations were the second largest employers of researchers in 2000–2020 at the EU level, with a shrinking share: dropping from 36.6% in 2010 to 32.7% in 2020. As already mentioned, this sector was the largest employer of researchers in 3 CE4 countries in 2010 and kept that position only in Slovakia in 2020 (Figure 2) The share of GERD performed by the HE sector is significantly lower: it fluctuated between 21% and 24% in 2000–2020 at the EU level, while in a much broader range, that is, 9.5–37.2%, in the CE4 countries. (Figure 3)

At an aggregate EU level, *the government sector* was the No. 3 employer FTE researchers with a shrinking share: 16.5% in 2000, 11.3% in 2020. The weight of the government sector was ranging between 20.1% (PL) and 32.3% (HU) in 2010, while 2.6% (PL) and 18.5% (CZ) in 2020. (Figure 2) The share of GERD performed by the government sector was in line with its share in employment, that is, 11.7%–14,6% in 2000–2020 at the aggregate EU level. In the CE4 countries this share varied from 24.7% (SK) to 32.2% (PL) in 2000 and between 2.0% (PL) and 19.7% (SK) in 2020. (Figure 3)

In one sentence, in a bit simplifying way, the share of the main research performer sectors in the CE4 countries differed markedly compared to the structure of the EU research sub-system. Yet as Figures 2 and 3 clearly indicate, major changes occurred in the CE4 countries in 2000–2020.

3.2 Diversity and change in the CE4 countries' research sub-systems

As already shown, the structural composition of the CE4 countries' research sub-systems was rather diverse not only in 2010 but in 2020 as well. (Figures 2–3) This diversity observed still in 2020 is somewhat surprising for those who would assume a more similar structural composition, given the broadly similar legacies of these countries. In brief, they had been characterised by a highly centralised, politically controlled academic sector,[8] with a limited (or hardly any) autonomy in certain fields of investigations, especially in social sciences and humanities, and a rigid division of labour between universities, focussing mainly on teaching, on the one hand, and the institutes of the Academies of Sciences,[9] almost exclusively performing research, on the other.[10] Hence, it worth looking at the dynamics of these sectors by taking two snapshots, that is, comparing the structural composition of the research sub-systems of these countries in 2000 and 2020.

Major structural changes have occurred since 2000 in the CE4 countries. The weight of the *business sector* in employing FTE researchers has increased by one third in Hungary and Poland and by over 10 in Czechia. In contrast, this weight has remained practically the same in Slovakia. The *higher education sector* has shrunk by 3.9 percentage points at the EU27 level, by 11.1 in Hungary, 15.9 in Poland, while its share has increased by 3 percentage points Czechia and 7 in Slovakia. The *government sector* has lost 5.2 percentage points at the EU27 level, and changes have occurred in the same direction in all CE4 countries, too: a contraction by 16–18 percentage points in Hungary and Poland, over 13 percentage points in Czechia and by 7.3 in Slovakia. (Table 2)

Table 2: Changes in the weight of the research performing sectors in employing FTE researchers, CE4 countries and the EU, 2020 compared to 2000 (percentage point)

	Business sector	Higher education sector	Government sector
Hungary	33.0	-11.1	-16.2
Poland	33.0	-15.9	-17.6
Czechia	11.0	3.0	-13.5
EU	9.2	-3.9	-5.2
Slovakia	0.3	7.0	-7.3

Source: own calculation based on Eurostat data
Note: Countries are ranked by the change in the weight of their business sector.

The sectoral composition of a research sub-system can be characterised by the share of BERD, GOVERD, and HERD, too. This metric also indicates major structural changes since 2000 in all CE4 countries. The weight of *business sector* in performing GERD has increased by 32.1

[8] Given the prominent role of the Academies of Sciences in most of these countries, probably it is useful to stress even nowadays that this term denotes all publicly financed research organisations, that is, mainly universities and other public research institutes.

[9] These institutes belong to the government sector in the EU and OECD classification of research performing sectors.

[10] On the historical legacies and early transition of the research sub-systems in Central and Eastern European countries, see, e.g. Acha and Balazs (1999); Adamsone-Fiskovica et al. (2011); Balazs et al. (eds) (1995); Chataway (1999); Kristapsons et al. (2003); Meske (2000); Meske et al. (eds) (1998); Meske (ed.) (2004); Radošević (1997), (1998), (1999); Radošević and Auriol (1999); Webster (ed.) (1996).

percentage points in Hungary, 26.7 in Poland, and 1.0 in Czechia, while decreased by 11.7 in Slovakia. The *higher education sector* gained a mere 0.8 percentage points at the EU level, 3.4 in Poland, 7.4 in Czechia, and 16.7 points in Slovakia, while lost 11.1 percentage points in Hungary. The *government sector* has lost 2.9 percentage points at the EU level, 5.0 in Slovakia, 8.2 in Czechia, 16.2 in Hungary and 30.3 in Poland. (Table 3)

Table 3: Changes in the weight of the research performing sectors in performing GERD,CE4 countries and the EU, 2020 compared to 2000 (percentage point)

	Business sector	Higher education sector	Government sector
Hungary	32.1	-11.1	-16.2
Poland	26.7	3.4	-30.3
EU	2.1	0.8	-2.9
Czechia	1.0	7.4	-8.2
Slovakia	-11.7	16.7	-5.0

Source: own calculation based on Eurostat data
Note: Countries are ranked by the change in the weight of their business sector.

In sum, while the structural composition of the CE4 countries' research sub-system showed a great diversity already in 2000 – for instance the weight of the business sector in employing FTE researchers was ranging from 17.8% (Poland) to 39.9%% (Czechia) and in performing GERD from 36.1% (Poland) to 65.8% (Slovakia) –, fairly significant changes have occurred since then in all the four countries, adding more colours to the observed diversity. *Changes have occurred in both directions in all the three major research performing sectors*, taking either the share of FTE researchers or the share of GERD performed. Thus, *neither a similar structural composition of the research sub-system can be observed, nor a move towards a similar structure*.

4 Business-academia co-operation in the CE4 countries

There are a variety of linkages in a successful NIS among its players (businesses, academia, intermediary organisations, service providers, policy-makers etc.). Firms are involved in different ways and to a varying degree in shaping STI policy strategies and actual policy measures. The types and quality of links between businesses and intermediary organisations (including actors offering funds for innovation activities) also influence the performance of a given NIS, just as external linkages, that is, the internationalisation of research, technological development and innovation (RTDI) processes and the impacts of external STI policies. Of these linkages, only business-academia (B-A) co-operation is discussed in this section. It is aimed at providing a map of business-academia collaboration in the EU countries, with a special emphasis on the CE4 countries, drawn by using several 'lenses' offered by various data sets.

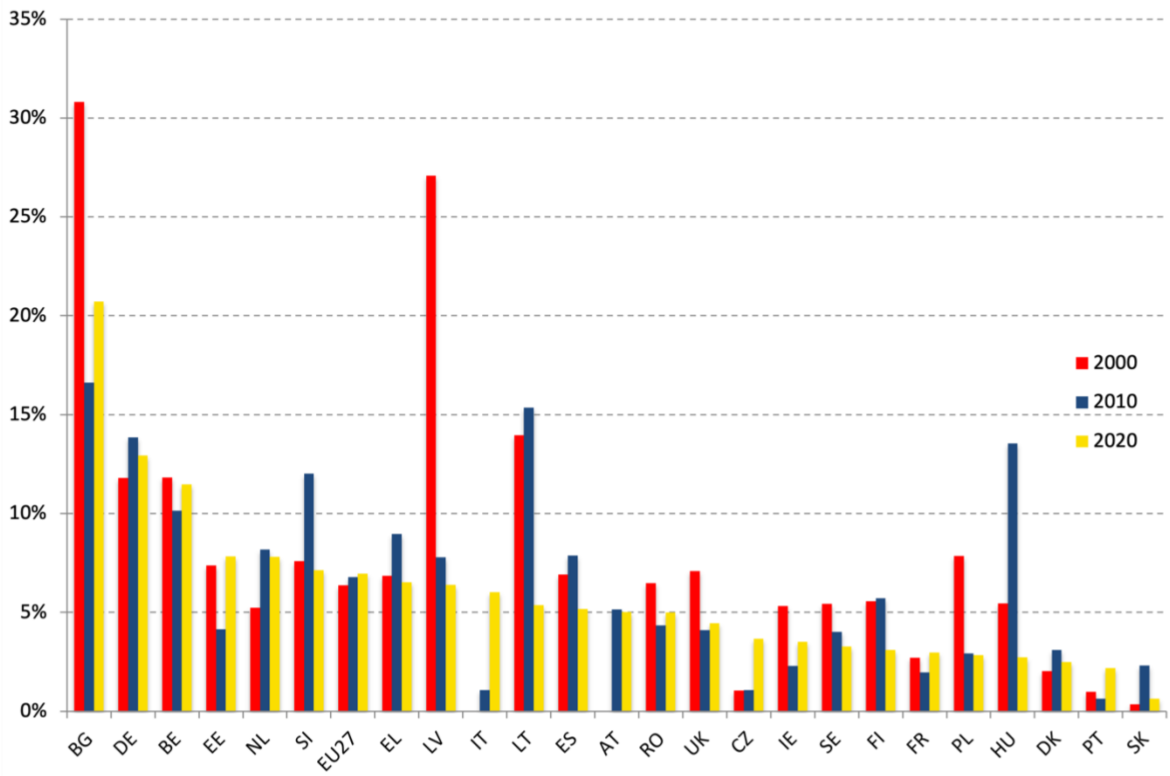
4.1 The weight of business resources in funding R&D activities

While at the EU level 6.4–7.0% of HERD (higher education R&D expenditures) was financed by businesses in 2000–2020, at a member state level one can find much more variation both in terms of the ratio of business sources and dynamics. (Figure 4) The share of business sources in funding HERD was above 10% in 3 countries, around 7–8% in 5 countries, 3–5% in

12 countries, and around or below 2% in 3 ones in 2020. In some countries this share decreased significantly, e.g., from 30.8% in 2000 to 20.7% in 2020 (BG), or from 27.1% to 6.4% (LV). Overall, this share grew in 8 countries by 2020, among these by 2.6 percentage points in Czechia and the Netherlands, while declined in 14 countries. This share increased significantly in Hungary and Slovenia by 2010 compared to 2000 and then plunged drastically by 2020.

The share of business sources in funding HERD was higher than the aggregate EU27 figure in 6 countries in 2020, of which *3 are new member states*. The relatively high ratio of business funding in the latter countries might be attributed to the low amount of HERD in absolute terms: a few projects commissioned by firms, with relatively low budgets by international standards, can lead to a high weight of business funding in HERD.

Figure 4: Share of businesses in funding HERD, EU countries in 2000, 2010, and 2020 (%)



Source: own calculations using Eurostat data
Notes
NL and EL: 2001 and 2011 data; AT: 2011 and 2019 data; IE: 2019 data; UK: 2018 data; SE: 2001, 2011, and 2019 data
Croatia, Cyprus, Luxembourg, and Malta are not included in this figure.

As for the CE4 countries, there are significant differences among them in the share of businesses in funding HERD. For example, this share in Czechia was 5 times higher in 2020 compared to Slovakia. It is also noteworthy that in Austria, which is an advanced, affluent EU country, this share was around or even less than half of the Hungarian figure for quite a long period, below the Estonian one and just slightly above the Czech one. Portugal was below the level of the CE4 countries for 11 years but overtook Slovakia in 2015 and then in 2018–2020. (Table 4 and Table 5)

Table 4: Share of businesses in funding HERD, CE4 and selected other EU countries, 2000–2010 (%)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Estonia	7.38	5.11	7.19	6.27	6.47	5.22	4.98	5.58	4.43	4.26	4.16
Slovenia	7.60	6.72	8.98	10.09	9.58	9.02	9.47	10.56	10.08	9.18	12.03
Austria	n.a.	n.a.	4.05	n.a.	4.47	n.a.	5.04	5.74	n.a.	5.20	n.a.
Czechia	1.06	0.70	0.92	0.98	0.59	0.82	0.67	0.72	0.61	1.04	1.07
Ireland	5.33	4.39	3.72	3.02	2.58	2.73	1.83	2.27	3.04	2.74	2.30
Poland	7.85	6.30	5.82	5.98	5.56	5.40	5.40	11.34	3.85	3.32	2.92
Hungary	5.47	4.35	11.77	10.62	12.88	11.79	12.98	13.70	14.65	15.52	13.56
Portugal	0.99	0.78	1.16	1.53	1.35	1.18	1.30	1.39	0.93	0.92	0.64
Slovakia	0.35	0.34	0.00	0.00	0.57	0.72	4.70	6.81	2.45	2.12	2.33

Source: own calculations using Eurostat data
n.a.: not available

Table 5: Share of businesses in funding HERD, CE4 and selected other EU countries, 2011–2020 (%)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Estonia	3.48	3.48	4.36	4.38	5.40	7.41	5.84	6.88	7.89	7.83
Slovenia	12.53	11.19	11.36	12.64	11.38	10.55	8.70	8.49	8.57	7.14
Austria	5.15	n.a.	5.09	n.a.	5.29	n.a.	5.12	n.a.	5.01	n.a.
Czechia	1.02	0.80	1.97	2.40	3.96	4.69	5.08	4.60	3.80	3.68
Ireland	2.15	1.97	1.97	1.97	2.66	2.91	3.17	3.16	4.63	n.a.
Poland	2.57	2.14	3.16	2.82	2.60	3.04	3.51	3.88	3.30	2.84
Hungary	11.29	9.47	8.61	9.05	8.02	9.62	6.07	5.39	2.57	2.73
Portugal	1.90	1.26	1.65	1.64	1.92	1.77	1.92	2.04	2.13	2.18
Slovakia	3.49	3.27	2.59	2.44	1.60	1.89	2.07	0.66	0.80	0.64

