KNOWLEDGE CREATION, DIFFUSION, AND USE IN INNOVATION NETWORKS AND KNOWLEDGE CLUSTERS

A Comparative Systems Approach across the United States, Europe and Asia

Edited by

ELIAS G. CARAYANNIS
DAVID F. J. CAMPBELL
CONTENTS

Preface vii

Introduction and Chapter Summaries ix

1 “Mode 3”: Meaning and Implications from a Knowledge Systems Perspective
   Elias G. Carayannis and David F. J. Campbell 1

2 Productive Research Teams and Knowledge Generation
   Frank T. Anbari and Stuart A. Umpleby 26

3 Re-Thinking Science: Mode 2 in Societal Context
   Helga Nowotny, Peter Scott, and Michael Gibbons 39

4 Knowledge Production: Competence Development and Innovation—Between Invention and Routine
   Wolfgang H. Guttel 52

5 The University/Business Research Networks in Science and Technology: Knowledge Production Trends in the United States, European Union, and Japan
   David F.J. Campbell 67

6 Innovation in Clusters and the Liability of Foreignness of International R&D
   Max von Zedtwitz & Philip Heimann 101

7 The Emergence of Regional Technological Capabilities and Transatlantic Innovation Networks: A Bibliometric Study of Public-Private, EU-U.S. R&D Partnerships
   Elias G. Carayannis and Patrice Laget 123
8 Measuring Science-Technology Interaction in the Knowledge-Driven Economy  
Martin S. Meyer  

9 The Different Dynamics of the Biotechnology and ICT Sectors in Finland  
Christopher Palmberg and Terttu Luukkonen  

10 The Transformation of the German System of Innovation: The Case of Biotechnology  
Edgar Grande and Robert Kaiser  

11 “Competence Centers” in Germany: How Can Policymakers Support the Improved Diffusion of Knowledge?  
Susanne Bührer  

12 Cooperation and Networking as a Side Effect of the German Delphi ’98  
Kerstin Cuhls  

13 Certification and Knowledge Management: An Approach Applied to the Space Transport Industry  
Frédéric Fontane, Patrice Houdayer, and Franck Vasseur  

14 Innovation Policy in the Knowledge-Based Economy: The Israeli Case  
Guy Ben-Ari  

15 Using National Innovation Systems to Enhance S&T Policy. A Knowledge-Based Approach with Examples from Japan  
Mark S. Hewitt  

16 Virtualization of Research Universities: Raising the Right Questions to Address Key Functions of the Institution  
Thomas Pfeffer  

Conclusion: Key Insights and Lessons Learned for Policy and Practice  

Index  

About the Editors and Contributors
Preface

Book Motivation and Scope

In this book, we attempt to address some fundamental “What” and “How” questions in both a conceptual and an applied manner. These questions include:

1. What is knowledge in research and technology development and deployment?
2. What is the role of emerging, dynamically adaptive, and transdisciplinary knowledge and innovation systems and infrastructures (such as innovation networks of networks and knowledge clusters of clusters) in the science enterprise?
3. What are the implications and lessons learned for science and technology public sector policies and research and development private sector practices?
4. How do the emerging network-centric and cluster-based knowledge infrastructures shape and become simultaneously shaped by science and technology policies and practices?
5. How does the organizing of the science enterprise according to “Mode 3”—namely, dynamically adaptive, continually reconceptualizing, redefining, and recombining systems and their elements, functions, and borders—impact the science enterprise and become in turn shaped by its evolving dynamics?
6. What policy learning should result from our collection of transatlantic perspectives?
7. Finally, could “Mode 3” serve as a means of inferring and identifying meaningful patterns in the chaotic dynamics of the ebb and flow of knowledge or, in other words, the punctuated processes of knowledge creation, diffusion, and use within and around the science enterprise?

In this book, we have attempted to compile an eclectic configuration of perspectives and treatises of mutually complementary and reinforcing themes on science and technology (S&T) as well as on research and development (R&D).
PREFACE

We hope that it will prove of interest and use for S&T policymakers, R&D managers, business decision makers, and students of innovation and knowledge dynamics alike.

Elias G. Carayannis  
David F. J. Campbell  

Washington, D.C./Vienna  
September 2005
The University/Business Research Networks in Science and Technology

Knowledge Production Trends in the United States, European Union and Japan

DAVID F.J. CAMPBELL

Research networks in science and technology, that involve and tie together universities and business firms are often being regarded as crucial for the performance of knowledge-based economies and societies. Advanced national systems of innovation increasingly depend on these networks. Globalization adds a dimension of complexity, since university/business networks often transcend the borders of nation states and link together different countries and regions. Networks also are classified as a possibility of integrating different modes of codified (explicit) and tacit knowledge.

For the purpose of analyzing the university/business research networks from a comprehensive perspective, the following research questions are applied:

1. Research Networks and Knowledge
The description of the knowledge-based economy and society demands that a focus and clarification are being put on knowledge. What is knowledge? We approach knowledge by discussing R&D (research and experimental development), S&T (science and technology), and innovation and how they possibly relate. More specifically, we present three theories or concepts of knowledge: Mode 1 and Mode 2, triple helix, and the technology life cycles. What these three concepts have in common, is that they agree in qualifying university/business research networks as essential.
2. Knowledge Production Trends

Our empirical analysis focuses on knowledge production trends in the United States, the European Union (EU, EU 15), and Japan. More specifically, we ask: What are the strengths and weaknesses of the different national (supranational) innovation systems? First, we look at the funding intensity of national, university and business R&D. Second, we assess the intensity and efficiency of scientific publications. Third, the intensity and efficiency of the “triadic” patent families are compared. Fourth, we evaluate the amount of cross-sectoral financing of university research by other sectors. The United States, the EU, and Japan represent knowledge-intensive societies and economies. At the same time, they also define and represent important clusters for the world system. The future evolution of knowledge partly manifests itself in the contemporary knowledge production trends of such advanced world regions.

In the conclusion, we reassess our framework of analysis. We discuss and summarize the presented theories of knowledge production, which consequently emphasize the importance of university/business research networks; and we demonstrate how the conceptual implications of these theories were translated into our empirical analysis design of knowledge production trends. Finally, we comment shortly on possible strengths and weaknesses of the R&D–based national innovation systems of the United States, the EU, and Japan. Using a metaphor, perhaps the knowledge systems of the United States, the EU, and Japan coevolve through mutual interaction, partly based on competition, partly applying cooperation: this approach, however, also offers an opportunity of mutual learning for the different systems.

WHAT IS KNOWLEDGE? R&D, S&T AND INNOVATION AS KNOWLEDGE CONCEPTS

A widespread consensus emphasizes that the advanced economies and, when the economy is understood as a subsystem of society, the advanced societies are knowledge-based. Empirically the advanced economies coincide to a large extent with the OECD (Organization of Economic Co-Operation and Development) countries; however, also some non-OECD countries ought to be regarded as knowledge-intensive, for example, Israel, Singapore, and Taiwan (Chinese Taipei).

