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## How companies respond to growing research costs: cost control or value creation?

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### Karl-Heinz Leitner\*

Center for Innovation Systems and Policy,  
AIT Austrian Institute of Technology,  
Giefinggasse 4, 1210 Vienna, Austria  
and  
Center for Entrepreneurship and Applied Business Studies,  
University of Graz,  
Elisabethstraße 50b/II, 8010 Graz, Austria  
Email: karl-heinz.leitner@ait.ac.at  
\*Corresponding author

### Bianca Maria Poti

CNR IRCRES,  
via dei Taurini 19, 00185 Roma, Italy  
Email: b.poti@ceris.cnr.it

### René J.M. Wintjes

UNU-MERIT,  
Boschstraat 24, 6211 AX Maastricht, The Netherlands  
Email: r.wintjes@maastrichtuniversity.nl

### Jan Youtie

Enterprise Innovation Institute,  
Georgia Institute of Technology,  
75 Fifth Street, NW,  
Suite 3000, Atlanta, Georgia 30308, USA  
Email: jy5@mail.gatech.edu

**Abstract:** Over the last two decades, R&D costs have been increasing significantly across almost all industries. While there is much literature studying different strategies to exploit R&D investments, we know little about the relative importance of controlling costs. Based on case studies of European and US multinational, R&D intensive companies, we study how firms deal with growing R&D costs. We investigate different strategies companies can employ to respond to growing research costs. Such strategies can be oriented towards controlling cost or focused on opportunities to create value. The case studies reveal that company spending on R&D is not perceived as a cost per se, but rather as an investment. Cost considerations are secondary factors and the main drivers of research investments are based on the expected value of innovations, risk and strategic competence development, and anticipating uncertainty concerning the kind of research that might be needed in the future.

**Keywords:** evolution of R&D costs; managerial strategies; cost drivers; cost control; internationalisation; open innovation; case studies; R&D management; R&D productivity; outsourcing.

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**Biographical notes:** Karl-Heinz Leitner is a Senior Scientist at the AIT Austrian Institute of Technology and Professor for Innovation Management at the University of Graz. His main research interests cover the new product development process, strategic management and the valuation of intellectual capital.

Bianca Maria Poti is an associate researcher at the National Research Council-IRCrES, Institute of research on economic and sustainable growth. She is currently a Contract Professor of Economics of Innovation at the University of Cassino.

René J.M. Wintjes is a senior researcher at the UNU-MERIT and dealing with regional development, innovation, policy and technological change.

Jan Youtie is a Principal Research Associate at the Georgia Tech’s Enterprise Innovation Institute and an adjunct in the Georgia Tech’s School of Public Policy. She specialises in advanced manufacturing, emerging technology assessment, and innovation and knowledge measurement.

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## 1 Introduction

Over the last two decades R&D spending has been on the rise in a range of industries. A number of studies (e.g., Grabowski et al., 2002; DiMasi and Grabowski, 2007) have shown that the cost of R&D has grown, including the costs of generating a patent, a new prototype or chemical entity, or a new product. In the pharmaceutical sector, for instance, studies have shown that development of a new drug has become five times more expensive than 20 years ago (Pammolli et al., 2011). Cost increases might be indicative of greater investment opportunities, but there is growing evidence that research productivity is declining. More regulation, increased safety and environmental concerns, and complexity of technologies are amongst others drivers of these cost increases (Scannell et al., 2012).

While the existing R&D management literature tends to focus on expected outcomes such as improved quality, time-to-market, effectiveness, or risk reduction, there is less literature investigating how management responds to the growing costs of R&D (Shields and Young, 1996; Schuhmacher et al., 2016). We address this gap by investigating approaches companies use to address the issue of R&D costs. We investigate how

management has been affected by growing R&D costs, if attention has shifted more towards R&D input factors and cost control, and if such a shift has produced a qualitative change in R&D strategies. Based on arguments from the strategic management literature and in particular the dynamic capability view of the firm (e.g., Teece, 2007; Eisenhardt and Martin, 2000) we describe various approaches companies may pursue. We propose that firms can follow more of a defensive approach by focusing on controlling and reducing costs, e.g., companies may save energy costs, outsource activities, eliminate specific research activities, or switch to cheaper resources (McGuckin et al., 2006). A second more proactive approach that can be considered is increasing the outcomes of R&D investments and seizing new value creating opportunities, where value creation is defined as increasing the financial returns from investments in R&D (e.g., Chesbrough, 2003). These strategic and proactive approaches are aimed at enhancing the dynamic capability of companies to innovate, which allows to organise new R&D activities in a more flexible way to respond more quickly to new opportunities for value creation; e.g. through open innovation, user-driven innovation, cooperation on R&D with external partners, launching corporate venture funds, and investing in foreign R&D to create value in local markets. We adopt a resource and capability-based perspective on strategy to investigate the role of internationalisation, scale versus scope, open innovation, and outsourcing strategies in response to growing R&D costs. In addition, we examine how companies deal with specific cost elements, such as personnel or equipment costs, when making these strategic decisions.

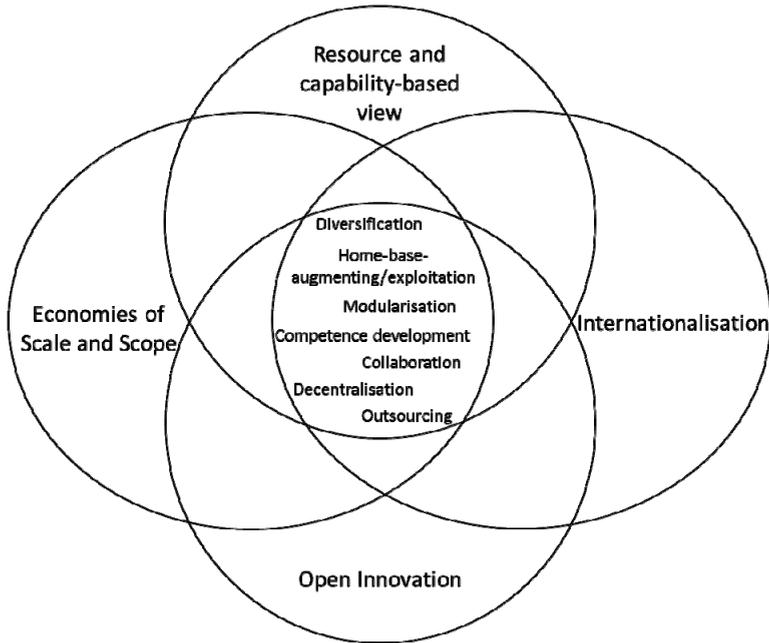
The study is based on cross-sectoral case studies of 13 European and 4 US large multinational, R&D intensive, companies. The cases were chosen to reflect a range of technology and R&D activities of interest from an R&D cost perspective including, for example, R&D relocation. We have focused on these large multinational firms to understand the broad range of possible strategies pursued by companies in different industries in response to growing research costs. Large multinationals have more opportunities for pursuing R&D investments, which can also lead to more opportunities for managing R&D costs. The paper is structured as follows. We begin with an overview of the literature investigating possible strategies companies choose to cope with growing research costs. We then describe the methodology of the study. After presenting the findings of the case studies we discuss and summarise implications for management and policy.

