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# HOW CAN WE STUDY INNOVATION SYSTEMS?

## - introducing an actor-centralised perspective

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# How can we study innovation systems?

## Introducing an actor-centralised perspective

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**Abstract**
The systems of innovation approach has helped advocating a view on innovation as dependent on the interaction over time between different actors and brought the role of institutions to the center of interest. However, the approach has remained a general framework rather than evolved into an analytical tool for the study of the dynamics of innovation activities. In this discussion paper, we introduce the concept of innovation system services, defined as the set of factors that have a significant potential influence on the opportunities of a certain groups of actors to perform a certain type of activities efficiently. We suggest that the relevant innovation system for the actors-activities nexus at hand can be defined as this set of system services. We examine this analytical framework in a case study on R&D investments of multinational enterprises in Sweden. In this context, innovation system services are defined as the set of external factors that the case study suggests to have significant impact on the decisions of MNEs to invest in R&D in Sweden. The focus on services allows us to analyse the influence of an innovation system on the long-term development of R&D in Sweden in a structured and coherent manner and to identify critical dynamics.

**JEL-codes: D29, O31, O32**

# 1. Introduction

Starting in the works of Freeman (1987) and Lundvall (1988), the systems of innovation approach (SI) has influenced the thinking of both academics and policy makers. The approach emphasises the interlinked nature of innovation processes and advocates a systemic view of these processes. As systemic, we understand such approaches that conceptualises "innovation" as an interactive activity with learning feedback loops from market to R&D and reverse (Kline and Rosenberg 1986; Dosi 1988).

Inspired by the same underlying "systemic" approach but recognising that for certain sets of problems, other system boundaries than those of national borders can create more appropriate definitions of a system, other scholars have contributed to the emergence of parallel streams of research. The technological systems approach, which studies interactions between actors in a shared techno-economic system, is strongly associated with Bo Carlsson (see e.g. Carlsson, 1997). Phil Cooke is one of the leading scholars discussing regional innovation systems; a variant of the national systems of innovation concept that sets the regional arena in focus (Cooke, 1992). Arguing that industry sectors often is a more relevant definition of the systems where innovations emerge, Breschi and Malerba (1997) advocated a sectoral innovation systems approach.

Common to all four variants of the innovation system approach is the focus on economically useful knowledge and on the creation, diffusion and use of this resource. The SI approach has emphasised the insight that innovations are processes of interactive learning, implicating that reciprocal flows of knowledge are essential for successful innovation, thereby reminding researchers of the importance of relations to external organisations for the innovative, knowledge-intensive firm. To gain, develop and exchange various kinds of knowledge, firms need to be embedded in a productive context. The SI approach has been successful, insofar that it has received certain attention from scholars and, to an even larger extent, from policy makers. However, the approach suffers from both practical and theoretical shortcomings.

As a response to the failure of mainstream neo-classical economics to incorporate networked innovation in a convincing manner, SI approaches have created a (rather a-theoretic) framework where the focus is on exactly those features that are absent in the mainstream analysis. In doing so, the ability to relate macro economic patterns to the behaviour of firms and individuals has, however, been lost. The aggregated indicators of generation, diffusion and use of knowledge that are typical for empirical papers citing the SI approach are generally difficult to interpret in a robust manner. Is

the generation of knowledge in the system, as measured by the number of patents or R&D personnel, too small, too large or optimal? The SI approach offers no robust guidance on how to evaluate or analyse such questions.[1]

With its focus on interdependencies between organisations and institutions over time, the SI approach has significant relevance as a general framework for innovation studies. However, the schematic SI approach has, as a consequence of its shortcomings, "… been used more as a label than as an analytical tool" Edquist (2005). To move from visualisation of complexity and relations to analysis of the workings of innovation systems, empirical efforts are needed. And in order to use the SI framework as a basis for generating hypotheses that can be tested in empirical work, the conceptual ambiguities must be reduced and specific applications of the systemic framework must be developed.

In this paper, we present an attempt to operationalise the studies of innovation systems. We argue that the analytical use of the SI approach in empirical studies can be advanced if the innovation system is defined as a set of services delivered to a particular group of actors.

# 2. Systems of innovation – concept or tool?

The innovation system approach has its roots in a realisation that a systemic view of a nation's organisations and institutions (the components of the national innovation system) and their interaction can complement orthodox economic theory in analyses of how innovations emerge and diffuse. The intellectual roots of this insight can be traced back through evolutionary schools of economic study with representatives such as Richard Nelson and Joseph Schumpeter to a long tradition of studies of the behaviour of systems which has come to dominate in such seemingly separated fields as engineering, biology and organisational theory.

Edqvist (2005) suggests that the most important scholarly task to enable sound empirical IS analysis is to address the more theoretical shortcomings of the approach. He further argues that to develop the SI approach towards a more "theory-like" approach, the theory's roots in "general systems theory" should be revitalized and utilized. Two stylized facts of the tradition of quantitative systems analysis can be used to illustrate and support Edquist's point.

