Knowledge production of firms: research networks and the ‘scientification’ of business R&D

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Abstract: Research and Development (R&D) expenditure grew during the 1980s and 1990s. The USA ranks first, Japan second and the EU third. Business R&D displays a cyclical pattern, university research, on the contrary, expanded more gradually. Interestingly, basic research grew faster than applied research. The consequences of this are paralleling efforts for different R&D activities, a re-conceptualisation of applied and university-related research and an increased demand, but also more opportunities, for direct university/business linkages. We will focus in this article on firms, identifying, which options they have to meet these challenges. We propose the concept of the ‘academic firm’. Through a limited ‘scientification’ of business R&D and participation in research networks, firms can enhance their knowledge production.

Keywords: knowledge production; knowledge-based economies and societies; basic research; applied research; experimental development; research networks; paralleling of R&D; scientification of business R&D; academic firm.


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Knowledge production of firms: research networks

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1 Introduction

There are concepts, which claim that university research and business R&D express increasingly similar features and eventually will overlap (Gibbons et al., 1994; Hicks and Katz, 1996; Katz and Martin, 1997; Howells and Nedeva, 2003). In the current literature a wide spectrum of arguments exists, emphasising that universities should develop an entrepreneurially oriented profile. However, we want to present the complementary question as being just as important: Why should not R&D performing firms become more like ‘academic firms’ through a limited ‘scientification’ and participate in research networks?

For the purpose of analysing that research question, we will outline in Section 2 the evolution of knowledge-based economies and societies. After a short review of key concepts of knowledge (Mode 1, Mode 2, and Triple Helix) we emphasise that R&D should be qualified as core indicators of knowledge. In the following section (Section 3) we present current R&D trends based on comparative empirical data for the USA, the European Union (EU 15) and Japan. R&D trends display how advanced and knowledge-based economies and societies perform. Based on these findings, we will derive consequences for the configuration of university/business interfaces with respect to the necessity of participating in research networks and to encourage a (limited) scientification of firms (Section 4).

2 The evolution of knowledge-based economies and societies: conceptual notions of knowledge

In conventional understanding the advanced economies and societies are characterised as knowledge-based (Feldman and Link, 2001). This results from the agreement that knowledge is crucial for economic performance, economic competitiveness and wealth (Grant, 1996). ‘Knowledge production’ can be conceptualised and measured differently. In a narrow approach one may focus on research or R&D (research and experimental development) by arguing that R&D indicators certainly reflect knowledge production substantially (OECD, 2001a; 2002). Science and technology, at least partially, can be explained by using R&D indicators. Basic research at universities qualifies as science, applied research and experimental development of the economy (business) represent
technology. Innovation or ‘systems of innovation’ – when conceptualised broadly (Lundvall, 1992; Kuhlmann, 2001) – add a further degree of comprehensiveness to S&T: innovation systems embed S&T (and R&D), but may not be reduced to S&T (R&D). Within that logic S&T represents a subset of innovation, and R&D a subset of S&T. Therefore, knowledge can be measured across different dimensions and dimension-assigned indicators: R&D, S&T and innovation.

Two recent theories provide insights for explaining the current dynamics of knowledge-based economies and societies:

- **Triple Helix** states that the interaction between academia, industry and the state is crucial. Therefore, one can speak of the interplay of universities, of the whole economy and of the institutions of government. They are linked together – as three helices –, coevolve through dense and nonlinear communication and negotiations (Etzkowitz and Leydesdorff, 2000; Leydesdorff and Etzkowitz, 1996). Triple Helix often is being regarded as an excellent description and a useful frame of reference for the contemporary US national system of innovation. Etzkowitz and Leydesdorff (Etzkowitz and Leydesdorff, 2000) emphasise particularly the crucial role of the universities for knowledge production. In a later publication Etzkowitz (Etzkowitz, 2003) also speaks of the ‘entrepreneurial university’, adding, as a part of a ‘second academic revolution’, a ‘third mission’ to teaching and research: ‘economic and social development’ (see furthermore Pfeffer, 2003).

- **Mode 1 and Mode 2**: In that theory (developed by Gibbons, Limoges, Nowotny, Schwartzman, Scott, and Trow), Mode 1 refers to the production of scientific knowledge in a traditional university setting. Mode 2 develops as a supplement to Mode 1. Mode 2 is characterised by the following principles: ‘knowledge produced in the context of application’; ‘transdisciplinarity’; ‘heterogeneity and organisational diversity’; ‘social accountability and reflexivity’; and ‘quality control’ (Gibbons et al., 1994). Thus it is crucial to embed university-based scientific research in a larger societal context, to link universities with business (industry) and to tie science and technology closer together. Ultimately, the boundaries between science and technology become blurred (Gibbons et al., 1994). By communicating intensively, the knowledge producers and knowledge users are directly connected during the whole process of knowledge creation: the interest to use knowledge effectively often demands participation already in the process of knowledge production (Gibbons et al., 1994). In a follow-up publication, the emergence of a Mode 2 society and thus a co-evolution of Mode 2 science and Mode 2 society are claimed by Nowotny, Scott and Gibbons (Nowotny, Scott and Gibbons, 2001; see furthermore Stuart A. Umpleby, 2002, and his concept of Science One and Science Two).
wants to couple its domestic university base more effectively with Japanese business R&D.

