Firm Boundary Decisions: The Market for Health-related R&D Services with an Empirical Case Study for Germany*

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* The authors thank three anonymous referees for helpful comments on this paper.

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Abstract: Despite frequent observations of blurring firm boundaries and broad agreement about the relevance of health-related innovation, little is known about R&D outsourcing in the health care sector and the corresponding market for health-related R&D services. To shed light on this issue, we first point to the strong links between the health care system and the R&D sector and, referring to governance and competence perspectives, suggest an extended classification of R&D services based on organizational flexibility and the transferability of complex knowledge. We then apply a descriptive empirical lens by exploring the market's size and structure. This is accomplished in terms of an exploratory case study of the German market for health-related R&D. We quantify the sector-specific performers and financiers of health-related R&D in 2001 and 2003, indicating that health-related R&D services denote an important element in the health innovation system that accounts for about 16% of total health-related R&D. Furthermore, we document that the value of health-related R&D services sourced from abroad exceeds that of "exported" services by a factor of three in 2001, and by a factor of five in 2003. Our findings suggest that health-related R&D is increasingly outsourced to foreign service providers at the expense of the domestic business enterprise sector. Finally, we discuss the policy implications of these arguments.

Keywords: Health care, research and development, outsourcing

JEL classification: L1, L8, O3, O5

1 Introduction

Improvements in human health are fueled by the advance of science and technology and its transfer to new products or processes (WHO 1996; OECD 2001). While in the past, most health-related R&D was performed inside individual firms, recent years have witnessed the blurring of firm R&D boundaries and the increasing relevance of networks and markets for technology sourcing (Pisano 1991; Galambos and Sturchio 1998; Hagedoorn 2002; Hagedoorn and van Kranenburg 2003). Outsourcing R&D, however, connotes a distinctive boundary decision that – given the size and relevance of health care in today's economies – should be assumed to result in considerable markets for health-related R&D services.

The above complex of issues has received scholarly attention from a multitude of directions: Empirical research on firm R&D boundary decisions (Pisano 1990; White 2000; Steensma and Corley 2001; Schilling and Steensma 2002) has mainly drawn from transaction cost theory (TCE) (Coase 1937; Williamson 1975, 1985) to study the conditions under which firms rely on particular governance structures. Yet TCE's dominance is increasingly challenged by what Williamson (1991) summarized as “competence perspective”, comprising resource-based (Penrose 1959; Wernerfelt 1984; Barney 1991) and knowledge-based views of the firm (Kogut and Zander 1992; Nonaka 1994; Grant 1996), as well as evolutionary perspectives of organizational routines and capabilities (Nelson and Winter 1982; Teece et al. 1997). While impending opportunistic behavior in arms-length market relations motivates TCE's “external” view of firms, the latter theories represent a more “internal” notion, pointing to firm-specific assets and their link to competitive advantage that may be nurtured by internalizing particular transactions. More applied work discussed ethical issues in R&D collaborations (Bodenheimer 2000; Chopra 2003), pharmaceutical contract research (Häussler and Helberger 2001), issues of health care structure, financing, and academic R&D (Deutsche Forschungsgemeinschaft 1999; Azoulay 2004), or potential options for health care reforms (Sachverständigenrat 2003; Augurzky et al. 2004; Oberender et al. 2006). Regarding the case of Germany, a few studies also investigated particular markets, notably R&D services in general (Koschatzky et al. 2003), health-related R&D expenditures (Statistisches Bundesamt 1992), or the German medical technology industry (Bundesministerium für Bildung und Forschung 2005; Hornschild et al. 2006).

This paper is motivated by two conclusions from the above review: First, prevailing research on firm R&D boundaries has largely ignored the concept of R&D services and the emergence of corresponding markets. Second, despite the health sector's commonly approved R&D dependence, no adequate R&D data are available.[1] We thus intend to contribute to the literature on firm R&D boundary decisions through an exploration of the market for health-related R&D services. Being faced with a broad and partially unexplored field and given highly country-specific health care and R&D structures, we focus on the specific case of Germany, drawing from two different yet complementary directions to shed light on this phenomenon.

We first apply a theoretical lens and point to the strong links between the health care system and the R&D sector that shape the "climate" in which firm R&D boundary decisions are made. Referring to governance and competence perspectives, we then ask how the emergence of a market for health-related R&D services can be conceived theoretically. We suggest an extended distinction of R&D services based on organizational flexibility and the transferability of complex knowledge and argue that a closer differentiation of R&D services might enrich our understanding of R&D boundary decisions. We then apply an empirical lens by exploring the market's size and structure. The paper's descriptive approach serves to provide an overview and highlight critical issues that may enable further in-depth empirical investigations.[2] The exercise quantifies the performers and financiers of health-related R&D and R&D services in 2001 and 2003 and yields sector-specific analyses. Most of all, we show that health-related R&D services denote an important factor in the health innovation system, comprising around 16% of total health-related R&D. Furthermore, we document that the value of health-related R&D services sourced from abroad exceeds that of "exported" services by a factor of three in 2001, and even by a factor of five in 2003. Our findings suggest that health-related R&D is increasingly outsourced to foreign service providers at the expense of the domestic business enterprise sector.

The paper is organized as follows: The next section applies the theoretical lens on R&D services. Our approach and data sources for measuring health-related R&D are presented in section three, while section four implements the empirical lens. The final section concludes.

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[1] OECD Health Data, for instance, do not include data about health-related R&D in the business enterprise sector (OECD 2001, 2002). Other OECD data do report R&D expenditure in the business enterprise sector, yet their classification by industry does not allow separating R&D expenditures that are health-related from those that serve other purposes. Furthermore, both databases do not allow discriminating between the sources and allocations of funds.

[2] Given the fundamental difficulties and effort involved in aggregating data on health-related R&D (see also section 3), we follow a descriptive approach by calculating data for two years only. The resulting time series is thus too short to allow for further econometric analyses.

2 Health-related R&D services: a theoretical approach

2.1 R&D in the context of the German health care system

Health-related R&D occurs in the context of the national health science and innovation system (NHSIS), i.e., the “set of institutions and individuals who ... create, store and transfer the knowledge, skills and artifacts which define new and improved health products and interventions and more efficient ways of delivering them” (OECD 2001). The NHSIS consist of core institutions engaged in health-related R&D such as pharmaceutical firms or university hospitals, and peripheral institutions like chemical firms that perform some health-related R&D besides their primary activities. It is linked to the general health care system, i.e., to the institutions and people that seek to advance, maintain and restore public health (Beske and Hallauer 2001). Given prior accounts of both systems (Statistisches Bundesamt 1992, 1998; Busse and Riesberg 2004; Reiss and Hinze 2004), we restrict our analysis to selected issues that dominate the German health care agenda and that shape the environment in which firms decide about health-related R&D and its economic organization.[3]

The first issue denotes the health care system's fragmentation of agenda-setting, decision-making and responsibility (Oberender et al. 2006). Most decision-making and control functions are exercised through self-government by the statutory (and, to some extend, private) health insurances and the self-governed lobbies (on the regional and national level) of physicians and hospitals, respectively, to whom the traditional structure grants decision autonomy over insurance coverage and reimbursement prices.[4] Patients, who are the receivers of health services and the system's ultimate financiers, are in a weak position. Self-governance and the protection of established power structures restrict market openness and transparency, thus impeding a level playing field for “real” competition. Furthermore, the multitude of actors and interests in the health care system, and the social security system in general, constricts coordinated actions, while their protection of vested rights creates a high degree of system inertia (Reiss and Hinze 2004). Another issue pertains to the context of clinical research, in particular multi-center studies, where multiple and tedious ethics committees and the strict disjunction between the in-patient and out-patient sectors have been associated with high complexity and unnecessary delays of the medical innovation process that is long-winded anyway (Deutsche

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[3] To be clear, the health care system is a major, yet not the only factor that shapes a firm’s decisions about the location of R&D. Others include the protection of intellectual property rights or the availability of high-skilled labor.