[1] An attempt to discuss this issue is made by Bergek et al. (2005) who suggest two bases for assessment of the functionality of an innovation system to be used in parallel: industry life cycle models and system comparisons

First, the tradition of system studies emphasises that a system is defined by its components and the interaction between these elements (Laszlo, 1996). Quantitative system studies are for example strongly focused on analysis of the dynamics of the system (in social systems, the relevant dimension is usually temporal dynamics, see e.g. Sterman 2000). However, in studies citing the SI approach, the concept of a system is merely used as a reference to the broader context in which the particular study is placed and a framework to which various aggregated indicators can be related; the actual dynamics of the innovation system is only rarely addressed or studied (Hekkert et al. 2006). This problem may partly be related to the fact that the study of relations between components if often found to be more difficult that the study of the components themselves. This problem is for example reflected in the data that is available for research from national bureaus of statistics. The most commonly studied indicators of innovation are measures of the components of the system, such as patent activity, number of employees in high-tech sectors, R&D spending etc, whereas "flows" of commercial ideas and innovations, which may be proxied by such measures as labour mobility, collaborative exchanges and IPR-trade are more seldom captured by national statistics. However, these empirical problems do not justify the insufficient attention paid to the dynamics of a studied system.

Secondly, the systems tradition emphasises the task of defining the borders of a system as the most central part of research design (Carlsson et al., 2002). This task, it is argued in modern systems theory, should be guided by the immediate research question at hand. A description of a system that is not accompanied by a specific research question does not carry any meaning. This basic insights is often absent in studies citing the IS-approach, where an innovation system is often discussed as an entity of its own right. The lack of robust empirical enquiries into the actual dynamics of innovation systems can be interpreted as a consequence of the broad definition of the system embodied in all SI approaches. As defined by Edquist (1997), the system of innovation includes "all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations". With such a definition, it is no wonder that empirically oriented research has difficulties in making the SI approach operational.

Johnson (2001) presents an interesting attempt to address the shortcomings of the SI approach. She suggests that rather than the traditional focus on the components of the system and measurement of the performance of the system "as a whole" through different indicators of innovation – an approach championed by e.g. Niosi et al. (1993) – it is fruitful to study "system functions". Focussing on the different functions of a system has a number of analytical advantages: it allows us to assess

and discuss the performance of the system in an informative manner, calls upon identification of bottlenecks hindering more effective functionality. Perhaps even more importantly, a focus on functionality provides a tool for setting system borders – certainly one of the most problematic areas in research following the innovation system approach. Later work has identified five functions served by a technological innovation system: to create and diffuse 'new' knowledge; to guide the direction of the search process among users and suppliers of technology; to supply resources, including capital, competencies and other resources; to create positive external economies through the exchange of information, knowledge and vision; and to facilitate the formation of markets (Johnson and Jacobsson, 2001).

While the focus on "functions" seems appealing from an analytical perspective, it is not clear to what extent the functions identified by the authors cited above are useful for empirical analysis. Many of the listed functions are slightly abstract and indirect; it is not clearly analysed how these functions actually benefit actors in the innovation system. In this matter, the SI functions approach is inheriting a focus on the "performance" of the system from the SI tradition. In fact, the tendency to consider the system as a whole rather than its individual components as the primary unit of analysis is strong in the majority of systems approaches to innovation, as is a tendency to seek to compare the performance of different systems (Carlsson et al., 2002).

To avoid some of the conceptual fuzzieness associated with analysis of "a system" while preserving a systemic view on innovation, we suggest that we need to move the point of analysis from the level of a system to the perspective of a defined group of actors in the system (c.f. Kaufmann & Tödtling, 2001). Moreover, we must determine what aspect of the group of actors that we are interested in studying, i.e. focus on a type of activity carried out by the actors. In other words, we propose an actors-activities nexus as the centre of analysis. For a particular actors-activities nexus, we define the relevant innovation system services as the set of factors that have a significant positive influence on the opportunities of the actors to perform the activities efficiently. This line of reasoning leads us to define the system of innovation as a set of services delivered to the actors-activities nexus. To identify these services, a researcher has to rely on empirical evidence, guided by the theoretical framework of the field of innovation studies. The question of whether to analyse systems of innovation dominated by geographic (nation, region) or sectorial factors then becomes an issue of which factors best fits the empirical evidence on the nature of the system services.

In the following section, we demonstrate the applicability of an innovation system services approach through the case of corporate decisions about how corporate decisions about the most advanced R&D of multinational firms are influenced by the strength and weaknesses of the Swedish innovation system.

# 3. Decisions about advanced R&D of multinational firms in Sweden

Research and development activities have been found to follow the general trend towards increased geographic distribution of corporate activities much slower than e.g. production (Carlsson, 2006; Narula, 2002). However, R&D is clearly spreading; both so that the R&D activities of MNEs become more distributed and so that R&D activities outside the "triad" (Europe, US and Japan) has risen for a long time (UNCTAD, 2004). Recent evidence suggests that this expansion may have stagnated (Gammeltoft, 2007). However, there is strong evidence that R&D activities are increasingly managed in a "globalised" manner. Early studies of multinational R&D assumed that economies of scale created a drift towards concentrating R&D to the home country, which in some cases could be outweighed by specific advantages of locating R&D in a "foreign" country. In this simplified view, an MNE was perceived as determining "the location of its R&D by reconciling centripetal and centrifugal forces" (Hirschey and Caves, 1981, cited in Pearce, 1999). Later studies emphasise complex interaction between three types of factors: (1) needs to follow international markets with R&D activities, (2) needs to adjust the R&D organisation to the increasing globalisation of production and (3) needs to tap into local fields of expertise (Edler & Meyer-Krahmer, 2002). Trends to emphasise streamlining of corporate R&D organisations to avoid overlapping R&D expertise where possible counteract this trend to some extent, but may also contribute to exodus of R&D from a traditional center ("home-base"), for example when firms acquire new R&D resources and decide to de-invest in the home-base in order to concentrate certain tasks to the new location.