Following Polanyi (1962) knowledge itself can be differentiated into ‘codified’ and ‘tacit’ knowledge. Codified (explicit) knowledge represents primarily a knowledge written down (physically, electronically or ‘virtually’), which can be stored and therefore – at least in principle – may be accessed by the public on a global scale, that means from every geographical location. The characteristics of codified knowledge allow in principle a legal protection through Intellectual Property Rights (IPR). A key feature of the knowledge production of universities is that they produce codified knowledge, where publications represent a core area of activity. Books as well as articles each express their specific profiles of strengths and weaknesses, which, to a certain extent, behave complementarily (Campbell and Felderer, 1997). Publications in the sciences define the ‘authorship’ and thus support the ‘reputation’ of those individuals, who are engaged in the scientific research.

Scientific knowledge (conventionally Mode 1) typically is a codified knowledge (Pavitt, 1998). Tacit knowledge, on the contrary, is embedded in the heads of the employees, in the corporate culture and organisational routines. Thus, conventionally, tacit knowledge can only move (migrate), when the employees move from one organisational context to another (Gibbons et al., 1994). The spreading of tacit knowledge demands personnel mobility. The tacit knowledge pool of a company impacts its competitiveness, since tacit knowledge is generated by experience-based learning and participation in the work process: learning-by-doing, learning-by-using and learning-by-interacting (Lundvall, 1992). Furthermore, tacit knowledge cannot be as easily imitated or copied as codified knowledge and plays therefore a crucial role in gaining and sustaining competitive advantages (Barney, 1991; 2001; Cool, Costa and Dierickx, 2002).

Lately, awareness is spreading that underscores the importance of tacit knowledge for technological knowledge and business R&D. However, also codified knowledge preserved and even enhanced its value for knowledge production. Innovation processes result from the interplay of codified and tacit knowledge (Potì, 2001; for different forms of knowledge transfer see Mangematin and Nesta, 1999). In this sense, it is necessary to leverage the full benefits of the intellectual capital of a firm by managing the accumulation and flows of both codified and tacit knowledge (Carayannis and Alexander, 1999). We can speak of a co-evolution of codified and tacit knowledge (and perhaps also of Mode 1 and Mode 2). Furthermore, parallel to the national systems of innovation, also local as well as global innovation systems co-exist and interact (Lundvall, 1992; Kuhlmann, 2001; see furthermore Lundvall, 1998; Archibugi and Lundvall, 2002). A continuous interaction between internal and external knowledge production operates (Liyanage, Greenfield and Dorn, 1999). In particular, for firms it becomes necessary to develop the ability to absorb and integrate external knowledge as well as to develop new knowledge internally. Firms, which depend on knowledge from external sources for making innovations, are challenged to adapt their technical as well as intellectual interfaces with the universities and research centers. Internally, the established incentive system and the corporate culture must support the firm’s innovative capabilities (or the ‘firm-specific innovation system’).

After discussing the general research trends at the macro level, which also structure the environment for the firm-based R&D processes, we outline in Section 4 that
participation in research networks and the 'scientification' of business R&D represent appropriate strategies for firms in dealing with the new knowledge demands.

3 Funding and performance trends of R&D: basic research, applied research and experimental development

3.1 Trends of the R&D quotas

R&D are key indicators for knowledge. The OECD (Organisation for Economic Co-operation and Development) clusters R&D into research (R) and experimental development (D). Research again can be sub-classified either as basic research or as applied research (OECD, 1994). Experimental development is located closest to a direct and commercial market application. Conventionally the market potential of basic research is more long-term oriented and applied research is located 'between' basic research and experimental development.

R&D can be funded and performed. Performance indicates 'where' R&D is carried out. The OECD recognises the following sectors: higher education sector; government sector; private non-profit sector (PNP); and the business enterprise sector (OECD, 2002). Each of these sectors funds and performs R&D. R&D performed by the higher education sector is university research. R&D carried out by the business enterprise sector is business R&D (often also called industry R&D). There operates the following division of labour for national research systems: university research is primarily basic research, with a focused funding by the public, and business R&D, primarily self-funded by the economy, concentrates on experimental development (National Science Board, 2002).

