Trapped by the high-tech myth: The need and chances for a new policy rationale

Havas, Attila

Institute of Economics, CERS, HAS

February 2014

chapter prepared for H. Hirsch-Kreinsen and I. Schwinge (eds) [2014]: *Knowledge-Intensive Entrepreneurship in Low-Tech Sectors: The Prospects of Traditional Economic Industries*, Cheltenham: Edward Elgar

Trapped by the high-tech myth: The need and chances for a new policy rationale

Attila Havas

1 Introduction

Evidence-based policy has become a buzzword in most policy domains, including science, technology and innovation (STI) policies. Research efforts have indeed provided a significant amount of evidence: insights as to the nature and dynamics of knowledge creation, diffusion, and exploitation processes, lending theoretical justification for policy interventions. These results have influenced policy documents of major supranational organizations, too, such as the EU, the OECD and various UN organizations. Policy-making processes – in a broader sense: policy governance sub-systems – themselves, together with the impacts of various STI policy tools have also become subjects of thorough analyses.

Evidence cannot be turned into an 'optimal' set of policy measures in an 'objective', 'scientific' way as it needs to be interpreted in the context of given policy issues and then translated into actions. Moreover, different schools of thought offer contrasting policy advice, and perhaps more importantly, various actors also influence the policy-setting processes, pursuing their own interests and values. Thus, in spite of major research results, policy-making is still more of an art than an easy-to-handle 'technology', that is, a set of proven methods prescribed in handbooks with engineering precision – and STI policies are no exception.

It is no surprise, therefore, that the world of STI policy-making is characterized by major puzzles. One of these is the apparent contradiction between the perceived 'European paradox' and the still dominant view of the importance of 'high-tech' research and 'high-tech' sectors. The first claims that the European Union achieves excellent research results, but is ineffective in exploiting those. The policy response should thus be to put more emphasis on fostering knowledge exploitation. Yet, various EU documents and the policy practice discernible from the composition of important monitoring tools still 'push' for a science-push model of innovation.

This chapter aims to analyze whether it is beneficial to focus on supporting high-tech research and promoting structural changes in favor of high-tech sectors, or, whether a different policy rationale, one promoting knowledge-intensive activities across the whole economy, would be more appropriate to enhance competitiveness and improve quality of life.[1] It is structured as follows: first, economics paradigms are compared briefly along their fundamental assumptions and underlying notions concerning innovation, as well as the major policy implications of these paradigms, contrasted with the policy rationales advanced by the EU and the OECD. The latter issue is analyzed in more detail by reviewing the choice and use of indicators in the Innovation Union Scoreboard (EC, 2013a), and in a 2013 league table compiled by the EC Directorate-General for Research and Innovation (EC, 2013b). The

[1] Financial support provided for research by AEGIS (EU RTD FP7, grant agreement No. 225134), and GRINCOH (EU RTD FP7, grant agreement No. 290657) is gratefully acknowledged. I am indebted to Gábor Kőrösi, Sandro Mendonça, Balázs Muraközy, Doris Schartinger, Matthias Weber, and seminar participants at the Institute of Economics, CERS, HAS for their comments on an earlier version.

concluding section highlights the potential drawbacks of the persistent high-tech myth, considers possible reasons for its perseverance and discusses policy implications of the systemic view of innovation.

2 ECONOMICS OF INNOVATION, POLICY IMPLICATIONS AND MODELS OF INNOVATION

The role of innovation in economic development is analyzed by various schools of economics in diametrically different ways.[2] The underlying assumptions and key notions of these paradigms lead to diverse policy implications.

2.1 Innovation in various schools of thought in economics

Innovation had been a major theme in classical economics. Then neo-classical (general equilibrium) economics essentially abandoned research questions concerned with dynamics, and instead focused on static comparative analyses and optimization. Technological changes were treated as exogenous to the economic system. Given compelling empirical findings and new theoretical insights on firm behavior and the operation of markets, various branches of mainstream economics[3] have relaxed the most unrealistic assumptions of neo-classical economics; especially perfect information, deterministic environments, perfect competition, and constant or diminishing returns. Yet, 'this literature has not addressed institutional issues, it has a very narrow concept of uncertainty, it has no adequate theory of the creation of technological knowledge and technological interdependence amongst firms, and it has no real analysis of the role of government' (Smith, 2000: 75).

The quintessential axiom of mainstream economics[4] is that rational agents seek to maximize their profits. Evolutionary economics of innovation, in contrast, stresses that *uncertainty* is inherent in innovation, and thus profit maximization is impossible on theoretical grounds. Whereas mainstream economics is concerned with the availability of *information*, innovation studies show that the success of firms depends on their accumulated *knowledge* – both codified and tacit – and *skills*, as well as *learning capabilities*. Information can be purchased, and hence can be accommodated in mainstream economics as a special good. Yet, knowledge – and *a fortiori,* the types of knowledge required for innovation – 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. Cumulativeness, path-dependence and learning lead to *heterogeneity* both at micro and meso levels (Castellaci, 2008a; Dosi, 1988; Dosi *et al*. (eds), 1988; Fagerberg *et al*. (eds), 2005; Hall and Rosenberg (eds), 2010; Malerba, 2002; Pavitt, 1984; Peneder, 2010).

---

[2] Space limits only allow an incomplete introduction to the main ideas. For more detailed and nuanced accounts see e.g. Castellacci (2008b), Dosi (1988), Dosi *et al*. (eds) (1988), Fagerberg *et al*. (eds) (2005), Freeman (1994), Grupp (1998), Hall and Rosenberg (eds) (2010), Laestadius *et al*. (2005), Lazonick (2013); Lundvall and Borrás (1999), Nelson (1995), OECD (1998) and Smith (2000).

[3] Mainstream economics is constantly evolving, driven by its own 'internal' dynamics as well as by integrating new notions, research questions and methods from various branches of economics. Its major features cannot, therefore, be precisely defined. For example, while representative agents were a central feature for decades, more recently heterogeneity has become a key issue, e.g. in the new trade theory.