[4] For a detailed structural overview of the German health care system, see, e.g., Busse and Riesberg (2004, p. 31; Oberender et al. 2006).

Forschungsgemeinschaft 1999). Furthermore, deficiencies in the education of clinical researchers and relatively weak incentives for patients and physicians to participate have contributed to making Germany relatively less attractive (compared to, e.g., the UK) as a reference state for clinical trials (Deutsche Forschungsgemeinschaft 1999; Projektträger im DLR Gesundheitsforschung 2004). Finally, Germany's health care system is characterized by intense regulation.[5] Attempts to contain skyrocketing health care costs resulted in more than 50 reform bills and 7000 by-laws since the mid-1970s (Oberender et al. 2006), including cutbacks in reimbursable services, case-based lump sums for hospitalization, coercive discounts, global budgets, aut-idem regulation, or disease management programs. Potential options for a “regime change” in health care (such as a single national insurance scheme vs. a capitation fee) also evoke furious controversy, yet tend to be postponed in favor of local adaptation of the current system (Augurzky et al. 2004).

As a result, there are significant interdependencies between the NHSIS and the health care system, and a profound impact on the R&D sector can be assumed due to the health care system's high degree of regulation, complexity, and intransparency. For instance, low predictability of health policy hampers firms' efforts to evaluate whether their present R&D, if transferable into viable products, will receive market approval under favorable conditions.[6] Firms are influenced by the uncertainty that surrounds health policy and thus base R&D decisions on their expectations for the future of the health care system. The health insurance system likewise impacts the incentives for R&D: Following Arrow (1963), it either implements retrospective coverage, paying health service providers based on the costs occurred, or prospective payment schemes, which the German system is increasingly adopting, where a-priori fixed sums are disbursed, independent of the actual costs occurred.[7] Referring to this classification, Weisbrod (1991) argues: “Under a prospective payment finance mechanism, the health care delivery system sends a vastly different signal to the R&D sector…: Develop new technologies that reduce costs, provided that quality does not suffer ‘too much’.”

In consequence, R&D efforts will be re-focused on either more cost-efficient technologies or on major innovations if firms expect that receiving insurance coverage is more likely with

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[5] The ratio of public over total health expenditure, indicating the leverage for public regulation, was 77% in 2005 (own calculation based on OECD Health Data 2007).

[6] DiMasi (2003) found the time span between the beginning of clinical studies (i.e., after basic research has been completed) and the final market approval of pharmaceutical products to be 90.3 months on average.

[7] More precisely, Germany adopted a prospective payment scheme in the inpatient sector in 2003/2004 (the German Diagnosis Related Groups, G-DRG). The outpatient sector, in contrast, uses a fee-for-service system (Lüngen and Lauterbach 2003).

such “block-busters” (Weisbrod and LaMay 1999). Yet there remains a third option: If other countries with more favorable regulatory regimes allow for fast adoption and higher sales, such lead markets (Beise 2004a, 2004b) may draw off health-related R&D investments.[8] R&D services may thus reflect such structural shifts as they offer a flexible means to react to the risks involved in conducting R&D in a complex and uncertain environment. Given the impact of the German health care system on the NHSIS, we argue, increased outsourcing of R&D may represent one consequence, especially if it pertains to foreign service providers.

2.2 Governance and competence views of firm R&D boundaries

Transaction cost economics (TCE) (Coase 1937; Williamson 1975, 1985) provides the prevalent theoretical rationale for firm boundary decisions. While it assumes markets to be the most efficient mechanism due to the division of labor and the costs of bureaucracy arising otherwise, it claims that they still involve transaction-related costs: As bounded rationality renders market contracts imperfect, hold-up hazards may arise from opportunistic behavior, depending on the uncertainty surrounding a transaction, its frequency, and in particular, specific transaction-related investments. As firms economize on combined production and transaction costs, they align their boundaries along these incentives. Outsourcing a transaction is more advisable than a hybrid or hierarchical governance structure when asset specificity, uncertainty, or transaction frequency are comparatively low (Williamson 1991).

In R&D, various sources of uncertainty impede a precise forecast of outcome, costs, and completion dates. R&D contracts are thus in parts left blank (Globerman 1980), thereby allowing for repeated rounds of re-contracting as soon as progress occurs (Pisano 1990). Furthermore, most R&D activities involve specific assets, either as specialized equipment or tacit knowledge, some of which may not be codified and easily transferred. Consider the following situation: If a supplier develops specialized knowledge for which other firms have little use, he is vulnerable to opportunistic exploitation by his sponsor, as threatening to switch partners is not credible. If, in contrast, only the supplier has some knowledge which several firms are interested in, its sponsor becomes vulnerable in turn. Appropriability concerns aggravate this situation since gaining proprietary access to his contractor's knowledge may be difficult for the sponsor due to potential spillovers and weak property rights that impede an exclusive discrimination (Teece 1986; Williamson 1991). In the context of the German health care system,

[8] For the case of pharmaceuticals, the sheer size of a country’s health sector has even been found to be linked to the incentives for conducting R&D in the respective market (Cerda 2007).

one might also argue that uncertainty and complexity create additional transaction costs that, in reaction, may prompt firms to shift their R&D efforts to other countries.

Empirical research supports various of TCE's predictions: Pisano (1990) and White (2000), e.g., found that hybrid or market-based governance structures become more likely when the number of potential R&D suppliers, serving as an inverse indicator for asset specificity, is rising. Regarding appropriability concerns as measured by the degree of competition, White (2000) found a shift to hybrid governance which may serve to shift the focus of technological competitition to other areas when appropriability in a specific context cannot be ensured. Lower project complexity was shown to favor market governance (Brockhoff 1992; Croisier 1998; Robertson and Gatignon 1998), while ambiguous results were obtained for market and technological uncertainty (Croisier 1998; Robertson and Gatignon 1998; White 2000; Schilling and Steensma 2002). Context-dependency certainly hampers an exact comparison of different studies, yet the mentioned findings are in line with David and Han’s (2004) meta-analysis of TCE-based empirical studies, which yielded a high explanatory power for the construct of asset specificity and a lower one for the uncertainty construct.

Proponents of the competence perspective (CP) have blamed TCE for treating firms exclusively as means for coordination and cost-economizing while neglecting their internal productive processes (Dosi et al. 2000). Yet as CP is rather heterogenous and semi-operationalized in comparison to TCE, it has been accused of ex-post sense-making and tautological reasoning (Williamson 1999; Priem and Butler 2001a, 2001b). Nonetheless, CP highlights several issues that were as yet neglected: Based on resource-based view logic (Penrose 1959; Wernerfelt 1984; Barney 1991), some scholars argue for hierarchical governance of a firm's core competencies (Prahalad and Hamel 1990) and strategic outsourcing of non-core activities (Quinn 1999, 2000) or of any non-competitive tasks (Poppo and Zenger 1998; Barney 1999). Knowledge-based approaches (Conner and Prahalad 1996; Grant 1996) assess governance choice by its contribution to a firm's efficiency in generating, processing, and exploiting specific knowledge, while research on organizational capabilities (Dosi and Marengo 2000) considers firms as the repositories of organizational and administrative routines (Nelson and Winter 1982), and points to their relevance as loci of learning and problem solving and the role of path dependencies for understanding firm heterogeneity and industrial structure.