Gross domestic expenditure on R&D (GERD) as a percentage of GDP (Gross Domestic Product) – also called the national 'research quota' – represents one possibility for measuring research intensity. Conventionally, because of the importance of knowledge, one would expect the research quotas to rise. Empirically, however, the results are more differentiated. Demonstrated for the OECD average, the R&D quota increased in the period 1981–1990 from 1.95 to 2.29%, but dropped to 2.09% until 1994, and recovered to 2.24% by 2000 (OECD, 2002; see furthermore National Science Board, 2002). This pattern does not indicate a linear growth, but more of a 'wave' curve. For the OECD average, between 65% and 70% of the R&D is performed by the business enterprise sector (OECD, 2002). There is a pattern of correspondence between the wave curve of the national R&D quotas and the business R&D quotas, again for the OECD average (OECD, 2002). On the other hand, the average OECD university research quota increased moderately but steadily from 0.32 to 0.38% during the whole period 1983–2000 (OECD, 2002). See the Figure 1.

In reference to these research quotas, that express R&D expenditure as a percentage of GDP, the following hypotheses can be formulated (OECD, 1998):

- Trends of national and business R&D expenditure: Expansion or decline of national R&D expenditure becomes duplicated by business R&D expenditure. To a certain extent the R&D expenditure cycles are connected with the economic cycles. Phases of economic growth support R&D expenditure, whereas periods with a lower economic growth profile put R&D expenditure under pressure.
Figure 1  The gross domestic expenditure on R&D by sector of performance (university, business and national R&D) for the OECD average (1983–2000): R&D expenditure as a % of GDP

Source: OECD (2002)
The cyclical behaviour of business R&D: Business R&D is primarily ‘experimental development’, implying specifically that this type of market-oriented R&D expenditure reveals a strong cyclical pattern that somehow ‘correlates’ with the economic cycles (now leaving the question about the direction of causation open; whether business R&D cycles induce the cycles of economic growth, or whether the opposite appears to be more true).

The stability of university research: University research, in contrast to business R&D, does not replicate the cyclical expenditure patterns of national R&D. For the OECD average, university research expenditure even expanded from 0.32 to 0.38% of the GDP during the years 1983–2000. This academic type of basic research expresses a structural growth, behaving largely non-cyclically. Academic research introduces elements of stability that compensate the cyclicity (and unpredictability) of business R&D in the context of the economic growth cycles.

Long-term public funding of basic research at universities: Public funding of university research may focus on two crucial objectives; first, supporting basic research, which often represents research activities with no immediate potential for market application; second, anti-cyclically counterbalancing the downturns of business R&D and of the economic cycles. This clearly underscores how public R&D and innovation policy is interconnected with public economic policy (Campbell, 2000; Grande, 2000).

3.2 R&D expenditure trends in constant market prices and purchasing power parities (1995) per a population of 500,000

Research quota indicators, despite their frequent use, also contain some methodic weaknesses: they do not reflect changes of GDP or of GDP per capita. Therefore, should GDP and R&D both grow, but with GDP growing faster than R&D, the R&D quota would decline. To capture such ‘levels’ of GDP and R&D expenditure, the following procedure is applied for calculating ‘real term’ R&D expenditure: using only R&D expenditure in million constant dollars in 1995 prices and purchasing power parities (PPP), per a population of 500,000 (half a million).

3.2.1 R&D expenditure trends in constant market prices and purchasing power parities (1995) per a population of 500,000: national R&D expenditure of the US, Japan and EU

Real R&D expenditure grew – for the US, Japan and the European Union – during the late 1980s, declined in the first half of the 1990s, however, regained a considerable growth momentum during the second half of the 1990s (see Figure 2). This growth profile for the late 1990s is more impressive than the conventional R&D indicator of the research quotas might suggest (compare Figures 1 and 2). When ranked, the US places during the whole period 1985–2000 always first, followed by Japan, and the EU ranks only third. In 2000, the US value is more than twice as high as the EU value. During the early 1990s there was a chance that Japan might outpace the US: however, after the mid-1990s the national R&D expenditure gap again widened in favour of the US. This all-time lead of the US raises the issue, which role R&D investment played for the growth of the US economy during the second half of the 1990s (OECD, 2001b; Campbell, 2000).
Figure 2  The gross domestic expenditure on R&D per a population of 500,000 (1985–2000). Currency unit: million constant $ in 1995 prices and purchasing power parities (PPP)

Source: Authors’ own calculations based on Campbell (2000; 2003) and OECD (2001a; 2002)
3.2.2 R&D expenditure trends in constant market prices and purchasing power parities (1995) per a population of 500,000: average R&D expenditure of the US, Japan and EU for basic research, applied research and experimental development