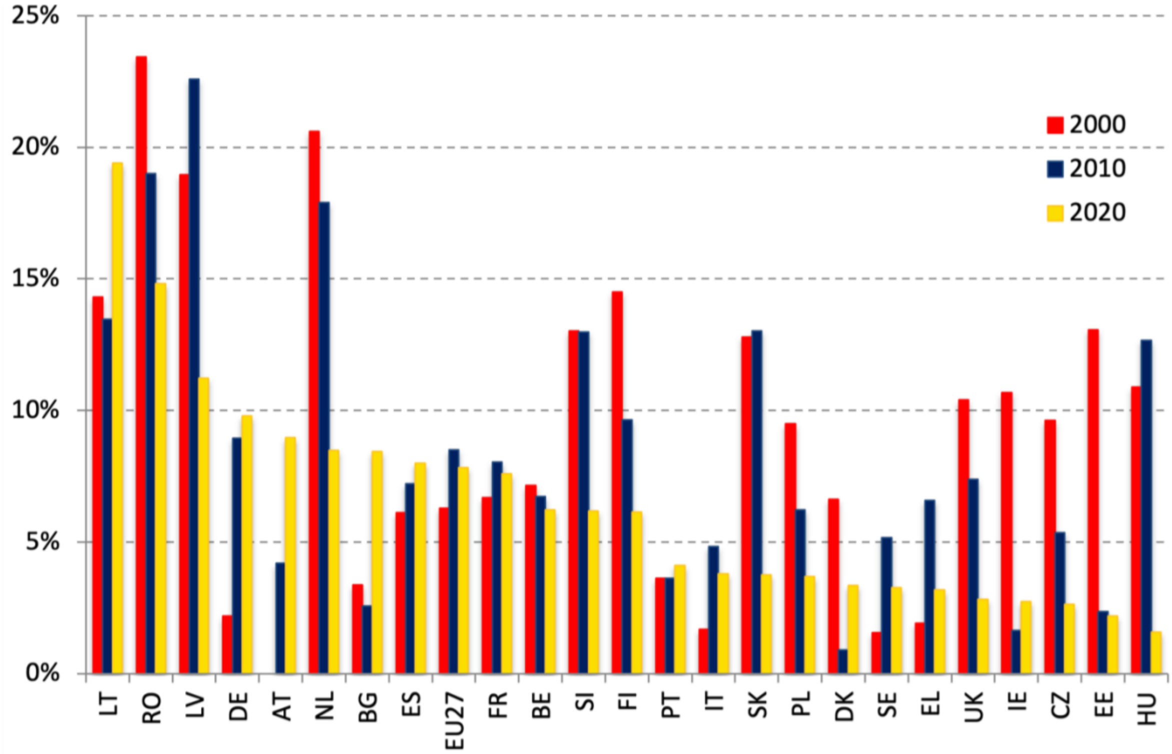
Source: own calculations using Eurostat data
n.a.: not available

The share of business sources in funding Government Intramural Expenditure on R&D (GOVERD) was 5.3–9.0% at an aggregate EU27 level in 2000–2020 and stood at 7.8% in 2020. As for the member states, this ratio was in the range of 1.6% (HU) and 19.4% (LT) in 2020. (Figure 5)

The share of GOVERD financed by businesses was higher in 9 member states than the EU27 figure in 2020, and *4 of these are new members*. The low volume of GOVERD in these latter countries, most likely, is an important factor in explaining the high value of this ratio.

As for the CE4 countries, there are significant differences among in the share of businesses in funding GOVERD in 2000–2020. For example, the Slovak figure was 3 times higher in 2011 and 2016 compared to Czechia. It is also noteworthy that in Austria, which is an advanced, affluent EU country, this share was less than half of the Slovak and Hungarian figure in 2011 and 2013, but then took the lead in 2017. This share was fluctuating in quite wide range in Estonia, Czechia, Hungary, Ireland, and Portugal. There was a common trend in the CE4 countries: the share of business funding in GOVERD plummeted significantly by 2020 compared to 2000, that is, by 9.3, 9.0, 7.0, and 5.8 percentage points in Hungary, Slovakia, Poland, and Czechia, respectively. (Table 6 and Table 7)

Figure 5: Share of businesses in funding GOVERD, EU countries, 2000, 2010, and 2020 (%)



Source: own calculations using Eurostat data
Notes
AT: 2011 and 2019 data; NL and EL: 2001 and 2011 data; SE: 2001, 2011, and 2019 data;
UK: 2018 data; IE: 2019 data
Croatia, Cyprus, Luxembourg, and Malta are not included in this figure.

Table 6: Share of businesses in funding GOVERD, CE4 and selected other EU countries, 2000–2010 (%)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Austria	n.a.	n.a.	6.01	n.a.	6.58	n.a.	6.80	9.34	n.a.	5.97	n.a.
Slovenia	13.03	9.91	10.74	10.83	10.73	12.06	14.23	13.13	12.72	11.69	12.99
Portugal	3.63	3.49	4.71	6.24	4.10	2.01	3.23	4.39	4.20	1.60	3.62
Slovakia	12.78	14.03	13.97	11.00	10.50	8.54	13.46	13.40	15.67	14.35	13.03
Poland	9.50	14.27	23.31	13.69	14.68	14.26	15.62	14.13	6.00	6.30	6.22
Czechia	9.63	6.56	9.59	7.75	9.00	9.43	8.22	7.37	6.69	4.75	5.37
Estonia	13.06	4.37	5.07	2.30	1.22	0.00	0.03	0.05	1.33	1.86	2.35
Hungary	10.88	13.05	6.40	5.72	7.17	10.28	14.34	12.35	13.27	12.63	12.67
Ireland	10.67	10.29	6.62	0.24	3.61	4.13	5.53	3.50	1.06	2.03	1.65

Source: own calculations using Eurostat data
n.a.: not available

Table 7: Share of businesses in funding GOVERD, CE4 and selected other EU countries, 2011–2020 (%)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Austria	4.20	n.a.	4.19	n.a.	6.04	n.a.	8.68	n.a.	8.96	n.a.
Slovenia	7.00	8.41	7.56	7.76	8.04	6.77	c	c	5.87	6.19
Portugal	1.02	1.53	1.66	1.18	1.90	5.90	4.95	5.59	2.80	4.11
Slovakia	12.52	13.17	8.17	13.42	8.64	12.00	8.76	4.15	3.73	3.75
Poland	7.39	4.95	4.34	n.a.	4.49	5.30	4.83	3.86	4.37	3.69
Czechia	3.96	4.50	3.68	3.76	2.77	4.01	3.56	3.87	3.62	2.64
Estonia	1.49	1.19	1.33	1.29	1.62	2.95	1.76	1.65	2.07	2.18
Hungary	11.53	9.84	9.73	7.81	8.83	5.99	5.16	6.63	3.39	1.58
Ireland	1.67	1.82	1.86	1.92	0.81	0.90	3.94	2.94	2.73	n.a.

Source: own calculations using Eurostat data
n.a.: not available
c: confidential

4.2 Information sources for innovation

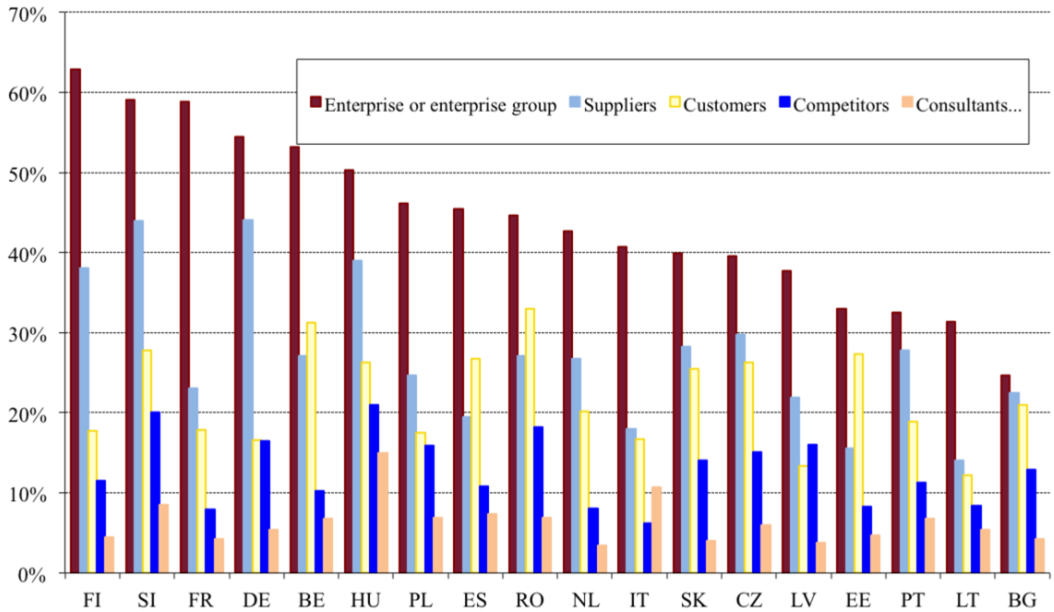
The quality of co-operation among the NIS players can be characterised by firms' assessments as to the importance of sources of information for their innovation activities. In all countries participating in CIS 2008 and CIS 2010 the largest share of firms regarded their own enterprise or enterprise group as a highly important source of information for innovation, and other firms – suppliers, customers, competitors, and commercial labs – were also highly appreciated by a large part of firms. Thus Figures 6–8 only present these business-type sources of information (for three periods). Overall, no major change can be observed in the three periods considered here in terms of the difference among of countries. Customers, however, became the second most important sources of information in 10 countries (of 16 ones) in 2008–2010, compared to 4 countries (of 18 countries) in 2006–2008. That trend was further strengthened in 2010–2012 with 14 countries (of 19 ones) where customers were considered as the second most important sources of information. Moreover, in Romania almost half of the respondents appreciated customers as a highly important source of innovation, and thus customers were ranked No. 1.[11]

The new EU member states were 'scattered': (i) they neither show a particular pattern in terms of the importance of the various sources of information; and (ii) nor are grouped closely together. In these three periods Slovene firms highly appreciated internal sources of information, together with suppliers and customers, while their counterparts in the Baltic states and Bulgaria were less 'impressed'. More detailed analyses would be needed to establish if these dissimilarities are due to cultural differences (managers are more 'enthusiastic', more generous in appreciating sources of information in Slovenia compared to the Baltic states and Bulgaria) or can be attributed to a genuine difference in terms of the usefulness of information sources. Noticeable changes can be observed in two new member states: a markedly higher share of Lithuanian and Slovak firms regarded these sources of information as highly important in 2008–2010 than in 2006–2008. These higher figures were recorded in 2010–

[11] It should be added, however, that a distinction between customers from the private vs. public sector was introduced in this period, and 32.9% of Romanian respondents regarded customers from the public sector as a highly important source of innovation, while 13.6% of them did so concerning customers from the private sector.

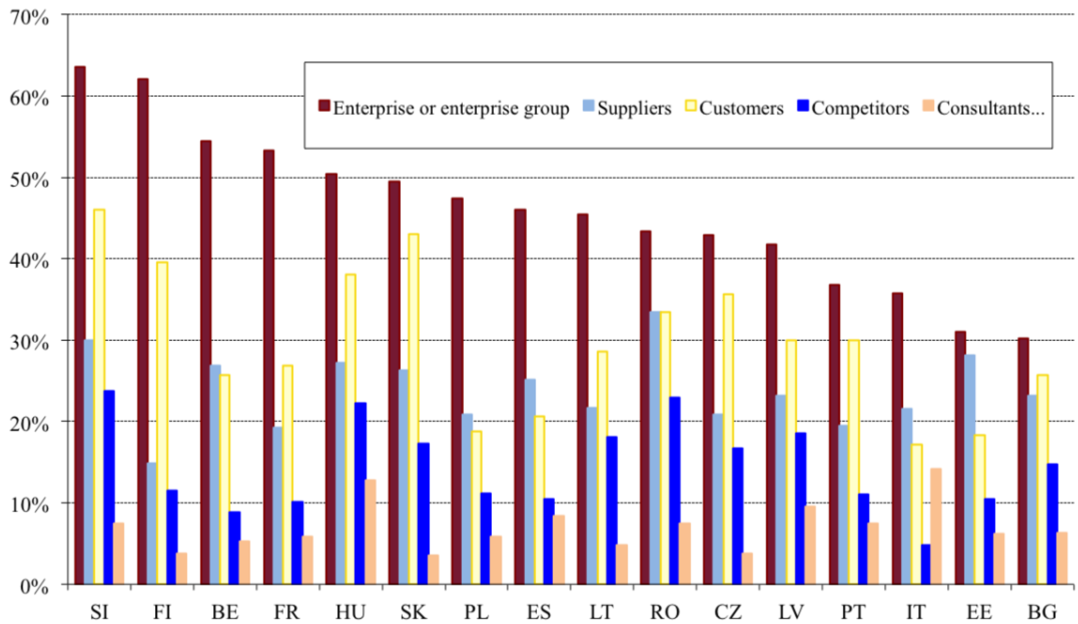
2012, too. As cultural changes usually take longer than 2–3 years, perhaps these data – together with the overall higher appreciation of customers as sources for information, noted above – suggest that respondents' replies do indicate the usefulness of various information sources.

Figure 6: Highly important 'business' sources of information for product and process innovation, EU members, 2006–2008



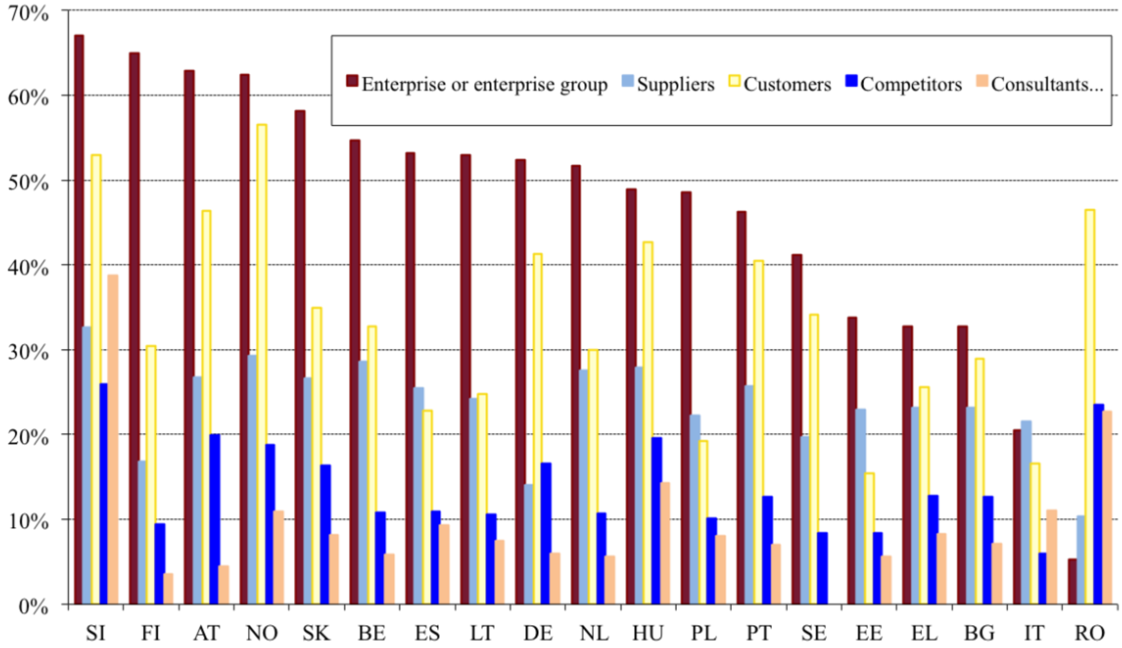
Source: Eurostat, CIS 2008
Note: Data for Cyprus, Luxembourg and Malta are not included in this figure.