What is the purpose of knowledge, and how does it behave? Conventionally, knowledge is closely associated with economic activities. Knowledge is necessary and used for high-quality and efficiently (effectively) produced and delivered products and services. One standard argument asserts that when advanced economies want to increase their wealth as well as sustain their competitiveness, they increasingly depend on knowledge. This argument implies recognizing knowledge as a crucial factor for competitive wealth creation (see, for example, IMD, 1996, p. 12, 2002). Knowledge, however, is not limited to economic purposes. Ramifications of knowledge extend, for example, even to politics or the political system: It is rational to argue that better-informed citizens are better
equipped for making sufficient voting decisions. Furthermore, knowledge also plays an important role in education and culture.

What is knowledge, and how can it be defined? Crucial for knowledge are R&D (research and experimental development) and S&T (science and technology). R&D and S&T produce or create knowledge (using here knowledge production and knowledge creation as synonymous terms). Depending on the purpose, R&D and S&T can be conceptualized either (1) as dimensions or axes of knowledge or (2) as systems (subsystems) of advanced societies. The “dimensional” understanding emphasizes method aspects of measurability, whereas the “systemic” design aims at revealing the dynamics of advanced and knowledge-based economies.

The OECD developed, implemented, and regularly improves specific indicators that measure R&D and thus allow a detailed and complex analysis of R&D (OECD, 1994). R&D can be broken down into the following components: research, on the one hand, and experimental development, on the other hand. Research again consists of basic research and applied research. In addition, the OECD distinguishes the following sectors: higher education (universities); government and private nonprofit institutions (which together may be interpreted as “university-related”; Campbell and Felderer, 1998, pp. 2–3); and the business enterprise sector (the economy). Each of those sectors finances as well as performs R&D. Performance indicates the location, that is, where R&D is carried out. The government sector typically funds more R&D than it performs, since significant portions of public R&D flow into the higher-education sector and the economy. Sectoral cross-financing serves as a crucial indication and evidence of transsectoral research cooperation. R&D performed in the higher-education sector is classified as university research, and R&D performed by the business enterprise sector, as business R&D (often also called industry R&D).2

Based on R&D, the S&T can be modeled. Basic university research clearly classifies as science, and the experimental development of business R&D classifies as technology. Applied research may branch into science as well as into technology. Certainly there are boundary difficulties. Some university activities focus directly on technology, and some elements of business R&D even are devoted to basic research (Campbell, 2001, p. 429). This implies that science focuses on basic university research, but the fringes even extend into other sectors. The same applies to technology, which concentrates on business R&D. However, technology is also not being exclusively performed by the economy.

When the S&T system is conceptually modeled upon the R&D system, then the question arises: How do R&D and S&T relate to each other? R&D could be conceptualized as a core nucleus or an underlying structure of S&T. Since the OECD established a decade-long tradition of improving the measurement of R&D, the R&D terminology represents an internationally standardized conceptual language. R&D indicators offer a common frame of reference for scholars and policymakers. Recalling the systems approach, this refers to different possibilities: (1) The R&D system is “smaller” and defines a subsystem (subunit) of
the “larger” S&T system; (2) R&D and S&T systems express similar extensions, however, drawing the boundaries between categories slightly differently; and (3) alternatively, modeling R&D as “larger” than the S&T system might also be conceptually consistent. However, the preferred approach in the analysis presented here is to understand the (“smaller”) R&D system as being embedded in the (“broader”) S&T system. This proposition is empirically reinforced by the fact that information and communication technology (ICT) expenditure always ranks considerably higher than R&D expenditure, when expressed as a percentage of GDP, the gross domestic product (World Bank, 2002; OECD, 2003b, Table 2).

The innovation system, again, is broader than R&D and S&T. The innovation system may be classified as “R&D plus,” implying that R&D is necessary, but not sufficient, for innovation (Lundvall, 1992, p. 6). For Lundvall (1992, p. 2) the innovation system focuses on the “production,” “diffusion,” and “use” of knowledge that is “economically useful.” Similarly, Kuhlmann (2001, p. 954) emphasizes that “public innovation policy” intends to enhance the competitiveness of an economy. Kuhlmann also stresses a comprehensive understanding of innovation policies that stretches into science, research, education, technology, and industry. Speaking of a national system of innovation (NSI) represents standard terminology. Borrowing a concept from research about the European Union, one could claim that multilevel systems of innovation always operate, understood geographically, this claim underscores a complex and interactive architecture of global (and supranational), national, and subnational (local) innovation systems (see also Kaiser and Prange, 2004, pp. 395, 405–406). We speak of an integration of R&D into S&T, understood functionally, again embedded in the context of the innovation system.

Already the early Lundvall is very explicit about acknowledging that the national innovation systems are not exclusive, but that differently aggregated innovation systems always exist, and that the national innovation systems become increasingly pressured and challenged by globalization and regionalization (“localization”). On the other hand, it is still useful to refer to national innovation systems, particularly for the analysis of public policy (Lundvall, 1992, pp. 1, 3–5; see also Lundvall et al., 2002; Lundvall and Tomlinson, 2002; see, furthermore, Carayannis and Gonzalez, 2003; Carayannis et al., 2003).

Within the context of a national innovation system, typically, for the OECD countries, the following division of R&D labor exists: Most of basic research is performed by the universities and most of the applied research and experimental development by the business enterprise sector. University research represents primarily basic research, and business R&D primarily nonbasic research (National Science Board, 2002, Vol. 1, pp. 4–29, Vol. 2, pp. A4–7 to A4–34; OECD, 2003a, Table 3). Basic university research is mostly publicly funded, business R&D primarily privately (OECD, 2003a, Table 1, 2003b, Tables 35, 36). Conventionally understood, basic university research often initiates a new generic or major technology life cycle that transforms basic university research into applied business R&D, converting the original ideas to commercialization, that

The following propositions we want to suggest:

1. **Possible definition of characteristics of basic university research**: University research may be defined as a research activity (research type) with the potential of initiating a long-term technology life cycle that again promises a potential for high revenues and/or profit after the new technology is brought closer to application and commercialization.

2. **The supplementary relationship of university research and business R&D**: Basic university research and business R&D ideally supplement each other. Universities provide the basic research, and the economy provides the capabilities of applied R&D and commercialization, which translate basic research into market products and services.

3. **Network-based linkages of universities and business**: Networking between universities and business, therefore, defines a crucial interaction for modern innovation systems. Knowledge-based economies depend on the effectiveness of such university/business research networks.

4. **Approaches for measuring the capability of a national innovation system**: The following research design would allow assessing university/business networks empirically; measuring the competences and performance of university research and business R&D, and then measuring the interaction between the university and business sectors (for example, by documenting the cross-sectoral funding flows between universities and business).

---

**KNOWLEDGE CONCEPTS: MODE 1 AND MODE 2, TRIPLE HELIX, AND TECHNOLOGY LIFE CYCLES**

In the following sections we review important concepts (theories) of knowledge that should support a better understanding of the empirical knowledge production trends in the United States, the EU, and Japan that are discussed later.