R&D clusters into basic research, applied research and experimental development. In the ‘Frascati Manual’ the OECD defined in detail these different research activities, and also standardised the measurement procedures of R&D for the OECD member countries (see OECD, 1994). In Figure 3 we display how on average – for the USA, EU and Japan combined – R&D expenditure developed according to those three R&D categories during 1985–2000.1 Experimental development ranks first, applied research second and basic research third. Each of these R&D categories achieved a real-term growth during the analysed period, experimental development fluctuated cyclically the most. This coincides with the circumstance that business R&D is primarily experimental development, and it demonstrates an expressively cyclical behaviour. Basic research has not declined. It, in fact, expanded even faster than applied research and has not become substituted by applied research. On the contrary, it appears that it is applied research, which is coming under some pressure of how to define or redefine its role ‘between’ basic research and experimental development. Knowledge-based economies and societies depend increasingly on basic research and experimental development. Based on the values of 1985, the R&D categories realised the following growth momentum until 2000: basic research 83.6%; applied research 30.5%; and experimental development 36.6%.

3.2.3 R&D expenditure trends in constant market prices and purchasing power parities (1995) per a population of 500,000: average R&D expenditure of the US, Japan and EU by sector of performance

For a further analytical insight into the changing relationship of basic and applied research and experimental development, one can focus on the sectors of R&D performance, by comparing the following sectors: university R&D; the aggregated R&D of the government and the private non-profit sectors, which may be classified as ‘university-related’ R&D (Campbell and Felderer, 1997); and the R&D of the business enterprise sector (business R&D). We already commented that university research represents primarily basic research, and business R&D is dominated by experimental development. R&D expenditure by sector of performance, again expressed in average values for the USA, the EU and Japan (1985–2000), demonstrates striking similarities with the R&D activity trends of basic and applied research and experimental development. First, business R&D is the most cyclical, while university and university-related R&D increased rather gradually. Second, the gap between university and university-related R&D has widened in further favour of university R&D.2 This might assert that in correspondence with applied research also the institutional sectoral cluster of university-related research experiences pressures. Third, based on the 1985 values, the sectors achieved the following sectoral R&D growth until 2000: university R&D 37%; university-related R&D 21.8%; and business R&D 46.5%.
Figure 3  The gross domestic expenditure on R&D per a population of 500,000 (1985–2000): average values for U.S., EU (EU 15) and Japan. Currency unit: million constant $ in 1995 prices and purchasing power parities (PPP)

<table>
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<tr>
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<tr>
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<td>1985</td>
<td>54.8</td>
<td>31.1</td>
<td>153.9</td>
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</table>

Source: Authors’ own calculations based on Campbell (2000) and OECE (2001a; 2002)
Figure 4  The gross domestic expenditure on R&D (by sector of performance) per a population of 500,000 (1985–2000): average values for U.S., EU (EU 15) and Japan. Currency unit: million constant $ in 1995 prices and purchasing power parities (PPP)

Source: Authors’ own calculations based on Campbell (2000) and OECD (2002)
3.2.4 R&D expenditure trends in constant market prices and purchasing power parities (1995) per a population of 500,000: R&D expenditure for basic research in the higher education and business enterprise sectors

Comparing the sectorally-generated basic research expenditure of the USA, EU and Japan (1986–1998), allows us to conclude with the following hypotheses (see Figures 5 and 6; see furthermore OECD, 2000, and Campbell, 2001):

- **Basic university research lies ahead of basic business research:** In the USA, EU and in Japan the level of basic university research is clearly higher than that of basic business research. This underlines the already previously stated division of R&D labour in national systems of innovation, where universities claim the primary competence for basic research. However, basic research activities of the economy should not be undervalued, since this offers opportunities for research linkages between universities and business.

- **Basic university research ranking – US, EU and Japan:** The US ranks first, followed by the EU, and Japan places third. This clearly demonstrates a specific potential of strength for the US innovation system. European universities also express a potential of international strength, based on their levels of basic research expenditure. That Japan places behind the US and EU might imply critical questions about the effectiveness of the Japanese university system. For example, when article output (bibliometrics) is referred to population, Japan also places behind the US and most EU countries (European Commission, 2002; National Science Board, 2002). Education and know-how, i.e. knowledge in general, are being regarded as crucial components for the global competitiveness of a national economy (Nowotny, Scott and Gibbons, 2001).