Figure 7: Highly important 'business' sources of information for product and process innovation, EU members, 2008–2010



Source: Eurostat, CIS 2010
Note: Data for Cyprus, Luxembourg and Malta are not included in this figure.

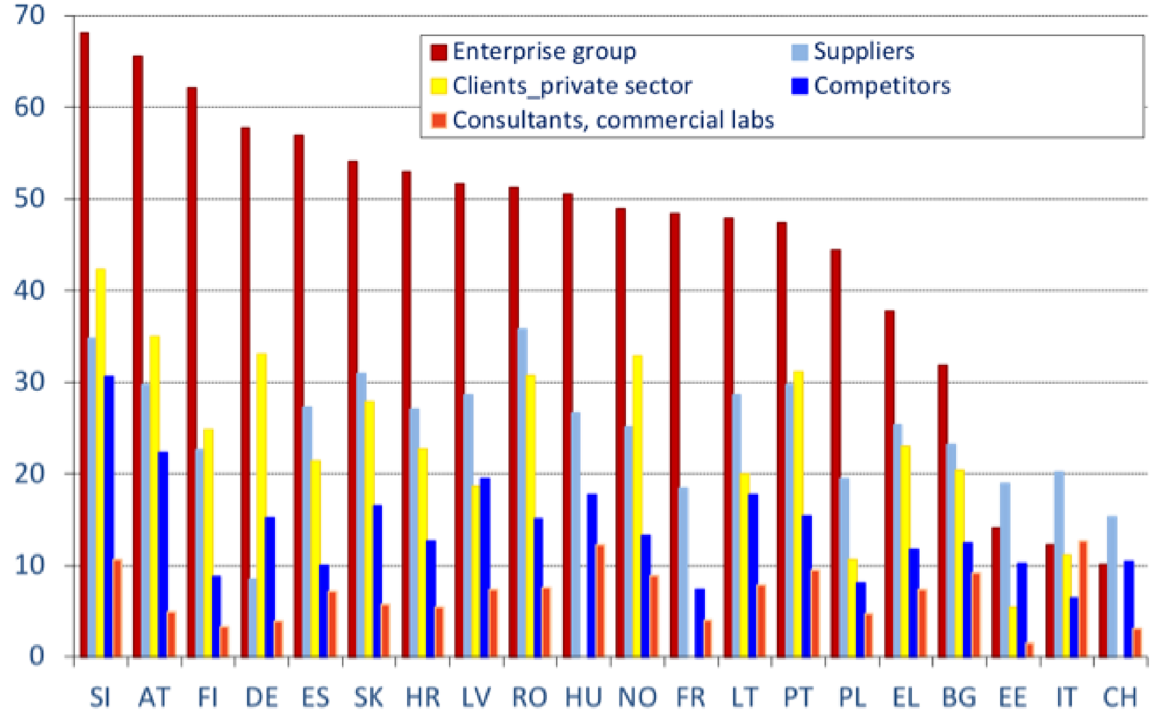
Figure 8: Highly important 'business' sources of information for product and process innovation, EU members, 2010–2012



Source: Eurostat, CIS 2012
Note: Data for Cyprus, Luxembourg and Malta are not included in this figure.

"Business" sources of information for product and process innovation remained high for most EU countries, including the CE4 countries, in 2014–2016 as well. These sources of information, however, were markedly less important for Estonian, Italian, and Swiss firms. (Figure 9)

Figure 9: Highly important 'business' sources of information for product and process innovation, EU members and Switzerland, 2014–2016



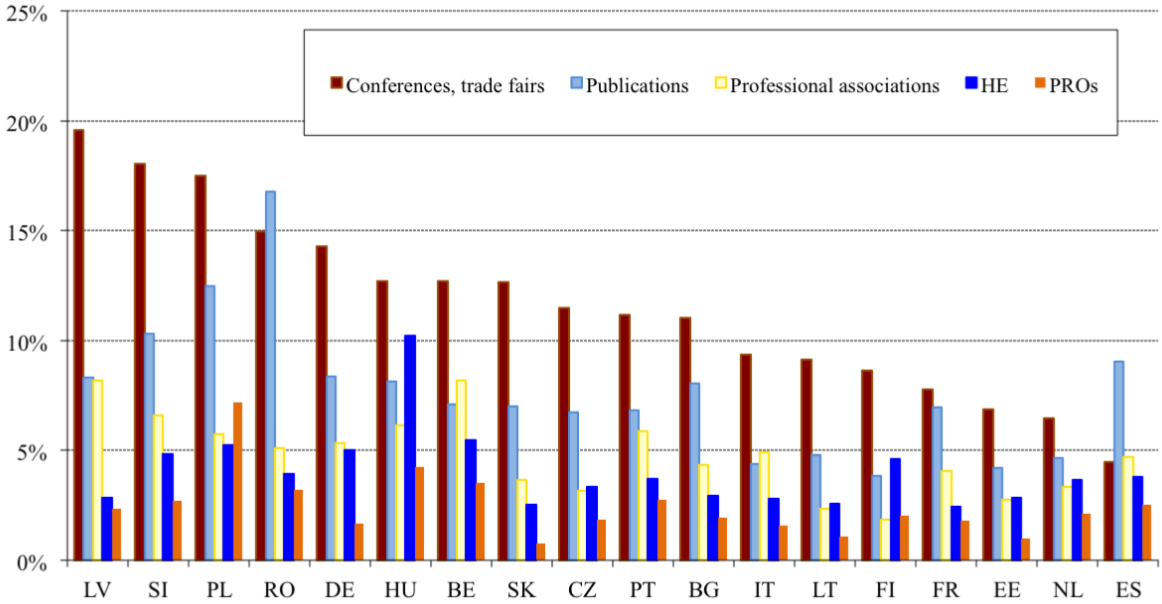
Source: Eurostat, CIS 2016

These data were not collected either in CIS 2018 or CIS 2020. The types of data are available are presented at the end of this sub-section.

The other sources of information for innovation – which can be called 'scientific' ones in a bit simplified way – are depicted on Figures 10–12 for three periods. These are "highly important sources of information" for a significantly lower share of innovative firms. In most countries, conferences, trade fairs, and exhibitions ranked first in this group, scientific journals and trade/ technical publications came second, followed by universities and public research institutes. No major change can be observed in this respect when comparing the periods considered here.

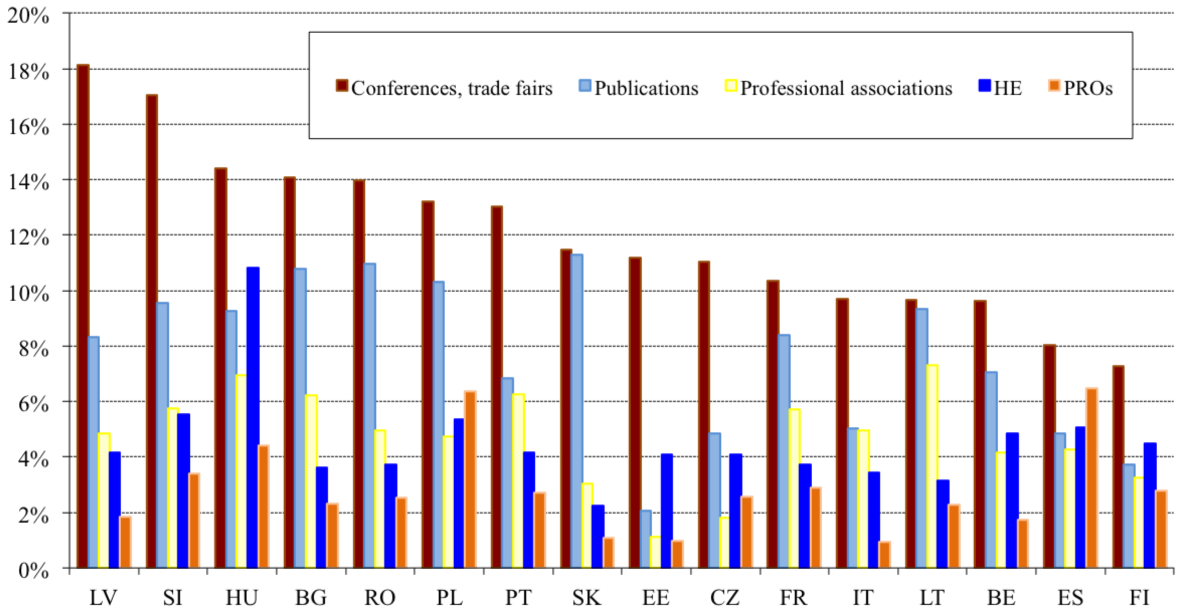
In the first two periods *a larger share of the respondents from the new member states* gave a high esteem to these sources of information compared to their counterparts in the more advanced EU members, with the exceptions of Germany and Belgium in 2006–2008. German data are not available for 2008–2010, and Belgian firms became somewhat more 'reserved' in that period. It should be added, that data for Austria, Denmark, Sweden, and the UK are not available for these two periods, and Dutch data only cover 2006–2008. Data are available for 19 countries for 2010–2012 (as opposed to 16 in 2008–2010). This larger sample includes Austria and Sweden (although only for one source of information), as well as the Netherlands (after a 'pause' in 2008–2010), and it shows a more varied picture: New and old member states are 'alternating' on the horizontal axis of Figure 12. Thus, the formerly observed, apparently marked difference between the new member states and the more advanced ones has to be taken with a pinch of salt.

Figure 10: Highly important 'scientific' sources of information for product and process innovation, EU members, 2006–2008



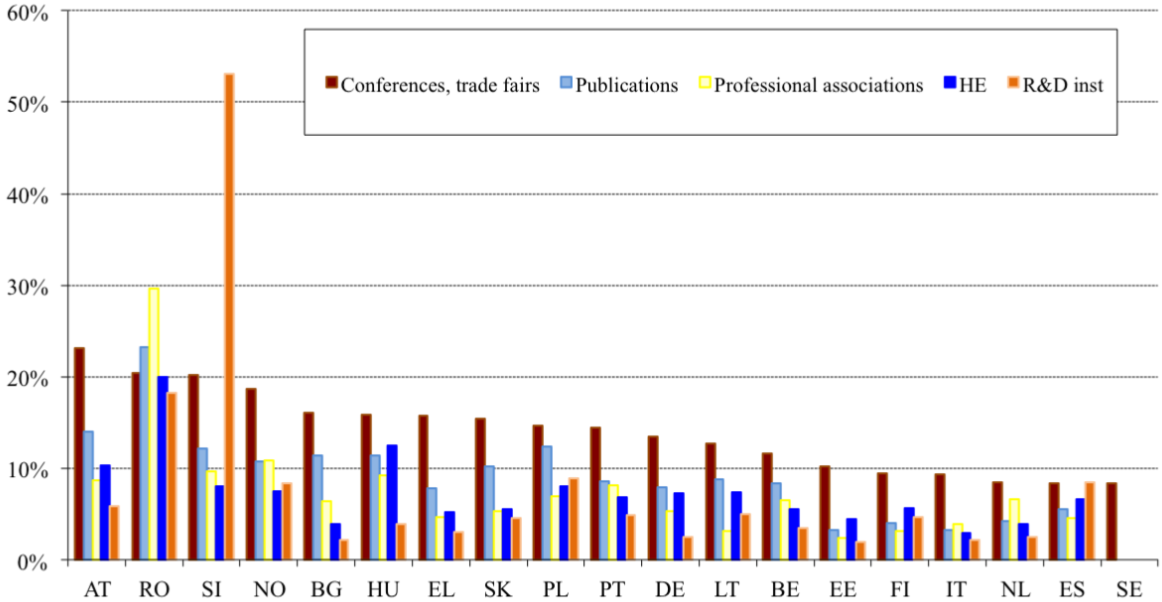
Source: Eurostat, CIS 2008
Note: Data for Cyprus, Luxembourg and Malta are not included in this figure.

Figure 11: Highly important 'scientific' sources of information for product and process innovation, EU members, 2008–2010



Source: Eurostat, CIS 2010
Note: Data for Cyprus, Luxembourg and Malta are not included in this figure.

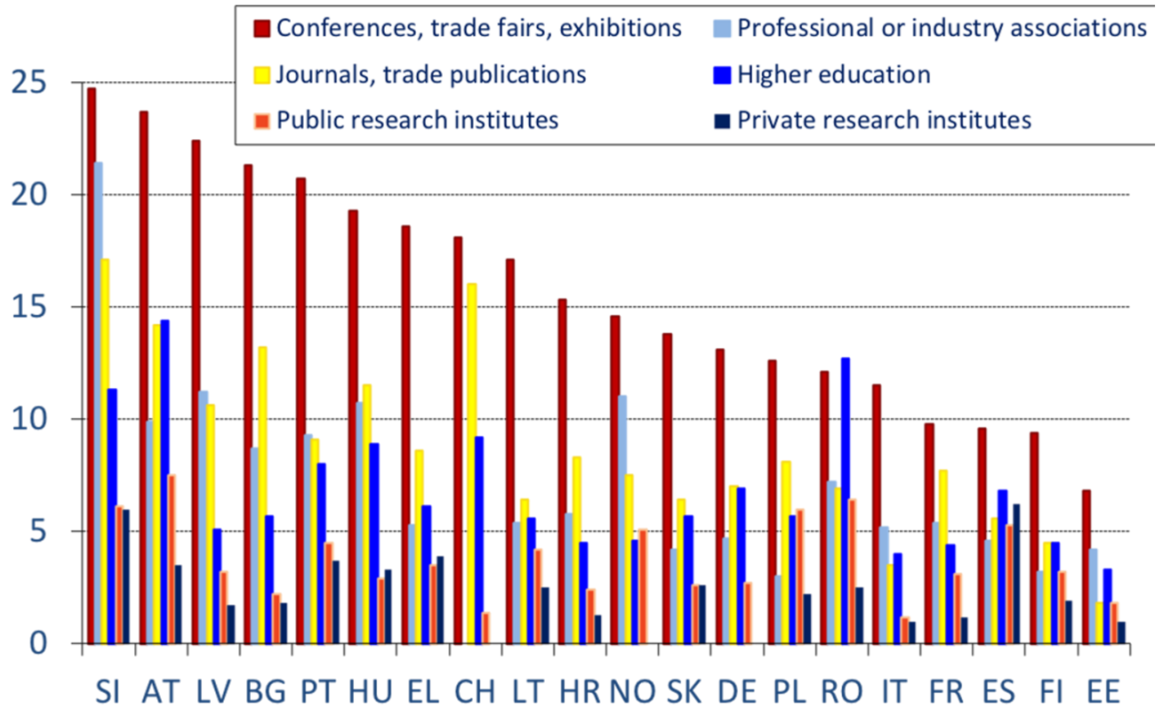
Figure 12: Highly important 'scientific' sources of information for product and process innovation, EU members, 2010–2012



Source: Eurostat, CIS 2012
Note: Data for Cyprus, Luxembourg and Malta are not included in this figure.