[4] The so-called new or endogenous growth theory is not discussed here separately because its major assumptions on knowledge are very similar to those of mainstream economics (Lazonick, 2013; Smith, 2000). 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.

Innovators are not lonely champions of new ideas. While talented individuals might develop radically new, brilliant scientific or technological concepts, successful innovations require different types and forms and knowledge, rarely possessed by a single organization. A close collaboration among firms, universities, public and private research organizations and specialized service-providers is, therefore, a prerequisite of major innovations. In other words, 'open innovation' is not a new phenomenon at all (Mowery, 2009, von Hippel, 1988). Innovation co-operations can take various forms from informal communications through highly sophisticated R&D contracts to alliances and joint ventures (Freeman 1991, 1994, 1995; Lundvall and Borrás, 1999; OECD, 2001; Smith, 2000, 2002; Tidd *et al*., 1997).

2.2 Policy rationales derived from theories

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

Evolutionary economics of innovation investigates the role of knowledge creation and exploitation in economic processes. This school considers various types and forms of knowledge, including practical or experience-based knowledge acquired through learning by doing, using and interacting. As these are *all* relevant for innovation, scientific knowledge is far from being the only type of knowledge required for a successful introduction of new products or processes, let alone non-technological innovations. As to the sources of knowledge, not only the results of in-house R&D activities, but those of other R&D projects are also widely utilized during the innovation process: extramural projects conducted in the same or other sectors, at public or private research establishments, home or abroad. More importantly, there are a number of other sources of knowledge, also essential for innovations, such as design, scaling-up, testing, tooling-up, trouble-shooting and other engineering activities, ideas from suppliers and users, inventors' ideas and practical experiments (Hirsch-Kreinsen *et al*. (eds), 2005; Klevorick *et al*., 1995; Lundvall (ed.), 1992; Lundvall and Borrás, 1999; von Hippel, 1988). Innovative firms also utilize knowledge embodied in advanced materials, other inputs, equipment and software. All rounds of the Community Innovation Survey clearly and consistently show that firms regard a wide variety of sources of information as highly important to innovation.[5]

The evolutionary account of innovation leads to sobering lessons concerning the very nature of policy-making, too: in a world of uncertainty, policy cannot bring about *the* optimum either. Furthermore, given the importance of variety, selection and uncertainty, the potentially successful policies are *adaptive* ones, that is, they rely on, and learn from,

[5] In contrast, the OECD classification of industries only takes into account expenditures on formal R&D activities, carried out within the boundaries of a given sector. More precisely, the so-called indirect R&D intensity has also been calculated as R&D expenditures embodied in intermediates and capital goods purchased on the domestic market or imported. Yet, it has been concluded that indirect R&D intensities would not influence the classification of sectors (Hatzichronoglou, 1997: 5). In other words, a number of highly successful, innovative firms, exploiting advanced knowledge created externally in distributed knowledge bases (Smith, 2002) and internally by non-R&D processes, are classified as medium-low-tech or low-tech companies, just because their R&D expenditures are below the threshold set by the OECD. Some policy-makers then might easily think that it is not a mistake to neglect these sectors *en bloc*.

feedback from the selection process, which in turn leads to further variation (Metcalfe and Georghiou, 1998). In other words, policy formation is increasingly becoming a learning process (Lundvall and Borrás, 1999). Thus, policy evaluation and assessment practices are of crucial importance (Dodgson *et al*., 2011; Edler *et al*., 2012; Gök and Edler, 2012; OECD, 1998, 2006a). Technology foresight can also contribute to design appropriate policies: more 'robust' policies can be devised when (i) multiple futures are considered, and (ii) participants of foresight processes, given their diverse backgrounds, bring wide-ranging accumulated knowledge, experience, aspirations and ideas into policy dialogues.

In sum, evolutionary economics of innovation posits that firms' performance is largely determined by their abilities to exploit various types of knowledge, generated by both R&D and non-R&D activities. Knowledge generation and exploitation takes place in, and is fostered by, various forms of internal and external interactions. The quality and frequency of the latter are largely determined by the institutions – the 'rules of the game' – and other properties of a given innovation system, in which these interactions take place. STI policies, therefore, should aim at strengthening the respective innovation system and improving its performance by tackling *systemic failures* hampering the generation, diffusion and utilization of any type of knowledge required for successful innovation[6] (Edquist, 2011; Foray (ed.), 2009; Dodgson *et al.*, 2011; Freeman, 1994; Lundvall and Borrás, 1999; OECD, 1998; Smith, 2000). From a different angle, deliberate, coordinated policy efforts are needed to promote knowledge-intensive activities in all sectors.

2.3 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.[7] The idea that basic research is the main source of innovation was already 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 driving force of innovation. Then both became the variants of the linear model of innovation when Kline and Rosenberg suggested the chain-linked model, stressing the 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 also been extended into the networked model of innovation, more recently called the multi-channel interactive learning model (Caraça *et al*., 2009).

In sum, the science-push model of innovation had become widely accepted before the market failure policy rationale was first expressed in the late 1950s, but the latter has certainly lent scientific support to the former by focusing policy-makers' attention to R&D as *the* decisive element of innovation processes.[8]

---

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

7 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.

8 For a thorough analysis refuting the high-tech myth, see e.g. Sandven *et al*. (2005).

3 INDICATORS: NEUTRAL MEASUREMENT TOOLS OR HERALDS OF POLICY CONCEPTS?

Significant progress has been achieved in measuring R&D and innovation activities since the 1960s (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.[9] Although there are widely used guidelines to collect data on R&D and innovation – the Frascati and Oslo Manuals (OECD, 2002 and 2005, 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 characterized 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 analyze 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.