- **Basic business research ranking – Japan, US and EU:** Japan lies slightly ahead of the US, although the values place closely, and in some years the US even outspent Japan. The EU places third, and the gap toward first ranking Japan and the second ranking US is considerable. While European expenditure for basic university research is remarkable, European basic business research expenditure lags behind. This might imply specific competitiveness deficiencies for the European national systems of innovation that again constrain some of the strengths of European universities. Conceptually, one may postulate that there exists a profound linkage potential particularly between basic business research and basic university research. In that logic, basic business research highlights interface opportunities for bridging between the economy and universities. Comparatively low values for Europe perhaps indicate that business does not, or cannot, access the research strengths of the European university base adequately. Contrary to that, a crucial strength of the US innovation system is expressed by the multitude of university/business interfaces, demonstrating the successful linking of universities and firms. For Japanese business the issue of quality improvement of the domestic Japanese university base gains in importance.

- **Global competition of basic university and basic business research:** Expenditure for basic university research and basic business research ranks generally higher in the second half of the 1990s than during the mid-1980s. While basic business research again fluctuates considerably, the growth of basic university research is stable and
thus more impressive. This supports the hypothesis of a continuing and increasing importance of basic research. There is not only a global competition with regard to the levels of R&D expenditure, but also more specifically concerning basic research expenditure. In such a conceptual framing, the US appears to occupy a ‘win-win’ position: US basic business research expenditure is almost equal with Japan, and US basic university research clearly outspends the other main competitors. Japan is challenged by lower basic university research expenditure and the EU by dramatically lower investments into basic business research. This basic research expenditure lead of the US even is amplified, when one takes the national R&D spending saliency of US again into account (compare Figure 2 with Figures 5 and 6).

4 Research networks and the ‘scientification’ of business R&D

The national innovation system may behave as a favourable or unfavourable environment for business R&D. It can stimulate business R&D, however, it depends on the abilities of a firm to perceive and to realise opportunities within a single country as well as globally. In addition to the strategic decision where (in which country) a firm should locate or re-locate R&D activities, companies are pressured to develop a design for their specific knowledge production and the associated R&D processes. Acknowledging the general R&D trends, we focus in this section on two relevant aspects for the innovating firm: first, there is a demand for paralleling basic research, applied research and experimental development. Firms optimise their R&D processes to reduce ‘time-to-market’ by paralleling their R&D activities. They use networks to access the necessary and highly specified knowledge from universities, but also from other firms. Second, codified as well as tacit knowledge define important key resources for firms (Barney, 1991; 2001; Grant, 1996; Eisenhardt and Santos, 2002). The ability of knowledge production and acquisition (for aspects of knowledge acquisition of firms see Güttel and Dietrich, 2001) may be improved through a limited ‘scientification’ of business R&D. Especially a broader absorptive capacity as well as incentive systems represent appropriate options.

4.1 Research networks: the paralleling of basic research, applied research and experimental development

The shortening business life cycles of products and services (European Commission, 1996; Tassey, 2001) imply two consequences, producing perhaps a paradoxical situation. First of all, there is a certain tendency for reduced ‘time horizons’, demanding that R&D outcome is implemented faster into market activities (OECD, 1998). Second, basic research promises the highest long-term economic revenue potential, since non-basic and short-term R&D outdates much faster. A conceptual conclusion to this dilemma lies in a redefinition of the relationship between basic research, on the one hand, and applied research and experimental development on the other.
Figure 5  University R&D expenditure for basic research per a population of 500,000 (1986–1998). Currency unit: million constant $ in 1995 prices and purchasing power parities (PPP)

Source: Authors’ own calculations based on Campbell (2001) and OECD (2000)
Figure 6  Business R&D expenditure for basic research per a population of 500,000 (1986–1998). currency unit: million constant $ in 1995 prices and purchasing power parities (PPP)

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Source: Authors’ own calculations based on Campbell (2001) and OECD (2000)
4.1.1 Paralleling the R&D activities

In the classical model, the different R&D activities are sequentially linked one after another (Lundvall, 1992; Narin, Hamilton and Olivastro, 1997). Major deficiencies of a ‘linear’ understanding are the considerable amount of time, consumed by the whole R&D cycle, and the constrained feedback from market application back to the basic research. In contrast to the linear model, the paralleling of basic research, applied research and experimental development demands that the different R&D activities should be considered, to phrase it in a challenging language, as ‘parallel processes’ (Campbell, 2000). In epistemological terms, theory and application (science and technology) become more directly coupled. Through connecting heterogeneous groups of knowledge producers and knowledge users, a mutual interaction within R&D is supported. The ‘paralleling’ of basic research, applied research and experimental research can be considered as a two-fold strategy: on the one hand supporting basic research as a counteracting strategy against shortening business life cycles, and, at the same time, also accelerating the market introduction of R&D. Paralleling processes can take place within the context of individual institutions or across different institutions and sectors (e.g., university/business interfaces).