'Scientific' sources of information for product and process innovation remained of major relevance for the CE4 countries in 2014–2016 as well. (Figure 13)

Figure 13: Highly important 'scientific' sources of information for product and process innovation, EU members, 2014–2016

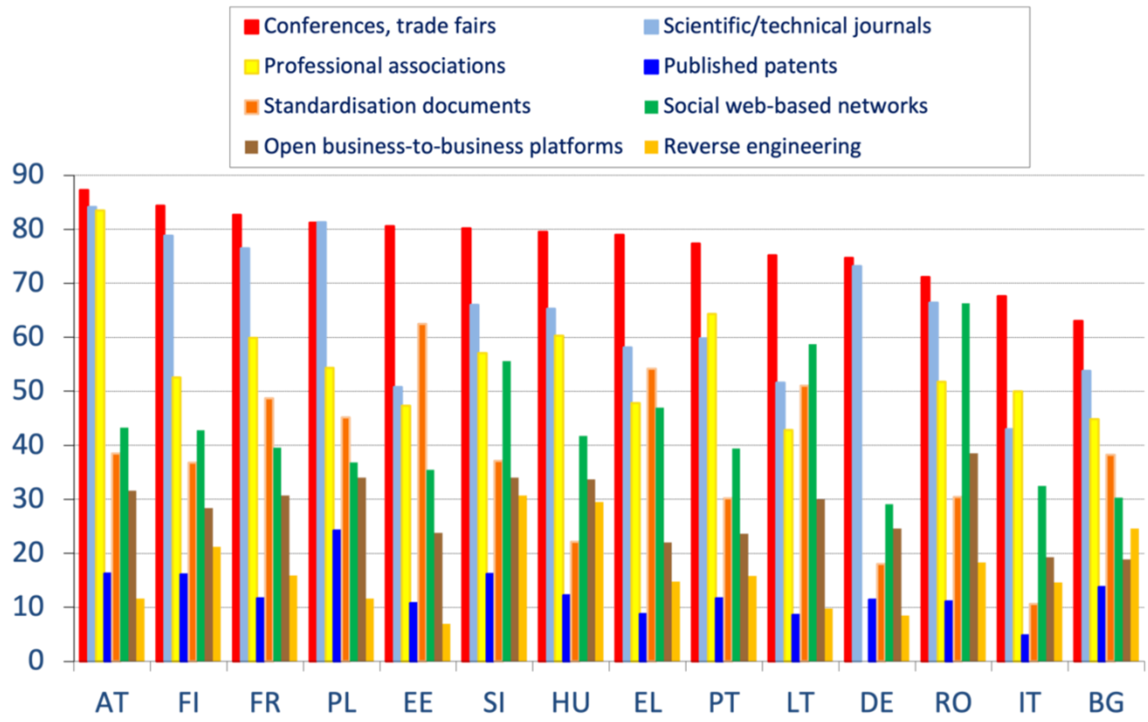


Source: Eurostat, CIS 2016

As already mentioned, data on information sources for innovation were collected by using somewhat different categories in the 2018 round of CIS, that is, distinguishing: i) Conferences, trade fairs or exhibitions; Scientific/technical journals or trade publications; Professional or industry associations; Published patents; Standardisation documents or committees; Social web-based networks or crowd-sourcing; Open business-to-business platforms or open-source software; Reverse engineering; and ii) Technical services purchased from private business enterprises vs Universities or other higher education institutions, government and public or private research institutes. While the first set of categories cannot be classified as 'business' vs 'scientific' sources of information for innovation, the second set of categories can be used as a 'proxy' to identify 'business' vs 'scientific' sources of information for innovation, although private research institutes are included in the second category.

Conferences, trade fairs or exhibitions were the most frequently mentioned channels to acquire information relevant for innovation in all countries where these data are available, followed closely in most countries by scientific/technical journals or trade publications; and professional or industry associations. It is worth noting that patents play a relative minor role in all countries: this channel is the least frequently mentioned in 10 countries of the 14 ones for which these data are reported and the penultimate channel in the remaining 4 ones. Data are available only for 2 of the CE4 countries. Their patterns are highly similar to the other countries. (Figure 14)

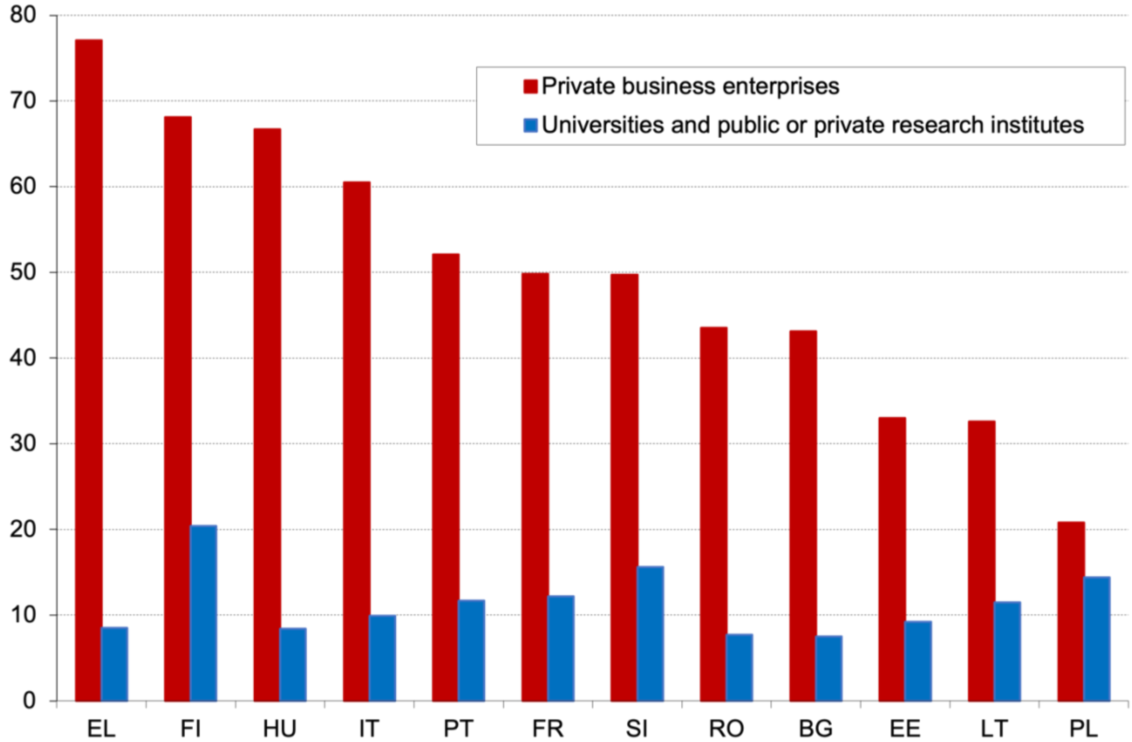
Figure 14: Channels to acquire information relevant for innovation, EU members, 2016–2018



Source: Eurostat, CIS 2016

In most countries a much larger share of firms purchased technical services from businesses compared to universities and research institutes in 2016–2018. The only exception is Poland where these two types of partners have a somewhat different wight. The difference between these partners is a substantial one even in Estonia and Lithuania where the business partners played a somewhat less important role than in the other 9 countries. Thus, there is a noteworthy difference between those two CE4 countries for which these data are reported: Hungary belongs to the majority group, while Poland is an 'outlier'. (Figure 15)

Figure 15: The share of enterprises that purchased technical services by cooperation partner, EU members, 2016–2018



Source: Eurostat, CIS 2018

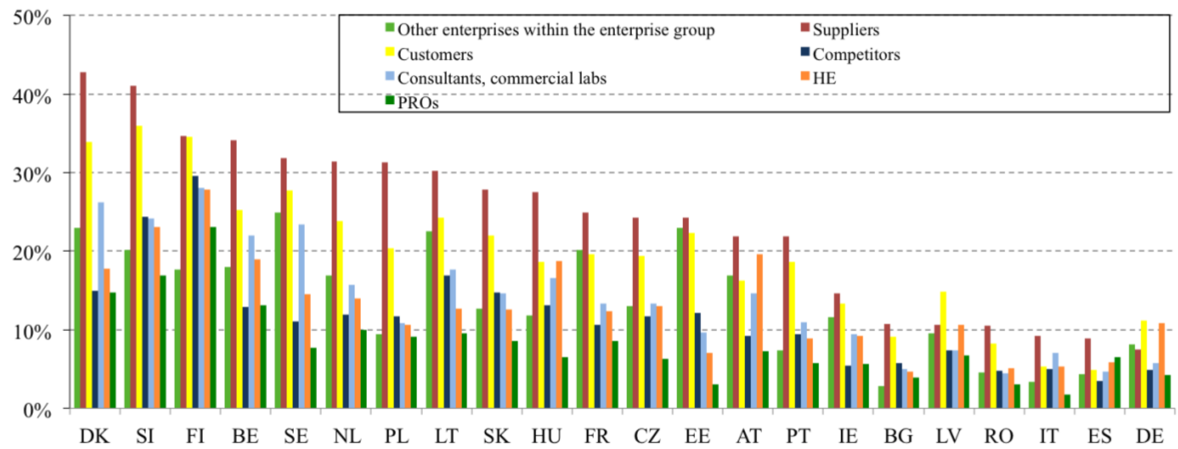
None of these data were collected in CIS 2020.

4.3 Innovation co-operation partners

Several factors influence innovation processes and performance; the frequency and quality of co-operation is certainly among those factors. Thus, when analysing business-academia (B-A) co-operation the frequency with which these various methods are used is an important piece of information. Further, it is also essential to note which co-operation method is the most valuable one for firms. Noteworthy changes have occurred in these respects in the first three periods considered here, and thus these developments are analysed separately below.

The largest share of innovative firms indicated innovation cooperation with their suppliers in all EU members participating in the CIS 2008 survey, except Latvia and Germany, where customers were the most sought-after partners. Yet, the frequency of these co-operations was wide-ranging from 7% (Germany) to 43% (Denmark). Customers were the second most frequently chosen partners in 20 countries (in Finland, the difference between suppliers and customers was a mere 0.15 percentage points). The overall frequency of innovation co-operations was lower in the EU10 countries (the new member states) in 2006–2008 than in the more advanced EU members, with two puzzling exceptions, namely Austria and Germany. (Figure 16)

Figure 16: Innovation co-operation partners, EU members, 2006–2008



Source: Eurostat, CIS 2008

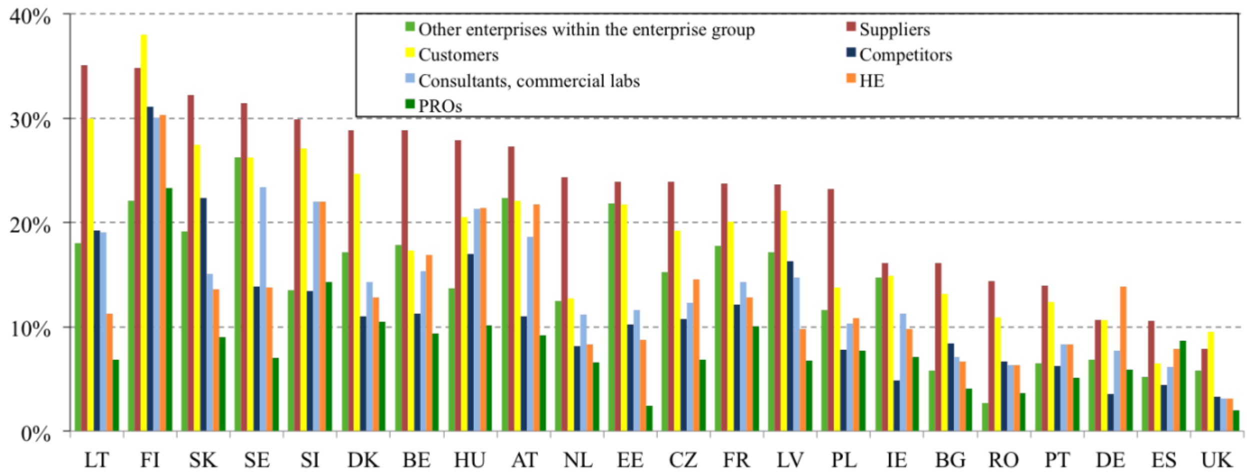
Note: Data for Cyprus, Luxembourg and Malta are not included in this figure.

Similar to the previous period, in 2008–2010 the highest share of innovative firms almost in all EU countries reported co-operation with suppliers, with the exception of Finland and the UK (where customers were the top co-operation partners), and Germany (HEIs). It is noteworthy that 23–35% of the innovative firms co-operated with suppliers in 15 countries, and 16% of them did so in another 2 countries, while the aggregate EU figure was 15.2%. Similarly, 21–30% of the innovative firms co-operated with clients or customers in 14 countries, and 13–15% of them did so in another 3 countries, while the aggregate EU figure was 12.6%. As for competitors or other enterprises in the sector, 8–31% of the innovative firms in 14 countries co-operated with them, as opposed to 6.7% at the EU level. Finally, 12–26% of the innovative firms in 16 countries co-operated with other enterprises within the enterprise group, which was well above the EU27 figure (9.3%). In short, innovation co-operation with 'business' partners was much more widespread in a large number of countries than suggested by the aggregate EU27 data. (Figure 17)

In this period there was *no clear division between the more and the less advanced member states* (or the ones belonging to various groups defined using the Summary Innovation Index). For example, Lithuania, Slovakia and Slovenia are next to Finland, Sweden and Denmark on Figure 17, while Bulgaria and Romania are in the same group as Germany, Spain and the UK.[12] In other words, the higher occurrence of innovation co-operation does not seem to be a decisive factor on its own: it does not necessarily mean a better innovation – and ultimately economic – performance.