An equally difficult task is to devise so-called composite indicators to compress information into a single figure in order to compile eye-catching scoreboards. A major source of complication is choosing an appropriate weight to be assigned to each component. By conducting sensitivity analyses of the 2005 European Innovation Scoreboard (EIS), Grupp and Schubert (2010) have shown how unstable the rank configuration is when the weights are changed (p. 72). Besides assigning weights, three other ranking methods are also widely used, namely: unweighted averages, Benefit of the Doubt (BoD) and principal component analysis. Comparing these three methods, the authors conclude: '(…) even using accepted approaches like BoD or factor analysis may result in drastically changing rankings' (ibid: 74). Hence, they propose using multidimensional representations, e.g. spider charts to reflect the multidimensional character of innovation processes and performance. That would enable analysts and policy-makers to identify strengths and weaknesses, that is, more precise targets for policy actions (ibid: 77).

Other researchers also emphasize the need for a sufficiently detailed characterization 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.

3.1 The European Innovation Scoreboard

As already stressed, firms exploit various types of knowledge for their innovation activities. Testing this general observation by using the Danish DISKO survey data, Jensen *et al*. (2007) introduced an elementary distinction between two modes of innovation: (a) one based on the production and use of codified scientific and technical knowledge, and (b) another relying on informal processes of learning and experience-based know-how (called DUI: Doing, Using

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

and Interacting). They have noted that none of the 22 indicators that had been used to compile the EIS 2004 captured the DUI mode of innovation, which is not an accident: ‘There now exist internationally harmonised data on R&D, patenting, the development of S&T human resources, ICT expenditures and innovation expenditures more generally, whereas at present there are no harmonised data that could be used to construct measures of learning by doing and using. We would contend, though, that these limitations of the data reflect the same bias at a deeper level. (…) The lack of DUI measures reflects political priorities and decision-making rather than any inevitable state of affairs’ (ibid: 685).

The EIS indicators have been revised several times since its first edition in 2000, and the scoreboard was renamed the Innovation Union Scoreboard in 2011. Its 2013 edition is based on 25 indicators, grouped by eight innovation dimensions. (EC, 2013a) A rudimentary classification exercise reveals a strong bias towards R&D-based innovations: 10 indicators are *only* relevant for, and a further four *mainly* capture, R&D-based innovations, a mere five are focusing on non-R&D-based innovations, while six could be relevant for both types of innovations. (Table 1) Given that (i) the IUS is used by the European Commission to monitor progress, and (ii) its likely impact on national policy-makers, this bias towards R&D-based innovation is a source of major concern.

Table 1: The 2013 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
Percentage youth aged 20-24 having attained at least upper secondary level education		X
Open, excellent and attractive research systems		
International scientific co-publications per million population	X	
Scientific publications among the top 10% most cited publications worldwide as % of total scientific publications of the country	X	
Non-EU doctorate students as a % of all doctorate students	X	
Finance and support		
R&D expenditure in the public sector as % of GDP	X	
Venture capital investment as % of GDP	x	
Firm investments		
R&D expenditure in the business sector as % of GDP	X	
Non-R&D innovation expenditures as % of turnover		X
Linkages & entrepreneurship		
SMEs innovating in-house as % of SMEs	b	b
Innovative SMEs collaborating with others as % of SMEs	b	b
Public-private co-publications per million population	X	
Intellectual assets		
PCT patents applications per billion GDP (in PPS€)	X	
PCT patent applications in societal challenges per billion GDP (in PPS€) (environment-related technologies; health)	X	
Community trademarks per billion GDP (in PPS€)		X
Community designs per billion GDP (in PPS€)		X
Innovators		
SMEs introducing product or process innovations as % of SMEs	b	b
SMEs introducing marketing or organizational innovations as % of SMEs		X
High-growth innovative firms	b	b
Economic effects		
Employment in knowledge-intensive activities (manufacturing and services) as % of total employment	x	
Contribution of medium and high-tech product exports to the trade balance	x	
Knowledge-intensive services exports as % total service exports	x	
Sales of new to market and new to firm innovations as % of turnover	b	b
License and patent revenues from abroad as % of GDP	X	

Legend:
X: only relevant
x: mainly relevant
b: relevant for both types

The current composition of IUS 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. Considering the economic weight of LMT sectors and the fact that the bulk of innovation in these sectors is not based on intramural R&D efforts (Sandven *et al*., 2005; von Tunzelmann and Acha, 2005, special issue of Research Policy on Innovation in LMT industries, Vol. 38, No. 3), a much more significant improvement is still needed to better reflect innovation processes by the IUS, and thus underpin effective and sound policies.

3.2 A new league table: research and innovation performance of EU member states and associated countries

The EC Directorate-General for Research and Innovation is publishing country profiles aimed at 'providing policy makers and stakeholders with concise, holistic and comparative overviews of research and innovation (R&I) in individual countries' (EC, 2013b: 2). The 2011 report identified nine groups of countries and then Hungary – together with the Czech Republic, Italy, Slovakia, and Slovenia – belonged to group 8, characterized by '*medium-low knowledge capacity* with an important industry base' (EC, 2011: 436). A new feature in the 2013 edition is a synthesis table with some striking figures: Ireland has the highest level of knowledge-intensity, and Hungary is ranked ninth, ahead of Germany, Austria and the EU average, for example, and just behind Denmark and Finland (Table 2).

Table 2: Overview of research and innovation performance in selected EU countries

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

Source: EC (2013b): 5
Note: Countries are ranked by the knowledge-intensity indicator.

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

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

(…) The five pillars have also been aggregated to a single composite indicator of structural change (…)' (ibid: 321–322).

Knowledge is understood again in a narrow sense: only higher education and R&D activities are supposed to create it and thus all other types of knowledge are disregarded. The name of this indicator is, therefore, misleading. The inclusion of high-tech exports and foreign direct investment in this composite indicator explains the unexpectedly high ranking of Ireland and Hungary: in both countries high-tech goods account for an extremely large share in exports (Table 3) and high-tech sectors are dominated by foreign-owned firms.