**The Knowledge Concept of Mode 1 and Mode 2**

In a book published in the early 1990s, a team of scientists, organized around Michael Gibbons, attempted to analyze new principles of knowledge creation. Their starting point is the traditional form of basic university research, the knowledge production in a university setting, captured by the authors with the notion of Mode 1. Mode 1, therefore, expresses an interest in the search for “first/basic principles” and in “discoveries” generated within a university-based disciplinary matrix, and governed by established academic communities with strong hierarchies. That homogeneity of interest is underscored by a common definition of success as excellence controlled by peers organized by discipline. The quality of research defines the primary criterion (Gibbons et al., 1994, pp. 1, 3, 8, 24, 33–34, 43–44, 167).
The new mode of knowledge production, Mode 2, can be characterized by the following principles: (1) knowledge produced in the context of application; (2) transdisciplinarity; (3) heterogeneity and organizational diversity; (4) social accountability and reflexivity; and (5) quality control (Gibbons et al., 1994, pp. 3–8, 167). Mode 2 developed out of Mode 1, and Mode 2 supplements Mode 1 (Gibbons et al., 1994, pp. 14, 17). While Mode 1 represents traditional university research, Mode 2 focuses on the mutual integration of university research and business R&D (thus Mode 2 also penetrates university research). The whole R&D spectrum of basic research, applied research, and experimental development is being repositioned and reframed into an application context. Discovery, on the one hand, and the application and fabrication of knowledge increasingly overlap (also experimentation and simulation). Application feeds back and supports the further development of theories. And applications are important for continuous innovation. In Mode 2 the concept of quality is broadened by incorporating additional aspects, for example, market competitiveness, cost effectiveness and social acceptance. Mode 2 focuses on problem solving. Success in Mode 2 may be defined as the efficiency or usefulness of knowledge for transdisciplinary problems and transdisciplinary problem solving. Knowledge exploitation often demands participation already in the process of knowledge production. Often heterogeneous groups of knowledge producers and knowledge users are tied together in network-style cooperation. Communication, communication intensity, and continuous renegotiation between the different groups are essential. A successful achievement of a problem solution might imply that the specific heterogeneous research networks dissolve; however, the communication patterns often prevail, enabling new combinations and recombinations of research networks. The heterogeneity of knowledge production implies that the processes of knowledge production are being carried farther into society. Knowledge production becomes more socially distributed, and the values and norms of a society reinfluence knowledge production. Communications between knowledge (science) and society mutually influence each other, with a tendency for the increasing complexity of society to correlate with an increasing complexity of the sciences (Gibbons et al., 1994, pp. 3, 4, 6–8, 11–14, 19, 29, 33–34, 38, 42, 44–45, 168). In contrast to “homogeneous growth”—an increase of output—the heterogeneous growth results from a recombination and rearrangement of networks that link different knowledge producers (Gibbons et al., 1994, p. 34). Since the supply of a problem-solving expertise in an application context often demands a specific setup of research teams, reconfigurations of networks can add a value per se for the problem-solving capabilities of a knowledge-production process.

The distinction between “codified knowledge” and tacit knowledge again marks an important argument of the authors. Codified knowledge represents knowledge that is, at least one way or the other, written down and stored. Codified knowledge, therefore, easily can transcend national borders and diffuse globally; it is mobile and migratory. Tacit knowledge, on the contrary, is
embedded in the heads of those engaged in working and is learned through experience. Organizations (institutions) can acquire tacit knowledge through hiring personnel. Technology consists of codified and tacit components. The importance of tacit knowledge for Mode 2 implies that the values (value systems) of academia (universities) and business (firms) become more similar, overlapping partially. This overlapping also enables and fosters so-called hybrid communities (Gibbons et al., 1994, 24–26, 37, 167–168).

The Knowledge Concept of Triple Helix

The triple helix model is based on three helices: state, academia, and industry (Etzkowitz and Leydesdorff, 2000, p. 111). Related to the sectoral classification of the OECD, the state coincides with the government sector, academia with the higher-education sector, and industry with the business enterprise sector. Etzkowitz and Leydesdorff (2000, pp. 111–112) propose different possible interactions between the helices: In the “strong state” model government controls academia and industry, in the “laissez-faire” model each of the three helices develops quite independently, separated by clear borderlines; finally, in the model of “trilateral networks and hybrid organizations,” the dynamics of the helices can be characterized by increased overlapping and the emergence of so-called hybrid organizations at the interfaces. This pattern of amplified interaction defines the preferred scenario for the development of the advanced and knowledge-based economies. In fact, it even defines (should define) the primary reference for the global evolution of societies.

Communication is important for R&D interaction within and between the helices. Communication helps in establishing complex networks, feeds into these, and partially also recodes networks. On the one hand, interaction across different helices is not necessarily stable, implying that an a priori synchronization of processes is not possible in a triple helix understanding. Through mutual co-evolution of the helices and adaptations in the university-industry-government arrangements, a certain degree of stable development, however, can be achieved. This even may lead to the formation of a globalized regime. General propositions of the triple helix are that (1) government-industry arrangements can cross-cut specific industrial sectors and link regional, national, and international clusters; (2) the “expectation of profit” is important for driving networking; (3) the modeling of innovation in a society may run through different stages; (4) the human capital factor gains in importance; (5) tensions resulting from the impossibility of a perfect a priori synchronization of interaction between the helices are not necessarily seen as negative, since they accelerate the dynamics of the whole system; (6) conventionally, the communication patterns within a helix (the specific context of academia, industry, or the state) express a higher degree of density than between helices, following the maturing of an advanced knowledge-based society, also an increase of communication is expected that cross-cuts and connects the different helices (Etzkowitz and Leydesdorff, 2000, pp. 112–114, 118–119).
Universities play a pivotal role in the triple helix model. Here even a second academic revolution and a third mission for universities are suggested. The combination of research and teaching still gives the academic universities a competitive advantage over the corporate universities. In addition, university-based scientific research increasingly develops the capabilities of directly initiating new lines of economic development. Regional (local) innovation clusters feed into the overall performance of a national innovation system. Also within the context of regional clusters the triple helix logic of university-industry-government relations operates. The attractiveness and potential of regional markets depends on the local availability of regional universities, fostering the regional business performance (Etzkowitz and Leydesdorff, 2000, pp. 109–110, 117–118). Different academic research groups develop as “quasi firms” and help proliferate a new type of university: the entrepreneurial university (Etzkowitz, 2003).

The Knowledge Concept of Technology Life Cycles

The literature normally distinguishes between three different types of technology life cycles (Tassey, 2001, pp. 39–40): (1) The product life cycle focuses on the whole life span of a product, ranging from its early initiation into market implementation and finally its replacement by a follow-up product. (2) Different products and product life cycles often are based on a common underlying technology, which defines then a generic technology life cycle. (3) The appearance of a new science, finally, can launch a new major technology life cycle or wave. From these propositions it follows that the major technology life cycle represents the most aggregated phenomenon, and the product life cycles, accordingly, represent the most disaggregated. Empirically, a high degree of heterogeneity results from the circumstance that a multitude of technology life cycles always overlap, again at different levels of aggregation. The transition from one generic life cycle to the next life cycle generation marks a crucial and risk-intensive period for both individual business enterprises and national innovation systems, where shifts of competitiveness may occur (Tassey, 2001, pp. 40, 54–55).