[12] Lithuania, Bulgaria, and Romania were in the group of "modest innovators" given their 2008-2009 performance, reflected in the Innovation Union Scoreboard 2010, Slovakia and Spain were among the "moderate innovators", Slovenia and the UK were "innovation followers", while Denmark, Finland, Germany Sweden formed the club of "innovation leaders". (UNU-MERIT, 2011)

Figure 17: Innovation co-operation partners, EU members, 2008–2010



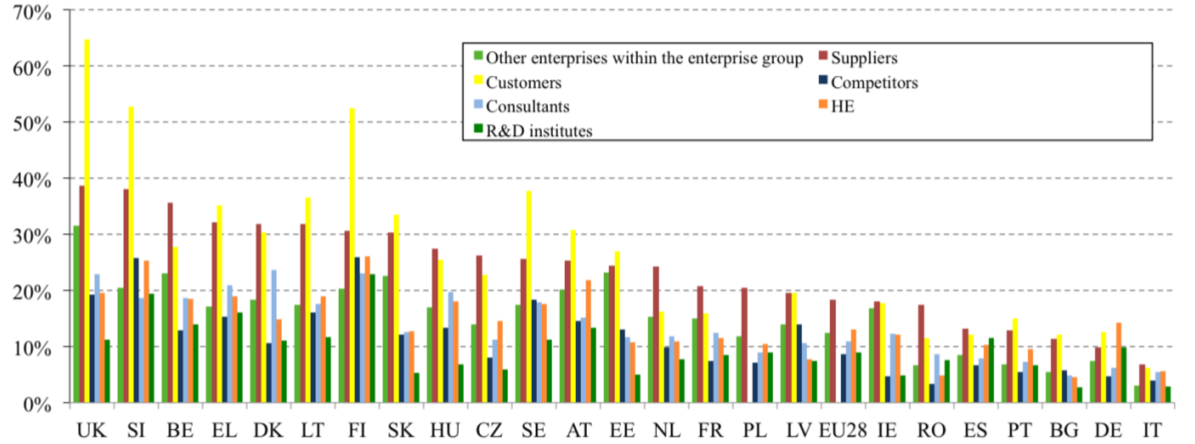
Source: Eurostat, CIS 2010

Note: Data for Cyprus, Luxembourg and Malta are not included in this figure.

In 2010–2012 the frequency of innovation co-operation increased to a significant extent in several countries. Customers became not only more sought-after partners compared to 2008–2010, but they were the most frequently mentioned ones in 10 countries, and in another 4 countries they were neck and neck with suppliers. Further, customers were No. 2 partners in 9 countries. From a different angle, suppliers lost their clear 'lead' observed in the previous two periods, and were the most frequently mentioned partners in 9 countries, and No 2 partners in 10 countries. Except Poland, customers and suppliers were the top 2 co-operation partners in the EU10 countries, too. (Figure 18) For this period, customers from the private vs. public sector were distinguished; the latter ones were especially frequently mentioned partners – that is, the share of customers from the public sector was at least 44% of the share of those from the privates sector – in 13 countries, including 5 of the EU10 countries, as well as 5 fairly advanced countries. (This distinction, however, does not appear on Figure 18.)

Again, there was *no clear division between the more and the less advanced member states* (or the ones belonging to various groups defined using the Summary Innovation Index). For example, Slovenia is next to the UK, Belgium, and Denmark, while Lithuania, Hungary, the Czech Republic, and Slovakia are close to Finland, Sweden, and Austria on Figure 18, and Bulgaria is in the same group as Germany, Spain, and Italy.

Figure 18: Innovation co-operation partners, EU members, 2010–2012

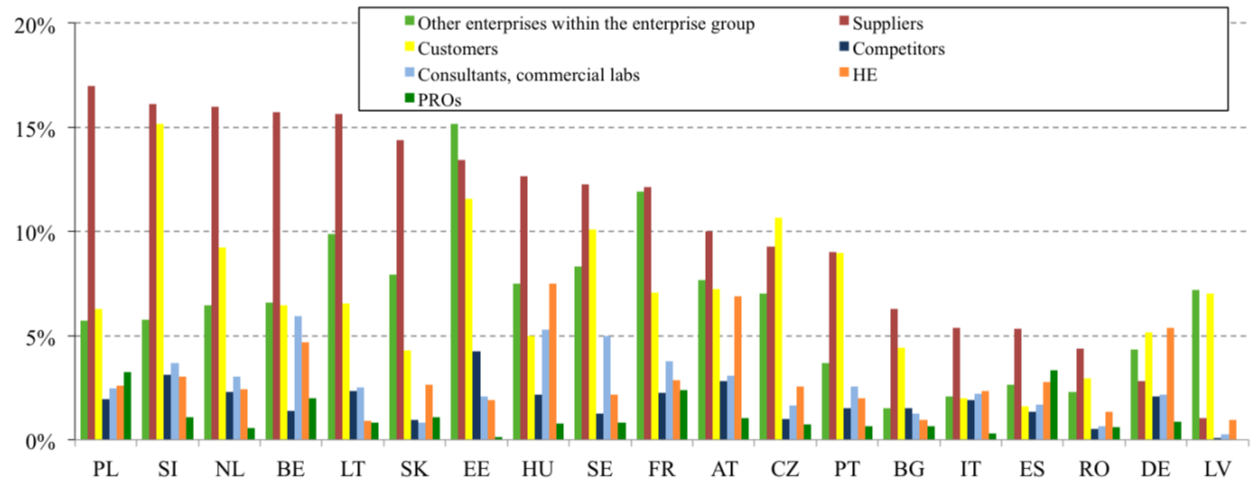


Source: Eurostat, CIS 2012
Note: Data for Cyprus, Luxembourg and Malta are not included in this figure.

In most EU countries co-operation with suppliers, customers, and other enterprises within the enterprise group is mentioned by a relatively large portion of firms as the most valuable method. (Figures 19–21)

Co-operation with higher education institutes was among the top three methods only in three countries in 2006–2008: HEIs were ranked first in Germany (5.4% of the innovative firms mentioned this method as the most valuable for innovation, and 5.2% perceived customers as the most valuable innovation co-operation partners), and second in Spain (2.8%) and Hungary (7.5%, in these two countries neck and neck with other enterprises within the enterprise group). PROs are assessed far less favourably: besides Spain, where they were ranked No. 2 (3.3%), nowhere else they were among the top 3. (Figure 19)

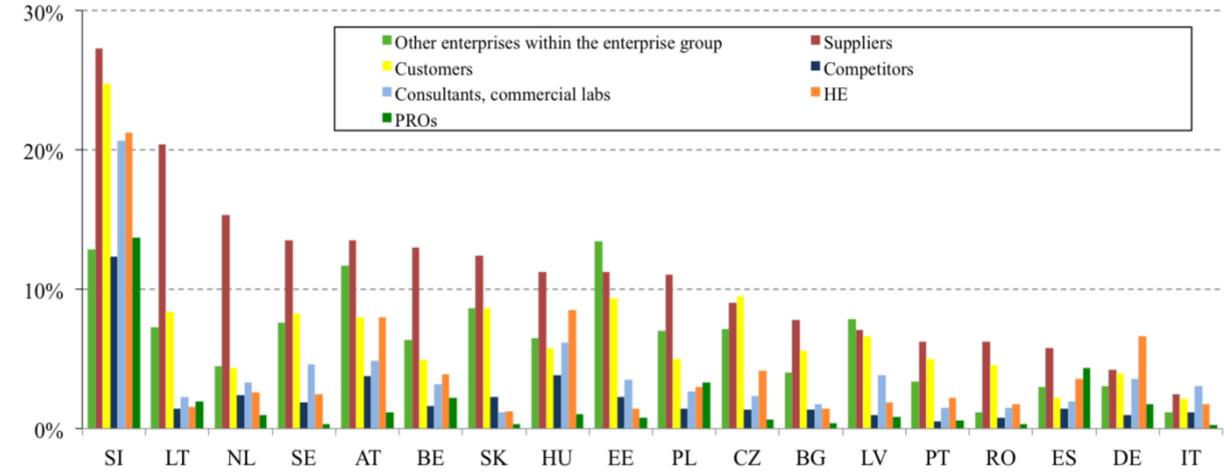
Figure 19: Innovation co-operation partners assessed most valuable, EU members, 2006–2008



Source: Eurostat, CIS 2008
Note: Data for Cyprus, Luxembourg and Malta are not included in this figure.

HEIs were assessed significantly more favourably in 2008–2010; co-operation with them was among the top three methods in eight countries. HEIs were ranked first in Germany (6.6%, followed by suppliers with 4.2%), second in Hungary (8.5%), while third in Austria (8.0%), Belgium (3.9%), Czechia (4.2%), Romania (1.7%), Slovenia (21.3%), and Spain (3.6%).[13] PROs were approved by a far lower share of innovative firms: in Spain they were again ranked No. 2 (4.3%), but in no other country they made into the top 3. (Figure 20)

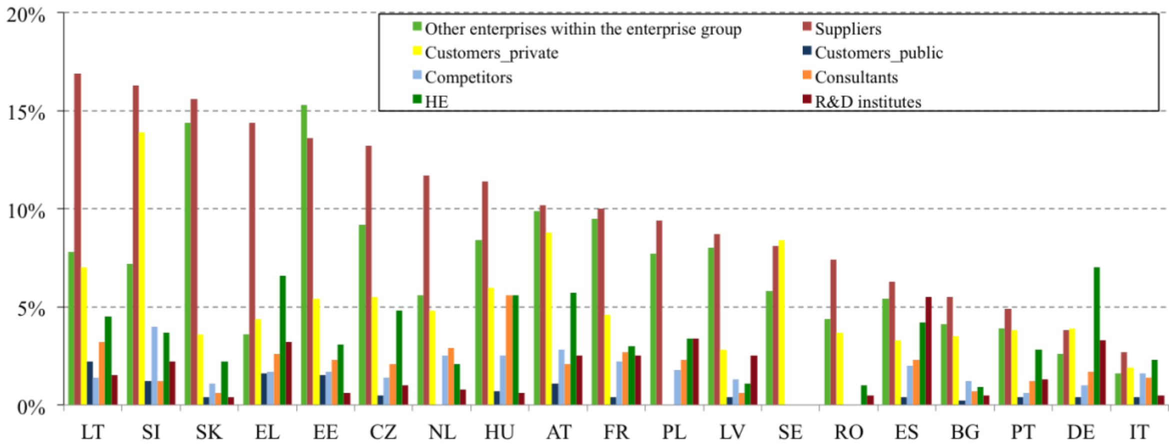
Figure 20: Innovation co-operation partners assessed most valuable, EU members, 2008–2010



Source: Eurostat, CIS 2010
Note: Data for Cyprus, Luxembourg and Malta are not included in this figure.

As for 2010–2012, HEIs were among the top 3 co-operation partners in four countries, that is, in Germany (No. 1 with 7.0%), Greece (No. 2, 6.6%), Hungary (No. 3 together with customers from the private sector and consultants, 5.6–6.0%), and Spain (No. 3, 4.2%). Research institutes, although in this period private ones were also included in this category, were not among the top 3 co-operation partners in any country. (Figure 21)

Figure 21: Innovation co-operation partners assessed most valuable, EU members, 2010–2012

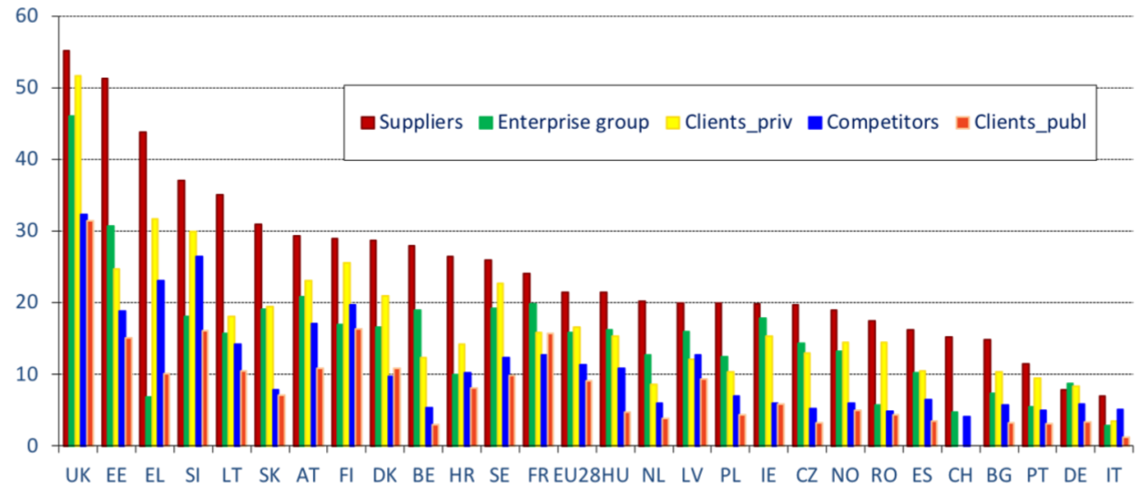


Source: Eurostat, CIS 2012
Note: Data for Cyprus, Luxembourg and Malta are not included in this figure.

[13] These figures also indicate that either only a small number of firms reply to this question of the CIS questionnaire in several countries, and thus with a low share of 'votes' universities can take one of the top three positions, or the respondents in some countries are more critical when the value of innovation co-operation methods is to be assessed than in other countries.