Table 3: Share of high-tech goods in industrial exports, 2001-2009 (%)

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

Source: own calculation based on OECD.Stat data, extracted on 9 Sept 2013
n.a.: not available

These 'twinned' characteristics warrant further remarks from the point of view of knowledge-intensity. The bulk of exported high-tech goods are developed outside Ireland or Hungary;[10] the main activity of most foreign subsidiaries is the assembly of high-tech goods by semi-skilled workers, and thus the local knowledge content is rather low. These features cannot be reflected in this indicator, and thus it does not necessarily express knowledge-intensity in the case of countries with similar structural characteristics. Hence, it may only be used 'with a pinch of salt' to compare countries' performance or devise policy measures.

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

Second, various types of foreign direct investment activities have different longer-term impacts on economic development. Globalization either poses threats to, or offers opportunities for, economic development, depending on the capabilities and investment promotion policies of the host country. To use an elementary dichotomy of foreign direct investment, one type can be called *'foot-loose'*, that is, characterized by low local knowledge content, and thus offer low-pay jobs. These companies are ready to leave at any time for cheaper locations.[11] The other types of investors, in contrast, are *'anchored'* into a national system of production and innovation: they conduct knowledge-intensive activities, create higher-pay jobs, build close contacts with domestic R&D units and universities and develop a strong local supplier base.[12] In brief, coordinated, mindful investment promotion, STI, human resource and regional development policies are required to embed foreign investors. In this way, skills can be upgraded, local suppliers' innovation capabilities can be improved to boost their competitiveness and intense, mutually beneficial business-academia collaboration can be nurtured. Otherwise most of the investment 'sweeteners' are wasted if foreign firms only use a given region or country as a cheap, temporary production site.

---

[10] BERD in the 'Manufacture of computer, electronic and optical products (C26)' sector was €152–155m in Ireland, €53–56m in Hungary, while €527m in Austria in 2009–2010. (Eurostat) Austria has been chosen for comparison given her similar size (in terms of population) and lower ranking in Table 2 by knowledge-intensity of economy. BERD in pharmaceuticals is not considered here given the sector's small share in Hungarian manufacturing (and high-tech) exports (around 10% of exports by C26).

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

[12] There are different types of firms among the 'anchored' ones, too. This simple dichotomy is used here just to highlight some elementary policy implications, not as a basis for sound policy recommendations.

4 DISCUSSION AND CONCLUSIONS

4.1 A persistent devotion to high-tech and its pitfalls

Several observers claim that the systems view on innovation has become widespread in academic and policy-making circles, both in national and supranational organizations. As for the latter, they are notably the European Commission and the OECD (Sharif, 2006; Dodgson *et al*., 2011). By discussing the indicators selected for the European Innovation Scoreboard (more recently: Innovation Union Scoreboard), as well as the use of these and related indicators in a 2013 league table of innovation performance of EU countries, this chapter has shown that the high-tech myth prevails. Glancing through various EU and OECD reports also confirms that the systems view has not become a systematically applied paradigm in policy circles[13] – in spite of a rich set of policy-relevant research insights. The 'push for science-push' is further reinforced by the images of scientists and/or their sophisticated equipment consistently used on the cover pages of various EU and OECD reports.[14]

The high-tech myth is so powerful that even those researchers who base their work on thorough analysis of facts are taken by surprise when the facts are at odds with the obsession with high-tech. A telling example is Peneder's excellent study on the 'Austrian paradox': 'On the one hand, macroeconomic indicators on productivity, growth, employment and foreign direct investment indicate that overall performance is stable and highly competitive. On the other hand, an international comparison of industrial structures reveals a severe gap in the most technologically advanced branches of manufacturing, suggesting that Austria is having problems establishing a foothold in the dynamic markets of the future' (Peneder, 1999: 239). In contrast, evolutionary economics of innovation claims that any firm – in either LMT or HT industries – can become competitive in 'the dynamic markets of the future' if it is successful in combining its own, firm-specific innovative capabilities with 'extra-mural' knowledge available in distributed knowledge bases. In other words, Austrian policy-makers need not be concerned with the observed 'paradox' as long as they help Austrian firms sustain their learning capabilities, and maintain thereby their innovativeness. That would lead to good economic performance – regardless of the share of LMT industries in the economy.

The science-push model neglects the importance of distributed knowledge bases – regional, sectoral and national innovation systems and clusters – in creating, diffusing and exploiting various non-R&D types of knowledge (Dodgson and Rothwell, 1994; Freeman, 1991, 1994; Lundvall and Borrás, 1999; Malerba, 2002; Nelson (ed.), 1993; OECD, 2001; Smith, 2002; Tidd *et al*., 1997), and hence it can easily misguide policy: in a 'hard-core'

---

[13] A recent OECD policy document equates innovation with R&D at several points: '*Innovation* today is a pervasive phenomenon and involves a wider range of actors than ever before. *Once largely carried out by research and university laboratories in the private and government sectors*, it is now also the domain of civil society, philanthropic organisations and, indeed, individuals' (OECD, 2010: 3, emphasis added). The same document has a sub-section entitled 'Low-technology sectors innovate', but the bulk of the text is on R&D.
A current EU document also consistently equates knowledge with R&D: investment in knowledge is understood as changes in R&D intensity, knowledge intensity of economic sectors is measured by BERD, and 'knowledge upgrade' is defined as increased R&D intensity (EC, 2013b: 7, 9, 10, 11). The same document, just like many other EC documents (e.g. EC, 2013c), speaks of a 'research and innovation system', and thus implicitly suggests that the (public) research system is not a sub-system of the national innovation system, but a separate entity. Research and innovation is used in a very loose way, practically as synonyms: 'There are still considerable differences between Member States in terms of their research and innovation efficiency. For a given amount of public investment, some countries achieve more excellence than others in science and technology' (ibid: 9).