According to Tassey (2001, pp. 37, 42, 55), a certain conceptual consensus was established about S, the “science” part in the S&T matrix: Basic university research is mostly publicly funded and thus represents by tendency a public good. The case with the T is more complicated: Technology represents a mixed good, consisting of private and public elements. The closer a generic or major technology life cycle—sometimes also paraphrased as R&D life cycle—moves to market application and commercialization (the disaggregated individual product life cycles), the more effective the conventional and private market forces that come into play. Crucial, therefore, is the conversion from basic university research to applied business R&D. Here, Tassey (2001, pp. 41–42, 47–48, 55, 58, 61) claims a significant risk increase for business. In that sensitive transition period, classified as the generic technology research phase, first the companies must be convinced of the future market and commercialization potential of the
new technology, and only then will substantial private investment follow. Specific reasons for the reluctance of firms to invest in early generic technology research are competition pressures that absorb many of the company’s activities; a certain noncompatibility of long-term and conventional R&D; the intrinsic technological and market risks of new technologies; and limitations of the firm’s capabilities in exploiting all of the commercial ramifications of a technology (Tassey, 2001, pp. 64–65). In general, firms are confronted with the following dilemma: Conventional (incremental) R&D accounts for most of the revenues, whereas radically new and high-risk R&D generates the profits. Market forces, therefore, operate partially biased, creating market failures of “underinvestment” in (new) R&D. The cyclicity of technology life cycles implies the danger of repeating specific market failure patterns. Infratechnologies support university/business interfaces: Companies, on the other hand, are even more hesitant to finance the infrastructure infratechnologies, because of the easy spillover of benefits to business competitors or society in general (Tassey, 2001, pp. 47, 50–52, 59–60).

There are several examples of early American technological innovations that, finally, were more successfully commercialized by non-American companies. Often the American-made innovation shifted in favor of the marketing capabilities of Japanese companies (Tassey, 2001, pp. 56–57). This should be interpreted as a need for optimizing the university/business interface of the United States innovation system. Public policy can respond by addressing specifically the market failure and the private underinvestment, connected to market failure. Depending on the concrete phase of the generic technology life cycle, the matching logic of market failures and policies demands sensitive tailoring. Research networks and research consortia can link firms, universities, and government, combining the features of complementary R&D expertise, cost sharing, and risk pooling. Once the technology matures and moves closer to practical commercialization, the conventional funding mechanisms of the private market mostly are appropriate. Industry consortia, positioned even closer to commercialization and without university partners, express durations often shorter than industry/university consortia (Tassey, 2001, pp. 62, 63, 65–66; see also Tassey, 2003a, 2003b, 2004).

**KNOWLEDGE PRODUCTION TRENDS IN THE UNITED STATES, THE EU, AND JAPAN**

The United States, the European Union, and Japan represent world regions on which advanced knowledge production focuses. An evaluation of these countries allows empirical conclusions about the dynamics of advanced, knowledge-based economies and societies. In the following, our overview of empirical knowledge production trends refers primarily to R&D data, always comparing the United States with the EU and Japan (see OECD, 2002, 2003b; National Science Board, 2002). University/business research networks in S&T depend on the
competency, intensity and, efficiency of knowledge production of the universities and of business. The presented indicators, therefore, will aim at mapping science and technology activities comprehensively and comparatively.

Intensity of Gross Domestic Expenditure on R&D: The National R&D Quotas

Gross domestic expenditure on R&D (GERD) as a percentage of GDP represents one possibility of expressing research intensity. Here, Japan ranks first, the United States second, and the EU third (see Figure 5.1). Until 1988 the United States was leading; however, in 1989 it was outpaced by Japan. While the margin of difference between Japan and the United States is narrow, the gap with the EU already is wider. The general empirical picture does not indicate a substantial increase of research intensity since the late 1980s. During the first half of the 1990s the national R&D quotas even declined, and then they recovered in the second half of the 1990s—only to a level comparable to 1990. The early 1990s decline correlates with a slowdown of economic growth during that period (OECD, 2001). This does not conclude a direction of causation, whether the economic recession or the R&D decline come first or whether, alternatively, both processes behave coupled. Theoretically, the concepts of a knowledge-based economy and society would suggest a research intensity increase, since R&D represents a crucial type of knowledge. The neutral wave pattern of the national research quotas (Campbell, 2000, p. 131) somehow runs contrary to our expectations. Partly this may be explainable by the nature of that indicator itself. The R&D quota does not reflect changes in the GDP “wealth levels”. Should, for example, the GDP grow faster than R&D, then, methodically speaking, the R&D quota declines.

Intensity of Gross Domestic Expenditure on R&D: National R&D

Should we want to understand the dynamics of knowledge-based economies and societies more comprehensively, it appears necessary also to analyze the levels of R&D spending. For such measures in real terms of R&D, we apply specifically the following approach: gross domestic expenditure on R&D, calculated in $5 million in constant prices and purchasing power parities (PPP) of 1995, per a quarter million population (250,000) (compare OECD, 2002, Table 3, Table E, with Campbell, 2000, pp. 132–133). These real-term pattern data reveal important differences, when compared with the research quotas (as defined above). For the period 1983–2000 a real-term growth can be stated for the United States, Japan, and the EU. The United States always ranks first, followed by Japan. In the mid-1990s the gap between the United States and Japan narrowed, since then, however, it has again increased in favor of the United States. The EU achieved only modest growth rates and clearly ranks only third. In 2000, the R&D funding level of the EU was even less than half the level of the United
States. This discrepancy should be taken seriously by the EU’s decision makers. The national R&D funding levels of the United States and of Japan, on the other hand, express a competitive intensity (see Figure 5.2). Put in a short summary, the real-term R&D funding levels behave in closer accordance with our theoretical expectations of knowledge-based economies and societies.

Source: Author’s own calculations based on OECD (2002).
Gross Domestic Expenditure on University and Business R&D: University and Business R&D

Real-term expenditure levels for R&D, disaggregated into university R&D (higher-education sector) and business R&D (business enterprise sector), allow a detailed sectoral analysis (see Figures 5.3 and 5.4).

1. University R&D
University research grew steadily during the whole 1983–2000 period. This steady, noncyclical expansion of university R&D expenditure could be interpreted as an element of stability for national innovation systems and as an indication of a steady supply of basic university research (Campbell, 2000, p. 135; 2001, p. 429). The United States always ranks first, Japan second, the EU third. However, the funding gaps appear to be narrow.

2. Business R&D
Business R&D also increases in real terms but fluctuates more. Since most of the national R&D expenditure is generated by business R&D, the cycles of business R&D correlate closely with the national R&D cycles. The United States ranks first, Japan second, and the EU third. The gap between the business R&D funding level of the United States and of the EU is substantial (almost threefold).