4.1.2 Paralleling and the demand for networking

One can argue that the ‘paralleling’ of R&D activities additionally supports the networking approach. Lundvall (1992) strongly emphasises the importance of ‘collective entrepreneurship’. Nelson (1990) claims that ‘cooperative pre-competitive research’ was an important policy contribution of Japan to globalising innovation systems. For the USA innovation system an interesting policy shift occurred during the 1980s and 1990s: regulations on Intellectual Property Rights became stricter, however, anti-trust regulations increasingly relaxed, thus favouring collaboration and networking considerably (Vonortas and Tolnay, 2001; Vonortas, 1997; and for the influence of policymaking on science and technology Gottweis, 1998).

A specific challenge lies in bridging university research and business R&D, and in linking basic university research with the experimental development activities of the business enterprise sector. There is a tendency that firms enforce their university/business interfaces (for different types of knowledge-related university/industry interactions see Schartinger et al., 2002). Krücken (2003) shows that the most effective mode of interaction is a personalised one. The reason lies in the need for a high degree of trust between the involved technology transfer partners, which again is necessary for transcending the cultural gap and the competitive situation within research networks (see furthermore Rycroft and Kash, 1999; Carayannis and Alexander, 2002). This means that firms must contribute in creating contexts, where trustful relations can exist and mature.

Sheppard and Tuchinsky (Sheppard and Tuchinsky, 1996) distinguish between different forms of trust in network organisations, where the identification-based and the knowledge-based form of trust is relevant in research networks. Identification-based trust, fully internalising the preferences of the ‘others’, represents the highest order of trust. Intensive interaction and cooperation are necessary for developing such common values and norms, enabling a trustful relationship. The second highest order of trust is knowledge-based and allows the different parties to predict the partner’s behaviour.
Prediction ability requires understanding. Again, repeated and multifaceted relationships contribute to the development of (knowledge-based) trust. Consequently, firms have to invest in setting up structures in which employees can develop trust through intensive cooperation within project teams and research networks over a longer period of time (see later Section 4.2.1).

4.2 The scientification of business R&D: business/university interfaces and incentives

One central thesis of Mode 2, claims that universities and firms, at least partially, converge in how they produce knowledge. Universities take over some corporate culture ‘values’ and develop them in favour of an ‘academic entrepreneur’\(^4\). Firms, on the other hand, also implement ‘norms of academic culture’, such as offering sabbaticals and training opportunities to their employees (Gibbons et al., 1994). The concept of ‘scientification’\(^5\) of business R&D may be defined as follows: the business enterprise sector allows or even encourages the introduction of a codified scientific knowledge production, by incorporating more systematically ‘elements’ or modes of university research. Improving the effectiveness of business R&D represents the ultimate rationale for a limited scientification of business R&D.

Despite a necessity for establishing trustful relationships, firms and universities must also continue their characteristics of diversity and identity (Turpin, 1999). An intensive interaction between business firms and universities offers possibilities for generating new knowledge in the university sector, where universities are not that much pressured by economic necessities. Business firms, on the contrary, can transform the scientific knowledge of universities into products and services to generate profits. Particularly the combination of these different and distinctive capabilities enhances advantages for both.

4.2.1 Interfaces between firms and universities

The support of interfaces between firms and universities involves aspects of organisational structures and of the absorptive capacity. Besides the organisational structures, which should be designed to provide a long-term and stable participation in research networks or cooperations with universities, the absorptive capacity – which is embedded in the corporate culture – plays a crucial role in obtaining new knowledge from external sources. Absorptive capacity is the firm’s ability to identify, assimilate, and exploit knowledge from the environment (see Cohen and Levinthal, 1989; Cohen and Levinthal, 1990; Mangematin and Nesta, 1999; Zahra and George, 2002). The capacity to recognise and assimilate relevant knowledge from universities more specifically could be stimulated through the recruitment of personnel with a university research background and a diversity of skills, through fostering personnel mobility between firms and universities (e.g. by offering sabbaticals) – and through systematically participating in scientific conferences. Furthermore, firms and universities should be inclined to set up ‘mixed’ project teams for specific tasks, where members of both institutions can work together intensively. These measures may increase the mutual understanding of different cultural norms and values and should be the basis for a tighter and trustful coupling of firms and universities in the context of research networks.
4.2.2 Incentive systems

Incentive systems should enhance the motivation of employees to share and codify knowledge. Particularly knowledge-intensive firms (Starbuck, 1992) are forced to reduce their dependency on their employees. For this reason they are interested that employees codify – at least to a certain extent – their knowledge, since this feeds directly into the knowledge base, which is permanently available for the firm. But there must be incentives for employees to codify their knowledge, because they are exposed to the risk of replacement (after they codify what they know).