A growing number of studies find that while location forces related to markets and production dominate the broad picture, knowledge augmenting activities grow more important over time (Narula, 1999; Narula & Zanfei, 2004; Criscuolo et al., 2005). With its small home market and a recent exodus of production, Sweden is an interesting place to study the role of the knowledge-related factors of an economic system to the attractiveness for R&D location. In this case study, we

employ the research purpose of studying how innovation system factors influence multinational firms' decisions about R&D investments in Sweden.

To investigate the dynamics behind decisions about R&D location, we decide to select an "extreme" sample, in that we settle for fresh investment initiatives in advanced R&D activities of MNEs. As the most advanced part of firms' R&D has been found to be least mobile (von Zedtwitz & Gassman, 2002), we decide to delimit our enquiry to the most advanced R&D activities, sometimes referred to as the R part of R&D. We specify this selection as follows: we study all events where one of the 20 largest spenders on R&D in Sweden have declared an intention to make major new investments in advanced R&D within Sweden in the five year period 2002-2007. To identify such events, we identify the 20 top spenders from data provided by the Swedish Institute for Growth Policy Studies (ITPS, 2007) and scan the annual reports for 2003 to 2006 for all the companies. We also search a Swedish media archive with all combinations of the search terms "R&D", "research", "investment", "invest" and "increase" (in English and with Swedish translations) with the names of the companies.[2] This selection procedure leaves us with eight events.[3]

| **Firm** | **Type of event** |
|---|---|
| Alfa Laval | Increased R&D spendings by 50% between 2004 and 2006. Explicit strategy to concentrate R&D to Sweden. |
| AstraZeneca | Further development of the global center of excellence for neurology in Södertälje, including investments in new lab facilities. |
| Ericsson | Announced ambition to double research investments over 2007-2009, with emphasis on Sweden. |
| Gambro | Increased budgets for Corporate Research unit in Lund, Sweden, by 150 % between 2003 and 2006. |
| Saab Automotive (GM) | A new centre for hybrid technology has been established in Trollhättan. |
| Sandvik | A new lab has been constructed in Västberga, Stockholm. |
| SKF | The firm has grown the R&D center for production development in Göteborg strongly over the period. |
| Volvo Cars (Ford) | Announced plans in June 2006 to build new centre for hybrid technology in Göteborg, to serve as center of excellence for the Ford corporation. |

Table 1: Identified events

To study the identified cases, we interview at least one R&D manager at the corporate level identified as active participant in the decision making process. Where possible, we complement this view with an interview with an R&D manager at an operational level, who has been involved in the execution

[2] Retriever, http://www.retriever-info.com

[3] Top level R&D managers of four further corporations with substantial R&D (Volvo, ABB, Scania, Electrolux and SAAB) have been interviewed in order to establish that no investment of the type which we seek to study has occurred during the period.

of the announced investment plans. The 14 interviews were performed following a semi-structured interview guide.[4] All interviews were recorded and transcribed.

## Alfa Laval – maintaining a Swedish focus through expansion

Alfa Laval traces its roots back to the beginning of the twentieth century, the first prototype of the company's signature product the dairy separator being displayed already in 1879. The company is currently a leading producer of engineering solutions and products intended to heat, cool and transport fluid. Alfa Laval can be found in almost 100 countries around the world and their sales for 2006 amounted to €2.1 billion. The firm has increased R&D spending by 50 % between 2004 and 2006 (although R&D as a share of turnover has remained constant throughout the period).

The firm has followed a main strategy of maintaining a technological lead through acquisition of firms that holds technological assets complementary to those of the corporation. In addition, the firm maintains a secondary strategy to concentrate its most knowledge intensive R&D to Sweden, where 200 of its 300 research engineers are located. While the firms acquired by Alfa Laval have brought new products and technologies to the corporation, very limited R&D resources has so far been brought into the firm through acquisitions. R&D resources of acquired firms have generally stayed within the new subsidiary but have not been further developed by Alfa Laval. However, the firm also maintains and expands its engineering hubs devoted to development and product adjustments in e.g. India, Russia and China, as a necessary response to market demands. Respondent #1 has global responsibilities for technology. He describes the concentration strategy of the firm as a viable long term option.

So far access to labour has not been a problem for Alfa Laval's central R&D team in Lund. However, there is a certain shortage of personnel in the smaller Tumba facility. Collaboration with other actors has not been very emphasised until recent years. Respondent #1 states, that under the previous management and with private ownership, the corporate culture was one of risk taking, which reduced the need to share risks and costs with external partners. In the late nineties, the corporation was split up and the Alfa Laval part of the firm returned to the stock market, where demands on reduction of risks and costs are constantly pressuring the firm. The need to share risks and the increased "applied" focus of the firms' R&D has created new needs for external linkages. In

[4] Respondents #10 and #11 and respondents #15 and #16 were interviewed jointly.

recent years the firm has for example participated in EU-financed R&D projects and commissioned research to university partners, in particular to universities in southern Sweden and a few other European universities with good reputations.