3. Comparative Assessment
Based on the intensity of university and business real-term R&D expenditure levels, the United States leads in university as well as business R&D. This could leverage important competitiveness advantages for the United States economy vis-à-vis Japan and the EU. Speaking in relative terms, the intensity of European university R&D expenditure approximates the levels of Japan and of the United States. The specific European problem is not so much an underfunding of university research as the underfunding of business R&D. Generating financial resources for business R&D should define a focus area of public policy in the EU. The Japanese profile demonstrates similarities with the United States. The fact that Japan’s basic university R&D expenditure level ranks only third behind the EU (Campbell, 2001, p. 429; OECD, 2003a, Table 3) could indicate that the Japanese innovation system perhaps one-sidedly emphasizes the funding intensity of business R&D. Europe’s competitive funding of universities and Japan’s focus on business are challenged by the financial win-win situation of the United States.

Intensity and Efficiency of Scientific Publications (SCI and SSCI)
Bibliometric indicators refer to scientific publications, most prominently to article publications. Articles, published in refereed journals are being regarded as a high-quality output of university R&D. Since university R&D is primarily basic
Source: Author's own calculations based on OECD (2002).
Source: Author’s own calculations based on OECD (2002).
research, bibliometrics allows the measurement of basic research (Campbell and Felderer, 1997, pp. 7–19). Conventionally, journals covered by the SCI (Science Citation Index) and SSCI (Social Sciences Citation Index) are being regarded as leading journals. SCI and SSCI represent two databases, compiled and maintained by ISI (Institute for Scientific Information). Not all scientific articles are institutionally university-based; however, a majority of the scientific articles indicates an output of university research (Narin et al., 1997, p. 325). In 1999, for example, 73.5 percent of the U.S. articles were academic and institutionally authored at universities (National Science Board, 2002, p. A5-99). The intensity of scientific publications may be expressed by referring the number of SCI and SSCI articles to population (250,000) (National Science Board, 2002, pp. A5-82 to A5-86). If this is done for the years 1987–1999, then the United States always ranks first, the EU always second, and Japan third. While the EU and Japan achieved a steady increase of article publication intensity (Japan, despite ranking third, even increased faster than the EU), the United States experienced an intensity decrease after 1989. This implies that the academic intensity gap between all three competitors is becoming smaller and suggests converging levels of publication intensity (see Figure 5.5).

The efficiency of university research can be modeled by referring scientific publications, which qualify primarily as an academic output, to the input of resources for academic research. Specifically, we decided to take again the article publications in SCI- and SSCI-covered journals as output measure. As input measure we refer to university R&D expenditure, calculated in $5 million in constant prices and purchasing power parities of 1995. The general pattern of that efficiency model seems to claim a decrease of efficiency for the period 1987–1999 (see Figure 5.6). This, however, could be a misleading interpretation. Should the financial volume of university R&D expand faster than the number of journals covered or newly admitted to SCI and SSCI, then the consequence would be a model-induced efficiency decrease. To maintain high-quality standards and to support the interest of only admitting avant-garde journals, there may operate gatekeeper and other restrictive threshold effects, implying a likeness that the market of journals, not covered by SCI and SSCI, grows faster than the population of the SCI- and SSCI-included journals. Therefore, for our applied efficiency model the methodological conclusion appears to be: not so much the importance of objective efficiency values as the relative ranking and placing of one university research system vis-à-vis the others. That means, for example, that we must question whether the U.S. university research system is more or less efficient than the academia of the main competitors? During the period 1987–1996 the American universities expressed an efficiency lead against the EU (ranking second) and Japan (ranking third). However, the efficiency gap between the United States and the EU constantly narrowed down, and in 1997 the EU started to outpace the United States. In 1998 and 1999 this new efficiency lead of the EU even expanded further in favor of the EU and to the disadvantage of the United States.
Based on such bibliometric indicators, several hypotheses can be offered for discussion.

1. **Publication Intensity in the Sciences**

The United States still leads, but the lead margin decreases against the EU and Japan. Projected linearly, this could imply that the EU (EU 15) publication intensity may outpace the United States before 2010.
2. Publication Efficiency in the Sciences

The EU has already overtaken the United States. Certainly, the number of (article) publications represents not the only available measure for university output. Other important bibliometric indicators are the frequency patterns of "citations" of articles (National Science Board, 2002, pp. A5–120 to A5–123) and the impact factors, which define the citation frequency of journals. Furthermore, one may emphasize that universities should also engage in other research output activities, for instance, developing and performing patenting
strategies. Still, the publication efficiency lead of the EU should not be ignored by American decision makers and policymakers.

3. United States versus EU

University R&D defines an area where the EU displays, in international comparison, a good performance, based on quality and efficiency criteria. The EU university system approaches levels of competitiveness similar to those of the United States. Thus, for the near future we expect that the American university system will become more seriously challenged by Europe. Referring to university/business interfaces in the context of globalization, American firms may increasingly be inclined to link and network also with European universities. A dilemma for the European national (supranational) innovation systems could be that European firms do not leverage the European university expertise effectively enough. Developing the university/business interfaces more purposefully should define a primary target area for European innovation policy (and helps to understand and to explain the enduring diffusion of the ideas of Mode 2 in Europe).

4. Japan

Japan improved the intensity and efficiency of its academic publications. However, Japan continuously ranks only third, behind the United States and the EU (even though Japan has a higher university R&D expenditure intensity than the EU). For the purpose of accessing high-quality university expertise and basic research knowledge, Japanese firms, in some cases, might be forced to collaborate with American and European universities (see, for example, Zedtwitz and Gassmann, 2002, p. 583). This also leads to the following question: Do, in the case of Japan, Japanese firms perform some R&D activities, which in the United States and the EU conventionally would be placed in a university context? That is, does Japan’s business R&D compensate for some of the domestic university R&D weaknesses?

Intensity and Efficiency of “Triadic” Patent Families

Conventionally, patents are qualified primarily as research output indicators of business R&D. Certainly, also academic institutions file patent applications. In parallel to their publication strategies, universities are interested in extending their research output portfolio by adding patents (National Science Board, 2002, pp. A5–120 to A5–123). Despite such new moves of the universities, the majority of patents still are generated by commercially oriented firms (Hall et al., 2001, pp. 11–12, Figure 3). In 1998, for example, of the U.S. patents no less than 80,291 had a U.S. origin; of these, only 3,151 patents were awarded to U.S. academic institutions (National Science Board, 2002, pp. A5–134, A6–56). “Triadic” patent families refer to patents that are granted by the U.S. Patent and
Trademark Office (USPTO), and, in addition, are filed at the European Patent Office (EPO) and the Japanese Patent Office (JPO) (OECD, 2003b, p. 69). “Triadic” patent families, therefore, reflect patent trends of the United States, the EU, and Japan more systematically. If, based on these triadic patent families, the patent intensity is calculated as the number of patents per a population of 250,000; then Japan clearly ranks first. Already significantly lower, the United States ranks second, and the EU only third (see Figure 5.7). While, during the period 1987–1998, the Japanese patent intensity stagnated and the EU’s patent intensity increased only modestly, the American innovation system achieved a growth increase of its patent intensity.