[14] See, e.g., the OECD's 'STI Scoreboard' and 'STI Outlook' series until 2007 and 2008, respectively, as well as the Eurostat's 'Science, technology and innovation in Europe' series in the late 2000s (OECD, 2004, 2005b, 2006b, 2007, 2008; EC, 2008, 2009, 2010).

translation it implies that public money should be primarily spent on promoting research efforts in a handful of fashionable S&T domains, and on boosting high-tech sectors. A recent EC document is also pushing – or only hoping? – for structural changes, along similar lines, although this is not explicitly articulated in that way: 'Furthermore, in dynamic fields such as ICT-based businesses and in emerging sectors Europe needs more high-growth firms. This calls for an innovation-driven structural change, but Europe is at present missing out on the more radical innovations which drive and lead such structural change' (EC 2013c: 5). In line with the science-push model, other modes of technological innovation are not mentioned in this document.

The EC documents are rather consistent in that respect over time: the so-called Barcelona target, namely achieving a 3% GERD/GDP ratio in the EU – first set in March 2002, and then relaunched in 2010 as part of the Europe 2020 strategy – is also driven by this rationale: R&D efforts need to be stepped up, because significantly larger inputs would thereby be transformed into useful outputs. In other words, research insights are translated into policy actions in a disappointing way in the Lisbon Agenda: '(…) the focus remains on (…) mobilizing investment for research and development, translating science into technology, and attempting to create a population of new technology-based firms' (Steinmuller, 2009: 29).

The policy rationale derived from mainstream economics, namely the market failure argument, in essence is 'informed' by the science-push model, but in turn it also provides strong scientific support to this type of policy-making, given its roots in rigorous, quantitative analyses. Three comments are in order. First, even when accepting the market failure rationale as a relevant one, '(…) it does not give any secure guide to how to identify areas of market failure, or the appropriate levels of public support which might follow from it.' (Smith, 2000: 85) Second, a policy action tackling a market failure would, in most cases, lead to another market failure. Patents, for example, distort prices to the detriment of customers, and may also result either in over- or under-investment in R&D, neither of which is 'socially optimal' (Bach and Matt, 2005). Third, the innovation systems approach has shown that the mainstream economics paradigm offers an inappropriate framework to fully understand innovation processes involving a fundamental element of uncertainty and characterized by cumulativeness and path-dependence. The market failure rationale thus rests on a theory that does not offer a sound, indisputable understanding of those processes that are to be influenced by policies justified by this very rationale. Spending public money guided by an inappropriate – or at best incomplete – policy rationale is, therefore, highly questionable.

In sum, policies driven by the science-push model – or its close 'relative', the market failure argument derived from mainstream economics – disregard non-R&D types of knowledge, which are of huge significance for innovation processes in the LMT branches of manufacturing and services. Given the substantial economic weight of these sectors in producing value added and creating employment, this policy ignorance is likely to lead to massive opportunity costs, e.g. in the form of lost improvements in productivity, 'unborn' new products and services, and thus 'unopened' new markets and 'undelivered' new jobs.

Scoreboards and league tables compiled following the science-push logic, and published by supranational organizations, can easily lead to 'lock-in' situations. National policy-makers – and politicians, in particular – are likely to pay much more attention to their country's position on a scoreboard than to nuanced assessments or policy recommendations in lengthy documents, and hence this inapt logic is 'diffused' and strengthened at the national level, too, preventing policy learning and the devising of appropriate policies.

4.2 Possible reasons for the observed persistence

Even without analyzing the complex issue of paradigm shifts in STI policy thinking and practice in a systematic and detailed way, it is worth considering some possible reasons why the science-push model is so popular and powerful. Although this chapter has not analyzed STI policy rationales at a national level, the ensuing discussion would include that level, too.

To start with a *simple* reason, the science-push model is based on a fairly *simple*, straightforward reasoning.[15] Moreover, it was compellingly explained and popularized many decades ago by Bush (1945), given the unprecedented achievements of major R&D efforts during World War II.[16] Impressive scientific results have been reported in the press ever since then, reiterating the relevance and usefulness of science in the mind of politicians and citizens at large.

The simplicity of policy-making following the science-push model can be important in further respects, too. To paraphrase Laestadius *et al*. (2005) who talk about the advantages of one-dimensional indicators, the so-called Barcelona target 'has obvious pedagogical advantages: people remember [it], they react on [it] and (at least believe that) they can identify the meaning of [it]. (…) As regards community creation it may be argued that a simple one-dimensional indicator (…) can be identified as a focal point for orchestrated political action: we can all unite on transforming Europe to a high-tech knowledge-based economy.'

The networked model of innovation and other concepts of the evolutionary economics of innovation are, in contrast, not only complex, but can also be 'vague' for policy-makers. Indeed, the systems of innovation approach can easily be interpreted sarcastically: if everything depends on everything else, there is no clear policy guidance.

International politics in the form of the so-called Triadic competition between Europe, Japan, and the US also played a role in strengthening the obsession with the science-push model already in the 1960s (Hirsch-Kreinsen *et al*., 2005), and it still features in recent EU documents: 'Overall, the EU remains specialised in medium-high R&D-intensity sectors which account for half of European companies' R&D investment. By contrast, more than two-thirds of US companies' R&D investment is clustered in high R&D-intensity sectors (such as health and ICT)' (EC 2013c: 7). This adamant obsession with the EU-US comparison is all the more puzzling when one takes into account some fundamental differences: the EU is not a federal structure, and despite the Single Market principle it is much more fragmented in many respects than the US, with severe consequences for e.g. capital flows and labor mobility – and hence for the diffusion and exploitation of knowledge –, as well as for the feasibility of large, mission-oriented R&D projects and EU-wide policy actions, including public procurement with regard to new products or solutions.