The increased importance of external relations is illustrated by the introduction of a new technological platform for the product area plate heat exchangers. According to respondent #2 who leads this effort, the new platform is expected to open up for a range of products which may constitute one third of turnover within a decade. In this work, Alfa Laval builds on existing competences and expertise in heat exchange technologies, but apply it to a different set of problems. To accomplish this, the firm finds it very useful to work with university researchers, mainly at Swedish technical universities, but also with a number of French universities. According to respondent #2, local linkages are seen as advantageous in two respects. First, for advanced technological collaborative projects, the language barrier to France and Germany may reduce the efficiency of the collaboration. Second, interaction with Swedish higher education institutions may allow the firm to affect educational and research agendas, thereby securing future access to collaboration partners and potential employees for the firm's Swedish R&D centres. For Alfa Laval, with its relatively limited resources for advanced R&D, local linkages and strong traditions seem to outweigh potential gains from distributing R&D spendings more widely.

## AstraZeneca – sustained commitment and new lab facilities

AstraZeneca is a multinational pharmaceutical company formed in a 1999 merger between Swedish Astra and British Zeneca. With 66,000 employees and a turnover of €18.2 billion, the firm is one of the ten largest pharmaceutical firms in the world. While corporate headquarters are located in London, AstraZeneca's R&D site in Södertälje is the global headquarter of the corporation's R&D organisation. The Södertälje site also harbours the global center for neurological research related to CNS and pain control. The corporation's efforts in this area are directed towards treatments for Alzheimer's disease and MS. The corporation has invested strongly in these areas, and the Södertälje Discovery unit for CNS and pain control has grown to some 250 employees. In 2006, extensive new laboratory facilities were inaugurated.

The corporation's decision to focus its CNS and pain control research to Sweden is described by Christer Köhler (responsible for this research on a global basis, respondent #4) as a result of a strong

Swedish tradition in these areas. While relations to other R&D-performing firms are of secondary importance ("There are only two or three biotech firms in the area which I see as potentially important for us"), the respondent describes the academic environment of Karolinska institutet as an important center of scientific expertise in these areas and the strongest traditional partner of the R&D unit. Respondent #4 states that the local linkages, described as a blend of formal and informal relations and including mobility of personnel between the firm's site and the local medical university Karolinska institutet, are a very important source of impulses.

According to Sverker Ljunghall, Director of Science relations at AstraZeneca (respondent #5), some 100 researchers in Södertälje combine a position at the firm with active positions at an academic institution. The respondent states that the Södertälje unit already has "thousands" of external partners, but foresees growing reliance on external R&D. The firm has a 50-50 vision for the balance between in-house and external efforts. In this context, respondent #4 is concerned about a perceived downturn in academic pharmaceutical and clinical research, which may affect future decisions about R&D investments in Sweden.

Salary levels are also a problem for AstraZeneca's recruitment of researchers. "We are unable to do certain recruitments as the Swedish tax levels make it impossible for us to offer the net wages expected by top candidates," states respondent #4. The low wage-level in Sweden does, to some extent, compensate for these problems.

Dr Köhler sees increased long-term funding for research, concentrated to certain areas, and committed support for science in basic schooling as the two key ingredients needed to restore confidence in Sweden as a competitive location for AstraZeneca's R&D.

## Ericsson – expansion at home base

Ericsson Research is one of the most advanced corporate research organisations of the modern world. While many corporate R&D functions have been turned into contract organisation serving internal (and often external) corporate customers, Ericsson Research still uses 70 % of its budget in projects initiated by the unit "on its own". However, Ericsson's corporate R&D has gone through a series of changes in the last decade, with a major reduction of budgets in some areas. In January 2007, Ericsson R&D Manager Håkan Eriksson announced a predicted doubling of the firm's research capacity in terms of research personnel from the hitherto level of 500 people. No increase in

the total R&D budget was foreseen – the increase of researchers was thought to be afforded through efficiency gains and internal reallocation of funds from development to research. Three areas have been pointed out as focal points for new research investments: multimedia, ip-based solutions for integration of fixed and mobile networks and the future of mobile network technology. Of the 500 researchers at Ericsson, about 300 currently work in Sweden. While not specifying where the additional researchers were to be employed, Håkan Eriksson described a planned "dramatic increase" of the number of researchers in Sweden, thought to maintain the relative dominance of Swedish locations for Ericsson research throughout the expansion.

The respondents both state that Ericsson sees Sweden as an advantageous location for R&D, and that the activities of Ericsson Research are not dependent on proximity to the firm's production. While the location of research may be determined by political and market-related factors, the availability of talented people is a key factor for the choices about where to expand the most advanced R&D.

The availability of collaboration partners is a very important factor for the firm. According to respondent #6, Ericsson puts special value on what is referred to as a beneficial cultural climate for collaborative efforts, which increases Sweden's attractiveness as a research location. There is a strong tradition of developing complex systems in Sweden, which is very important for Ericsson. The firm can have particular R&D tasks done in India, but integrative R&D close to its complex products is best done in their Swedish R&D labs.