Following this notion, internalization of R&D activities may help to access, disseminate and protect competitively-relevant knowledge (Kogut and Zander 1992; Grant 1996; Kogut and Zander 1996), especially when R&D problems are complex and ill-structured (Nickerson and

Zenger 2004; Macher 2006), or if external knowledge is "sticky" (von Hippel 1994), requiring frequent and costly interactions to transfer it. Outsourcing, on the other hand, occurs when no direct access is required, if suppliers possess superior capabilities, or due to path dependencies when knowledge incomplementarities prohibit successful integration (Argyres 1996). In a health-related context, for example, pharmaceutical companies outsource most parts of their clinical trials as they involve various aspects of health care for which other organizations (university hospitals, contract research firms) have superior capabilities.

2.3 A classification of R&D services

R&D services emanate from a firm's decision to have other organizations perform certain R&D tasks and pay them in return. In Figure 1, we refer to the trichotomy of economic organization regarding markets, hierarchies, and networks (hybrid governance structures) to suggest an extended classification that might, as we argue, better capture the richness of R&D services. It builds on two dimensions which are relevant for such knowledge-intensive relations: first, organizational flexibility, relating to the time to ramp up or alter a transactional relation, and second, suitability for complex knowledge transfer, as commissioned R&D still entails a need for organizational learning. In this context, the stereotypical competitive market is clearly flexible as the price mechanism allows for fast communication without external control or personal commitment, while it is less suited for transferring complex knowledge as "[p]rices ... are unsuccessful at capturing the intricacies of idiosyncratic, complex, and dynamic exchange" (Powell 1990). Networks, while less flexible, are built on trust, complementary strengths and the mutual benefits that arise from repeated and open-ended interaction, making them well suited for access to sophisticated reliable knowledge (Powell 1990; Powell et al. 1996). Hierarchies, finally, are rather inflexible due to the difficulties involved in reorganization. Yet their routine-based, bureaucratic nature supports the dissemination of knowledge from repeated activities rather than complex and reliable ones (Powell 1990; Williamson 1991).

In a stylized outsourcing-based perception, R&D services range close to the market domain. Here, firms choose their service providers based on price-performance considerations and devoid of personal commitment. Yet two other arrangements are imaginable where this strict market orientation may not hold, as suggested by the arrows in Figure 1. First, consider the commissioning of R&D to subsidiary companies or to a corporate R&D center. While financially, these service relations would most likely be treated like any market transaction – albeit on an in-house market – the overarching corporate hierarchy might still imply closer bonds between the parties involved. The second variant relates to the provision of R&D services by organizations that already form a network relationship with the sponsoring firm, potentially in some other context. In this constellation, one may hypothesize a higher amount of trust among the transaction partners as compared to an anonymous market relation.

< Insert Figure 1 about here >

While the above classification suggested the shapes in which R&D services may occur, we now refer to the previous section on firm boundaries to discuss when each type of R&D service relation might be chosen. For R&D tasks that are of medium knowledge-complexity, “hierarchical” R&D services might be preferred, provided that the necessary capabilities are available in-house. Due to the routine-based advantages of hierarchies, this choice seems especially logical if the demanded services pertain to regular activities or could be scheduled in advance. Here, TCE could provide the “big picture”, explaining the choice against markets and networks by relating it to a low number of potential suppliers and the resulting high asset specificity. On the other hand, CP may fill in the details and explain why, instead of pure internalization, an internal R&D service is chosen. It would point to the subsidiaries' specific capabilities and to their path-dependent evolution that involves high switching costs. Many of the large pharmaceutical companies, for instance, operate various R&D labs that are distributed around the globe and that specialize in particular therapeutic areas or scientific disciplines (Cockburn forthcoming). Supplying and demanding R&D services across such R&D networks appears to be a plausible (yet under-researched) mode of coordinating across decentralized R&D units.

In contrast, if R&D tasks are less complex, yet unscheduled and urgent such as overhead work arising from an unforeseen operational necessity, in-house R&D services could be too inflexible and basic market-based R&D services should be expected. From the perspective of TCE, this relates to the situation when multiple potential suppliers exist, which should be particularly likely when the task involves less complex R&D “commodities” that build on a widely available knowledge base. This situation also supports CP's proposition that such knowledge would not be regarded as competitively relevant. At the same time, it enables the supplier, for whom the respective field might be a core competence, to strive for economies of learning and scale. Such relations can be found in the pharmaceutical industry, where data-intensive clinical trials are often outsourced to specialized contract research organizations (Häussler and Helberger 2001; Azoulay 2004).

Finally, increasing technological complexity underlying the demanded task should increase the probability of “hierarchical” or “network” R&D services. The exact choice would depend on the number and existence of potential suppliers, on the possibility of advance scheduling and on the profoundness and necessary reliability of the knowledge to be transferred. A choice of hybrid governance, according to TCE, could indicate a low to medium number of potential R&D suppliers and a rather competitive environment. Yet this situation would raise the question why an R&D service relation is chosen at all instead of simply forming a network. Here, CP might again offer a potential starting point: If the particular capabilities are not available in-house, cooperative R&D (a network) can not be an option. Yet if the firm intends to build up the respective capabilities itself, complex knowledge transfer and organizational learning must be ensured, which may be best provided by means of “network” R&D services, for example when a medical technology company commissions an R&D project to a university institute.

3 Measuring health-related R&D

3.1 General approach and methodological issues

Measuring health-related R&D is not trivial due to institutional complexity, diversity in financing and performance, and issues involved in defining its scope such as: How far up the chain does one look in terms of basic research, for example in fields like biochemistry, or how does one treat R&D on risk factors like smoking (OECD 2001)? Furthermore, for lack of health-specific R&D data, we can only conduct secondary analyses of surveys and official statistics, as couched by the Frascati Manual: “Building up a reasonable picture of GERD (Gross Domestic Expenditure on R&D) for health may involve mixing and matching data from a variety of sources” (OECD 2001). A common approach thus starts with those categories that are clearly health-related and then uses different proxies to add health information from other categories (Statistisches Bundesamt 1992; OECD 2001, 2002). It must be noted, though, that the official statistics provide only aggregate data. Using these data allows for an exploratory overview, yet it does not discriminate health-related R&D services according to our classification as put forward in section 2.3.

Separate analyses for the business enterprise, higher education, and government and private non-profit sectors are conducted due to different data sources and the adequateness of sector-specific classifications of health-related R&D (Statistisches Bundesamt 1992). Given the difficulties involved in providing an aggregate picture of health-related R&D, and to enable a comparable analysis across all sectors, we resorted to data from 2001 and 2003, which are the two most recent years for which all sector-specific data are available. Additional assumptions are explicitly mentioned in the following. We are happy to share all underlying data and calculations.