Sociological factors are also likely to play an important role. Top STI policy-makers, as well as the majority of middle-ranking staff, tend to be former scientists or engineers, and thus naturally with a strong inclination towards the Bush-model (Bush, 1945). Civil servants

---

[15] 'Despite the fierce criticism they have attracted from the more popular systemic approaches, these linear models paradoxically continue to influence thinking amongst decision-makers and public opinion because they have the virtue of being simple (or of appearing to be so)' – writes Caracostas (2007: 475), drawing on his extensive work experience as a 'policy-shaper' at the EC. Since then, Balconi *et al* (2010) have assembled a set of arguments 'in defence of the linear model'.

[16] Hirsch-Kreinsen *et al*. (2005) offer two further historical considerations: the internal organization and management methods of large corporations in the 20th century, as well as the cold war, namely the 'sputnik panic' and the US reply to that.

at finance ministries, who prepare decisions on the budget lines earmarked for public funding for RTDI activities, are usually trained in mainstream economics, and thus they are not advancing the policy rationale of the evolutionary economics of innovation, either (Dodgson *et al*. 2011; Lundvall and Borrás, 1999). Prestigious scientists have also become influential in setting STI policies, and their influence is strengthened by their formal positions, too (as chief scientists, advisors to politicians, presidents of learned societies, members of advisory boards, etc.).[17] Finally, the quest for evidence-based policies has significantly increased the intellectual standing and influence of formal modeling among policy-makers (Caracostas, 2007: 479). It should be stressed in light of this that (a) the complexity of innovation systems cannot be translated into econometric models,[18] and (b) in new (endogenous) growth models a main variable is R&D – and not knowledge in its broad sense, even if R&D and knowledge are used as synonyms in many papers.

4.3 Policy implications of the systemic view of innovation

A fundamental element of the pragmatic critique of the innovation systems approach certainly holds: policy implications derived from evolutionary theorizing are demanding in terms of both analytical efforts needed to underpin policies and policy design capabilities. The market failure rationale is an abstract concept; its policy implications are supposed to apply to any market in any country, and at any time – but as already stressed, exactly for being abstract, it cannot provide appropriate guidance for policy design. The systemic failures argument, in contrast, cannot offer 'one-size-fits-all' recipes. Instead, it stresses that it is an empirical task to identify what type of failure(s) is (are) blocking innovation processes in what part of the system in order to guide the design of appropriate policies.[19] Besides thorough analyses, it is likely to demand extensive dialogue with stakeholders, too. This is not a trivial task, and the possibility of summarizing widely applicable, easy-to-digest and thus appealing policy 'prescriptions' in one or two paragraphs is excluded on theoretical grounds.

The systemic approach implies, too, that several policies affect innovation processes and performance – and perhaps even more strongly than STI policies. Hence, the task of designing effective and efficient policies to promote innovation is even more complex as policy goals and tools need to be orchestrated across several policy domains, including macroeconomic, education, investment promotion, regional development, and labor market policies, as well as health, environment and social policies aimed at tackling societal challenges.

In an interesting 'cross-tabulation' of innovation research themes and policy perspectives, den Hertog *et al*. (2002) identified 'black boxes', that is, themes not covered by research and also unknown (unidentified) by policy-makers. Given the importance of non-STI policies affecting innovation policies, it would be useful to add a black box at a 'meta level', too: that is, the impacts of non-STI policies – or even more broadly, that of the framework conditions – on innovation processes and performance.

---

[17] These factors have been at play in Australia, too: 'Despite significant input from innovation researchers on the value of innovation systems thinking, the Summit's outcomes were largely shaped by neo-classical economic orthodoxy and a continued science-push, linear approach advocated by the research sector' (Dodgson *et al*., 2011: 1150).

[18] This critique has been 'anticipated' and answered by Lipsey and Carlaw (1998: 48): 'For obvious reasons, many economists prefer models that provide precise policy recommendations, even in situations in which the models are inapplicable to the world of our existence. Our own view is that, rather than using neo-classical models that give precise answers that do not apply to situations in which technology is evolving endogenously, it is better to face the reality that there is no optimal policy with respect to technological change.'

[19] For various taxonomies of systemic failures, see, e.g. Bach and Matt (2005), Malerba (2009) and Smith (2000).

It is also worth revisiting two issues previously addressed in this chapter from a new angle. The first one is the design and use of scoreboards or league tables for assessing countries' performance. A straightforward implication of the systemic view is that, 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. 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 realize that poor performance as signaled by certain indicators, and leading to a low ranking on the scoreboard, does not automatically identify the area(s) necessitating the most urgent policy actions. For example, in the case of several indicators measuring performance in 'high-tech', for a country at a lower level of economic development it might be more relevant to focus scarce public resources on improving the conditions for knowledge dissemination and exploitation, rather than spending money on creating scientific knowledge. This is a gross oversimplification, of course, that is, 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. Moreover, as the Hungarian and Irish cases have shown, a high value of a composite indicator would not necessarily signal good performance: the devil is always in the details.

The second issue is the major differences between mainstream economics and the evolutionary economics of innovation. The choice of an economics paradigm to guide policy evaluation is likely to be decisive: assessing the impacts of the same policy measure by following the neo-classical paradigm leads to certain conclusions on efficacy and efficiency, while doing so within the evolutionary frame yields drastically different ones (Lipsey and Carlaw, 1998). Policy-makers need to consider these differences, too, when making a choice as to which paradigm is to be followed.

Finally, some basic principles for policy-making can be distilled from the systemic view of innovation. Given the characteristics of the innovation process, public policies should be aimed at promoting learning in its widest possible sense: competence building at individual, organizational and inter-organizational levels; in all economic sectors, in all possible ways, considering all types of knowledge, emanating from various sources. Further, as it already occurs in some countries, innovation (and other) policies should promote the introduction of new processes and methods in public services and administration, too. New indicators that better reflect evolutionary processes of learning and innovation would also be needed to support policy-making in this new way. Developing, piloting and then widely collecting these new indicators would be a major, demanding and time-consuming project, necessitating extensive international cooperation.