Both respondents (#6 and #7) see Sweden as a strong option for future research investments. For a location to be truly attractive for Ericsson, it must feature co-location opportunities with strong universities and other public research institutes and firms with matching competences. A good example of this is Kista in Stockholm where close co-location facilitates collaboration and access to talent for recruitment. To further facilitate collaboration public financial support schemes are said to be extremely important.

An important point to note is that the closer the objective of collaboration is to the market, the more difficult is it to collaborate successfully over a distance. According to respondent #7, even the distance between different regions within Sweden may be too great to allow efficient collaboration when collaborating on projects closely related to the firm's complex technical products. For early phases, such as standardisation R&D, Ericsson must work with other firms outside Sweden and,

preferably, with university researchers. Collaborative projects financed by the EU are described as an important vehicle for such efforts.

The opinion that collaboration in itself can work smoothly on a distance in the "Research"-phase does not, however, mean that Ericsson is not dependent on "basic" research capacities in Sweden in order to perform research in Sweden. According to the respondents, the firm cannot recruit without excellent research milieus in the local environments. The firm is supporting some local milieus with high standards through collaborative projects to help secure future recruitment.

## Gambro – new research venture gone abroad

Gambro was started in 1964 to commercialize its founder's invention of an artificial kidney. The company has its roots in Lund in Sweden and has since expanded through both organic growth and a number of acquisitions.

In the period 2003-2006, Gambro more than doubled its (admittedly small) budgets for its Corporate Research unit in Lund while maintaining the number of employees at a level of about 70 people. The Chief Science Officer of Gambro, Dr Maris Hartmanis (respondent #8) explains that the budget expansion is a result of a corporate level decision to enter a new strategic R&D area through increased external R&D. The firm is a leading developer of products, therapies and services for home dialysis and blood purification. However, recent scientific advances in the area of stem cell research bear the promise that the types of syndromes for which renal treatment is needed may be treatable. Such advanced is good new for renal patients all over the world, but something of a mixed joy for the firm that makes a living of supplying the necessary technology for current treatment. In 2005, Gambro therefore decided that if someone is to achieve a breakthrough with regenerative medicine based on stem cell research, it must be the firm itself. The respondent, who has a background as researcher in life sciences, was recruited to lead this endeavour which was given an initial budget of 120 MSEK over three years, most of which is committed to externally funded research.

To build competence within this new field, the firm saw it as natural to turn to publicly funded institutions for collaboration. For Gambro, which has its R&D centre in Lund and a small corporate headquarter in Stockholm, collaboration with the leading Swedish medical university Karolinska institutet would seem a good alternative. However, the respondent states that previous experience

with setting up new relations to this university, and to universities in Sweden in general discouraged him; the bureaucracy that the firm encountered in previous contacts had slowed their processes down immensely. Thus, for its stem cell initiative, Gambro utilised its contacts with universities in Stuttgart (DE) and Denver (US). These institutions were able to present standard legal solutions which were used to speed up negotiations and, according to the respondent, "understood our sense of urgency in this matter".

As a result of this experience, all of Gambro's R&D investment for stem cell research has ended up outside Sweden. The respondent also describes it as very likely that if the initiative proves successful, and the firm decides to invest in more in-house R&D in this area, these activities will be built up around the existing linkages between universities and the firm's local smaller R&D departments. The Lund facilities and Sweden will in this case loose out on what might otherwise have been new national R&D jobs.

The respondent describes both local competence and opportunities for public co-financing of research as important prerequisites for the establishment of a new initiative of the present kind, where collaboration with external partners is an essential element. In his opinion, both former factors were present in the case of Karolinska – the decision to locate R&D outside Sweden was in this case a consequence of failure of interest and responsiveness on behalf of the proposed collaboration partner.

## Saab Automotive – finding a place in a global organisation

Saab has its roots in the aeronautical industry and was originally founded to build war planes in 1937. After the Second World War the company began to produce automobiles. Since 1991, Saab Automotive is a wholly owned subsidiary of General Motors (GM). This multinational corporation, which until very recently was the worlds largest carmaker (now superseded by Toyota), has extensive car development and research efforts ongoing throughout the world. In total GM has around 1.000 people working on hybrid technology, whereof at least 850 are located in the U.S. R&D interest for hybrid technology is spurred by growing market demand.

Within GM, there is a general attempt to focus operations to the US. Respondent #9 describes the particular US-Swedish situation as a balance act between the potential cost-reduction effects of focusing and the lower price on R&D personnel in Sweden. In 2007 a new R&D centre for Hybrid

motor technology was opened in Trollhättan, the traditional centre of Saab production and R&D. According to Ingemar Nilsson, R&D manager in Trollhättan (respondent #9), the corporation needs a European center of excellence hybrid technology development to be able to successfully incorporate this technology in European production facilities. The center in Trollhättan is tasked to create a hybrid technology option within the current SAAB platform, and then make this technology available to GM, to be integrated in global car platforms.[5]

The fact that Volvo Cars and Volvo Technology (the latter a part of the Swedish VOLVO group, the former a subsidiary of the Ford corporation) were building competence in hybrid technology at the same time does not seem to have hampered recruitment for the new center. According to respondent #9, there was nobody in Sweden who had ever worked with this technology before anyway (and hardly anyone in other parts of Europe). The firm has recruited some people that have experience from working with high voltage technology, for example from [the Swedish subsidiary of] ABB. Respondents #9 and #10 agree that the presence of other advanced firms has been and continues to be important for recruitment. It has not been difficult for the company to attract qualified R&D personnel, and they believe that there are enough qualified doctoral students available to meet the company's current recruitment needs.