3.2 Sector-specific procedures and data sources

We apply a product-based view to the business enterprise sector (BES) and analyze which industries perform R&D on pharmaceuticals or medical technology. A classification by industry, in contrast, would be misleading: While the pharmaceutical industry performs R&D on non-health-related subjects like cosmetic products as well, some R&D on pharmaceuticals and medical technology is also conducted outside its "core" industries such as in the chemical industry (Statistisches Bundesamt 1992). Industry abbreviations in the analysis conform to NACE, the European classification of economic activities (Statistisches Bundesamt 2003d). All BES data were derived from the biennial, voluntary R&D survey conducted by the Stifterverband Wissenschaftsstatistik (2004; 2006). Here, external R&D expenditures can be considered as demand for R&D services (Koschatzky et al. 2003). If a direct extraction was not possible due to confidential data or the statistic's level of detail, we used the respective category's share in the next-higher category, thereby assuming transferability of the upper category's characteristics to the sub-category. If several categories where involved, a weighted sum or share was calculated. As only voluntary survey data are available for the BES, real numbers are most likely slightly higher.

For the higher education sector (HES), we apply a classification by field of science (Statistisches Bundesamt 1992). Data were extracted from different volumes of the Federal Statistical Office's annual compulsory surveys (Statistisches Bundesamt 2005b, 2005c) and other, individual surveys. In the HES, health-related R&D is conducted in universities and university hospitals on the subjects of human medicine (incl. dentistry), pharmaceutics, technical health care and medical instruments, nutrition science, health economics and management, and sports medicine. As mentioned before, health-related basic research in fields like biotechnology, biology, or chemistry could not be considered, which is likewise true for certain interdisciplinary areas or central institutions, for which no measure of health-relatedness exists. Explicit R&D expenditures, however, are not directly available due to the unity of research and teaching in German universities and university hospitals. The official approach to measure R&D thus proceeds as follows: Third-party funds are regarded as purely R&D-related, while R&D expenditures from basic funds are calculated by means of subject-specific R&D

coefficients that represent the mean fraction of R&D among research, teaching, and administration (Statistisches Bundesamt 2005b). The subject group of human medicine is the only exception where a global assumption is made (Hetmeier 1998). The figures for nutrition science, health economics and management, sports medicine, technical health care, and pharmaceutics had to be derived from the next-higher categories by means of their staff numbers' share, for which data have kindly been provided by the Federal Statistical Office, as they are not included in the official publications. Except for "human medicine", all numbers would be slightly higher, as fixed percentage allocation for central university institutions and retirement reserves could not be included. We used the proxy "third-party funds from the business enterprise sector" to measure the supply of R&D services by the HES.

The government and private non-profit sector (GOV/PNP) comprises various research facilities that range from basic research (e.g., the Max-Planck, Helmholtz, or Leibniz societies) to applied contract R&D (e.g., the Fraunhofer society) (Statistisches Bundesamt 1998; Bundesministerium für Bildung und Forschung 2006). All data were extracted from the different volumes of the official financial statistics of public of publicly funded organizations for science, research and development (Statistisches Bundesamt 2005a). Unfortunately, the official classification proceeds by fields of research, among which only one, "R&D in the field of human medicine", is exclusively health-related. The statistics' rather general categories thus prevent a closer analysis of fields other than human medicine. This is highly relevant in the context of basic research, such as for Max-Planck institutes that operate in fields like biochemistry or biology. It is even more relevant for applied research on medical technology, a potential domain of the Fraunhofer society, whose relevant institutes will most likely be associated with the fields of mechanical or electrical engineering. The real amount of health-related R&D in the GOV/PNP sector is thus likely higher than our data indicate. Although a prior study (Statistisches Bundesamt 1992) mentions health- and institution-specific R&D coefficients, those have never been updated, as an inquiry with the Federal Statistical Office confirmed. A resumption of this approach or more detailed data on the allocation of R&D expenditures would thus seem to be helpful. The only additional source of information pertains to a classification by socio-economic objective (SEO), which is surveyed for international reporting purposes every four years (we focus on data from 2000 and 2004). Here, the SEO of "protection and improvement of human health" relates to all R&D activities with a primary reference to health. Where applicable, the respective data were used additionally. To measure the supply of health-related R&D services by the GOV/PNP sector, we used the proxy “income from economic activity and assets”.

4 Health-related R&D services: empirical evidence

4.1 Business enterprise sector

In 2001, the German business enterprise sector conducted health-related R&D worth more than EUR 3.4 billion, rising by 30% to almost EUR 4.5 billion in 2003 (Table 1). The pharmaceutical industry performed around two thirds of this R&D, followed by producers of medical technology products. A significant amount was also performed in industries other than the traditionally health-related ones (mainly in the chemical industry as we will show below), while the service industries account for only a small fraction. Besides the general increase in R&D spending from 2001 to 2003 that has been documented as a (apparently temporary) rise across all industries (Stifterverband Wissenschaftsstatistik 2006), Table 1 shows that all reported industries except the service industries increased their health-related R&D expenditures, with the pharmaceutical industry exhibiting the highest increase (around 35% as compared to around 25% for the medical and optical technology companies and the “other” industries).

< Insert Table 1 about here >

In line with our classification scheme for health-related R&D in the business enterprise sector, Tables 2 and 3 list the corresponding R&D on pharmaceuticals and medical technology products. Regarding the former, Table 2 indicates expenditures of almost EUR 2.8 billion in 2001 and of EUR 3.6 billion in 2003, comprising 80.4% and 80.3% of all health-related R&D in the BES, respectively. While pharmaceutical companies naturally comprise the largest share, the chemical industry is also relevant for pharmaceutical R&D, indicating – as suggested above – its contribution to the group of “other industries” in Table 1. The service industries and the remaining industries are comparably less important.

< Insert Table 2 about here >

Slightly less than EUR 676 million (in 2001) and EUR 887 million (in 2003) of the business enterprise sector's total health-related R&D were conducted on medical technology (Table 3), corresponding to 19.6% and 19.7%, respectively. Furthermore, the degree to which R&D on medical technology is conducted in its “core industry” (93% and 88% in 2001 and 2003, respectively) is much higher than in the case of pharmaceutical R&D. While the service industries are rather insignificant, both the remaining electrical engineering sector and the other industries account for a small amount of medical technology R&D, which, however, more than doubled from 2001 to 2003, indicating that firms from other industries may have jumped on the bandwagon of “medical technology”.

< Insert Table 3 about here >

Health-related R&D services supplied by the business enterprise sector are calculated based on the R&D funds that the national and foreign business enterprise sectors allocate to German firms. These data, however, do not allow for a direct discrimination of national funds by receiving industries. We thus assume that the service industries perform only contract-based and no self-serving R&D. For all other industries, we assume that their share in the supply of R&D services equals their general share in funding from the business enterprise sector.

The findings are intriguing: In 2001, health-related R&D services worth of EUR 731 million were supplied by the business enterprise sector (21.2% of all health-related R&D conducted by the BES) that decreased significantly to EUR 651 million (14.5%) in 2003 (Table 4). While the pharmaceutical industry's relative share ranks highest, it is still slightly lower than its share in total health-related R&D. The service industries, having a high share by definition, account for around 14%. All remaining industries have slightly lower to similar shares than with respect to total health-related R&D. The above analysis suggests three insights: first, a notable division of R&D labor in the pharmaceutical industry. Second, despite an overall increase in health-related R&D, the German BES has become less attractive as a supplier of health-related R&D services, which – as we will show below – stems from the fact that R&D funds are increasingly directed to foreign receivers. And third, the relatively low share of specialized R&D service providers may be attributed to the still developing German contract research industry (Häussler and Helberger 2001), or to statistical reasons, as R&D service companies that possess manufacturing capabilities may be assigned to the group of pharmaceutical producers.