## **2 Literature review**

A vast literature has emerged in the last two decades describing R&D management strategies pursued to adapt to environmental challenges, new opportunities, continued globalisation, and increasing demand for high-tech products (e.g., Amidon, 1996; Chiesa, 2001; Gassmann et al., 2008). These strategies include outsourcing, licensing-in IP, acquisition of high tech SMEs, and new collaborative and open R&D arrangements. Such strategies are expected to lead to improved quality, effectiveness, risk reduction or cost-efficiency. This paper will examine several of these strategies to respond to growing R&D costs drawing from two influential strands in the strategy literature, the resource-based and dynamic capabilities perspective on strategy. In addition, we draw on the literature on internationalisation, economies of scale and scope and open innovation

to explain different strategies that firms can pursue to respond to growing R&D costs. Figure 1 illustrates the framework which guides our research on R&D cost management.

**Figure 1** Framework for analysing cost control and value creation strategies



*Source:* Own illustration

The resource-based view (RBV) maintains that firms have (and have access to) bundles of resources that lead to business performance (Wernerfelt, 1984). Resources are a distinctive source of competitive advantage to the extent that they are valuable, rare, in-imitable, and non-substitutable, scarce, specialised and appropriable (Amit and Shoemaker, 1993). R&D activities depend on these internally owned and controlled resources as well as on access to external resources (Verona, 1999). R&D can create value for the firm, in the form of physical capital (e.g., specialised laboratories, prototyping, testing equipment), human capital (e.g., scientists and engineers with special expertise), and organisational capital (e.g., R&D centres and managers) (Williamson, 1975) resources. Since ownership, control and securing access to specific resources is considered very important in this view, one might expect that, if R&D achieves the goals set through value indicators, then the company would be reluctant to change the allocation of resources.

The dynamic capabilities strand combines RBV with evolutionary economic perspectives to explain how firms respond to environmental uncertainty and dynamism (Teece et al., 1997). Dynamic capabilities tend to emphasise learning and organisational processes. Perspectives on dynamic capabilities in Eisenhardt and Martin (2000) focus on obtaining and releasing new resources such as through acquisition, divestiture, and alliance, and integrating and reconfiguring these resources. Helfat and Peteraf (2009) put forth technical fitness and evolutionary fitness as dynamic capability performance measures.

The resource and capability-based perspectives on R&D strategy have implications for understanding trends in R&D cost management. Examples of such trends include decentralisation and outsourcing R&D to international locations versus R&D re-centralisation and integration, open innovation, and acquisition strategies. From the RBV perspective, R&D costs are something to which resources are allocated and should be managed in order to secure access to necessary resources and maintain current R&D activities in the most cost-effective organisational setting. In contrast, from the dynamic capabilities point of view, a company does not know which R&D activities will be needed in the future, so R&D and associated costs will be changed to enhance firm value. Such changes could include expanding open innovation sources and decentralised R&D locations in developing countries or recentralising these resources. In the context of this framework, we next review the literature on internationalisation, scale versus scope, open innovation, and outsourcing.

*Internationalisation of R&D* is an increasingly important trend. The literature on internationalisation of R&D has recognised that globalisation is driven by different rationales (e.g., Bartlett and Ghosal, 1990). Empirical studies show that in most cases internationalisation of R&D follows the internationalisation of sales and production (e.g., Birkinshaw et al., 1998). The literature distinguishes two broad motives for internationalisation: the market motive to improve the way existing assets are utilised, and the knowledge motive, to improve existing assets or create new technological assets (Narula and Zanfei, 2005). Asset exploiting R&D (Dunning and Narula, 1995) or home-base-exploiting (Kuemmerle, 1999) addresses the market motive by adapting existing technological assets to foreign local conditions, such as consumer preferences, regulations, or environmental conditions, where competitive advantages are widely regarded as a prerequisite. Asset augmenting R&D (Dunning and Narula, 1995) or home-base-augmenting (Kuemmerle, 1999) in contrast, refers to the acquisition and internalisation or creation of new knowledge and technology in the host country (Narula and Zanfei, 2005).

Internationalising R&D not only can produce benefits, but also adds to the costs resulting from decentralisation. Additional costs may occur because firms are very much bound to the innovation systems of their home countries (Narula, 2002). Developing an external network structure to gain access to complementary location-specific assets requires time and capital, thus increasing the costs of integration. Additional internationalisation costs can result from

- 1 missed benefits and higher coordination efforts which, in turn, are reflected in reduced economies of scale and scope
- 2 the need to overcome institutional and social limitations
- 3 increased obstacles – arising from geographical or technological distance – in transferring knowledge within a multinational enterprise (Criscuolo, 2004).

Labour costs have been interpreted differently in the literature on the internationalisation of R&D and innovation. These interpretations have to do with resource bottlenecks. Resource bottlenecks may result from a limited availability of skilled personnel. An absolute shortage of skilled personnel may occur, because personnel with needed qualification is not available, or a relative shortage of personnel may occur, because skilled personnel are not available at the going wage level. Empirical evidence (e.g.,

Lewin et al., 2009) shows that a shortage of highly skilled science and engineering talent leads to the diversification of R&D, but direct cost advantages, such as labour costs, rarely affect the internationalisation of R&D. Other scholars (e.g., Gassmann and Zedtwitz, 1999) perceive the organisational cost of the R&D process as the main driver for the dispersion of R&D activities. This dispersion usually operates as more of a cost containment strategy than a value creation strategy.

In applications of the RBV to foreign direct investments, Buckley and Casson (1998) and the original ownership specific advantages, location advantages, internalisation advantages (OLI) paradigm of Dunning (1981) interpret foreign R&D either as home-base-exploiting or home-base-augmenting. In a dynamic capabilities view on transnational companies, R&D is viewed as being less linear, more systemic, and more demand-oriented. Exploiting and augmenting strategies co-evolve, and the flows of knowledge can come from any part of the transnational network. Moreover, the direction of the flows of knowledge are not fixed and the various ‘faces of R&D’ (e.g., generate, absorb, diffuse knowledge) are not fixed into certain roles for particular parts of the transnational network (which includes all kinds of partnerships). Dynamic capabilities allow companies more easily to identify and seize new opportunities for value creation and adapt to sudden changes.

Another aspect of R&D concerns *size and diversification*, which is associated with the idea of achieving economies of scale and scope in R&D. Here research productivity in the broadest sense has been associated with success in innovation, typically measured by research output, such as patents (Henderson and Cockburn, 1996) or major innovations (Acs and Audretsch, 1988). Chandler (1990) suggests that the research process itself allows for significant economies of scale, where economies of scale arise from fixed costs such as: the costs of running research laboratories, maintaining high quality personnel, or legal and regulatory expertise (Plotnikova, 2010; DiMasi et al., 2005). Large firms may be able to spread these fixed research costs over larger R&D projects and over a larger expected sales base. Furthermore, large firms may have advantages in securing finance for risky R&D projects, as size is correlated with the availability and stability of internally generated funds (Cohen, 2010). However, scale and high fixed costs also creates risks, not only in high losses in the case of a failing project, but also because resources devoted to failing projects will not be usable for other projects. In the case of two rival technologies, it may be better to invest in both, spreading R&D costs over these projects.

Arrow (1962) and Teece (1980) claim that research and the production of knowledge allows to exploit considerable economies of scope. Economies of scope in R&D mainly arise from internal knowledge spillovers or from a network of external partners. Firms may benefit from diversified research and innovation activities through the exchange of knowledge across various projects, and through the ability to incorporate knowledge from related fields (and across R&D locations) into an R&D project (Plotnikova, 2010; Henderson and Cockburn, 2001). Moreover, diversified multi-product firms may provide economies of scope by reducing the risk associated with prospective returns to innovation (Cohen, 2010). In this context, the use of standardisation, modularisation and networking can also increase the efficiency of R&D investments and product development and allow for economies of scale and scope (Mikkola, 2006) for the pursuit of specific product strategies such as modularisation and platform-based product development strategies.