The vehicle industry is the largest receiver of public R&D subsidies in Sweden (Vinnova, 2007) and SAAB has over the past years participated in a number of government-funded R&D schemes intended to support car development in Sweden. Several of these projects and programmes have revolved around the development of hybrid engine technology and have involved the creation of university courses to build national expertise on the subject. It is noteworthy that the first hybrid technology project in Trollhättan was funded by the government. In 2004, public R&D funding was offered through a large government programme, which was partly triggered by GM's threats to invest in its German subsidiary at the expense of Trollhättan. The current subsidy program will expire in January 2008. Judgment on it's continuity has yet to be revealed. However, in 2007 a new hybrid competence center has been set up at Chalmers University of technology where Saab together with Swedish truck manufacturers Scania and Volvo collaborates with strong financial support from the Swedish government. Volvo Cars is not participating, rather choosing to rely on its own centre of excellence described below.

[5] Cars are built on specific platforms that often do not change at all between model years. The same platform, which consists of the undercarriage, suspension system etc. can perhaps even by used for ten years, while the look, feel and other aspects of the vehicle are changed.

While it is difficult to evaluate whether the company would have initiated a hybrid initiative in Sweden in the absence of such a research program, the respondents agree that government subsidies is an influential factor. More generally, external contacts and options for external co-funding of research is seen as increasingly important. The local R&D department, which was created in 2005, is located close to the factory floor and belongs to the production department. The aim of this centralization of the previous project-based organization was to increase internal coordination and continuity, and to increase the firm's abilities to manage external R&D and apply for external funding.

The R&D division in Trollhättan is described by respondent #9 as working in close contact with colleagues in the U.S. and Germany and, increasingly, with centres in Asia. The respondent states that this global network is more important to Saab than the domestic one, and that this development is accentuated over time. In terms of domestic relations, a number of universities are the most important partners. These relations include a number of jointly sponsored PhD-candidates. Cooperation with other firms in Sweden is relatively uncommon because of competitive issues. In this aspect, however, the local "Innovatum" platform represents an important exception. Through this regional organization (sponsored by the regional administration of Västra Götaland) and the public funding schemes SAAB can create collaborative contacts with partners and competitors on "neutral grounds". To facilitate such collaboration, Saab has re-localized part of the 50 research personnel working with hybrid motor technology to Innovatum.

Respondent #10 claims that initial success will pave the way for a continued R&D effort in Sweden: "I believe that we are going to be able to grow this Swedish center of expertise further. We have built competence acknowledged by GM, which has resulted in some further commissions on advanced corporate research projects. The fact that we were able to create this competence with a modest infusion of cash from GM has created very positive attitudes towards the research system of Sweden."

## Sandvik – new lab with old roots

Sandvik was founded in 1896 after its founder was the first individual to be able to use the Bessemer method for steel production. Today, the company has a number of competitors offering interchangeable products, which creates the needs for constant innovation and improvement to

remain competitive. In 2003, Sandvik established a new R&D centre in Västberga, Stockholm. The lab, which represents a significant investment in terms of facilities and equipment, serves as competence center for the area "hard materials" for the Sandvik group. The director of the lab, Dr Ulf Rolander (respondent #12) sees the choice of Västberga as location for this investment as strongly influenced by historical factors. "We were considering different locations for the lab, but all of them were within the Stockholm region. Even Sandviken [where the firm has its global headquarters] would have been an impossible choice if we did not want to build the lab starting from scratch. We had considerable human R&D resources spread out over a number of environments around Västberga."

The centre in Västberga belongs to the Sandvik Tooling division which can be defined as a business area within the company. Within the centre, all steps in the production of Sandvik Tooling products are found; quality control, classification of material and other tasks in the product creation chain. Even if the main task of the center is R&D for hard materials it includes a large production center that can produce a considerable volume of some of their products. 140 people work in the Västberga center, among those a large number of engineers and a handful with PhD level education. Most of the work being done in the research center is to find replacement products that are of higher quality and effectiveness than the products they replace. Work on totally new products and processes are a smaller part of the work being done.

Around 10-15 doctoral students partly financed by the company are associated with the Västberga lab. Although their work generally is not directly focused on Sandvik products, these contacts are described as very valuable by respondent #12. Not only does the more general work done by PhD students generate impulses to innovation at the lab, but the collaborative mode of working also helps secure recruitment needs for the lab and for Sandvik. Through collaboration, the firm is able to scan candidates for recruitment and, in fact, affect research agendas of entire academic research groups. Through its well-established contacts to a number of academic environments, a joint-knowledge network has been established with Sandvik as a central node. There are also benefits in working with the universities because they in some cases have very specialized and expensive research equipment, the purchase of which would be hard to justify for Sandvik.