< Insert Table 4 about here >

Table 4 also points to foreign sponsorship of R&D services, indicating the degree of internationalization that has increased by 3.8 percentage points from 2001 to 2003. It is more important in the pharmaceutical industry and the group of “other” industries, while it matters less for the remaining industries. This may relate to different forms of inter-firm cooperation on the international level, but most likely origins from the respective industry structures: As international corporations are more common in the pharmaceutical and chemical industries (that dominate the “other industries”), a higher degree of international R&D engagement or R&D services that are provided between affiliated firms can be expected.

The business enterprise sector's demand for health-related R&D services amounts to around EUR 983 million in 2001 and EUR 1,199 million in 2003 (Table 5). Notable in this context is the pharmaceutical industry’s high share of the total demand (85%), which is more than its share in performing R&D services or health-related R&D in general, and most likely stems from the fact that the pharmaceutical industry is the largest sponsor of clinical trials, of which many aspects are outsourced to specialized service providers. Even more striking is the fact that the demand for health-related R&D services increased by around 22%, as compared to the decreasing relevance of the BES in supplying R&D services.

< Insert Table 5 about here >

As Table 5 also indicates, the pharmaceutical industry's demand for R&D services is even higher than the business enterprise sector's total supply of such services, a difference that has become more pronounced in 2003. This raises the question: Who conducts the health-related R&D services demanded by the business enterprise sector (Figure 2)?[9]

< Insert Figure 2 about here >

In 2001, almost two thirds (about EUR 650 million) of the total demand by the pharmaceutical industry are received by the national business enterprise sector, while 24% (around EUR 234 million) are allocated to foreign service providers (including firms, universities, and other research institutions). While this is a significant outflow of R&D funds, some fraction of it is likely provided by affiliated foreign companies, especially in the globalized pharmaceutical industry. Only 10% (about EUR 98 million) of the total demand in 2001 were spent on the domestic government and PNP sector, universities included. In 2003, however, the share of the BES as a receiver of R&D funds even dropped to around 46%, while the share of foreign service providers increased to 44% (the share of the GOV/PNP sector remained constant at 10%). In other words: Given the general increase in demand for R&D services (Table 5), R&D outsourcing to countries other than Germany has almost doubled from 2001 to 2003, thus explaining the decreasing relevance of the German BES as an R&D service supplier (Table 4). In comparison, medical and optical technology companies rely more on the higher

[9] Figure 2 is only concerned with the pharmaceutical and the medical technology industry. While the service industries are too insignificant as demanders of R&D services, the group of “other” industries is comprised of a large number of different industries and thus only represents a rough estimation.

education and GOV/PNP sectors as a service provider, while their foreign R&D service relations are less distinctive. Furthermore, there have been no structural changes in the providers of medical technology R&D services from 2001 to 2003.

4.2 Higher education sector

Health-related R&D conducted in the higher education sector amounts to more than EUR 2.2 billion in 2001 and almost EUR 2.4 billion in 2003, thus increasing by around 8% (Table 6). By far the largest part was performed in the field of human medicine, i.e., in medical schools and their affiliated hospitals. The second highest amount pertains to the field of pharmaceutics, while all other fields are relatively insignificant.

< Insert Table 6 about here >

As measured by third-party funding from the BES, the HES supplied health-related R&D services worth more than EUR 320 million in 2001 and almost EUR 372 million in 2003, representing an increase of around 16% (Table 7). Regarding the role of health-related R&D services in the HES in general, a comparison of Tables 6 and 7 indicates an increase of one percentage point, i.e., from 14.5% of total health-related R&D in 2001 to 15.5% in 2003. Hence, supplying R&D services appears to have become more important for the higher education sector. By far the largest share was provided in the field of human medicine, mostly through clinical trials in university hospitals, followed by pharmaceutics and technical health care and medical instruments.[10]

< Insert Table 7 about here >

4.3 Government and private non-profit sector

In the government and private non-profit sector, R&D expenditures in the field of “human medicine” amount to about EUR 481 million in 2001 and EUR 490 million in 2003, representing only a minor increase of less than 2% (Table 8). Helmholtz research centers account for the largest part, followed by the Max-Planck and Leibniz societies as well as public research institutions with similar shares. All other institutions, in contrast, have shares in the

[10] Data about suppliers of third-party funds are not provided for individual fields of science, but only on the level of universities vs. university hospitals. While the numbers for human medicine were thus extracted from the category “university hospitals”, data on the other fields of science were estimated by multiplying the respective expenditures on health-related R&D with the general share of third-party funding of the category “universities”. Given the generally low amount of health-related R&D in the respective fields (and their low relevance compared to the field of human medicine), we believe this estimation to be justifiable.

medium to lower single-digit range. Finally, independent but publicly supported institutes at universities are responsible for around 10%.[11]

< Insert Table 8 about here >

Measuring health-related R&D by the socio-economic objective (SEO) of “protection and improvement of human health”, however, yields significantly higher numbers (Table 8). Neglecting differences between 2000 and 2001 (and between 2003 and 2004, respectively), the Helmholtz society again achieves the largest and almost equal share, which similarly applies also to the public research centers (whose share, however, decreased from 2001 to 2003) and the Leibniz society. Noteworthy differences exist only in the case of the Max-Planck society in both absolute and relative numbers: While in 2001, R&D on human medicine was much higher than R&D on the SEO of “human health”, the former decreased until 2003, while the latter increased. This might be due to the possibility that some of the Max-Planck society’s medical basic research that is not directly attributable to the SEO of health was reduced, whereas, at the same time, other fields of health-related R&D became more important.

Regarding R&D on the SEO of “human health”, the Fraunhofer society and other publicly funded organizations both have significantly higher shares than with respect to “human medicine”, indicating that the former approach better represents non-medical, health-related R&D such as work that is closer to engineering or the natural sciences. Of course, this approach by SEO cannot include all health-related R&D expenditure either. Yet it seems to provide a richer picture and may thus help to interpret the official R&D data in the field of “human medicine”, suggesting that in 2001, health-related R&D expenditures may have been 50% higher than what the data by “fields of science” lists as R&D expenditures on “human medicine”, a factor that increases to 75% in 2003. In contrast to the almost constant R&D spending as reported above, the approach by SEO would thus reflect a growth in health-related R&D from 2001 to 2003 by more than 18%.