Innovation co-operation with business partners remained of major relevance for the CE4 countries in 2014–2016 as well, especially in Slovakia. (Figure 22)

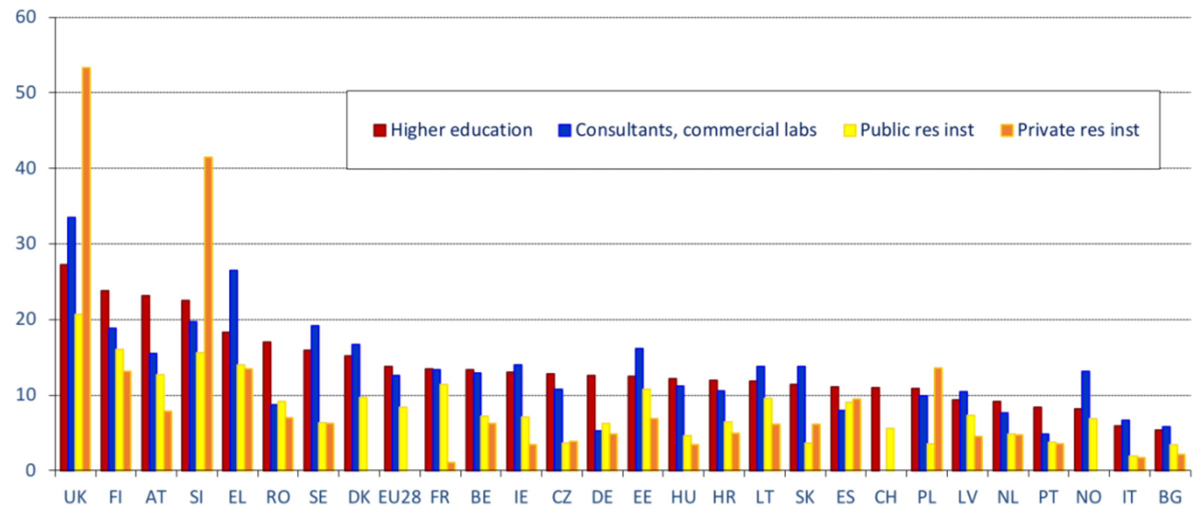
Figure 22: Innovation co-operation with business partners, EU members, 2014–2016



Source: Eurostat, CIS 2016

Innovation co-operation with academic partners was less frequent in the CE4 countries in 2014–2016, compared to the one with business partners as well. (Figure 23)

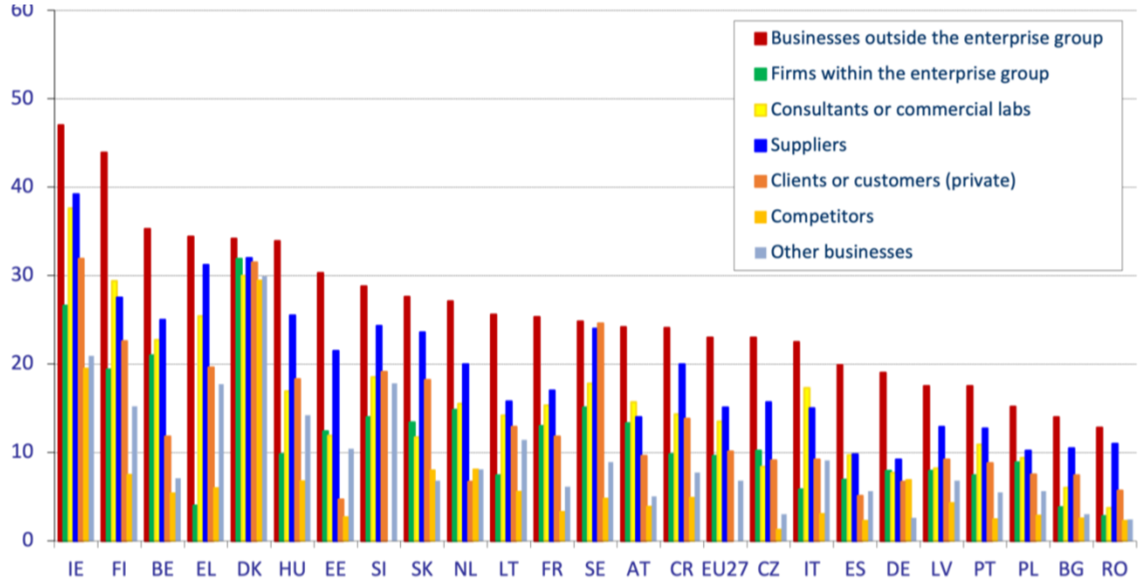
Figure 23: Innovation co-operation with academic partners, EU members, 2014–2016



Source: Eurostat, CIS 2016

Innovation co-operation with business partners remained significantly more frequent than that is with academic ('scientific') partners in 2016–2018 as well. Firms outside the enterprise group were the most frequently mentioned business partners, but several other types of businesses were also of importance in most EU countries. The frequency of co-operations was higher in Hungary and Slovakia than the EU27 figure. Again, we can find both advanced (FI, BE, DK, NL, FR, SE, AT) and less advanced countries (EL, EE, CR) in this group. The Czech figures are slightly below the EU27 ones, while the frequency of innovation co-operation with business partners in Poland is among the lowest in the EU. Thus, there is no similar pattern in the CE4 countries in this respect, either. (Figure 24)

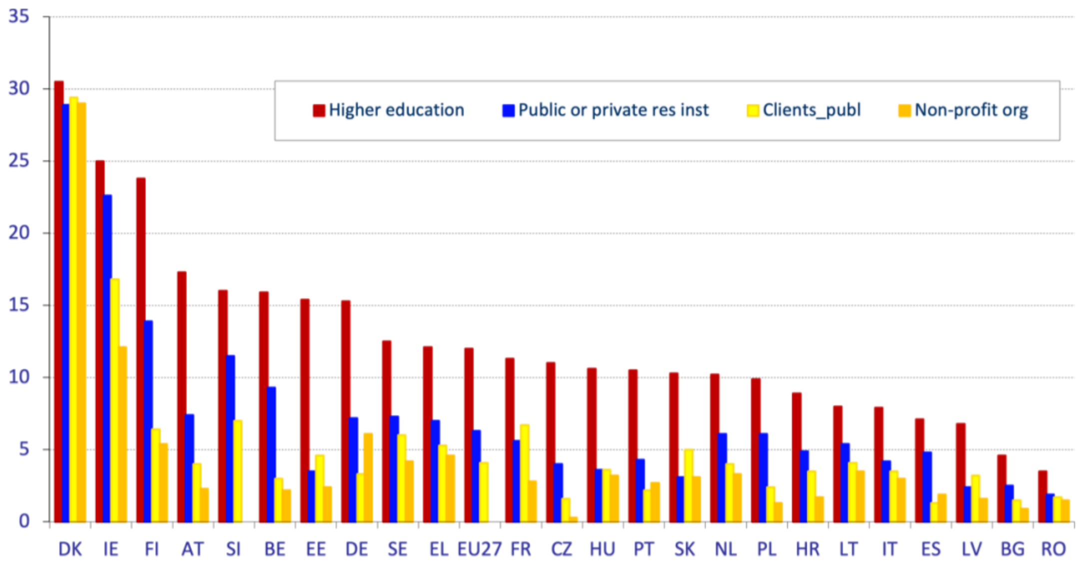
Figure 24: Innovation co-operation with business partners, EU members, 2016–2018



Source: Eurostat, CIS 2018

As already stressed, innovation co-operation with non-business – mainly academic – partners was a less frequently used innovation co-operation method in all EU countries also in 2016–2018. In most EU countries universities and research institutes were the most frequently mentioned partners, but clients from the public sector played a major role, in a few countries even a more important one than research institutes (DK, FR, SK, and LV). As for the CE4 countries, their figures were close to the EU27 ones. Clients from the public sector were more important partners in Slovakia compared to the other three countries, while research institutes played a more significant role in Poland than in the other CE4 countries.

Figure 25: Innovation co-operation with non-business partners, EU members, 2016–2018

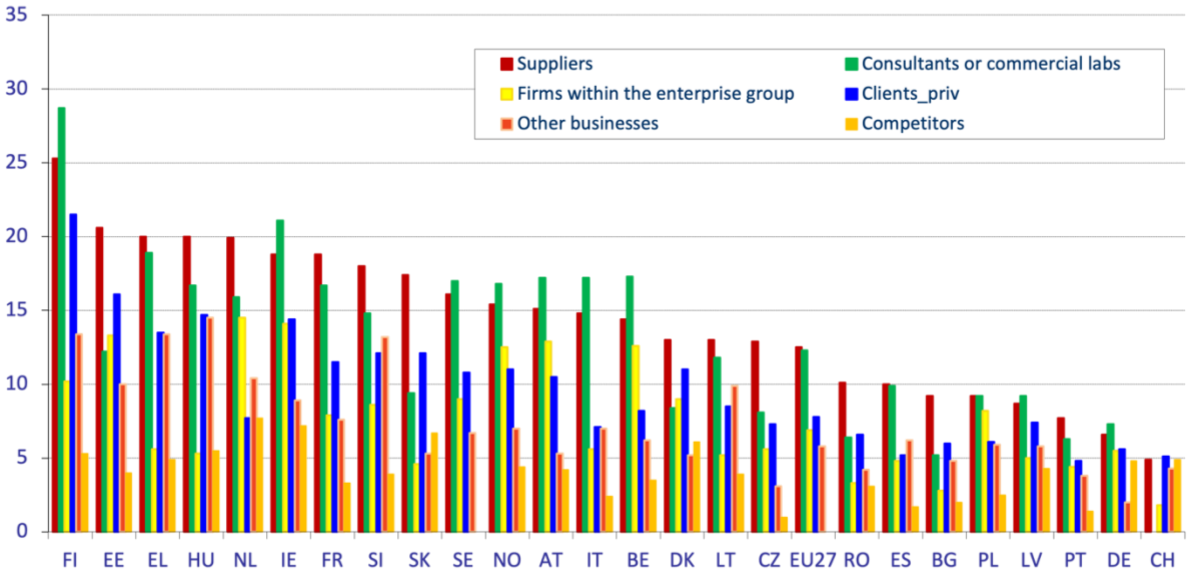


Source: Eurostat, CIS 2018

The frequency of innovation co-operation with business partners was markedly lower in quite a few countries (e.g., in Ireland, Finland, Belgium, Greece, Denmark, Hungary, Estonia, Slovenia, Slovakia, the Netherlands, Lithuania, France, and Sweden) in 2018–2020 compared to the previous periods. The other noticeable difference is that supplier became the most frequently mentioned partners in 16 countries, while consultants and commercial labs played that role in 10 countries.

The frequency of co-operations was higher in Hungary and Slovakia than the EU27 figure. Again, there are both advanced (FI, NL, FR, SE, AT, BE, DK) and less advanced countries (EL, EE, SI, LT) in this group. The Czech figures are at around the EU27 ones (some are above, others slightly below). The frequency of innovation co-operation with business partners in Poland moved closer to the EU aggregate figure. Still, the data for CE4 countries indicated different patterns. (Figure 26)

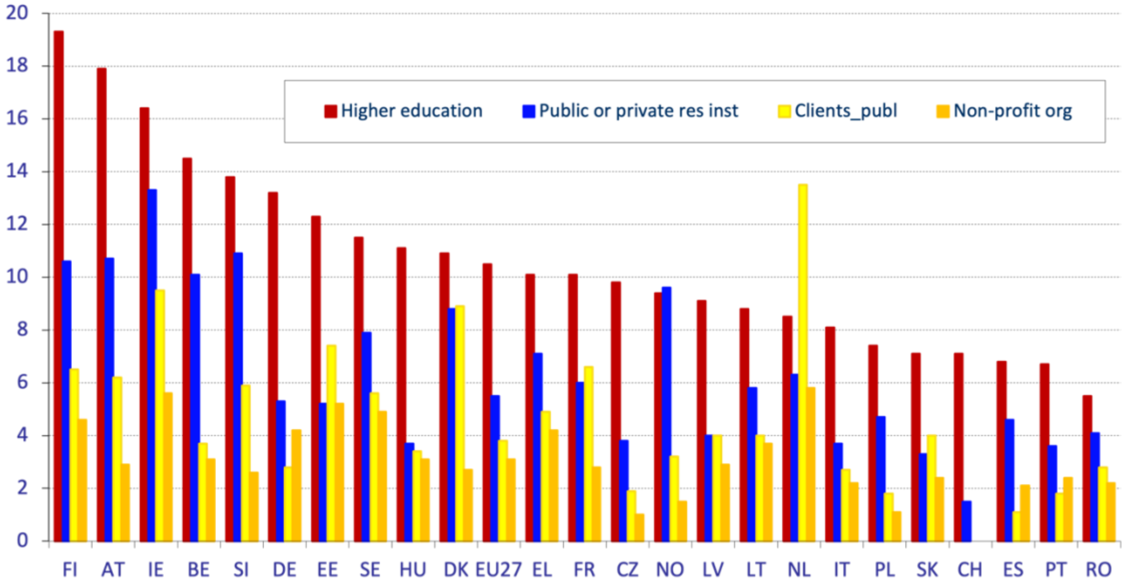
Figure 26: Innovation co-operation with business partners, EU and EFTA countries, 2018–2020



Source: Eurostat, CIS 2020

Innovation co-operation with non-business – mainly academic – partners also became a less frequently used innovation co-operation method in all EU countries also in 2018–2020. In most EU countries universities and research institutes were the most frequently mentioned partners, but clients from the public sector played a major role, in a few countries even a more important one than research institutes (DK, FR, NL, and SK). As for the CE4 countries, the Hungarian and Czech figures were close to the EU27 ones, while the Polish and Slovak ones were below that level. Further, clients from the public sector were more important partners in Slovakia compared to the other three countries, while research institutes played a somewhat more important role than in the other CE4 countries. (Figure 27)

Figure 27: Innovation co-operation with non-business partners, EU and EFTA countries, 2018–2020



Source: Eurostat, CIS 2020

5 Innovation performance of the CE4 countries

Significant progress has been achieved in measuring R&D and innovation activities since the 1960s (Gault, 2020; Gault (ed.) 2023; Grupp, 1998; Grupp and Schubert, 2010; Smith, 2005) with the intention to provide comparable data sets as a solid basis for assessing R&D and innovation performance and thereby guiding policy-makers in devising appropriate policies.[14] Although there are widely used guidelines to collect data on R&D and innovation – the Frascati and Oslo Manuals (OECD, 2002; and OECD, 2005 and 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 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 processes, 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.

There is a fairly strong – sometimes implicit, 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. Two caveats are in order here. First, a major methodological snag 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.

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[14] "The annual European Innovation Scoreboard (EIS) provides a comparative assessment of the research and innovation performance of EU Member States and selected third countries, and the relative strengths and weaknesses of their research and innovation systems." (EC, 2020: 6) The same (or similar) sentence appears in earlier editions of the EIS, too.

Comparing these three methods, the authors conclude: "(…) even using accepted approaches like BoD or factor analysis may result in drastically changing rankings." (ibid: 74) That methodological difficulty reveals a substantive one: both for thorough, more reliable analyses, and better policy decisions the multidimensional character of innovation processes and performance needs to be reflected. Grupp and Schubert (2010: 77), therefore, propose using multidimensional representations, e.g., spider charts. That would enable analysts and policy-makers to identify strengths and weaknesses, that is, more precise targets for policy actions.

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.

Keeping in mind these caveats, the modest intention here is to describe the dynamics of CE4 innovation performance in two simple ways: (i) using three series of elementary data, namely the share of innovative firms up to 2014–2016 and then on the so-called innovation-active firms, that of turnover from innovation, as well as labour productivity; and (ii) recalling their position on various scoreboards, relying on composite indicators.

Although various indicators measuring patenting activity are widely used, either as a proxy of, or even a direct measure of, innovation performance, these are not reported here as patenting is more of a signal of strategic intentions – to commercialise an idea at a later stage or prevent competitors from using certain pieces of information – than a measure of innovation activities. In any case, interested readers can easily find comparable data on patenting activities e.g., among the European Innovation Scoreboard (Innovation Union Scoreboard) indicators.

5.1 The share of innovative and innovation-active enterprises

Data on the share of innovative enterprises only available up to 2014–2016. The share of innovative enterprises in Czechia has remained slightly below the EU aggregate figure since 1998–2000. The other three CE4 countries seem to play in a different league. (Table 8)

In more detail, this ratio has fluctuated quite considerably in Slovakia since 1998: in the range of 19.5–30.3%. There is neither a clear increasing nor a decreasing trend in the share of innovative firms in Hungary, Poland, and Slovakia. This ratio in Hungary was falling from a fairly low level (23.3%) in 1998–2000 to 16.4% in 2010–2012, then started increasing to a moderate extent. An inverted U shape (growth followed by contraction) can be observed in Poland, with an increasing share in 2014–2016 breaking the downward trend in the right 'leg' of the inverted U. Following a sharp increase in 2002–2004, a sort of oscillation can be observed in Czechia, in a relatively close range, that is, 35–39%.