Dr Jan-Olof Nilson (respondent #13) has at the time of the interview recently been appointed responsibility to review the firm's contacts to external research milieus in the area of material sciences, the long term objective being to focus a planned increase of resources for collaborative

R&D to those milieus that are most important for the firm. Respondents #12 and #13 both point out that Sandvik is world leading in a number of areas concerning its core business so they need the institutions that they work with to also be world leading within their cooperation to be a relevant partner for Sandvik. In spite of this need for excellence, respondent #13 states that Sandvik as a firm has relatively limited contacts to foreign research environments, a fact that should been seen in the light of a strong concentration to Sweden (in particular to Sandviken and Stockholm) of the firm's R&D. The respondent explains that the firm appraises Swedish expertise in material sciences as internationally leading in most fields relevant to the firm. The respondent expresses some concern that two particular areas of importance for Sandvik has lost out in competitiveness during the last few years, which may increase the need for further foreign contacts. From the Västberga horizon, the contacts to foreign research milieus are appreciated as quite significant by respondent #12, contacts to Sheffield and Birmingham being good examples. Being the largest company in their field Sandvik often gets cooperation offers from around the world, but Sandvik's R&D is foreseen to remain strongly based in Sweden.

## SKF – concentrating process oriented R&D to HQ region

SKF is a world leading producer of services and solutions in all areas concerning lubrication systems, seals, mechatronics and rolling bearings. Celebrating its 100th anniversary in 2007 the company is represented in over 130 countries around the world with over 100 manufacturing sites. Sales for 2006 amounted to €5.5 billion and the company employs 41,000 people.

While the firm has maintained its headquarters in West Sweden where it was first founded, R&D functions were placed in the Netherlands already in the 1960s. SKF's main centre for product-oriented R&D remains in the Netherlands, but in 2001, a second R&D centre dedicated to production process R&D was established in Gothenburg. Since the establishment of the Manufacturing Development Center (MDC), SKF has continuously increased its funding, which means that the centre has grown from 20 to 60 employees.

Ulf Sjöblom (respondent #14), who heads MDC, states that the reorganisation sought to gather shattered resources to gain critical mass and avoid duplicative efforts. The decision for Gothenburg is described as based on two main factors. "It was thought necessary to locate the new centre close to a good university with one we could collaborate and from which we could recruit. We also sought

good communications." The fact that a large portion of the available R&D personnel had Swedish background also contributed to the decision.

The respondent describes collaboration with the local technical university as particularly intensive, but the firm works together with a number of universities around the world, in particular in order to orient the research towards new areas. The respondent is critical to the Swedish academic funding system, which he feels make the universities so desperate to "sell" their collaborative participation to firms in order to secure public funding that they cannot uphold a strong research profile. While a long-term loss of competitiveness on behalf of its academic partners could affect future decisions about R&D locations, SKF plans to continue to concentrate manufacturing R&D to Sweden and MDC. The respondent states that important functions for the centre, such as formal collaboration with other firms and universities can be run efficiently from the centre, at least within Europe. For longer collaborations, SKF also often assign an employee to another location for a limited time.

## Volvo Cars – new center with complications

Volvo's first car left the factory in Gothenburg in 1927 and since then safety, security and quality have been paramount to the company's brand and image. In1999, the Volvo group sold its car operation to Ford Motor Company. Traditionally, Volvo Cars' strategy has been to keep its R&D on a project basis where construction director's work both in a research environment and in a production environment. This strategy has been complemented with access to the local research organization Volvo Technology – a joint R&D resource to Volvo Cars and the trucks and busses corporation Volvo AB. As a part of the Ford corporation, Volvo Cars is however increasingly integrated in the international R&D strategies of this multinational giant, which includes ambitions to impose division of labour between subsidiaries. As part of such a strategy, Volvo has been selected as a "Center of Excellence for Safety" within Ford Motor Company. In June 2006, it was announced that Volvo was also to become Ford's global competence center for hybrid engine technology.

According to press statements by Volvo Chief Executive Fredrik Arp, a new unit of 20 engineers would be established in Göteborg, to be expanded to "50 or 100 engineers" within two years. However, things did not proceed quite as planned. Simultaneously with the announcement of the new Swedish R&D effort, Ford announced that it was switching its focus from hybrid technology to alternative fuels. In December 2007, only a portion of the announced initiative had been realised.

In the process of integrating Volvo Cars in the Ford corporation, the firm has prioritized embedding the applied R&D competence of Volvo Cars in Ford's global activities, but it is commissioned to build new direct R&D relations within Sweden. In contrast to respondent #9 at Saab, the respondents at Volvo Cars believe domestic networks to be currently more important to the company's R&D activities than international ones. This change may reflect remaining relations to the Volvo corporation, but also reflects the relative strength of the automotive cluster in the West Sweden region. The international dimension is however gaining importance, both in terms of linkages within the corporation and as manifested by a growing number of foreign subcontractors and producers.

Volvo's largest cooperation partner in the academic world is the "local" university of Technology in Gothenburg. These two partners have worked together for a long time and they have developed an understanding of each others' needs and skills. Volvo has endeavoured to build up a focused competence within the university in the areas of electrical technology and vehicle safety, two areas which Volvo has traditionally been very successful in implementing within their products. Personnel mobility is described as "reasonably frequent", and there are around 20 industrial doctorate students active within the company working on various projects. Usually new such graduates are taken into the company in order to develop new knowledge within specific areas, but generally speaking their presence is one of the things that ensure an academic competence within the company. Volvo also works with foreign universities, but the level of engagement is relatively limited. Much of the R&D happens in cooperation with the subcontractors supplying various parts into Volvo Cars' products.