As mentioned in section 3.2, we use the category “revenue from economic activity and assets” to estimate the GOV/PNP sector's supply of health-related R&D services. These funds originate from R&D contracts, patent licensing, dividends, or income from rentals or interest. Note that, as the data can not be separated any further, the actual supply may be slightly lower as not all funding pertains to contract R&D. Yet the data on these funds only pertain to the field

[11] Such “An-Institute” (university affiliated institutes) are reported separately as they belong to different other groups.

of “human medicine”. It is not surveyed for the SEO of “protection and improvement of human health” which, as the case of total health-related R&D above showed, suggests that the amount of health-related R&D services would actually be higher. As Table 9 indicates, the GOV/PNP sector supplied health-related R&D services worth of almost EUR 67 million in 2001 and EUR 75 million in 2003, representing a 12% increase. The main suppliers include the Helmholtz society, public and other publicly supported organizations (most likely affiliated institutes) and the Leibniz society. Academies, scientific libraries and museums are irrelevant, while all other organizations' share is in the lower single-digit range. What is striking is the Fraunhofer society's low share. This figure is probably biased by the statistical classification that only pertains to R&D on the subject of human medicine. Much of the Fraunhofer society's health-related R&D, however, is likely performed in fields like engineering or the natural sciences, and an according R&D coefficient would be useful. This conjecture can be cross-validated by additional calculations based on the Fraunhofer society's annual financial report (Fraunhofer Gesellschaft 2004). These data indicate that for its Life Science Alliance (comprising four institutes in 2003), R&D funding from contracts with the business enterprise sector might be around four times as high than what Table 9 suggests.

< Insert Table 9 about here >

4.4 Market overview

To consolidate the previous analyses, Table 10 shows that in 2001, health-related R&D worth more than EUR 6.3 billion was performed in Germany, increasing by 24% to almost EUR 7.9 billion in 2003. The business enterprise sector is the largest performer, with most of its R&D pertaining to pharmaceutical products and being performed by the pharmaceutical industry. Conducting slightly more than one third of all health-related R&D in 2001, and slightly less in 2003, the second-highest share relates to the higher education sector. In this sector, the field of human medicine (university hospitals) accounts for the largest part by far. Only a low share pertains to the GOV/PNP sector, yet due to statistical limitations as discussed above, the sector's actual significance is probably higher. Finally, foreign organizations conducted a similarly low share of health-related R&D that was funded by German statistical entities. The relevance of the foreign sector, however, almost doubled from 2001 to 2003.

< Insert Table 10 about here >

With regard to the structure of funding and performance of health-related R&D in Germany, Table 11 indicates that the business enterprise sector is more important as financier (61.6% in

2001, 67.1% in 2003) than as performer (54.1% in 2001, 56.9% in 2003). Note that regarding R&D funded by the BES, we used the numbers as reported by the other sectors, which are higher but may be better suited to capture all financial relations due to the compulsory surveys in these sectors. Furthermore, it is striking that no significant cross-financing occurs between the market- (BES) and non-market sectors (HES, GOV/PNP). In other words, both groups finance R&D mostly by themselves.

< Insert Table 11 about here >

To provide an overview of the German market for health-related R&D services, we assume that foreign funds in the BES exclusively origin from foreign firms. We can not account for foreign funding in the other sectors, as no information is available. Another issue remains: Both the HES and the GOV/PNP sector report much higher funding from the BES than the BES itself. One explanation relates to the fact that participation in the BES statistic is voluntary, while participation in the other surveys is mandatory. Yet it may also be due to the fact that the BES reports only external R&D expenditures (demand for R&D services), while the other sectors subsume all kinds of financial relations (e.g., supervision of doctoral theses or donations) as funding from the BES. Koschatzky et al. (2003) already mentioned this difference and found that the HES in particular reports around twice as much funding from the BES. Our calculation reverts to the data as reported by the BES, thus representing a rather conservative estimate ("the lower bound") of the market of health-related R&D services.

In sum, more than EUR 1 billion were spent on health-related R&D services in 2001, rising by around 22% (and thus slightly slower than total health-related R&D) to almost EUR 1.3 billion in 2003 (Table 12). These data represent an (almost) constant share of around 16-17% of all health-related R&D expenditures, and thus demonstrate the importance of R&D services for health-related R&D. As our previous analyses indicated, only a small part (less than 10%) of all health-related R&D services is supplied by the HES and the GOV/PNP sector, whereas the greater part of external, health-related R&D funds are allocated inside the domestic BES or to foreign service providers.[12] Most intriguingly, however, Table 12 indicates that the amount of "imported" health-related R&D services (provided by foreign organizations) is much higher (by a factor of around three in 2001 and five in 2003, respectively) than what German R&D service providers supplied ("exported") to the foreign sector. Furthermore, the supply of R&D services from abroad has – at the expense of the domestic BES – more than

[12] As mentioned above, health-related R&D services provided by the GOV/PNP sectors, and thus, health-related services in general, would also be higher if the data allowed for insight into fields other than human medicine.

doubled from 2001 to 2003. In other words, R&D activities are increasingly shifted to foreign countries, pointing to a non-trivial outflow of R&D funds and a comparably lower interest of foreign firms to have health-related R&D services conducted in Germany.

< Insert Table 12 about here >

5 Summary and conclusion

Despite frequent observations of blurring firm boundaries and broad agreement that health-related innovation highly matters, little is known about the economic relevance of R&D outsourcing in the health care sector. To approach this issue, we discussed firm R&D boundary decisions by means of a macro-level exploration of the German market for health-related R&D services. Applying a theoretical lens, we argued that the uncertainty and complexity surrounding the health care system significantly impact health-related R&D, and that R&D services may denote a flexible means of reaction, especially if they imply outsourcing to foreign organizations. We have referred to governance and competence perspectives to discuss why a market for health-related R&D services might emerge at all. Finally, we suggested an extended distinction of R&D services based on organizational flexibility and the transferability of different types of knowledge, and argued that these considerations might be better suited to approach the phenomenon of R&D outsourcing at large.

The empirical perspective provided evidence of the market's actual size and characteristics, thereby pointing to its high share in total health-related R&D. In light of the health care sector's high growth in many of today's economies and the relevance of R&D for improving and protecting human health, health-related R&D services comprise an important element in the health innovation system. We also presented some indication for our conjecture that the health care system's various imperfections may have a negative impact on health-related R&D, as imports of health-related R&D services were found to be significantly higher than exports, growing by more than 100% from 2001 to 2003. Of course, R&D location decisions are influenced by other factors as well – cost considerations, the availability of specialized knowledge, or the strength of the patent system – and further research will be necessary to disentangle their relationship (Berndt et al. 2007; Cockburn forthcoming). Yet nonetheless, our findings reflect the growing disaggregation and globalization of R&D in the health-related industries, and – most importantly – the pharmaceutical industry, a fundamental phenomenon that is likely to continue in the future.

There are of course several limits to this analysis. Our two lenses did not provide one congruent, but rather two complementary views on the German market for health-related R&D services. While we provided the most fine-grained and actual picture possible, we relied on official, aggregate data, thereby pointing to the various difficulties involved in providing an overview of health-related R&D. In consequence, there is ample opportunity for further in-depth empirical research to investigate the links between the health care system and the observed patterns of R&D outsourcing. Further attention should also be given to find additional empirical support for our classification of R&D services. Nonetheless, we believe that national case studies like the present one do have value despite their imperfections, and more such studies are needed to finally draw international comparisons in this important field. In a broader context, gaining a better understanding of the issues raised in this paper could support health policy makers to better understand the impact they exert on the R&D sector, and likewise, on the innovativeness of the health care system.