This should not deny that firms also are interested in not-codified knowledge to prevent easy knowledge spillovers to competitors. One objective of scientific publications is distribution, thus spreading the information content. Firms do not want to make public all their knowledge, since this would reduce their competitive advantages. R&D-performing firms must find a crucial balance between scientifically and non-scientifically codified knowledge. Scientifically codifiable knowledge offers incentives to the researchers etc. of a company, by creating a working environment, in which employees can achieve and improve a firm-transcending reputation. Simulating a semi-academic corporate culture (‘institutional atmosphere’) should motivate employees to codify knowledge at a high rate. There must be a good match between the market strategies of a firm and the amount of codified knowledge, which is published through traditional scientific channels.

For firms it is necessary not only to motivate the employees of the R&D department(s), but also the ideas for innovations with respect to products, processes or projects may also come from other departments and the incentive system should enforce the generation of knowledge corporation-wide. However, the opportunities for improving the knowledge production by implementing an incentive structure, which is primarily based on monetary incentives, are limited. Besides the negative effects of monetary incentives on intrinsic motivation (Osterloh and Frey, 2000), firms have the problem of finding convenient indicators for assessing the quality of codified knowledge. It is rarely possible to find a (linear) causal relationship between a single idea and the market-relevant innovation that could be measured monetarily. Contrary to the university system, where several indicators are available to evaluate the quality of codified knowledge (e.g., the review system of refereed journals), business firms lack such well-defined indicators. To evaluate the quality of internally published new knowledge (for example in internal journals, corporate intranets) the firm can set up ‘content teams’, whose members are experts within the relevant knowledge fields. These teams have to recommend or decide, whether an article should be published by (within) the internal publishing media of the firm. If the available criteria are transparent enough, the firm may even couple the production of codified knowledge and a ‘management by objectives’-system, where ‘knowledge goals’ can be defined in advance. The achievement of these goals can offer a rationale for allocating financial bonuses individually and for long-term decision-making about personnel development.

Concerning tacit knowledge, incentives can only be defined in limited ways, because no ‘objective’ criteria exist for proving the quality of tacit knowledge. One cannot measure what cannot be fully codified. Instead – as a non-monetary incentive – firms also should encourage participation in research networks. This is based on the consideration that during the cooperation process the tacit knowledge will transfer through practice. Aspects of such participation may include long-ranging access to external researchers,
scientific conferences, and joint publications with scientists from universities or the exchange of ‘experience-rounds’ (e.g., communities focusing on certain R&D themes). Through participation the employee is in a position of acquiring reputation (which could extend career opportunities) and new – codified as well as tacit – knowledge. The latter will influence the organisational knowledge base positively. Participation in research networks opens up channels for newly produced knowledge, which the firm may transform into specific competences for generating competitive advantages. But firms have to face the risk of knowledge spillovers (‘knowledge risks’), because there are only rarely one-way knowledge flows. Firms must balance the utility of participation against the full leveraging of their strategic goals.

5 Conclusion

Referring to ‘real term’ R&D expenditure, one can state that R&D grew during the 1980s and 1990s. R&D input is the highest in the US and in Japan, in the EU already considerably lower. This R&D expenditure saliency of the US may partially explain the success and competitiveness of the US economy during the 1990s, and should be of a particular concern for European policymakers, since the European R&D input lags considerably behind. Knowledge, and R&D and S&T more specifically, represent a crucial set of factors, fostering international competitiveness. Global competitiveness rankings of national economies indicate the importance of adequate R&D funding (IMD International Institute for Management Development, 2003a; 2003b; 2003c). However, R&D funding-levels alone are not sufficient for determining economic success, when the structural and institutional patterns of a national innovation system are neglected. The US R&D-funding lead, partially, results from a higher spending on defense R&D (OECD, 2002): on the other hand, defense R&D is more effective than no R&D spending. Business R&D fluctuates and cycles the most, university research increased rather constantly. The financial volume of business R&D clearly outpaces the financial volume of university research. However, the non-cyclical growth of university research adds stability to the performance of advanced and knowledge-based economies and societies.

In financial volume terms experimental development ranks first, applied research ranks second (already considerably lower) and basic research ranks third. Two specific trends are: basic research grows faster than applied research, and university research faster than university-related research. This does not automatically imply that applied research or university-related institutions are experiencing a decline in importance. However, there might be a reform demand for applied research and/or university-related institutions. Increasingly, direct links between university research and business R&D or, more specifically, between basic university research and the experimental development of the business enterprise sector are being established. This crucial shift of knowledge production also is reflected in concepts like Mode 1/Mode 2 and Triple Helix. Basic university research expresses an increased impact potential for follow-up economic activities, particularly if connections to university/business interfaces are implemented. Applied research or university-related institutions that only mediate between university research and business R&D run the risk of being outmaneuvered by these direct university/business links. This generates some pressures for re-defining applied research and university-related institutions: making them more academic and tying them closer to
Knowledge production of firms: research networks