*Open innovation* as introduced by Chesbrough (2003) is one of the most prominent innovative network strategies discussed in recent years. Open Innovation aims to increase

the productivity and efficiency of R&D activities by exploiting external resources and commercialising internally generated ideas with new partners. Open innovation brings forth additional R&D options as not the entire R&D budget is spent on in-house projects. It also allows for the greater application of collaborative arrangements and business models. Strategic collaborations, licensing, corporate venturing, and contract research for third parties, are proposed to exploit both external and internal R&D results (Schuhmacher et al., 2016). These diverse organisational options allow companies to react more quickly to new demands for R&D, and reduce the risk of missing out on new value creating opportunities.

Open innovation changes how risks in relation to R&D investments can be shared and minimised. It changes the structure of R&D organisations and systems. Many large companies also develop partnerships with scientific research organisations in order to have access to leading edge science under a different cost model. These partnerships can take many forms including university/government laboratory-industry research centres, regional clusters of businesses, universities, and government laboratories, and consortia of businesses. In these types of collaborations, specialised centres of excellence are particularly important. Frost et al. (2002) find that specialised centres of excellence make a greater contribution to firm performance than more broad-based partnerships within a multi-national enterprise. The increased complexity of R&D processes strengthens the need for collaboration. Collaboration, while stemming from a diverse range of motives for collaboration (e.g., reducing risks and costs), also can increase management and transaction costs. However, many studies show that the benefits of collaboration outweigh the associated costs (Hagedoorn et al., 2000). Collaboration can be more expensive (for example, the transaction costs can be higher than the internal coordination costs, and higher than the costs to purchase R&D results on the market), but the extra costs of building partnerships can also be seen as investments, a sort of sunk cost which reduces future transaction, communication or collaboration costs.

Although *outsourcing* of manufacturing activities has long been taking place, outsourcing of R&D and supporting activities has expanded significantly in recent years. Lower cost countries such as China and India have developed increasing capabilities such that they are among the global leaders in technology-intensive fields such as nanotechnology and information technology (see e.g., Kostoff, 2012; Arora et al., 2001). Businesses seek to establish locations in these countries to take advantage of these capabilities at a reduced cost. In addition, these businesses themselves have simplified and restructured to become leaner companies that can better make use of these capabilities. Hamel and Heene (1994) maintain that core competencies are not simply organisational characteristics, but rather are based on the ability to coordinate and make use of an organisation's knowledge flows. Outsourcing enables accessibility to distinctive capabilities but as Schmid and Schurig (2003) indicate, firms must have the resources, capabilities and competencies to access and exploit these capabilities.

In sum, this paper brings together the literatures on different perspectives on strategies to provide a framework for understanding trends in the organisation of R&D. The paper focuses on two alternative types of solutions highlighted in this literature: controlling costs or enhancing opportunities to create value. This paper will address these two positions drawing on results of case studies with R&D managers in large corporations in Europe and the USA.

### **3 Methodology**

We have chosen a case study approach for studying empirically managerial responses to rising research costs (Yin, 2003). As suggested by many authors, this is a very powerful method for building a rich understanding of complex phenomena (Eisenhardt and Graebner, 2007) including ‘how’ and ‘why’ questions (Yin, 2003).

The case studies referenced in this paper combined several data collection methods including semi-structured interviews (lasting 40 to 90 minutes), and background research to prepare the interviews (for more details see Leitner et al., 2011). The interviews were conducted using a semi-structured questionnaire including some common questions and questions specific for different sectors. The interview guideline included the following topics: development of R&D costs (how different cost components of R&D cost – wage, capital, material – developed in the last five years and if these changes had a disruptive effect), the drivers of the evolution of R&D costs, management strategies, and R&D cost indicators. Particular attention was devoted to issues related to management strategy: the importance of R&D costs in defining the company’s research strategy; management focus on cost control or outcome measures; methods used to control R&D cost in the past; relevance of R&D costs for defining R&D budgets; the relationship between R&D costs and R&D location decisions, and future strategies to contain R&D costs. See Appendix B for the interview guideline.

The interviews were conducted in spring 2011, R&D data were reported for the business year 2010. The interviews were recorded and transcribed. Various secondary material provided by the firms or gathered through desk research (reports about R&D expenditures) informed us with background knowledge about the selected firms. These secondary information sources were triangulated with data drawn from the interviews to avoid post hoc rationalisation, contributing to construct validity (Yin, 2003).

We selected 13 major European and 4 US firms in our study from six different industries (aerospace, automotive, chemicals, energy, electronics, telecommunications). The companies chosen for the case studies are large, R&D intensive multinationals, identified via the EU R&D Scoreboard which is a collection of the top R&D-intensive companies in Europe and other global regions (European Commission, 2009). Companies chosen as case studies were selected because they have a range of technology and R&D activities and are engaged in activities which are interesting from a R&D cost perspective (such as R&D relocation). We focused on large multinational firms from different industries in order to study the full range of possible strategies pursued by companies to respond to growing R&D costs. For example, Boehringer Ingelheim’s Institute for Molecular Pathology (IMP) represents a specialised research centre of a large pharmaceutical company. GDF Suez exemplifies large scale, collaborative R&D in the energy sector. Fagor Electrodomesticos illustrates R&D approaches within a standardised setting of technology platforms for electronic household appliances. The pharmaceutical companies reflect the conduct of R&D in an environment marked by substantial government regulation. Four non-European (i.e., US) case studies were selected from a single industry cluster (electronics, information and communications technology, semiconductor) to enhance the comparability of the cases between Europe and the USA without having to consider any sectoral differences. See Appendix A for the final list of selected companies and interviewees.

The collected cases were analysed in an iterative process. The process combined within-case analysis and cross-case analysis. Typical characteristics and patterns were analysed with respect to each case. In the subsequent cross-case analysis, these findings were compared with findings from the other cases. We looked for similarities as well as significant differences between the cases. Identified similarities represented an answer to our research question about which type of strategy the top research companies followed to address increasing R&D costs. Differences enabled us to test our research assumptions and potentially generate new insights.

## **4 Results**

We report the main results along a few selected issues starting with the question about the importance of controlling specific R&D cost elements. We then present findings concerning the relationship between R&D internationalisation and R&D costs and move on to the role of collaboration strategies to control costs. Finally, we discuss how companies are responding to growing product complexity, a key driver for growing R&D cost, by focusing more on scale or scope strategies. Table 1 gives an overview of selected findings from the case studies.

### *4.1 Specific control of certain cost elements*

According to the managers we interviewed, personnel costs are the largest component of R&D costs. Personnel costs accounted for about half of total R&D costs in 2010 for most of the companies we interviewed. The second largest component was capital costs (e.g., costs of equipment, machinery, information technology) which made up about 20%, followed by purchased R&D at 14% and material and supplies at 8% on average. The remaining 8% include other costs such as patenting costs. Because personnel costs were the main cost category it might be assumed that companies endeavoured to control salaries. However, we found little evidence that reducing personnel costs was a major issue. R&D managers from case study companies were not explicitly concerned with controlling salaries. In fact, they were likely to find ways to pay higher salaries than the norm to attract or retain employees with a particular expertise. It was not found to be easy or desirable to minimise salaries since the recruitment, motivation and retention of highly qualified staff is a crucial aspect of R&D management. This is especially true in those countries (some European countries, but also the USA) where universities have difficulties in attracting sufficient numbers of science, technology, engineering and mathematics students. These difficulties put the supply of graduates below optimum levels, which require companies to pay higher salaries to attract talented R&D employees.

However, improving worker productivity was mentioned several times as being an important strategic objective. This objective has been realised through various managerial activities. One way of ensuring that staff working in research facilities are used productively is to provide full service packages around the scientific use of facilities, that is, to ensure that the facilities themselves and the staff delivering such services operate at their full potential.