However, defining precise health policy implications that are geared toward location decisions of health-related R&D will depend crucially on the kind of R&D that is outsourced. For instance, costly and science-intensive basic R&D (the "R" side) is usually conducted in clusters of firms with similar or complementary competencies, often in collaboration with academia and other research institutions (Berndt et al. 2007). Outsourcing such R&D to other countries might reflect a lack of sufficiently large clusters or deficiencies in the national innovation system at large, rather than the health care system in particular. If, on the other hand, clinical trials (the "D" side of R&D) are outsourced to foreign countries, two possibilities can exist: One is that early-stage, knowledge-intensive clinical trials are shifted abroad, indicating a lack of local capabilities for conducting such trials, regulatory hurdles, or structural issues in the health care system, such as, for instance, the separation between the in-patient and out-patient sectors. The other possibility relates to the "off-shoring" of the costly and labor-intensive later stages of clinical trials. Driven by the attempt to speed up drug development through large scale trials, while at the same time reducing cost, recent research has documented that the pharmaceutical industry is increasingly shifting such activities to emerging countries (Berndt et al. 2007; Thiers et al. 2008). If the later is the main driver for having health-related R&D services conducted abroad, policy makers will face a situation that bears good and bad news alike: The (relatively) good news is that activities are off-shored that most likely pertain to low-skilled rather than high-skilled R&D jobs. The bad news is that the leverage of health policy measures will be limited, as competing on cost with low-cost locations will be futile. In this case, policy makers should rather focus on devising regulatory frameworks that ensure the quality of globalized development processes, and on measures that help extend or (at least) retain the domestic “upstream” phases of health-related R&D.

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Table 1: Health-related R&D conducted in the business enterprise sector

	2001 Expenditure		2003 Expenditure	
Industry	in 1,000 EUR	in %	in 1,000 EUR	in %
Producers of pharmaceuticals	2,218,250	64.4	2,994,273	66.7
Medical and optical technology companies	632,432	18.4	785,675	17.5
Service industries	99,262	2.9	90,042	2.0
Other industries[1,2]	494,921	14.4	621,740	13.8
Total	3,444,865		4,491,730	

[1] Industries included (NACE code): DA, DB, DE, DF, DG, DH, DI, DJ, DK, DL, G, H, J, L-N.
[2] Includes a small amount of R&D on medical technology conducted by the pharmaceutical industry.
Source: Own calculations based on Stifterverband Wissenschaftsstatistik (2004; 2006).

Table 2: R&D on pharmaceuticals conducted in the business enterprise sector

	2001 Expenditure		2003 Expenditure	
Industry	in 1,000 EUR	in %	in 1,000 EUR	in %
Producers of pharmaceuticals	2,218,250	80.1	2,994,273	83.1
Chemical industry	443,972	16.0	501,922	13.9
Service industries	95,359	3.4	85,669	2.4
Other industries[1]	11,413	0.4	22,849	0.6
Total	2,768,994		3,604,713	

[1] Industries included (NACE code): DA, DB, DE, DF, DH, DI, DJ.
Source: Own calculations based on Stifterverband Wissenschaftsstatistik (2004; 2006).

Table 3: R&D on medical technology conducted in the business enterprise sector

	2001 Expenditure		2003 Expenditure	
Industry	in 1,000 EUR	in %	in 1,000 EUR	in %
Medical and optical technology companies	628,233	93.0	780,785	88.0
Electrical engineering industry	28,768	4.3	62,267	7.0
Service industries	3,903	0.6	4,373	0.5
Other industries[1]	14,967	2.2	39,592	4.5
Total	675,871		887,017	

[1] Industries included (NACE code): DG, DI, DJ, DK, 30, 31, 32, G, H, J, L-N.
Source: Own calculations based on Stifterverband Wissenschaftsstatistik (2004; 2006).

Table 4: Health-related R&D services supplied by the business enterprise sector

	2001			2003		
Industry	in 1,000 EUR	in %	Foreign sponsors in %	in 1,000 EUR	in %	Foreign sponsors in %
Producers of pharmaceuticals	425,480	58.2	13.2	387,901	59.5	17.8
Medical and optical technology companies	107,774	14.7	4.5	91,416	14.0	10.3
Service industries	99,262	13.6	1.2	90,042	13.8	1.9
Other industries[1]	98,699	13.5	19.1	82,061	12.6	20.4
Total	731,215		11.1	651,420		14.9

[1] Industries included (NACE code): DA, DB, DE, DF, DG (without 24.4), DH, DI, DJ, DK, 30, 31, 32, G, H, J, L-N.
Source: Own calculations based on Stifterverband Wissenschaftsstatistik (2004; 2006).

Table 5: Health-related R&D services demanded by the business enterprise sector

Industry	2001 in 1,000 EUR	2001 in %	2003 in 1,000 EUR	2003 in %
Producers of pharmaceuticals	839,292	85.4	1,023,348	85.4
Medical and optical technology companies	70,310	7.2	90,030	7.5
Service industries	6,715	0.7	6,378	0.5
Other industries[1]	66,308	6.7	79,110	6.6
Total	982,625		1,198,866	

[1] Industries included (NACE code): DA, DB, DE, DF, DG, DH, DI, DJ, DK, DL, G, H, J, L-N.
Source: Own calculations based on Stifterverband Wissenschaftsstatistik (2004; 2006).

Table 6: Health-related R&D conducted by the higher education sector

Field of science	2001 Expenditure in 1,000 EUR	2001 Expenditure in %	2003 Expenditure in 1,000 EUR	2003 Expenditure in %
Human medicine	2,141,400	97.1	2,327,906	97.4
Pharmaceutics	49,532	2.3	48,593	2.0
Technical healthcare and medical instruments	5,247	0.2	5,587	0.2
Nutrition science	3,853	0.2	4,213	0.2
Health economics and management	2,959	0.1	3,002	0.1
Sports medicine	1,542	<0.1	1,583	<0.1
Total	2,204,533		2,390,884	

Source: Own calculations based on (Statistisches Bundesamt 2003b, 2003c, 2003e, 2005b, 2005c).

Table 7: Health-related R&D services supplied by the higher education sector

Field of science	2001 in 1,000 EUR	2001 in %	2003 in 1,000 EUR	2003 in %
Human medicine	313,048	97.6	364,601	98.1
Pharmaceutics	5,901	1.8	5,241	1.4
Technical healthcare and medical instruments	862	0.3	1,057	0.3
Nutrition science	417	0.1	534	0.1
Health economics and management	353	0.1	348	0.1
Sports medicine	21	<0.1	25	<0.01
Total	320,602		371,807	

Source: Own calculations based on (Statistisches Bundesamt 2003b, 2003c, 2003e, 2005b, 2005c).

Table 8: Health-related R&D conducted by the government and private non-profit sector

Institution	Field of science: human medicine				SEO: protection and improvement of human health			
	2001		2003		2000		2004	
	in 1,000 EUR	in %	in 1,000 EUR	in %	in 1,000 EUR	in %	in 1,000 EUR	in %
Public research centers	62,987	13.1	65,388	13.3	97,972	13.5	88,205	10.2
…Federal institutions	n/a	n/a	n/a	n/a	76,318	10.5	85,259	9.9
…State/communal institutions	n/a	n/a	n/a	n/a	1,654	0.2	2,946	0.3
Helmholtz society	212,557	44.2	228,998	46.7	320,074	44.1	382,420	44.4
Max-Planck society	85,265	17.7	58,278	11.9	60,921	8.4	87,168	10.1
Fraunhofer society	11,910	2.5	18,035	3.7	33,699	4.6	44,362	5.2
Leibniz society	71,871	14.9	76,092	15.5	127,524	17.6	149,040	17.3
Academies	312	0.1	318	0.1	297	0.0	1,104	0.1
Other publicly supported organizations	35,811	7.4	42,146	8.6	85,733	11.8	108,855	12.6
Scientific libraries and museums[1]	723	0.2	843	0.2	0	0.0	0	0.0
Total	481,436		490,098		726,220		861,154	
…Institutes at universities[2]	48,661	10.1	51,998	10.6	67,403	9.3	75,217	8.7

[1] Includes public and publicly supported libraries, archives, centers of information, and museums.
[2] "An-Institute" (university-affiliated institutes).
Source: Own calculations based on Statistisches Bundesamt (2002; 2003a; 2004; 2006).