Shortened business life cycles imply for firms an increased demand for basic research and for access opportunities to basic university research. The 'entrepreneurial university' (Etzkowitz, 2003) represents, to a certain extent, a concept that emphasises the effective coupling of universities with business. Complementarily, one might expect also a proliferation of 'academic firms' that allow, and encourage, a partial scientification of their business R&D and the participation in research networks: besides supporting firms in their R&D networking activities with universities, the academic firm, furthermore, should encourage a higher codification rate of (scientific and non-scientific) knowledge (see Figure 7 for a summary). A key function of scientific publications is to motivate researchers to codify knowledge, because scientifically acknowledged authorship spreads reputation. Through an adoption of parts of the incentive structure of universities, the firms may support the production of knowledge and, more specifically, of their R&D-based knowledge.

Figure 7 The entrepreneurial university and the academic firm: factors for an increased linkage of the knowledge production of Universities and Firms

<table>
<thead>
<tr>
<th>Entrepreneurial University</th>
<th>Academic Firm</th>
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<tr>
<td>Characteristics:</td>
<td>Characteristics:</td>
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<tr>
<td>Research in the context</td>
<td>Support of the interfaces between the economy and the</td>
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<td>of application.</td>
<td>universities.</td>
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<tr>
<td>Linkage of basic research</td>
<td>Support of the paralleling of basic research, applied</td>
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<td>with applied research</td>
<td>research and experimental development.</td>
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<tr>
<td>and experimental development.</td>
<td>Incentives for employees to codify knowledge.</td>
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<tr>
<td>University/business</td>
<td>Support of collaborative research and of research</td>
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<td>interfaces. Pluralisation</td>
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<td>of the funding base of</td>
<td>A limited &quot;scientification&quot; of business R&amp;D.</td>
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<td>universities.</td>
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Source: Authors’ own conceptualisation based on R&D trends and the concepts of Mode 1/Mode 2 and Triple Helix

Universities and firms cover a broad functional spectrum. Based on knowledge production in terms of R&D, possible functional definitions are: (1) a research-centered rationale for the university system may be phrased as performing basic research with a high quality; and (2) a research-centered rationale for the economic system can be defined as performing R&D with a high potential for commercial revenue and profit. A certain functional and gradual conversion of universities and firms, captured by notions like the 'entrepreneurial university' and 'academic firm', should support networking and,
finally, performance. Partially this can be achieved through importing elements of the rationale of the ‘other’ system. However, there are limits to that conversion, and also to the scientification of business R&D. Universities and firms still are different institutions, and they also have to emphasise different functions in order to remain distinguishable. Where and how to draw the lines that cluster functional differences and similarities between universities and firms remains a crucial task: for policy and for our theories about knowledge. The interaction between universities and firms will continue to represent a key challenge for knowledge-based economies in advanced societies.

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IMD International Institute for Management Development (2003b) *Executive Summary by Stéphane Garelli*, Lausanne.


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Notes
1 While OECD statistics for the USA and Japan normally disaggregate R&D into basic and applied research and experimental development, this is not always the case for the EU member countries (OECD, 2001a, Table 3). Thus the aggregated percentage shares of the R&D categories for the USA and Japan were used, here, as estimators for the percentage shares of these R&D categories for the total aggregated R&D of the USA, Japan and EU. ‘Not specified R&D’, in the case of Japan, was omitted with regard to the estimation of the percentage shares.
2 Even though Japan, around 1995–1996, modified its R&D counting methodology and reduced the percentage share of the national Japanese R&D that is performed by the higher education sector (OECD, 2002, Table 18).
3 As the OECD does not supply R&D breakdowns for basic and applied research and experimental development for all of the EU member countries, a complex estimation procedure was employed for the EU. The years were clustered into 1986–1989 and 1990–1998, calculating averages for basic university and basic business research for these two periods. In the case of missing national data, the comprehensive EU averages were taken for compensation. These were for the share of basic research as a percentage of the university and business R&D: 58.1% (1986–1989) and 57.2% (1990–1998) for university research; and 5.2% (1986–1989) and 4.8% (1990–1998) for business R&D. Concerning the Netherlands, the average national values for basic university research were compensated by the average supranational EU values, because of Dutch peculiarities (see Footnote 10 in Campbell, 2001; Tables 1 and 3 in OECD, 2000; see furthermore Table 3 in OECD, 2003).
4 Considering a long-term analysis of organizational change and reform of universities, see for example (Pechar and Pellert, 1998).
5 The term ‘sciences’, as used here, covers all of the sciences, including the social sciences and humanities. (With regard to a German-speaking audience, we would translate ‘scientification’ as ‘Verwissenschaftlichung’ into German).