**Table 1** Selected findings from the case studies

<i>Case</i>	<i>Main cost drivers and challenges</i>	<i>(Cost) criteria for decision-making</i>	<i>Main strategy</i>
Boehringer Ingelheim	Research facilities and infrastructure, which comprise 30% of R&D costs.	Focus on input control as the measurement of outputs is very difficult and not meaningful. Capital costs important criteria.	Collaboration and sharing expensive facilities with other firms, research organisations and universities. Less leeway to contain wage costs, for instance salaries for top researchers are now negotiated in a global market.
Bosch	Wage costs are still the dominant element. Environment is an important cost driver but at the same time business opportunity.	R&D costs are of increasing importance taken into consideration for location decisions.	Pooling of competencies and strengthening interdisciplinary collaboration (e.g., enlargement of the R&D centre in Stuttgart). Strategic assessment of project portfolios and modularisation of product development.
Avio	Wage costs are still the dominant element.	All R&D programmes are steered and subjected to internal authorisation. Cost aspects are relevant, but a secondary issue. A rigid cost/benefit analysis does not fit with research aims, even if the projects are more short-term oriented.	The strategic decision process is top down, and at the same time business oriented. Collaboration (R&D networks) for risk sharing and access to research finding relevant.
Eni	Costs development is driven by more difficult conditions for exploitation on the global scale.	Development of an evaluating system to assess the value created by research activities. Economic evaluation is made in terms of expected monetary value for each technology and all activities, contingent on the conditions, e.g., climate change.	Dynamic capability orientation by developing an internal system for evaluating the value created by research activity. Increased collaborations on the global scale to share costs and risks of exploitation, e.g., in Arctic areas or dealing with bad quality oil.

*Source:* Author interviews conducted with research managers, spring 2011.

**Table 1** Selected findings from the case studies (continued)

<i>Case</i>	<i>Main cost drivers and challenges</i>	<i>(Cost) criteria for decision-making</i>	<i>Main strategy</i>
Bracco	<p>Cost of the pre-clinical and clinical activity tend to increase for higher safety requirements.</p> <p>Internal training cost increased in the last three years.</p>	<p>A number of input, throughput and output indicators are used.</p> <p>Bracco uses patenting as an output and productivity indicator rather than a cost consideration.</p>	<p>Decisions on R&amp;D projects do not follow R&amp;D cost considerations.</p> <p>One objective concerns the design and implementation of production processes with high efficiency, with particular attention to reducing the environmental impact.</p> <p>There is an internal monitoring system linked to productivity contingent to situation indicators.</p>
GDF Suez	<p>Similar development of the cost categories in the past. Economic crisis as main challenge.</p>	<p>Due to the technological complexity and uncertain market conditions it is not possible to develop indicators to express the cost effectiveness or profitability of R&amp;D.</p> <p>The main effect of the past economic crisis is not to reduce the R&amp;D budget overall, but focusing on shorter-term projects designed to improve processes rather than engaging in riskier, more long-term projects.</p>	<p>Questions of location are most relevant as a result of the need for proximity to the consumer and the use of local resources rather than considerations on cost of R&amp;D.</p> <p>Standardisation and re-use other important strategies to cope with costs.</p> <p>Concentration of efforts and investments in fewer shared sites and installations in collaboration with major companies.</p>
Rhodia	<p>R&amp;D investment decisions are crucially influenced by considerations regarding research staff turnover.</p>	<p>Strategic criteria as obtained from the market analysis and screening act as key criteria rather than cost. No R&amp;D team will be closed because of cost, except for a critical situation.</p>	<p>Decisions are taken very carefully what is developed internally and what in cooperation.</p> <p>Rhodia maintains a key strategic partnership with the French national research agency. The partnership has boosted the investment in disruptive research capabilities.</p>

*Source:* Author interviews conducted with research managers, spring 2011.

**Table 1** Selected findings from the case studies (continued)

<i>Case</i>	<i>Main cost drivers and challenges</i>	<i>(Cost) criteria for decision-making</i>	<i>Main strategy</i>
Fagor Electro-domesticos	Wage costs are the key component of R&D costs in Fagor. The only other important component is the costs related to prototyping.	Costs are not as important as cash flow from R&D projects. Use of a conventional stage-gate management process to assess each project's potential to create a return on investment.	Against the background of strong economies of scale, investment need to be focused as early as the strategic idea generation stage. Less external collaboration in R&D due to management costs. The standardisation of technology platforms is a key lever to control costs.
Motorola	Wages and fringe are largest ones, followed by support functions, intangible coordination and intellectual property costs.	Research is an investment rather than a cost: achieving research cost efficiencies could hamper ability of company to achieve return on investment. Too strong focus on cost efficiency can hamper disruptive innovations.	Motorola reduced its global network to achieve greater synergies. Outsourcing of R&D is important. Acquisitions enable new capabilities which are too time consuming to develop in-house.
Medtronics	Growing cost in the clinical stage.	The company allocates a specific budget for research projects. Scrutiny of detailed costs within research budgets is not as meticulous as is the case for the development budgets which are part of a stage-gate process.	Global outsourcing of particular aspects of the company's research to help with R&D cost management. Clinical trial costs, transferring parts into countries with lower wage costs (e.g., Eastern Europe).
Tellabs	R&D costs have risen in recent years, reflecting greater demands for speed and product complexity. There are more R&D driven feature releases and new hardware today than there were in past years.	Research productivity is not measured per se. The company tracks the revenue and profitability of certain categories of products, new growth platforms introduced in the past five years.	New partners in lower cost countries (China and India). These locations were chosen more for their fit to the company's R&D cost management than to enhance market penetration with local content. Open innovation to enable the company to acquire capabilities for more quickly entering into new markets.

*Source:* Author interviews conducted with research managers, spring 2011.

**Table 1** Selected findings from the case studies (continued)

<i>Case</i>	<i>Main cost drivers and challenges</i>	<i>(Cost) criteria for decision-making</i>	<i>Main strategy</i>
Texas Instruments	<p>Technological complexity is an important cost driver.</p> <p>Software re-use is an important issue as well.</p>	<p>R&amp;D costs are maintained at the industry average, with fluctuations managed through partnering or ending partnerships based on the extent of connections with markets with more growth potential, reuse/spillovers across multiple products.</p>	<p>Most of the R&amp;D is done in-house but some process R&amp;D is done in collaboration.</p> <p>Market access and talents are as important as costs for locational decisions.</p> <p>Strategic alliances with foundries, acquisitions to enter a niche or attain manufacturing capacity, university research in long-range areas are important strategies.</p>
DSM	<p>Many cost categories are exogenous to DSM.</p> <p>Increased complexity of integrating technologies.</p>	<p>Return on investment in the future.</p> <p>R&amp;D is managed as a business, like any other department. Research productivity is measured by: share of innovative products in total sales, but also counting patents and using special business models.</p>	<p>Revert to open innovation in order to address complexity of R&amp;D, and a more business-like approach of R&amp;D.</p> <p>Due to a lack of researchers in organic chemistry in Europe and the US, DSM established new R&amp;D centres in China.</p>
Philips	<p>Choice to develop innovation competence in emerging markets (health sector and China).</p> <p>Wages are main component: hiring many 'customer-facing R&amp;D staff' who interact with customers on future innovation needs.</p>	<p>Favour R&amp;D costs and competence development that reduce uncertainty and costs of future R&amp;D projects.</p>	<p>Oversees R&amp;D serves to meet particular market needs rather than to reduce costs.</p> <p>Open innovation: 'inside-out – make our skills and resources available to the outside'; and 'outside in' – bring in and draw on capabilities from others around the globe.</p>
TELENOR	<p>Wages are the largest one, followed by travel, training, outsourcing and ICT.</p>	<p>Use of a conventional stage-gate management process to assess each project's potential to create a return on investment.</p>	<p>Operational research management to increase research productivity is linked to 'time to market' to gain competitive advantage rather than controlling cost. Tight operational research project management is a key lever to speed up time to market.</p>

Source: Author interviews conducted with research managers, spring 2011.