It would not be a well-substantiated claim to establish the impacts of the 2008 global financial and economic crisis on innovation activities in the CE4 countries merely relying on this set of figures.[15] Interestingly, the share of innovative firms considerably increased in Slovakia by

[15] Izsak and Radošević (2015) is analysing the impacts of the crisis on innovation policies, in particular on public spending, in various EU regions. See also Izsak et al. (2013).

2008–2010 compared to the previous period, dropped sharply in 2010–2012 and skyrocketed in 2012–2014. No noteworthy change was recorded in Poland in this period.

Table 8: The share of innovative enterprises in the CE4 countries, 1998–2016 (%)

	1998–2000	2002–2004	2004–2006	2006–2008	2008–2010	2010–2012	2012–2014	2014–2016
EU	n.a.	39.5	38.9	n.a.	39.0	36.0	36.8	39.5
Czechia	30.3	38.3	35.0	39.3	34.8	35.6	35.7	37.3
Slovakia	19.5	22.9	24.9	21.7	28.1	19.7	30.3	23.3
Hungary	23.3	20.8	20.1	20.8	18.4	16.4	18.2	21.2
Poland	17.3	24.8	23.0	19.8	16.2	16.1	15.8	17.7

Source: Eurostat, various rounds of CIS
n.a.: not available

The Eurostat introduced a new category, that is "innovation-active enterprise" when collecting data for the 10th round of CIS, the Community Innovation Survey, covering the 2014–2016 period. "An innovation-active firm is one that has had innovation activities during the period under review, including those with ongoing and abandoned activities. In other words, firms that have had innovation activities during the period under review, regardless of whether the activity resulted in the implementation of an innovation, are innovation-active." (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Innovation-active_firm) By definition, the share of innovation-active firms should be larger than that of innovative ones. Data available on the shares of both types of firms for 2014–2016 confirm this claim. (Table 8 and Table 9)

Considering data obtained in the 10th–12th rounds of CIS, two noteworthy changes can be observed. The share of innovative-active Czech enterprises has overtaken the aggregate EU figure by 2018–2020. Further, while Polish figures had been below the Hungarian ones since 2006–2008 up to 2016–2018, in 2018–2020 Poland surpassed Hungary and almost the closed the gap with Slovakia.

Table 9: The share of innovation-active enterprises in the CE4 countries, 2014–2020 (%)

	2014–2016	2016–2018	2018–2020
EU	50.6	50.3	52.7
Czechia	46.3	46.8	56.9
Slovakia	30.7	30.5	36.6
Poland	22.0	23.7	34.9
Hungary	29.0	28.7	32.7

Source: Eurostat, various rounds of CIS
Note: An innovation-active firm is one that has had innovation activities during the period under review, including those with ongoing and abandoned activities. In other words, firms that have had innovation activities during the period under review, regardless of whether the activity resulted in the implementation of an innovation, are innovation-active. (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Innovation-active_firm)

5.2 Turnover from innovation

Data on the share of turnover from innovation – making a distinction between goods new to the firm vs. new to the market – need to be taken by a pinch of salt.[16] Some of the counterintuitive figures are highlighted by red in Table 10. For example, the share of turnover from product and process innovations new to the market is significantly higher than that of from product and process innovations new to the firm in Estonia in 2014 and 2016, followed by a dramatic drop in 2018. Further, much higher data are recorded for the UK in 2014 and 2016 compared to previous years. The same applies to Slovakia what is even more noteworthy if one takes into account the relatively low share of innovative enterprises. Of course, one cannot exclude on logical grounds that a small share of innovative firms can be that much innovative. Then, however, drastically smaller shares are observed in 2018 and 2020. Finally, quite a few figures are surprisingly low for Belgium, Finland, Denmark, and Sweden (highlighted by blue), especially when those are compared to Bulgarian, Greek, Lithuanian, or Slovak data.

To focus on CE4 countries, Table 11 presents data for these countries, as well as Estonia (a leading transition country), Portugal (a classic 'cohesion country', with somewhat similar size and level of socio-economic development), and Slovenia (the fifth Central European new member state). Surprisingly, Slovakia was the frontrunner from 2006 until 2016 – but with some questions, as already stressed. Estonia came second up to 2016, but again with puzzles, and then took the lead in 2018. It is also noteworthy that Hungary was close to Ireland in some respects and ahead of Slovenia for quite a few years. The Czech figures do not show major 'deviations' in the first 12 years and then a sudden drop is reported.

In sum, probably one should not overestimate the significance of these data – although the turnover from innovation should be a highly relevant indicator. Instead of using the reported data to jump to pretentious conclusions (e.g., by journalists, spin doctors or politicians), the 'outlier' figures, highlighted above, should be taken as eye-opening questions to improve the quality and coherence (comparability) of the Community Innovation Survey.

[16] Data are not available for 2012.

Table 10: Turnover from innovation, selected EU countries, 2004-2020 (% of total turnover)

	2004		2006		2008		2010		2014		2016		2018		2020	
	Firm*	Market*	Firm*	Market*	Firm*	Market*	Firm*	Market*	Firm*	Market*	Firm*	Market*	Firm*	Market*	Firm*	Market*
EU	7.4	6.3	10.4	10.0	n.a.	n.a.	n.a.	n.a.	13.6	8.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Belgium	8.2	4.8	7.8	6.7	7.2	7.8	10.0	9.3	12.5	5.5	21.1	*6.4*	n.a.	n.a.	n.a.	n.a.
Bulgaria	4.1	8.5	9.1	17.0	14.0	17.0	15.4	16.1	11.3	9.7	13.4	*11.2*	*3.6*	*2.8*	4.6	2.8
Czechia	7.8	7.7	7.6	16.0	12.9	16.1	15.9	15.1	15.8	14.8	13.9	13.5	*6.4*	*6.4*	8.3	6.1
Denmark	*5.8*	*5.2*	*7.9*	*7.4*	8.5	12.3	17.8	16.7	11.2	10.4	16.4	*4.5*	n.a.	n.a.	n.a.	n.a.
Germany	10.0	7.6	11.3	10.2	16.4	3.8	17.1	5.3	16.7	4.7	9.4	17.6	11.3	*3.5*	10.6	3.4
Estonia	7.6	4.4	13.3	6.3	8.8	5.8	*18.9*	*9.7*	*9.1*	*27.7*	*5.3*	*24.5*	*10.8*	*2.3*	n.a.	n.a.
Ireland	4.5	5.6	7.2	9.6	9.4	7.6	n.a.	n.a.	5.5	24.9	17.7	13.0	n.a.	n.a.	n.a.	n.a.
Greece	6.2	4.8	12.4	22.8	n.a.	n.a.	n.a.	n.a.	13.9	10.2	*21.0*	*21.7*	*13.4*	*10.4*	10.6	9.7
Spain	10.0	3.8	12.1	10.5	12.7	11.1	20.7	18.2	19.4	13.9	9.1	8.9	9.3	6.9	*15.3*	6.4
France	5.6	6.2	n.a.	n.a.	9.4	10.2	11.5	8.8	14.4	10.1	10.1	6.4	*3.9*	*4.9*	n.a.	n.a.
Italy	5.6	6.3	7.3	7.3	9.0	8.3	14.8	15.3	9.2	10.2	10.3	12.8	10.5	6.3	9.2	4.3
Latvia	1.6	3.6	3.0	5.0	4.4	9.2	n.a.	n.a.	12.6	12.3	14.6	13.7	*5.2*	*3.2*	c	c
Lithuania	5.3	4.4	10.6	10.0	9.3	9.2	9.6	5.7	17.2	9.2	*25.6*	7.4	5.9	3.6	7.2	4.3
Hungary	2.6	4.3	8.3	12.5	9.5	16.6	9.8	20.1	16.2	12.9	8.3	12.4	*4.7*	*4.1*	5.1	2.6
Netherlands	4.4	4.0	8.1	10.0	6.1	8.5	9.1	9.5	9.8	15.3	8.7	12.3	n.a.	n.a.	n.a.	n.a.
Austria	5.4	5.2	9.0	8.3	7.9	7.5	11.2	8.5	12.3	8.4	12.6	9.5	8.6	6.3	7.3	5.7
Poland	5.4	8.1	9.2	7.6	9.6	8.2	8.7	11.5	9.2	7.3	9.4	8.3	*4.2*	*2.2*	3.9	3.6
Portugal	5.6	4.4	9.5	11.1	9.1	11.0	n.a.	n.a.	6.3	5.1	7.3	8.6	7.4	4.8	10.2	4.3
Romania	9.5	7.1	28.6	10.1	23.5	9.7	31.6	14.4	28.8	18.9	*29.9*	*5.5*	*6.7*	*2.2*	4.3	1
Slovenia	6.9	7.4	11.5	8.9	13.3	11.1	11.6	9.7	17.5	9.5	10.7	8.2	n.a.	n.a.	n.a.	n.a.
Slovakia	6.4	12.8	15.5	13.5	13.2	14.9	20.1	27.9	9.1	*32.0*	*16.2*	*27.3*	*3.7*	*7.5*	3.0	*11.9*
Finland	*5.1*	*9.7*	*5.9*	13.3	12.0	8.0	10.9	13.3	*8.8*	*6.4*	*7.3*	*9.7*	*8.9*	*5.4*	14.3	*5*
Sweden	*5.1*	*8.3*	n.a.	n.a.	*6.2*	*7.9*	n.a.	n.a.	*5.1*	*6.8*	*8.8*	*6.8*	n.a.	n.a.	n.a.	n.a.
United Kingdom	7.6	6.4	13.8	10.6	n.a.	n.a.	n.a.	n.a.	*41.4*	*27.7*	*35.7*	*34.2*	n.a.	n.a.	n.a.	n.a.

Source: Eurostat, various rounds of CIS
* New to the firm, New to the market
n.a.: Not available; c: Confidential

Table 11: Turnover from innovation, CE4 countries, Estonia, Ireland, Portugal, and Slovenia, 2004–2016 (% of total turnover)

	2004		2006		2008		2010		2014		2016		2018		2020	
	Firm*	Market*	Firm*	Market*	Firm*	Market*	Firm*	Market*	Firm*	Market*	Firm*	Market*	Firm*	Market*	Firm*	Market*
Czechia	7.8	7.7	7.6	16.0	12.9	16.1	15.9	15.1	15.8	14.8	13.9	13.5	6.4	6.4	8.3	6.1
Estonia	7.6	4.4	13.3	6.3	8.8	5.8	18.9	9.7	9.1	27.7	5.3	24.5	10.8	2.3	n.a.	n.a.
Ireland	4.5	5.6	7.2	9.6	9.4	7.6	n.a.	n.a.	5.5	24.9	17.7	13.0	n.a.	n.a.	n.a.	n.a.
Hungary	2.6	4.3	8.3	12.5	9.5	16.6	9.8	20.1	16.2	12.9	8.3	12.4	4.7	4.1	5.1	2.6
Poland	5.4	8.1	9.2	7.6	9.6	8.2	8.7	11.5	9.2	7.3	9.4	8.3	4.2	2.2	3.9	3.6
Portugal	5.6	4.4	9.5	11.1	9.1	11.0	n.a.	n.a.	6.3	5.1	7.3	8.6	7.4	4.8	10.2	4.3
Slovenia	6.9	7.4	11.5	8.9	13.3	11.1	11.6	9.7	17.5	9.5	10.7	8.2	n.a.	n.a.	n.a.	n.a.
Slovakia	6.4	12.8	15.5	13.5	13.2	14.9	20.1	27.9	9.1	32.0	16.2	27.3	3.7	7.5	3.0	11.9

Source: Eurostat, various rounds of CIS
* New to the firm, New to the market
n.a.: Not available

5.3 Change in labour productivity

Innovation, especially process, managerial and organisational innovations, can enhance productivity, and thus data on labour productivity can also be used to characterise innovation performance. Using this lens, the top CE4 performer is Slovakia with an improvement by 61.9 percentage points between 2000–2020 (when taking the level of real labour productivity in 2010 as 100). Poland is a close second with 61.1 percentage points. Compared to the 2010 level, Poland has achieved the biggest improvement, but it had a higher level of labour productivity in 2000 compare to Slovakia. Czechia and Hungary recorded smaller improvements, that is, 47.9, and 41.4 percentage points, respectively. It should be noted, though, that Czechia was ranked 1 among the CE4 countries in 2000. (Table 12 and Table 13)

Table 12: Real labour productivity per hour worked in the CE4 countries, 2000–2011 (2010 = 100)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Poland	71.6	74.0	78.1	81.5	84.6	86.0	88.4	90.7	91.4	94.3	100.0	104.7
Slovakia	65.1	67.4	72.2	77.9	80.1	82.7	87.7	94.3	96.3	93.6	100.0	101.6
Czechia	72.0	77.5	78.7	82.8	86.2	90.7	96.3	100.4	100.0	97.7	100.0	101.7
Hungary	71.0	75.1	79.4	82.3	87.2	92.8	96.8	99.2	101.8	98.7	100.0	102.6

Source: Eurostat and own calculations

Table 13: Real labour productivity per hour worked in the CE4 countries, 2012–2020 (2010 = 100)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	Change*
Poland	106.5	107.7	109.5	112.2	114.5	120.0	128.2	134.3	132.6	61.1
Slovakia	103.1	105.6	107.6	111.4	111.8	114.3	117.2	119.8	127.0	61.9
Czechia	102.1	102.4	103.6	109.0	108.6	112.4	113.9	117.0	119.8	47.9
Hungary	101.3	102.1	100.9	102.5	100.2	103.3	107.5	112.0	112.4	41.4

Source: Eurostat and own calculations
* Change by 2020, compared to 2000

When comparing the CE4 countries' nominal labour productivity to the that of the EU27 aggregate, their ranking is different in terms of the rate of improvement in 2000–2020: Poland is No.1, followed by Slovakia and Hungary with the same level of progress, and Czechia is ranked 4. Further, the differences are smaller among the four countries. (

Table 14 and Table 15) Czechia was closest to the EU level in 2020 (78.9%), followed by Slovakia (76.1%). Hungary and Poland were markedly further below (66.4% and 63.6%, respectively). From a different angle, the two frontrunners in 2000, that is, Czechia and Slovakia, kept their positions in 2020 as well. It is worth noting, however, that Slovakia was slightly ahead of Czechia in 2008 and then with a significant lead in 2009–2015.