REFERENCES

Bach, L. and M. Matt (2005), 'From Economic Foundations to S&T Policy Tools: a Comparative Analysis of the Dominant Paradigms', in Llerena, P. and Matt (eds) *Innovation Policy in a Knowledge-Based Economy: Theory and Practice*, Heidelberg: Springer.

Balconi, M., S. Brusoni, L. Orsenigo (2010), 'In defence of the linear model: An essay', *Research Policy*, **39** (1), 1-13.

Bleda, M. and P. del Río (2013), 'The market failure and the systemic failure rationales in technological innovation systems', *Research Policy*, **42** (5), 1039-1052.

Bush, V. (1945), *Science: the Endless Frontier*, U.S. Government Printing Office: Washington, D.C. available at http://www.nsf.gov/od/lpa/nsf50/vbush1945.htm (accessed 10 September 2013).

Caraça, J., B-Å. Lundvall, S. Mendonça (2009), 'The changing role of science in the innovation process: From Queen to Cinderella?', *Technological Forecasting and Social Change*, **76** (6), 861-867.

Caracostas, P. (2007), 'The policy-shaper anxiety at the innovation kick: how far do innovation theories really help in the world of policy', in F. Malerba, S. Brusoni (eds) *Perspectives on Innovation*, Cambridge: Cambridge UP, pp. 464–489.

Castellacci, F. (2008a), 'Technological paradigms, regimes and trajectories: Manufacturing and service industries in a new taxonomy of sectoral patterns of innovation', *Research Policy*, **37** (6-7), 978-994.

Castellacci, F. (2008b), 'Innovation and the competitiveness of industries: Comparing the mainstream and the evolutionary approaches', *Technological Forecasting and Social Change*, **75** (7), 984-1006.

den Hertog, P., E. Oskam, K. Smith, J. Segers (2002), 'Usual Suspects, Hidden Treasures Unmet Wants and Black Boxes in Innovation Research', position paper, Utrecht: Dialogic.

Dodgson, M. and R. Rothwell (eds) (1994), *The Handbook of Industrial Innovation*, Cheltenham: Edward Elgar.

Dodgson, M., A. Hughes, J. Foster, S. Metcalfe (2011), 'Systems thinking, market failure, and the development of innovation policy: The case of Australia,' *Research Policy*, **40** (9), 1145-1156.

Dosi, G. (1988), 'Sources, procedures and microeconomic effects of innovation', *Journal of Economic Literature*, **24** (4), 1120-1171.

Dosi, G., C. Freeman, R.R. Nelson, G. Silverberg, L. Soete (eds) (1988), *Technical Change and Economic Theory*, London: Pinter.

EC (2008), *Science, technology and innovation in Europe*, 2008 edition, Luxembourg: Office for Official Publications of the European Communities.

EC (2009), *Science, technology and innovation in Europe*, 2009 edition, Luxembourg: Office for Official Publications of the European Communities.

EC (2010), *Science, technology and innovation in Europe*, 2010 edition, Luxembourg: Office for Official Publications of the European Communities.

EC (2011), *Innovation Union Competitiveness report: 2011 edition*, Luxembourg: Publications Office of the European Union.

EC (2013a), *Innovation Union Scoreboard 2013*, Brussels: Directorate-General for Enterprise and Industry, European Commission.

EC (2013b), *Research and Innovation performance in EU Member States and Associated countries: Innovation Union progress at country level*, Luxembourg: Publications Office of the European Union.

EC (2013c), *State of the Innovation Union 2012: Accelerating change*, Luxembourg: Publications Office of the European Union.

Edler, J., M. Berger, M. Dinges, A. Gök (2012), 'The practice of evaluation in innovation policy in Europe', *Research Evaluation*, **21** (3), 167-182.

Edquist, C. (2011), 'Design of innovation policy through diagnostic analysis: identification of systemic problems or (failures)', *Industrial and Corporate Change*, **20** (6), 1725-1753.

Fagerberg, J., D.C. Mowery, R.R. Nelson (eds) (2005), *The Oxford Handbook of Innovation*, Oxford: Oxford UP.

Foray, D. (ed.) (2009), *The New Economics of Technology Policy*, Cheltenham: Edward Elgar.

Freeman, C. (1991), 'Networks of innovators, a synthesis of research issues', *Research Policy*, **20** (5), 499-514.

Freeman, C. (1994), 'The economics of technical change: A critical survey', *Cambridge Journal of Economics*, **18** (5), 463-514.

Freeman, C. (1995), 'The "National System of Innovation" in historical perspective', *Cambridge Journal of Economics*, **19** (1), 5-24.

Godin, B. (2006), 'The Linear Model of Innovation: The Historical Construction of an Analytical Framework', *Science, Technology & Human Values*, **31** (6), 639-667

Gök, A. and J. Edler (2012), 'The use of behavioural additionality evaluation in innovation policy making', *Research Evaluation*, **21** (4), 306-318.

Grupp, H. (1998), *Foundations of the Economics of Innovation: Theory, measurement and practice*, Cheltenham: Edward Elgar.

Grupp, H. and T. Schubert (2010), 'Review and new evidence on composite innovation indicators for evaluating national performance', *Research Policy*, **39** (1), 67-78.

Hall, B.H. and N. Rosenberg (eds) (2010), *Economics of Innovation*, Amsterdam: North-Holland.

Hatzichronoglou, T. (1997), 'Revision of the High-Technology Sector and Product Classification', *OECD STI Working Papers*, 1997/2.

Hirsch-Kreinsen, H., D. Jacobson, S. Laestadius, K. Smith (2005), 'Low and Medium Technology Industries in the Knowledge Economies: The Analytical Issues', in H. Hirsch-Kreinsen, D. Jacobson, S. Laestadius (eds) *Low Tech Innovation in the Knowledge Economy*, Frankfurt: Peter Lang, pp. 11-29.