**Table 1** Selected findings from the case studies (continued)

<i>Case</i>	<i>Main cost drivers and challenges</i>	<i>(Cost) criteria for decision-making</i>	<i>Main strategy</i>
Astra Zeneca	<p>Despite open access growing costs for databases.</p> <p>Growing R&amp;D costs due to regulation.</p> <p>Only limited possibilities to control personnel costs, for good people this is a global market, potential to reduce costs only for PhDs.</p>	<p>Cost (early stages) and net present value (later stages) as important measures.</p>	<p>Partnership is a key tool to reduce cost and spread risk.</p> <p>R&amp;D location decisions still driven mainly to gain access to scientists and engineers in those countries and greater market understanding.</p> <p>Laboratory automation is used to increase efficiency of R&amp;D, new facilities to integrate technologies and equipment represents a scale increase rather than cost reduction measure.</p>
Rolls-Royce	<p>Costs have grown due to technological complexity, regulation and environmental trends.</p>	<p>Decisions about R&amp;D investment are based on expected outcomes, risk and strategic competence development.</p>	<p>Customisation for output value and standardised platform for reducing costs of R&amp;D.</p> <p>R&amp;D networks including universities and firms along the value chain for cost reduction and output value increase.</p>

*Source:* Author interviews conducted with research managers, spring 2011.

Investments in equipment and facilities are the second largest cost category. In some industries (e.g., pharmaceutical, energy) they have been considered by the respondents to be the most significant cost drivers. Boehringer Ingelheim's IMP institute located in Vienna predicts the share of R&D costs for facilities and equipment will increase in the next years but at a slower pace, whereas quality assurance costs will increase at a much faster rate. Strategies to cope with these costs include various cost sharing models and cooperative arrangements with other research institutes at the same locations. In the case of Philips, adopting open innovation prompted an arrangement to begin renting their clean-room facilities to third parties. This arrangement helped to justify the costs of such facilities.

Due to growing patenting costs, some enterprises are more careful in filing patents. Several of the US cases make reference to intellectual property (IP) costs, and the importance of maintaining a strong patent portfolio while at the same time managing the costs of this portfolio with greater selectivity in patenting investments. Motorola previously viewed patents as an investment and developed a large portfolio, but now is more selective in patenting to maintain IP parity with competitors. The US firm Medtronic reported that extensive litigation has added to the rise of patenting costs. This is in line with findings in recent studies which reveal that litigation costs are an important topic in the US due in part to changing IP regulations in the last two centuries (Jaffe and Lerner, 2004). Some companies monitor competitor patent positions as part of their strategy to be selective in patenting. In contrast, Bosch aims to maintain its technological position through the filing of patents, with cost issues not mentioned as an important consideration.

#### *4.2 R&D costs as drivers for internationalisation and offshoring*

There are several reasons for establishing international R&D centres; cost is not the main reason. In general, locational decisions concerning R&D facilities are important and related both to output value, increasing the need for proximity to customers and leveraging of local skills, and to cost considerations. Texas Instruments has facilities in 30 countries and with its Bangalore India facility that opened in 1985, it was one of the first semiconductor firms to establish R&D facilities in lower cost locations. Outsourcing of process and manufacturing has driven some of these research locations. However, Texas Instruments' locational decisions are not only based on cost. Access to markets and talent are of equal strategic importance. Tellabs, which develops and provides telecommunications equipment to large carriers, has multiple R&D locations to help the company with cost management. Tellabs uses R&D partnerships in lower cost locations too. However, the last four years Tellabs has consolidated R&D into less locations to promote greater alignment with strategic business units, and to reduce expenses as well. Medtronic, a producer of electronic medical devices, performs large clinical trials in the USA, while early stage clinical work is done in Eastern Europe. To manage costs, gain access to scientists, and facilitate market entry, Medtronic maintains R&D facilities in ten countries, of which half are European countries. Relative costs do, of course, influence where a certain activity will be located. However, locational decisions are more complex than being based on cost alone. Each move needs to be considered carefully, since "... it is difficult to pull teams back. No R&D team will be closed down because of cost.

Indeed, except for a critical situation, for instance, a threat to the company's survival, cost is not a key factor" as the interviewed Rhodia manager argues.

Motorola, active in the mobile device and network industries, has reduced its global locations to increase coordination and realise greater product synergies and returns on the research investment. However, development, as opposed to research, continues to be outsourced to foreign locations. The Motorola case may be a weak signal for a reverse trend; it has integrated ten international research centres in order to focus on innovation objectives rather than disparate research objectives.

The offshoring of R&D to India and China in particular has been rapid and the lessons about its cause and effect are complex. European multinationals make investments in R&D in North America, where access to advanced facilities is better (including more expensive equipment) and thus the main motivation. Attracting R&D investment into Europe has occurred but is not driven by low cost arguments. What we see across all these perspectives is that cost is not the primary concern.

Although manufacturing and IT as well as accounting and human resources have been outsourced, the outsourcing and offshoring of R&D was for a long time considered inadvisable. It has now become accepted in many industries. Companies have learned how to diffuse knowledge gained from R&D throughout their global organisation as well as how to effectively manage geographically dispersed project teams.

Locational decisions are also discussed with respect to cost management. Establishing centralised research locations to exploit regional spillovers as one strategy was supported in the cases. For example, Bosch set up a new centre for research and advanced engineering near Stuttgart in 2009 to pool competencies and strengthen interdisciplinary collaboration. The core Philips research facility remains located at the high-tech campus in Eindhoven, although growth in R&D takes place in other locations around the globe. Texas Instruments has added capacity at its headquarters location through the 2008 opening of the Kilby Labs to perform proof of concept research and integrate with future revenue generating products. Boehringer Ingelheim's IMP has been able to engage in cost sharing with research organisations in the same location and to get funding support from the city government of Vienna to underwrite the costs of shared facilities and databases. In general, there were no remarkable differences between the European and US firms concerning their internationalisation and offshoring strategies. However, the US cases (Motorola, Texas Instrument) suggest that they are more proactive and faster in their selling off capabilities, opening new R&D sites, centralising or decentralising the R&D organisation as an approach for the management of R&D costs.

### *4.3 Collaboration strategies*

All the case studies highlighted the recent importance of collaboration with external partners. External partnerships were observed to be driven by and in response to a diversity of factors. A network can enable the firm to tap into resources that increase output value or lower costs. Sometimes collaborative approaches have been applied to facilitate cost management, but this is achieved ultimately via a strategic and long term structural effect in the 'knowledge production' system. Networks were shown to provide sources of competitive advantage contributing to firm heterogeneity since their effect is largely inimitable. It is an 'industry trend' to derive advantage from collaboration. Philips uses a strategy for 'inside-out' innovation – through participation in external projects, offering laboratories as user facilities, and selling IP – and 'outside in' innovation

through external collaboration. A key R&D management consideration at Rhodia relates to decisions as to which competencies to develop internally and which ones to develop through external partnerships, including the value chain. “We will not develop any competence at any cost” maintained an interviewed R&D manager at Rhodia. The scale of capital investments in the energy sector requires external partnerships, according to GDF Suez. Avio Spa chose a combination of intra and extra-mural R&D through external collaborations with universities and SMEs to deal with competitive pressures and changing environmental regulation. These collaborations help to reduce costs induced by the need for more important efforts in R&D and they produce a social leverage effect, since for the same internal investment, Avio puts in motion a larger external R&D outcome.