Patent efficiency, for example, can be modeled by referring the number of patents to $5 million (in constant prices and purchasing power parities of 1995) of business R&D expenditure. The ranking sequence of patent efficiency differs from the ranking of the patent intensity. Japan still places first, but the EU second, and the United States only third (see Figure 5.8). Patent efficiency suggests a competitive contest between Japan and Europe. While Japan’s efficiency performance actually decreased during the period 1987–1998, the EU, after a short drop around 1991, improved its patenting efficiency performance in the second half of the 1990s. In 1997 and 1998, the EU’s patent efficiency approached already closely the Japanese efficiency level. American patent efficiency, on the other hand, stayed quite constant. Recalling that the intensity level of the EU’s business R&D expenditure clearly lags behind that of the United States and Japan, this dramatic efficiency increase of the EU patents is surprising (compare again Figures 5.4 and 5.8).

Put in summary, and based on the presented “triadic” patent family indicators, several conclusions can be proposed.

1. The Role of Patents for a National Innovation System

There is a consensus that patents should be regarded as important for economic activities. Patterns and trends of patents are well documented (see Hall et al., 2001). “Patent-to-science” or “patent-to-paper” citations (Narin et al., 1997, pp. 318, 322, 328), for example, supply additional information about university/business interfaces in knowledge-based economies. On the other hand, we still lack systematic information about the commercial revenues or profits generated by patents. Case studies are available, but not necessarily representative. There is a crucial need for a comprehensive mapping of the patent-based revenues in the context of national innovation systems.

2. The Lead of Japan

Japan ranks first with regard to the intensity and efficiency of triadic patent families. While the United States increased its patent intensity during the last years, the margin in favor of Japan still is considerable. Japan’s patent efficiency, however, is heavily contested. First, Japan’s patent efficiency is decreasing. Second, the EU approaches a similar level of patent efficiency.
3. The United States and the EU

The United States managed to increase its patent intensity, and the EU its patent efficiency. The comparatively lower funding levels of business R&D represent a...
crucial problem for the EU, indicating an underinvestment in business R&D. In the case of the United States, business R&D already is funded substantially. A crucial challenge for the American innovation system, therefore, could be seen in improving patent efficiency. If the American patent efficiency would be similar to that of Japan, then the United States patent intensity would equal Japan’s.

The concepts of Mode 1 and Mode 2, triple helix, and technology life cycles clearly emphasize that for a knowledge-based economy and for advanced national innovation systems the university/business research networks are of crucial importance. There exist several possibilities of measuring university/business interaction in R&D and S&T. One approach maps the amount of cross-sectoral financing of R&D, since a “transsectoral” flow of financial resources mostly indicates research collaboration. Methodically, cross-sectoral financing implies that one sector also finances the R&D of other sectors. The OECD distinguishes four sectors: higher education (universities); government; private nonprofit (PNP); and business enterprise (economy). To assess university/business R&D linkages, it is therefore appropriate to look at the amount of university R&D that is funded by business and the private nonprofit sector. This qualifies as “private cross-sectoral financing” of university R&D.

The empirical analysis for the years 1987–2000 allows a discussion of the following trends for the United States, the EU, and Japan (see Figure 5.9).

1. General Trend

The percentage amount of university R&D, externally cross-financed by business and the private nonprofit sector, continuously increased from the mid-1980s. The EU experienced the greatest increase, followed by the United States. In Japan, however, that percentage share expanded only modestly.

2. Ranking

The United States ranks first, the EU second, and, already considerably lower, Japan third. The United States still benefits from a margin lead against the EU; however, that margin became smaller during the late 1990s.

3. University/Business Research Networking in S&T

The cross-sectoral funding data suggest that research-based linkages and networks between universities and firms indeed increased empirically. This reinforces our conceptual assumptions about the importance of university/business interfaces. Furthermore, in contemporary Europe the university/business gap, between academia and firms, may not be as large anymore as is often conventionally believed. Europe’s private funding is almost competitive with the United States. This receptiveness of universities to private funds also defines opportunities for globalizing firms, interested in accessing American and European universities more systematically.

4. Japan

Cross-sectoral funding indicators suggest that, relatively speaking, the domestic Japanese university base still is not optimally coupled with the Japanese
Implications might be that Japan’s economy is forced to develop its strategies and profile of competitiveness in favor of industries, which are not that science-dependent; Japanese firms partially perform R&D activities, traditionally covered by university research in other advanced countries; for the purpose of accessing high-quality university knowledge, Japanese firms may be inclined to link with universities outside Japan (Zedtwitz and Gassmann, 2002, p. 583).
There appears to be a need for improving the quality and performance of Japanese university R&D. Thus Japan might define an environment, suitable for the ideas and concepts of Mode 1 and Mode 2 that focus on an effective coupling of university and business knowledge production.

**CONCLUSION: DISCUSSION OF KNOWLEDGE CONCEPTS AND THEIR IMPLICATIONS FOR UNIVERSITY/BUSINESS RESEARCH NETWORKS**

How do different modes of knowledge production relate to each other? The theory of Modes 1 and 2 makes the following distinction: Mode 1 represents the traditional core activity of universities; Mode 2, on the other hand, stretches far out into society but also penetrates the “periphery” of university research. Mode 2 does not replace Mode 1; Mode 2 supplements Mode 1, and there operates a pattern of coevolution between Mode 2 and Mode 1 (Gibbons et al., 1994, pp. 14–15, 17). Analytically interpreted, the purposes of Mode 2 are (1) serving as a bridge and linkage between scientific basic research at universities and the general interest of economy and society in knowledge-based problem solving; (2) principles that both emphasize the importance of university/business networks in R&D or S&T and practically support the establishment of an effective university/business networking; (3) finally, feedback to the university and even influence on and changes in how basic university research (Mode 1) is being performed and organized. In a follow-up publication, Nowotny, Scott, and Gibbons (2001, pp. 245, 248–249) discuss whether Mode-2 science is becoming embedded in a Mode-2 society, implying a coevolution of Mode-2 science and Mode-2 society.

Mode 2 has already impacted and influenced other fields, such as the management sciences (see Hatchuel, 2001; Hodgkinson et al., 2001; Huff and Huff, 2001; Pettigrew, 2001; Starkey and Madan, 2001; Weick, 2001) and the development of alternative knowledge concepts: Science One and Science Two, a knowledge approach engineered by Umpleby (2002), reveals interesting features for a systematic comparison of Science One/Two and Mode 1/2. With regard to Mode 1/2, and also triple helix, one certainly could discuss whether these knowledge concepts primarily reflect empirical trends or whether they also emphasize a normative component by placing an interest in how research should be carried out?