Jensen, M.B., B. Johnson, E. Lorenz, B-Å. Lundvall (2007), 'Forms of knowledge and modes of innovation', *Research Policy*, **36** (5), 680-693.

Klevorick, A.K., R.C. Levin, R.R. Nelson, S.G. Winter (1995), 'On the sources and significance of interindustry differences in technical opportunities', *Research Policy*, **24** (2), 185-205.

Laestadious, S., T.E. Pedersen, T. Sandven (2005), 'Towards a new understanding of innovativeness – and of innovation based indicators', *Perspectives of economic, political and social integration*, **11** (1-2), 75-121.

Lazonick, W. (2013), 'The Theory of Innovative Enterprise: Methodology, Ideology, and Institutions', in J.K. Moudud, C. Bina, P.L. Mason (eds) *Alternative Theories of Competition: Challenges to the Orthodoxy*, London: Routledge, pp. 127-159.

Lipsey, R.G. and K. Carlaw (1998), 'Technology policies in neo-classical and structuralist-evolutionary models', *STI Review*, No. 22, pp. 31-73.

Lundvall, B-Å. (ed.) (1992), *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, London: Pinter.

Lundvall, B-Å. and S. Borrás (1999), *The Globalising Learning Economy: Implications for Innovation Policy*, Luxembourg: Office for Official Publications of the European Communities.

Malerba, F. (2002), 'Sectoral systems of innovation and production', *Research Policy*, **31** (2), 247-264.

Malerba, F. (2009), 'Increase learning, break knowledge lock-ins and foster dynamic complementarities: evolutionary and system perspectives on technology policy in industrial dynamics', in D. Foray (ed.) *The New Economics of Technology Policy*, Cheltenham: Edward Elgar, 33-45.

Metcalfe, S.J. and L. Georghiou (1998), 'Equilibrium and evolutionary foundations of technology policy', *STI Review,* No. 22, pp. 75-100.

Mowery, D.C. (2009), '*Plus ca change*: Industrial R&D in the "third industrial revolution"', *Industrial and Corporate Change*, **18** (1), 1-50.
Nelson, R.R. (ed.) (1993), *National Innovation Systems: A comparative study*, New York: Oxford UP.
Nelson, R.R. (1995), Recent evolutionary theorizing about economic change, *Journal of Economic Literature*, **33** (1), 48-90.
OECD (1998), 'New Rationale and Approaches in Technology and Innovation Policy', *STI Review*, No. 22.
OECD (2001), *Innovative Networks: Co-operation in national innovation systems*, Paris: OECD.
OECD (2002), *Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development*, 6th edition, Paris: OECD.
OECD (2004), *OECD Science, Technology and Industry Outlook 2004*, Paris: OECD.
OECD (2005a), *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, 3rd edition, Paris: OECD.
OECD (2005b), *OECD Science, Technology and Industry Scoreboard 2005*, Paris: OECD.
OECD (2006a), *Government R&D Funding and Company Behaviour: Measuring Behavioural Additionality*, Paris: OECD.
OECD (2006b), *OECD Science, Technology and Industry Outlook 2006*, Paris: OECD.
OECD (2007), *OECD Science, Technology and Industry Scoreboard 2007: Innovation and performance in the global economy*, Paris: OECD.
OECD (2008), *OECD Science, Technology and Industry Outlook 2008*, Paris: OECD.
OECD (2010), *The OECD Innovation Strategy: Getting a head start on tomorrow*, Paris: OECD.
Pavitt, K. (1984), 'Sectoral patterns of technical change: towards a taxonomy and theory', *Research Policy*, **13** (6), 343-373.
Peneder, M. (1999), 'The Austrian Paradox: "Old" structures but high performance?', *Austrian Economic Quarterly*, **4** (4), 239-247.
Peneder, M. (2010), 'Technological regimes and the variety of innovation behaviour: Creating integrated taxonomies of firms and sectors', *Research Policy*, **39** (3), 323-334.
Radosevic, S. (2002), 'The electronics industry in central and eastern Europe: an emerging production location in the alignment of networks perspective', *Working Paper* No. 21, School of Slavonic and East European Studies, University College London.
Sandven, T., K. Smith, A. Kaloudis (2005), 'Structural change, growth and innovation: the roles of medium and low-tech industries, 1980-2000', in H. Hirsch-Kreinsen, D. Jacobson, S. Laestadius (eds) *Low Tech Innovation in the Knowledge Economy*, Frankfurt: Peter Lang, pp. 31-59.
Sharif, N. (2006), 'Emergence and development of the National Innovation Systems concept', *Research Policy*, **35** (5), 745–766.
Smith, K. (2000), 'Innovation as a Systemic Phenomenon: Rethinking the Role of Policy', *Enterprise & Innovation Management Studies*, **1** (1), 73-102.
Smith, K. (2002), 'What is the "Knowledge Economy"? Knowledge intensity and distributed knowledge bases', *UNU/INTECH Discussion Paper Series*, 2002-6
Smith, K. (2005), 'Measuring Innovation', in J. Fagerberg, D.C. Mowery, R.R. Nelson (eds) *The Oxford Handbook of Innovation*, Oxford: Oxford UP, pp. 148-177.
Steinmuller, E. W. (2009), 'Technology policy: the roles of industrial analysis and innovation studies', in D. Foray (ed.), *The New Economics of Technology Policy*, Cheltenham, UK and Northampton, MA, USA: Edward Elgar, pp. 17–32.

Tidd, J., J. Bessant, K. Pavitt (1997), *Managing Innovation: Integrating technological, market and organizational change*, Chichester: John Wiley & Sons.

von Hippel, E. (1988), *The Sources of Innovation*, Oxford: Oxford UP.

von Tunzelmann, N. and V. Acha (2005), 'Innovation in "Low-Tech" Industries', in J. Fagerberg, D.C. Mowery, R.R. Nelson (eds) *The Oxford Handbook of Innovation*, Oxford: Oxford UP, pp. 407-432.