The challenge is identifying the most suitable approach for each technological engagement, be it in-house research, sub-contracted R&D, partnership-based R&D, acquisition of R&D based operations, further technology monitoring or abandoning a particular technology choice. Fagor Electrodomesticos has engaged in collaborative product introduction with other manufacturers, however, it claims that using external sources is actually more expensive (because of management costs) even if it offers greater flexibility. The Spanish household good manufacturer expects that a process of forging alliances and consolidation will be one way for businesses in the industry to achieve the economies of scale necessary to be globally competitive.

Texas Instruments conducts most of its research in-house, but makes extensive use of strategic alliances with foundries for R&D in the area of manufacturing processes. Moreover, the US cases studied exhibited prominent use of acquisitions as a cost effective way to enter new markets, increase capabilities, and add new products. In the future five years, interviewees suggested that there will be greater use of open innovation methods, in part to manage R&D costs. Fagor Electrodomesticos exemplifies this approach with plans for lower wage strategies for R&D in Asia and greater use of worldwide alliances.

Nearly all the case studies referred to university and government laboratory collaborations. These collaborations were observed to result in new value-chain relationships and R&D specialisation, where knowledge and technology is processed at a more sophisticated level. Universities were found to be playing an increasingly important role in industrial R&D, especially in basic research but also in fundamental aspects of applied research. Companies were not just sponsoring university teams, but were working more closely with them in various ways. Public Research Organisations and specialised small R&D performers were evidenced to be offering new services in this milieu as well serving as research providers and as innovation intermediaries. In such a setting, securing a premium price for products and services (knowledge) or being engaged in prestige projects and consortia has become a commercial aim. Rather than regarding collaborations as an activity that leads to cost increases, these activities are also regarded as value-adding.

#### *4.4 Growing product complexity and R&D costs*

One of the most prevalent cost drivers mentioned by the companies was the increasing complexity of products, which in turn is partly driven by customer demand for better performing products that are more flexible, energy-efficient, and safe. Complexity was

observed to have a cost effect. Several interviewees indicated that their products incorporated and integrated a larger number of diverse features and technologies (stressed for instance by DSM, Motorola and Texas Instruments), had extensive integration requirements with others along with global supply chains (e.g., Bosch), and featured ever more customisation. The Medtronic case presented the example of the pacemaker which incorporated 195 US patents since 2001. In addition, some of the case studies indicated that the sheer number of products is on the rise and companies such as Bosch and Fagor Electrodomesticos have responded through a product development approach based on modularisation principles. Motorola has underscored the importance of synergies in the application of products to more than one market.

One response to the interdependence of different technologies has been the development of standardised, open, platform-based products in cooperation with partners. However, this is not to say that the outcome is a standardised product. On the contrary, such platform standardisation has allowed research costs to be controlled and technological complexity leveraged for competitive advantage particularly in sectors and markets in which competition on the basis of cost is no longer the main differentiator.

Efficiencies have been seen in the extent to which innovations can be re-used. The CEO from an electronics company argues: "We aim to develop basic tools that in the end do not make individual solutions necessary, we define common interfaces and thus reduce costs of R&D and finally for the product. Here you need to co-operate with external partners." Greater integration with upstream customers and downstream supply chains has enabled efficiencies from re-use (GDF Suez case).

Fagor Electrodomesticos took advantage of HOMETEK to enable the development of standards for the kitchen technology that advance interconnections across household appliance interfaces. Historically, due to Fagor's growth strategy of acquiring successful brands, each national operation often worked with its own technology platform for individual products. Since the creation of HOMETEK, a key focus has rested on introducing an element of standardisation to enable better collaboration between the R&D and engineering teams in different locations. This collaboration allows for a faster pace of R&D and innovation and increases the scale of R&D investment in each platform. The central R&D team has calculated that the current 49 platforms can be reduced to 31 to support the company's whole product range. However, the process of standardising has been and is a sensitive one, since each local/national engineering team felt ownership of a particular platform.

Texas Instruments has encouraged software re-use through toolkits and model applications across product generations and business units. However, investments were found to be needed to implement re-use approaches. Personnel transfer may be necessary and specialised management systems may be required to address complexity, customisation, and cost sensitivity in encouraging re-use and coordination of hardware and software. Of course, such strategies cannot be pursued in every industry and re-use is contingent on the technology and type of products. For the case study companies in the energy and chemical industry, such strategies were not found to be relevant.

Some cases point towards the importance of balancing costs and other corporate strategic objectives. The Rhodia case reveals the relevance of balancing its portfolio of key strategic technologies and competencies. Several cases (DSM, Texas Instruments) emphasised the joint strategic importance of cost management along with access to labour and market presence or innovation and market presence.

## **5 Conclusions**

This paper sought to examine the role of cost in the operational and locational decisions related to R&D of 17 large multinational companies in Europe and the USA. These findings are subject to several limitations. We interviewed one or two senior managers in each organisation, so their views may not constitute that of the majority, even though we did triangulate their responses with information from company annual reports and articles about company R&D. A small sample of multinationals was included in this study, and these multinationals were primarily headquartered in Europe, although balanced with a few US cases. These multinationals were in a handful of industries including information and communications technology, pharmaceuticals, energy, chemicals, electronics, aerospace, and media. Although these industries do not constitute a majority, they are particularly R&D intensive. Moreover, these interviews were conducted during a period of global economic downturn, so the extent to which they are applicable to other cycles is unclear. Within these limitations, the results deliver some of the first systematic data about how large companies respond to rising R&D costs.

The study shows that multinational companies have various reasons for establishing international R&D centres, but cost is not the primary reason. Some companies entered India and China to reduce costs as well as to access talent, but salary inflation was mentioned in association with these two countries in recent years. As international R&D centres become established in the cost structure, they simply become locations where costs can increase. It is therefore not surprising that ‘offshoring’ of R&D is undertaken for reasons other than to reduce R&D costs, as the literature on dynamic capabilities might indicate. Strategic factors related to R&D and innovation capabilities are as likely to be factors in setting up these locations as is cost (Phene and Almeida, 2008). Cost factors are taken into consideration in the establishment of international R&D centres, but over time dynamic capabilities are developed and new value creation becomes even more significant for locational decisions.

Collaboration is an important source of dynamic capability for companies to deal with the ever-changing R&D context, even if it involves additional costs. Collaborative approaches are manifest in various forms, many of which can be included under the umbrella term ‘open innovation’. Although there may be additional administration costs and inefficiencies associated with collaboration, the benefits far outweigh the costs according to many of our interview subjects. Collaboration facilitates specialisation, which allows risk and equipment to be shared and expertise to become flexible and virtual. These benefits extend over many years in the preparation and maintenance of R&D capability in specific competence areas. Open innovation may be used to increase the value of the investments (e.g., by selling patents on the market) as well as to contain costs (e.g., by sharing in-house facilities with external parties). The dynamic capability perspective in particular delivers arguments for increased collaboration which allows for flexible development, recombination and deployment of investments in R&D. This approach includes a tendency towards division of labour and sharing of risks for increasing R&D investments, rather than merely off-shoring for market reasons. This perspective also encompasses user-led research demand, and accessing a larger pool of patents.

Technology and innovation requirements also reinforce the need for collaboration. There is a growing need for multidisciplinary projects and the fusion of technologies and

research strategies (e.g., bioinformatics and electro-mechanical engineering). This also requires new interfaces between R&D and other functions in an organisation, such as marketing, sales, design, and strategy building and similarly with other organisations in the value chain. Some companies achieve collaboration through strategic partnerships with (several) universities. Others are doing it by focusing R&D on innovation objectives instead of scientific objectives.