Some key propositions and implications of the knowledge concepts of Mode 1/Mode 2, triple helix, and technology life cycles therefore are:

1. **Mode 1/Mode 2 and the University/Business Interface**
   Mode 2 focuses, conceptually, on the university/business linkage. This, partially, may explain the success and proliferation of the concepts of Mode 1 and Mode 2 in Europe. European university research in the sciences expressed, historically, a high quality (when, for example, Nobel Prizes are taken as an indication; see
Nelson and Wright, 1992, p. 1941). However, sometimes a linkage gap is claimed in Europe between university research and business R&D, constraining the effective coupling of university research and business R&D, and constraining the establishment of university/business S&T networks.

2. **Triple Helix and the University/Business Interface**

The triple helix model focuses conceptually on the state, academia, and industry, paraphrased as helices, and on their interaction. In systems theory notions, the state may be reconceptualized as the political system and industry as the economic system. In academia, several systems cross-cut: the university system, the science system, the R&D system, and the educational system. Interaction between the helices often is nonlinear, dynamic, and unstable. One advantage of the triple helix appears to be that interaction tensions are not being interpreted per se as negatively; thus tensions can drive dynamics. Communication and communication-based negotiations within each helix and between the helices are crucial for fostering a coevolution of the state, academia, and industry. The triple helix model design offers a useful framework of orientation for policy and policymaking. The practicability of the triple helix might explain why, in the United States, the triple helix is better known and more frequently referred to than Mode 1 and Mode 2. Also in triple helix understanding—and this marks a similarity with Mode 1 and Mode 2—the universities play an important role in knowledge production and innovation: A claimed “third mission” or “second academic revolution” for universities emphasizes the importance of universities in economic development, which increasingly depends on input from university research (Etzkowitz and Leydesdorff, 2000, pp. 109–110, 117–118). In that context, Etzkowitz (2003, p. 110) uses his term of the “entrepreneurial university”.

3. **Technology Life Cycles and the University/Business Interface**

The concept of technology life cycles, when compared to Mode 1/Mode 2 and the triple helix, is closest to practical application. It reflects, on the one hand, the flow of knowledge, its transformation from science to technology and market commercialization, and, on the other, points toward the challenges and specific problems that arise when basic university research should be translated into business activities. Technology life cycles reflect the different phases of business R&D and indicate where and how public policy can intervene. Also for the technology life cycle, the university/business interface is crucial. The effective coupling of universities and business offers opportunities for increased efficiency, and for shortening the duration of the whole cycle, until the full market maturity of knowledge (technology) has been achieved. The shortening of a technology life cycle leverages advantages of competitiveness for individual firms and also for national innovation systems. In practical terms, the measuring of a technology life cycle can be difficult. As in the nonlinear, sometimes chaotic, interaction of the helices in the triple helix model, the empirical display of technology life cycles may also become complex. Simultaneously, there always
operate several technology life cycles, partially overlapping and at different levels of aggregation, and a social situation with no agreement among practitioners about where the borders between the different technology life cycles are exactly.

4. Codified/Explicit and Tacit Knowledge

In the literature there is no consensus whether codified (explicit) or tacit knowledge is more important for the process of knowledge production. Nelson and Wright (1992, p. 1958), for example, claim that technology increasingly becomes like science. The author team around Gibbons et al. (1994, pp. 24–25), on the contrary, prefers to emphasize the importance of tacit knowledge for technology and business R&D. Codified knowledge, through intellectual property rights and patents (Coriat and Orsi, 2002; see also Carayannis and Juneau, 2003), creates competitive advantages for firms. On the other hand, a spillover of codified knowledge to competitors cannot always be prevented, and codified knowledge may lose its value for the inventing firm when copied or imitated. Contrarily, the interest in accessing tacit knowledge often implies a need for hiring personnel (Gibbons et al., 1994, p. 26). Speaking of a coevolution of codified and tacit knowledge, therefore, appears to be more appropriate. This distinction between codified and tacit knowledge refers to a whole set of interesting questions. Is, for example, “noncodified knowledge” identical with “tacit knowledge,” or does tacit knowledge only represent a subgroup of noncodified knowledge? Furthermore, is it possible, at least partially, to “codify tacit knowledge,” and if so, to what extent? What are the limits of converting tacit to codified knowledge?

5. Globalization of R&D and of Codified and Tacit Knowledge

Firms globalize their R&D activities so that they can access abroad a high-quality science base and/or a mature lead market. Firms are challenged by effectively managing the globalization innovation, creating also a demand for “technology-based globalization indicators” (Rycroft, 2003). The incentives and pressures for firms, home-based in small or medium-sized markets, to internationalize are even greater than for firms already located in larger markets (Gerybadze and Reger, 1999, pp. 264–271). Firms that concentrate their R&D–conducting units in their domestic home base rely on a “national treasure R&D” strategy. Locating development (D) units abroad, for the purpose of accessing “customers and standards,” represents a market-driven R&D strategy; placing research (R) units abroad, out of an interest in linking to local science qualifies as technology-driven R&D. Combining the international market drive with the international S&T drive finally results in a global R&D strategy program for corporations (Zedtwitz and Gassmann, 2002, pp. 580–581). Based on a literature review and on empirical findings, Zedtwitz and Gassmann (2002, pp. 570, 573, 582–583) claim that historically the American and Japanese corporations were more oriented toward the domestic national R&D market, whereas European firms very early emphasized the international market-driven model of R&D. Recently, however,
American and Japanese firms are also pushing forward with a globalization of their R&D. American firms express a globalization tendency in favor of the market drive, and Japanese firms focus on the S&T drive. Speaking generally, university/business research networks in S&T are not necessarily limited and tied to a national innovation system. Firms can try to link with a foreign university base, to benefit from a possible quality lead of basic university research in other countries. Globalizing R&D also implies establishing references to codified and tacit knowledge on a global scale. Nelson and Wright (1992, pp. 1957–1958, 1961) underscore that the specific environments for the economies of different nation-states eventually converge, thus transforming the different nation-state–based markets into one global market. International business played (and plays) an important role in this process of global environmental convergence. Here the argument should be stressed that corporations also globalize so that they can access directly the local pools of tacit knowledge in different world regions.

6. The Importance of University/Business Interfaces and S&T Research Networks

Research networks are composed of different organizations or institutions, linked together for R&D and S&T. There exists a broad typology not only of possible research networks (S&T networks), but also of research networks with empirical experience. Research networks can refer to university-university, business-business, university-business, or university-business-public research cooperation and may occur in a local, national, or global context. The purpose of research networks is to foster synergy effects by pooling complementary knowledge (codified and tacit), leveraging and integrating different (financial) resources, supporting a sustainable flow of knowledge (R&D, S&T), and balancing risk. With that understanding the research networks that link universities with business represent a specific—and crucial—subcategory of research networks. Despite some conceptual differences, the models of Mode 1 and Mode 2, the triple helix, and technology life cycles commonly emphasize the particular importance of the university/business interface. This conceptual convergence underscores how university/business networks support business opportunities, open a window of opportunity for public policy intervention, and impact and reinforce the comprehensive competitiveness of a national innovation system.