Table 9: Health-related R&D services supplied by the government and private non-profit sector

Institution	2001		2003	
	in 1,000 EUR	in %	in 1,000 EUR	in %
Public research centers[1]	10,123	15.1	10,183	13.6
Helmholtz society	32,576	48.8	38,913	51.9
Max-Planck society	4,388	6.6	2,847	3.8
Fraunhofer society	3,801	5.7	5,374	7.2
Leibniz society	8,091	12.1	8,594	11.5
Academies	1	<0.1	6	<0.1
Other publicly supported organizations	7,808	11.7	8,953	12.0
Scientific libraries and museums[2]	34	<0.1	40	<0.1
Total	66,822		74,910	
…Institutes at universities[3]	9,612	14.4	11,257	15.0

[1] Includes federal, state, and communal research centers.
[2] Includes public and publicly supported libraries, archives, centers of information, and museums.
[3] "An-Institute" (university-affiliated institutes).
Source: Own calculations based on Statistisches Bundesamt (2003a; 2004).

Table 10: Total health-related R&D in Germany

Sector	2001		2003	
	in 1,000 EUR	in %	in 1,000 EUR	in %
Business enterprise	3,444,865	54.1	4,491,730	56.9
Higher education	2,204,533	34.6	2,390,884	30.3
Government and private non-profit	481,436	7.6	490,098	6.2
Abroad[1]	234,436	3.7	525,436	6.7
Total	6,365,270		7,898,148	

[1]External R&D expenditures by the business enterprise sector that are allocated to foreign countries.
Source: Compilation of previous data.

Table 11: Total health-related R&D in Germany by financing and performing sector

	Financing sector (in 1,000 EUR)					
	2001			2003		
Performing sector	BES	GOV/PNP	Abroad	BES	GOV/PNP	Abroad
Business enterprise sector (BES)	3,297,625	66,230	81,010	4,328,978	65,984	96,768
Higher education sector	320,602	1,858,931	25,000	371,807	1,995,077	24,000
Government and private non-profit sector (GOV/PNP)	66,822	399,730	14,884	74,910	403,198	11,990
Abroad[1]	234,436	-	-	525,436	-	-
Total	3,919,485	2,324,891	120,894	5,301,131	2,464,259	132,758

Source: Compilation of previous data.

Table 12: The German market for health-related R&D services

	2001		2003	
	Supply	Demand	Supply	Demand
Business enterprise sector	731,215	982,625	651,420	1,198,866
Abroad	234,436	81,010	525,436	96,768
Higher Education, government and private non-profit sectors	97,984	-	118,778	-
Total	1,063,635	1,063,635	1,295,634	1,295,634

Source: Compilation of previous data. In this table, the numbers for the HES and GOV/PNP sectors are based on data reported by the BES. Numbers based on data reported by the HES and GOV/PNP sectors themselves would be higher (see Tables 7 and 9 as well as the discussion in section 4.4).

Figure 1: Classification of R&D services

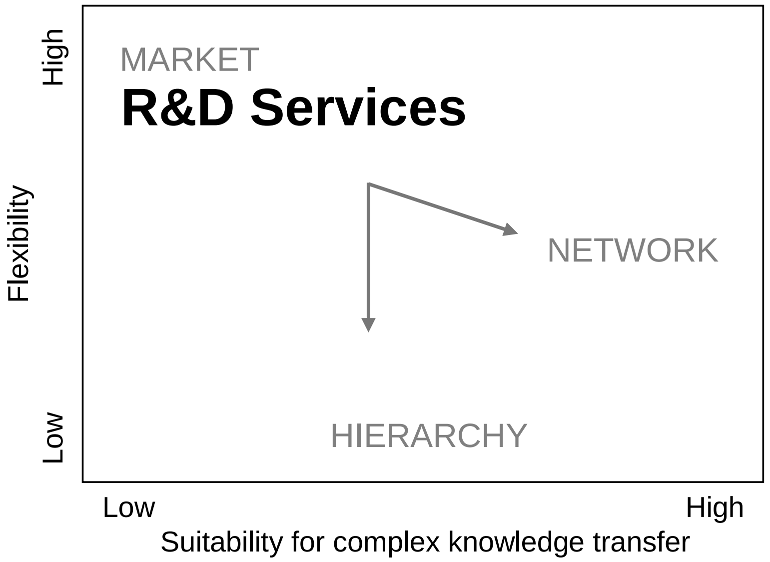
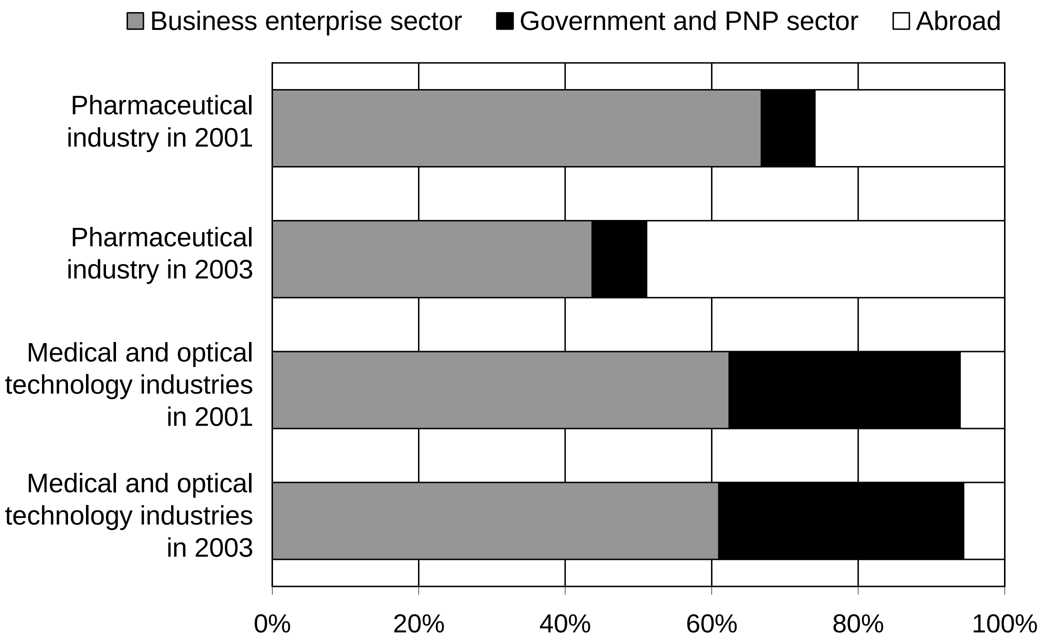


Figure 2: Health-related R&D services by demanding industry and supplying sector



Source: Own calculations based on Stifterverband Wissenschaftsstatistik (2004; 2006)