Table 14: Nominal labour productivity per hour worked in the CE4 countries, 2000–2011 (EU27 = 100)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Czechia	61.1	65.7	64.3	68.1	69.7	70.4	70.9	74.0	74.0	74.7	72.1	71.7
Slovakia	56.5	58.6	61.2	64.9	65.3	67.0	69.4	72.3	75.1	74.2	78.5	76.8
Hungary	51.5	55.4	58.1	59.9	60.9	63.2	63.5	64.3	68.0	69.6	70.0	71.1
Poland	45.8	46.4	48.2	49.3	50.8	50.2	49.5	50.3	50.9	53.0	56.7	58.5

Source: Eurostat and own calculations

Table 15: Nominal labour productivity per hour worked in the CE4 countries, 2012–2020 (EU27 = 100)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	Change*
Czechia	71.3	72.2	73.9	75.2	74.5	75.8	76.5	77.8	78.9	17.8
Slovakia	77.0	78.0	78.7	78.3	72.9	70.5	70.0	70.6	76.1	19.6
Hungary	69.5	69.4	67.2	66.9	63.5	63.4	65.4	66.7	66.4	14.9
Poland	59.4	58.7	58.6	59.5	59.1	60.1	62.6	64.9	63.6	17.8

Source: Eurostat and own calculations
* Change by 2020, compared to 2000

Comparing the data in Table 8 and Tables 12–15 confirms that countries with the higher share of innovative enterprises have the highest level of productivity: Czechia and Slovakia. Poland, however, presents a puzzle: while it has the lowest share of innovative enterprises, it has achieved the second largest improvement in real labour productivity, almost the same level as Slovakia. In a detailed analysis several further factors need to be considered, including structural changes, business cycles, changes in product portfolios, prices and profits. For example, while at a micro level innovation indeed is the main source of productivity improvement (strictly defined), at a macro level a higher level of productivity can be achieved by re-allocating resources from less efficient firms (sectors) to more efficient ones.

5.4 European Innovation Scoreboard, Summary Innovation Index

The European Commission is using the European Innovation Scoreboard (EIS) as its principal measurement and monitoring tool to assess the innovation performance of the EU member states. Its set of indicators has been revised several times since its first edition in 2002. A composite indicator, called the Summary Innovation Index (SII), is also calculated annually to summarise innovation performance and rank member states by this tool. Given this prominent role of the SII, it is worth looking at it in some details. Its 2017–2020 editions are based on 27 indicators, grouped by 8 innovation dimensions. (EC, 2017, 2018, 2019, 2020) A rudimentary classification exercise reveals a strong bias towards R&D-based innovations: 8 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 are focusing on non-R&D-based innovations. (Table 16) Given that (i) the EIS is used by the European Commission to monitor progress, and (ii) its impacts on national policy-making processes, this bias towards R&D-based innovation is a source of major concern.

Table 16: The 2017–2020 Innovation Union 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

Despite this bias, the SII is a widely used metrics by analysts, experts, and policy-makers. Thus, it cannot be ignored what it tells about the CE4 countries. By considering the SII in 2006–2020, Czechia was the best performer among the CE4 countries in 2006, kept that position in 2020 and improved her score to the highest degree. Hungary also kept its 2006 position in 2020 (No. 2 in the group) and had the second place in terms increasing her score. Slovakia and Poland were ranked 3 and 4, respectively, but Poland had made a slightly more progress. Following the EIS classification, all the CE4 countries were "moderate innovators" in 2020 (and before). (Table 17)

Table 17: Summary Innovation Index, CE4 countries and the EU, 2006–2020

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Change
EU	0.493	0.506	0.504	0.516	0.531	0.532	0.545	0.554	0.476	0.493	0.495	0.501	0.512	0.514	0.533	0.040
Czechia	0.374	0.390	0.369	0.374	0.411	0.416	0.405	0.422	0.399	0.404	0.409	0.412	0.416	0.428	0.443	0.069
Hungary	0.298	0.303	0.314	0.315	0.341	0.344	0.335	0.351	0.315	0.343	0.345	0.344	0.354	0.340	0.352	0.054
Slovakia	0.296	0.302	0.304	0.312	0.299	0.304	0.350	0.328	0.317	0.326	0.319	0.336	0.332	0.333	0.326	0.030
Poland	0.263	0.275	0.265	0.276	0.272	0.282	0.268	0.279	0.240	0.272	0.280	0.290	0.288	0.294	0.296	0.033

Source: European Innovation Scoreboard. various editions

Table 18: Rankings of the CE4 countries by the Global Innovation Index, 2007–2020

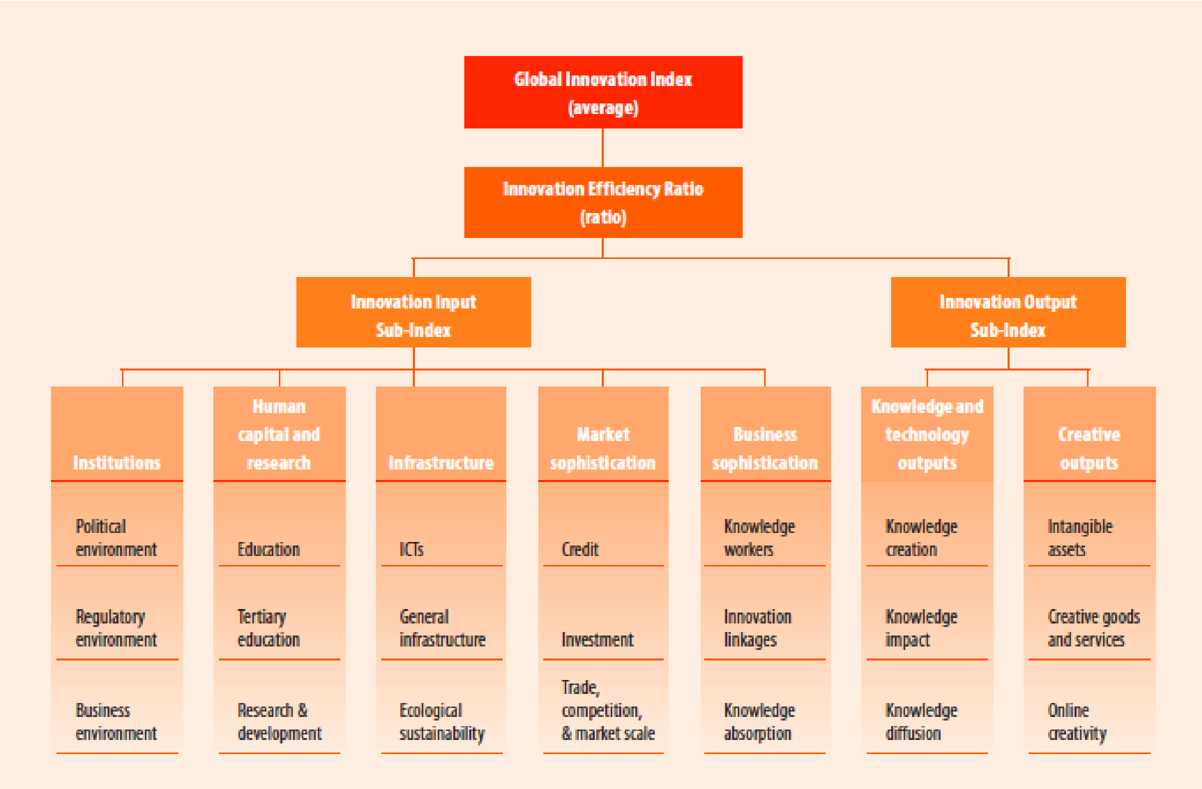
	2007	2008/ 2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Change
Czechia	32	33	27	27	27	28	26	24	27	24	27	26	24	-8
Hungary	36	47	36	25	31	31	35	35	33	39	33	33	35	-1
Slovakia	35	35	37	37	40	36	37	36	37	34	36	37	38	+3
Poland	56	56	47	43	44	49	45	46	39	38	39	39	39	-17

Source: Global Innovation Index, various editions

5.4 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 28.

Figure 28: Framework of the Global Innovation Index 2016–2020



Source: Global Innovation Index editions in 2016–2020

To assess the relevance of these 80 indicators, and especially the 'match' between the themes (or headings) captured by the 7 pillars would go beyond the scope of this paper. In other words, GII results are simply presented here, without assessing their aptness for analytical or policy purposes.

Czechia had the highest ranking among the CE4 countries in 2007 (No. 32) and kept that position by climbing to No. 24 in 2020. Slovakia came second in 2007 (No. 35) – but by 'slipping' three positions by 2020 (No. 38), she was third in the CE4 group in that year. Hungary improved her ranking, came from third in 2007 (No. 36) to second in 2020 (No. 35). She was already second in the group for six years in 2010–2016 and was even ranked first in 2011. Then she lost 6 positions in 2017, compared to the previous year. Poland has achieved a noteworthy improvement, from No. 56 in 2007 to No. 38 in 2017, and then No. 39 in 2018–2020. Thus, it was just behind Slovakia in 2020.

6 DISCUSSION AND POLICY IMPLICATIONS

6.1 Diversity in structures and structural changes – despite unifying external forces

For centuries various external powers had imposed uniformity on certain, very large parts of the territory where the current CE4 states are located. The one, which is most vividly remembered, is the Soviet Union. Thus, observing these countries from a distance, they certainly used to share major structural similarities and some of those might have long-term repercussions. The 'block' view (the cold war between the East and West) dominated politics and business developments for more than four decades in the second half of the 20th century. Given these legacies (structural features and the level of socio-economic development in the CE4 countries, as well as the dominant way of thinking and discourse since the cold war) Western politicians, business people, analysts and journalists tend to share, and thus reinforce this view of 'uniformity' to some extent even nowadays. Moreover, there is a mild, but noticeable – and certainly understandable – 'drive' also from the academic community to produce findings that can be generalised across the new member states, but at least for the CE4 countries, that is, to focus on identifying shared or similar features and mechanisms. Yet a closer look at the structure of the national innovation systems in these countries, as well as at their performance, points to a different direction.

While the structural composition of the CE4 countries' research sub-systems showed a great diversity already in 2000, fairly significant changes have occurred since then almost in all countries, adding more colours to the observed diversity. *Changes have occurred in both directions* (growth and contraction) *in all the three major research performing sectors*, taking either the share of FTE researchers or the portion of GERD performed. Thus, *neither a similar structural composition of the research sub-system can be observed, nor a move towards a similar structure*.

Several factors might have influenced these restructuring processes, including conscious STI policy efforts, differences in working conditions among the three main research performing sectors, the type and pace of privatisation – in turn, all the political, economic and legal factors influencing privatisation –, structural changes in the economy, brain drain to other occupations or to foreign countries, fiscal policy, ideological stances vis-à-vis the Academy of Sciences, etc. It is unlikely that a single factor can be identified as a major one. Similarly, foreign investors have played a major role in privatisation. The weight of the business sector in performing R&D activities has increased considerably in Hungary and Poland, while in Slovakia that ratio has decreased.

As for the CE4 countries' innovation systems, the share of innovative firms differs significantly. Further, data on the types and frequency of innovation co-operation methods used by businesses also suggest a noteworthy diversity.

In sum, *country differences do matter even when one considers a group of countries characterised by broadly similar historical legacies and in the recent past undergoing the transition processes to market economy,* which also brought in some major similar features and necessities.

6.2 Measuring innovation performance

The principal measurement and monitoring tool to assess the innovation performance of the EU member states is the European Innovation Scoreboard (EIS). Its 2017–2020 editions are based on 27 indicators, grouped by 8 innovation dimensions. (EC, 2017, 2018, 2019, 2020) A rudimentary classification exercise reveals a strong bias towards R&D-based innovations: 8 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 are focusing on non-R&D-based innovations. The set of the EIS indicators can be seen either as a half-full or a half-empty glass. Compared to the EIS 2004 – as assessed by Jensen et al. (2007) – it is an improvement. Yet, *a much more significant improvement is still needed for a better reflection of the diversity of innovation processes*, which is indispensable for devising effective and sound policies. First, the economic weight of low- and medium-low technology (LMT) sectors is significant in terms of output and employment. Second, while the bulk of innovation activities in LMT sectors are not based on intramural R&D efforts, these sectors also improve their performance by innovations. Firms in the LMT sectors are usually engaged in the DUI mode of innovation (that is, relying on learning by doing, using and interacting), but they also draw on advanced S&T results available through the so-called distributed knowledge bases (Robertson and Smith, 2008; Smith, 2002), as well as advanced materials, production equipment, software and various other inputs (e.g., electronics components and sub-systems) supplied by the so-called high-tech (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 firms in the HT sectors, and also provide strong incentives – and ideas – for their RTDI activities. (Robertson et al., 2009)

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. (Pavitt, 1999; Tidd et al., 1997) Thorough empirical analyses have also shown that those companies are the most successful, which consciously combine the STI and DUI modes of innovation. (Jensen et al., 2007)

For the above reasons it would be desirable that *the European Commission* would monitor and assess the member states' RTDI activities by taking into account both the STI and DUI modes of innovation. In other words, indicators should not be biased. On the contrary, *all types of innovations should be considered, irrespective of the form, type and sources of knowledge* exploited (codified vs. tacit; scientific vs. practical; R&D vs. engineering and other production activities, co-operation with various partners, including users, suppliers and the academia), as well as *the sectoral classification of firms* (LMT vs. HT, manufacturing vs. services). That type of monitoring toolkit would be needed to make the EU STI policies sounder, and thus make those more effective and efficient. Moreover, the approach and practice followed by the EC also influences the member states, especially those at the lower level of economic development, and thus including the CE4 countries. Replies given by policy-makers to a survey, commissioned by the European Research and Innovation Area Committee (ERAC) indicate that the dominant way of thinking is still based on the science-push model of innovation in most EU member states. (Edquist, 2014a, 2014b)

Given the diversity among innovation systems (in this case: among national 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. By its very nature, 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, analysts and policy-makers need to realise that poor performance signalled by a composite indicator, and leading to a low ranking on a certain scoreboard, does not automatically identify the area(s) necessitating the most urgent policy actions. For example, when indicators measuring performance in 'high-tech' have a decisive weight in a scoreboard, for a country at a lower level of economic development it is not necessarily an appropriate way of spending public money to try to achieve a higher ranking on that particular scoreboard. It might be more relevant to focus scarce public resources on improving the conditions for knowledge dissemination and exploitation, rather than funding research aimed at creating scientific knowledge in direct competition with advanced, much more affluent countries in those S&T fields where the costs of research are prohibitive. This is a gross oversimplification, of course, that is, being far from any policy recommendation at the required level of detail. It is only meant to reiterate that it is a demanding task to devise policies based on the innovation systems approach.[17]

The CE4 countries, 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 balanced, sustainable socio-economic development.

New indicators that *better reflect the evolutionary processes of learning and innovation* would also be needed to support 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. As it is the best interest of *the CE4 countries*, they *could take the lead in such an initiative*.

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[17] Moreover, as the Hungarian and Irish cases, discussed in Havas (2015b) have shown, a high value of a composite indicator would not necessarily signal good performance: the devil is always in the details.

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