We also identified a few differences across sectors. For firms in industries characterised by research equipment and infrastructure intensity (e.g., pharmaceuticals, energy), cost sharing models and new collaboration arrangements with other research organisations and universities have become more important. For companies which produce complex products consisting of a large number of elements (compared to for instance chemicals), modularisation and platform-based product development strategies have become more relevant.

The study suggests very clearly that spending on research was not primarily considered a cost that should be controlled, but seen as a strategic investment. The case studies indicate that the managers were not primarily concerned by or focused on cost reduction or cost containment. Instead decisions about R&D investment were based on expected value creation, risk and strategic competence development. There may be, of course, underlying cost related factors which may only be revealed with the passage of time. For example, after a few years of working in an open innovation environment some areas of 'outsourced' R&D may be perceived as 'unaffordable'. This means that the analysis and resulting narrative needs to be focused on 'the cost of doing research' rather than the cost of inputs at various stages of the research process or the accumulated cost of all research activity during the innovation process.

Value creation is the predominant emphasis of R&D managers. Cost does not appear to be a key factor in directing and managing R&D and responding to growing R&D costs. This is, though, not a pure 'either/or' decision between cost control and value creation (Godener and Söderquist, 2004). It does not mean that managers are not concerned with research cost, but rather that cost considerations follow investment decisions. Costs become most significant in special and typically disruptive circumstances – e.g., when the business is downsizing. This finding implies not that R&D managers, or scientists and technologists working in R&D can be profligate. It means that the intelligent focusing can have a much greater effect on the value of R&D on the business than cost reduction within the R&D department. It also means that reducing the risks associated with R&D investment and reducing the cost of failure by deciding more wisely 'what to do' is more important than just reducing the cost of 'how to do'. In this context, it is important for R&D managers and will become more important in the future to develop dynamic capabilities and business models that can adjust R&D to the changing technological, market and regulatory environment.

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## References

- Acs, Z.A. and Audretsch, D.B. (1988) 'Innovation in large and small firms: an empirical analysis', *American Economic Review*, Vol. 78, No. 4, pp.678–690.
- Amidon, R.D. (1996) 'The challenge of fifth generation R&D', *Research-Technology Management*, Vol. 39, No. 4, pp.33–41.
- Amit, R. and Shoemaker, P. (1993) 'Strategic assets and organizational rent', *Strategic Management Journal*, Vol. 14, No. 1, pp.33–46.
- Arora, A., Arunachalam, V.S., Asundi, J. and Fernandes, R. (2001) 'The Indian software industry: structure and prospects', *Research Policy*, Vol. 30, No. 8, pp.1267–1288.
- Arrow, K. (1962) 'Economic welfare and the allocation of resources for invention', in Nelson, R.E. (Ed.): *The Rate and Direction of Inventive Activity*, pp.609–619, Princeton University Press, Princeton.
- Bartlett, C.A. and Ghoshal, S. (1990) 'Managing innovation in the transnational corporation', in Bartlett, C.A., Doz, Y. and Hedlund, G. (Eds.): *Managing the Global Firm*, pp.215–255, Routledge, London.
- Birkinshaw, J.M., Hood, N. and Jonsson, S. (1998) 'Building firm-specific advantages in multinational corporations: The role of subsidiary initiative', *Strategic Management Journal*, Vol. 19, No. 3, pp.221–241.
- Buckley, P.J. and Casson, M.C. (1998) 'Analyzing foreign market entry strategies: extending the internalization approach', *Journal of International Business Studies*, Vol. 29, No. 3, pp.539–562.
- Chandler, A. (1990) *Scale and Scope*, MIT Press, Cambridge, MA.
- Chesbrough, H. (2003) *Open Innovation: The New Imperative for Creating and Profiting from Technology*, Harvard Business School Press, Boston.
- Chiesa, V. (2001) *R&D Strategy and Organization*, Imperial College Press, London.
- Cohen, W.M. (2010) 'Fifty years of empirical studies of innovative activity and performance', in Hall, B.H. and Rosenberg, N. (Eds.): *Handbook of the Economics of Innovation*, North-Holland, Amsterdam, Vol. 1, pp.129–213.
- Criscuolo, P. (2004) *R&D Internationalisation and Knowledge Transfer: Impact on MNEs and their Home Countries*, Dissertation, University of Maastricht.
- DiMasi, J. and Grabowski, H. (2007) 'The cost of biopharmaceutical R&D: Is biotech different', *Managerial and Decision Economics*, Vol. 28, Nos. 4/5, pp.469–479.
- DiMasi, J., Hansen, R. and Grabowski, H. (2005) 'Reply: extraordinary claim require extraordinary evidence', *Journal of Health Economics*, Vol. 24, No. 5, pp.1034–1044.
- Dunning, J.H. (1981) *International Production and the Multinational Enterprise*, Allen and Unwin, London.
- Dunning, J.H. and Narula, R. (1995) 'The R&D activities of foreign firms in the United States', *International Studies of Management & Organization*, Vol. 25, Nos. 1–2, pp.39–72.
- Eisenhardt, K. and Martin, J. (2000) 'Dynamic capabilities: what are they?', *Strategic Management Journal*, Vol. 21, Nos. 10–11, pp.1105–11021.
- Eisenhardt, K.M. and Graebner, M.E. (2007) 'Theory building from cases: opportunities and challenges', *Academy of Management Journal*, Vol. 50, No. 1, pp.25–32.
- European Commission (2009) *The 2009 EU Industrial R&D Investment Scoreboard*, Joint Research Centre, Institute for Prospective Technological Studies, Seville.
- Frost, T.S., Birkinshaw, J. and Ensign, P. (2002) 'Centers of excellence on multinational corporations', *Strategic Management Journal*, Vol. 23, No. 11, pp.997–1018.
- Gassmann, O. and von Zedtwitz, M. (1999) 'New concepts and trends in international R&D organization', *Research Policy*, Vol. 28, Nos. 2–3, pp.231–250.