The old linear model of innovation lined up, in a sequential first-then order: basic research, applied research, and experimental development (Narin et al., 1997, p. 318). The new model of innovation speaks more of a “paralleling” of basic research, applied research, and experimental development (Campbell, 2000, pp. 139–141; 2001, p. 432) either within the context of individual institutions/organizations—for example, a firm or larger corporation trying to operate simultaneously across more than one technology life cycle—or by connecting institutions/organizations across different sectors.

The triple helix model explicitly refers to Modes 1 and 2, by claiming that the triple helix emphasizes the level of social structure, while Mode 2 resembles
a historically emerging structure for the production of scientific knowledge (Etzkowitz and Leydesdorff, 2000, p. 118). If that idea is reframed, the following distinction could be made: Mode 2 focuses on the evolution of knowledge at the university/business and science/technology interface, embedded in a coevolution of Mode 2 and Mode 1. The triple helix appears to be more interested in patterns of interaction between academia, industry (business), and state (government). These patterns have structural, functional, and institutional (organizational) connotations. Another reference to Modes 1 and 2 is the following triple helix question (Etzkowitz and Leydesdorff, 2000, p. 116): Did the European science and research systems, before the establishment of autonomous universities, resemble something like a premodern version of a Mode 2 system? If this analogy (metaphor) is accepted, then the implementation of institutionally autonomous universities, with their science base and basic research structured according to a disciplinary logic (a disciplinary matrix), implied advantages during a particular phase of knowledge evolution of national innovation systems in Europe. However, a too-effective establishing of Mode 1 science could imply constraints on the newly emerging coevolution of Mode 1 and Mode 2. The historically more practical and application-oriented American universities, feeding into the emergence of a “professional hybrid” (Nelson and Wright, 1992, pp. 1942, 1944–1946, 1948–1949), perhaps were better equipped for the demands of Mode 2 and the needs of advanced, knowledge-based economies. Depending on the specific knowledge phase (or knowledge cycle), payoffs for competitiveness may differ.

The theories of Mode 1 and Mode 2, the triple helix, and technology life cycles all emphasize the importance of university/business linkages for research networks in science and technology. Empirically, this can be analyzed through different research designs, for example, by focusing on research networks and their interference with innovation and knowledge management (Vonortas, 1997, Vonortas and Tolnay, 2001; Rohn, 2000; Güttel and Dietrich, 2001). More specifically, one could also ask whether evaluation and evaluation policy of science and technology impact and support university/business and university/society linkages (Shapira and Kuhlmann, 2003; Campbell, 2003). Furthermore, different public policy fields may be covered for analytical purposes, for example, information technology (Grande, 2000). Alternatively, we can test if and how research networks are associated with technological learning (Carayannis and Alexander, 2002), the complexity challenge (Rycroft and Kash, 1999), and other cooperative partnership initiatives (Shapira, 2001).15

The presented empirical analysis of knowledge production trends in the United States, the European Union, and Japan applied the following rationale: evaluating the funding intensity and performance of university research and of business R&D. University research performance was represented by scientific publication data, and business performance by patent data. This is carried by the assumption that university/business (university/society) research networks, linking university science (basic research) with business technology (applied research and experimental development), are supported by the following factors:
(1) an adequate funding of university research and of business R&D (2) and a competitive performance of university research as well as of business R&D. If universities and business display in their knowledge domains a strong performance, then university/business research networks also promise a greater benefit potential for the whole knowledge-based economy and society. (3) Displaying the sectoral cross-financing of university research by private money, finally, offered a more direct measure for assessing the amount of university/business research networking.

The summary of the empirical knowledge production trends allows a discussion of the following hypotheses.

1. United States
The United States can be characterized by high levels of funding intensity of university research and business R&D. The R&D funding lead gives the United States certain leverage powers against its main competitors. The U.S. university research system performs effectively; however, it might gradually come under pressure by the EU. The U.S. patent efficiency is weaker. Increasing the U.S. R&D efficiency could become an important issue during the next years. That the United States spends comparatively more on defense R&D might explain the efficiency paradox partly (OECD, 2003b, Tables 2 and 5). This, however, would point toward the challenge of establishing intelligent and creative linkages between defense R&D and commercially oriented R&D.

2. European Union
The EU’s science or university research system marks potentially a competitive area for the European innovation system. On the whole, the EU’s (EU 15) scientific publication efficiency even outpaced the American publication efficiency recently. Problematic for the EU is the underfunding of European R&D, particularly the too low investments in business R&D. It remains to be seen, whether the funding of European business R&D can be increased substantially.

3. Japan
Japan demonstrates high funding levels for university and business R&D, constantly challenging the U.S. funding lead. In comparison with the United States and the EU, the domestic Japanese university base displays a series of weaknesses. Japanese business R&D, on the other hand, behaves competitively.

ACKNOWLEDGMENT
Work and research carried out for this chapter was part of a research project, generously funded by the Jubiläumsfonds of the Oesterreichische Nationalbank, Austria (project no. 10076). The acting supervisor of that project was Professor Hans Pechar: University of Klagenfurt, Faculty of Interdisciplinary Studies (IFF, Vienna Location), Department of Higher Education Research (HOFO).
NOTES

1. A specific characteristic of knowledge is that the use of knowledge does not decrease, but actually—from an aggregated perspective of society—increases its value (see the classical argument by Lundvall, 1992, p. 18).

2. Since business R&D connotes more broadly than industry R&D, we qualify business R&D as a more appropriate term. Business is associated with industry and services.

3. EU language likes to speak about “multilevel governance” within the EU framework (Hooghe and Marks, 2001; Bomberg and Stubb, 2003, p. 9).

4. Innovation, and all other manifestations of aggregated knowledge, finally could be “constructed” by two “meta-dimensions”: the one refers to R&D and S&T; the other to education. Our analysis is based primarily on the research dimension.

5. Considering some of the recent organizational trends of universities, see, for example: Pechar and Pellert, 1998; and Pfeffer, 2003.

6. This application context, however, should not imply that basic research becomes replaced by applied research (Gibbons et al., 1994, pp. 4, 33–34).

7. Codified knowledge sometimes is also discussed under the term “explicit” knowledge.

8. The aggregated EU consists here always of the 15 EU member countries, as of 2003.

9. For Japan we always use those data, which the OECD “adjusted”. From 1996 onward, the regular and the adjusted R&D for Japan are identical (see, e.g., OECD, 2003b, Table 2).

10. This indicator also can be labeled as the “national research quota”.


12. Private non-profit funding often originates from private foundations, which again, at least partially, may be endowed by business. Some of the donated business money thus distributes through mediating foundations.

13. Obviously, depending on the theoretical design, also the political and economic systems may cross-cut with other systems.

14. A “regional” research network could be understood sub-national or trans-national.

15. Convincingly, Shapira (2001, p. 990) states: “Interestingly, the management literature emphasizes that the most successful business partnerships and alliances are those where there is a strategic commitment to learning.”

REFERENCES