- Gassmann, O., Reepmeyer, G. and von Zedtwitz, M. (2008) *Leading Pharmaceutical Innovation: Trends and Drivers for Growth in the Pharmaceutical Industry*, 2nd ed., Springer Verlag, Berlin-Heidelberg.
- Godener, A. and Söderquist, K.E. (2004) 'Use and impact of performance measurement results in R&D and NPD: an exploratory study', *R&D Management*, Vol. 34, No. 2, pp.191–219.
- Grabowski, H.G., Vernon, J. and DiMasi, J.A. (2002) 'Returns on research and development for 1990s new drug introductions', *Pharmaco Economics*, Vol. 20, No. 3, pp.11–29.
- Hagedoorn, J., Link, A. and Vonortas, N. (2000) 'Research partnerships', *Research Policy*, Vol. 29, Nos. 4–5, pp.567–586.
- Hamel, G. and Heene, A. (1994) *Competence-based Competition*, Wiley, Chichester.
- Helfat, C.E. and Peteraf, M.A. (2009) 'Understanding dynamic capabilities: progress along a developmental path', *Strategic Organization*, Vol. 7, No. 1, pp.91–102.
- Henderson, R.M. and Cockburn, I.M. (1996) 'Scale, scope and spillovers: the determinants of research productivity in drug discovery', *RAND Journal of Economics*, Vol. 27, No. 1, pp.32–59.
- Henderson, R.M. and Cockburn, I.M. (2001) 'Scale and scope in drug development: unpacking the advantages of size in pharmaceutical research', *Journal of Health Economics*, Vol. 20, No. 6, pp.1033–1057.
- Jaffe, A. and Lerner, J. (2004) *Innovation and Its Discontents: How Our Broken Patent System is Endangering Innovation and Progress, and What to Do About It*, Princeton University Press.
- Kostoff, R.N. (2012) 'China/USA nanotechnology research output comparison-2011 update', *Technological Forecasting and Social Change*, Vol. 74, No. 9, pp.1733–1747.
- Kuemmerle, W. (1999) 'The drivers of foreign direct investments into research and development – an empirical investigation', *Journal of International Business Studies*, Vol. 30, No. 1, pp.1–24.
- Leitner, K-H., Butler, J., Cerulli, G., Dunnewijk, T., Kampik, F., Kasztler, A., Meijers, H., Poti, B., Thomas, M., Trier, E., Slipersæter, S., Wintjes, R. and Youtie, J. (2011) *Analysis of the Evolution of the Costs of Research – Trends, Drivers and Impacts*, Final Report, Study Commissioned by DG Research & Innovation, Contract: RTD/B2/2009/COST-2009-01, September.
- Lewin, A.Y., Massini, S. and Peeters, C. (2009) 'Why are companies offshoring innovation? The emerging global race for talent', *Journal of International Business Studies*, Vol. 40, No. 6, pp.901–925.
- McGuckin, R., Mart van Ark, H., Dougherty, M. and Inklaar, R. (2006) *Appendices to 'Internationally Comparable Science, Technology and Competitiveness Indicators'*, Economics Program Working Paper Series EPWP #06-01, The Conference Board, New York.
- Mikkola, J.H. (2006) 'Capturing the degree of embedded in product architectures', *Journal of Product Innovation Management*, Vol. 23, No. 2, pp.128–146.
- Narula, R. (2002) 'Innovation systems and 'inertia' in R&D location: Norwegian firms and the role of systemic lock-in', *Research Policy*, Vol. 31, No. 5, pp.795–816.
- Narula, R. and Zanfei, A. (2005) 'Globalization of innovation: the role of multinational enterprises, in Fagerberg, J., Mowery, D.C. and Nelson, R.R. (Eds.): *The Oxford Handbook of Innovation*, pp.318–345, Oxford University Press, Oxford.
- Pammolli, F., Magazzini, L. and Riccaboni, M. (2011) 'The productivity crisis in pharmaceutical R&D', *Nature Reviews Drug Discovery*, Vol. 10, No. 6, pp.428–438.
- Phene, A. and Almeida, P. (2008) 'Innovation in multinational subsidiaries: the role of knowledge assimilation and subsidiary capabilities', *Journal of International Business Studies*, Vol. 39, No. 5, pp.901–919.
- Plotnikova, T. (2010) *Success in Pharmaceutical Research: The Changing Role of Scale and Scope Economies, Spillovers and Competition*, Jena Economic Research Papers No. 045.

- Scannell, J.W., Blanckley, A., Boldon, B. and Warrington, B.J. (2012) 'Diagnosing the decline in pharmaceutical R&D efficiency', *Nature Reviews Drug Discovery*, Vol. 11, No. 3, pp.191–200.
- Schmid, S. and Schurig, A. (2003) 'The development of critical capabilities in foreign subsidiaries: disentangling the role of the subsidiary's business network', *International Business Review*, Vol. 12, No. 6, pp.755–782.
- Schuhmacher, A., Gassmann, O. and Hinder, M. (2016) 'Changing R&D models in research-based pharmaceutical companies', *Journal of Translational Medicine*, Vol. 14, No. 105, DOI: 10.1186/s12967-016-0838-4.
- Shields, M.D. and Young, S.M. (1996) 'Managing innovation costs: a study of cost conscious behavior by R&D professionals', *Journal of Management Accounting Research*, Vol. 6, No. 1, pp.175–196.
- Teece, D.J. (1980) 'Economies of scope and the scope of the enterprise', *Journal of Economic Behavior and Organization*, Vol. 1, No. 3, pp.223–247.
- Teece, D.J. (2007) 'Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance', *Strategic Management Journal*, Vol. 28, No. 13, pp.1319–1350.
- Teece, D.J., Pisano, G. and Shuen, A. (1997) 'Dynamic capabilities and strategic management', *Strategic Management Journal*, Vol. 18, No. 7, pp.509–533.
- Verona, G. (1999) 'A resource-based view on product development', *Academy of Management Review*, Vol. 24, No. 1, pp.132–142.
- Wernerfelt, B. (1984) 'A resource-based view of the firm', *Strategic Management Journal*, Vol. 5, No. 2, pp.171–180.
- Williamson, O. (1975) *Markets and Hierarchies*, Free Press, New York.
- Yin, R.K. (2003) *Case Study Research: Design and Methods*, Sage Publications, Thousand Oaks, CA.

## Appendix A

### Overview of case study organisations

<i>Name</i>	<i>Location</i>	<i>Sector</i>	<i>Position of the interviewees</i>
Boehringer Ingelheim	Austria	Pharmaceuticals	Administrative Director of the R&D Unit
Bosch	Germany	Automotive	Director Coordination Technology
Avio	Italy	Aerospace	Head of RTD
Eni	Italy	Energy	Vice President Technology Planning R&D Department
Bracco	Italy	Pharmaceuticals	Director Research Centre
GDF Suez	France	Energy	Director Research Centre Research Program Manager
Rhodia	France	Chemicals	Vice President R&D Head of Finance R&D
Fagor Electrodomesticos	Spain	Electronics	R&D Director
Motorola	USA	Telecommunications	Director of Research

*Overview of case study organisations (continued)*

<i>Name</i>	<i>Location</i>	<i>Sector</i>	<i>Position of the interviewees</i>
Medtronics	USA	Electronics	Vice President of Innovation Excellence
Tellabs	USA	Electronics	Research Fellow
Texas Instruments	USA	Electronics	Senior Research Fellow
DSM	The Netherlands	Chemicals	R&D manager
Philips	The Netherlands	Electronics	R&D control
TELENOR	Norway	Telecommunications	Research Director
Astra Zeneca	UK	Pharmaceuticals	Portfolio Manager
Rolls-Royce	UK	Aerospace	Research Director

**Appendix B***Main themes of the interview guideline*

## Interview guideline

## 1 Development of R&amp;D costs

How have the components of R&D costs (wage, capital, material, etc.) developed in the last five years?

Have these been steady-state changes or disruptive changes?

How do you expect that R&D costs will change in the next five years?

## 2 Drivers for the costs of R&amp;D

What have been the main drivers for the costs of R&D? (e.g., regulation, market competition, complexity of the process, funding)?

How important are spillovers in your company? Do spillovers have an impact on the costs of R&D?

What effect has the market environment on the costs of R&D?

## 3 Management strategy

What is the relative importance of costs of R&D (compared to access to labour, closeness to market, get ideas from outside, etc.) for defining your research strategy?

Is your management focus more on cost control (e.g., salaries, outsourcing) or on increasing the output and outcome of R&D (licensing, new business models, etc.)?

What have you done in the past years to contain the costs of R&D in our company? (e.g., outsourcing, strategic alliances, terminating projects at an early stage, platforms, new business models)?

What is the relative importance of costs of R&D for defining your R&D budget?

Have you closed any R&D locations in the past? What have been the reasons?

To what extent do changes in the costs of R&D have an impact on location decisions?

In which locations do you intend to expand your R&D activities in the future?

What are other strategies you may pursue to contain the costs of R&D in the future?

4 R&D cost indicators

How do you measure the costs of R&D?

How do you define and measure R&D productivity?

Do you think research productivity has grown in the last ten years? What have been the driving forces for the development of productivity?