Public funding has in some cases been an important catalyst in starting up new directions in R&D and to increase the cooperation between Volvo and other actors with co-aligned interests – notably competitors Saab Automotive, trucks- and busses manufacturers Scania and Volvo and supplier Autoliv. This kind of support is something that aids in the continuity of certain type of research which could be of a more sporadic nature if this kind of support would not be available.

## Cross case analysis

Analysing these cases, we identify three types of innovation system factors that seem to have influenced the processes leading to decisions about R&D investments in Sweden.

First, the access to skilled labor that has a solid educational background, language skills, cross functional interdisciplinary abilities and commitment to lifelong learning within their fields is of ever increasing importance for Swedish multinational companies. Without the necessary skills and abilities to perform the research needed domestically even firms with strong R&D bases in Sweden worry that lack of talent will eventually force them to relocate certain areas to larger labor markets. On a similar vein, the price of R&D labour is identified by some respondents as an important, albeit secondary, factor currently acting in favour of Sweden as R&D location.

Second, the opportunities to network with similar companies, subcontractors, consultants and government representatives can be instrumental in setting up the prerequisites needed to build or maintain a global level research ability within a geographical area. Most respondents agree that it is difficult to engage in intensive cooperation over long distances, and all agree to statements such as "co-location facilitates collaboration".

Third, timely public co-funding and R&D subsidy schemes may lead to the creation of a new knowledge base and foster new networks.

These findings are congruent with the broad literature on innovation systems and multinational R&D. Two interesting observations regarding the strength of these factors, which are not well-documented in previous studies, also emerge from our case study.

Our case suggest the difference between firms with a solid R&D presence and headquarters in Sweden and firms who after mergers and acquisitions find themselves part of a larger corporation. While MNEs to some extent can be said to continuously evaluate locations for any activity against each other under consideration of a multitude of factors (Dunning, 1993), the case of advanced R&D offer interesting some observations. For foreign-owned multinationals in Sweden, it seems very important to be able to refer to a strong, relevant knowledge base in Sweden which may create attention at a group level and identify the national subsidiary as a global knowledge center of excellence in that particular field. This tendency is illustrated in the events associated with Volvo cars and Saab automotive. Innovation system factors can thus been regarded as attractors of internationally mobile R&D investments, in particular for investments from foreign-owned corporations. The studied events at Alfa Laval, AstraZeneca, Ericsson and Sandvik, on the other hand, illustrate cases where the so called centripetal forces of R&D internationalization are overcome by centrifugal forces. In these cases, innovation system factors play a more passive role; the

important thing is that the conditions for R&D in Sweden not are perceived to be clearly less advantageous compared to competing locations. As that has not been judged to be the case, firm internal factors and the power of strong tradition have been allowed to determine the locational choices of these investments.

A parallel general observation from our case study is that the influence of IS factors seems to be particularly important in times of "turbulence" for corporate R&D. Whether realized through organizational factors as in the case of SKF or Sandvik or through the development of potentially "disruptive" technologies that creates needs for the creation of new competencies as in the case of Gambro, Volvo Cars or Saab Automobiles, it is in the face of changing priorities that innovation system factors may influence decisions about outcomes and thereby set off path dependent processes that determine the locational choices of future R&D investments. The case of Gambro is a particularly interesting example of how a firm, when it is attempting to create new knowledge platforms in the early phases of an innovation cycle (Utterback, 1994), can take decisions based on innovation system factors that can have large implications for long-term R&D investment patterns.

# 4. Innovation system services for advanced corporate R&D

Guided by the case study on factors influencing the location decisions of MNE R&D investments in a Swedish context, we have elaborated five innovation system services. These services, which are listed in Table 2 below, are found to cover the most important geographically bounded mechanisms through which an MNE may achieve benefits from locating its R&D to a particular location. The identification of five distinct system services allows us to break down a rather general research problem ("how do innovation system factors influence multinational firms' decisions about R&D investments in Sweden") into a comprehensive framework based on empirical findings. This framework may be explored further through explorative analysis.

Note that a system service not should be confused with an externality in the sense of neo-classical economics. None of these five services should be interpreted as delivering "free" benefits to firm. As evident from our case study, firms have to make different kinds of efforts to benefit from these services, and their ability (and, indeed, interest) to do so are decided by firm-internal factors. Differences in capabilities and interests may for example be constituted by the different degrees of

connectedness to other actors / embeddedness in the innovation system as discussed by e.g. Laursen and Salter (2006) and Birkenshaw et al. (2002). It should also be observed that while the interviews suggest that there is a strong national dimension to these services, most of the services can be argued to be influenced by international and regional factors. Furthermore, is must be noted that while the services are found from a cross-sectoral study, the dynamics of the services are clearly *sectoral*.

Service 1: Supply of highly skilled labour
Service 2: Price of highly skilled labour
Service 3: Opportunities for collaboration and local out-sourcing
Service 4: Opportunities to network
Service 5: Co-funding and subsidies
**Table 2: List of services for advanced corporate R&D**

These five services are found to affect the localisation decisions of each firm (although in different degree and possibly in different manners across the population of firms). As illustrated by figure 1, the decisions of an individual firm A are likewise found to affect the power of the system services.

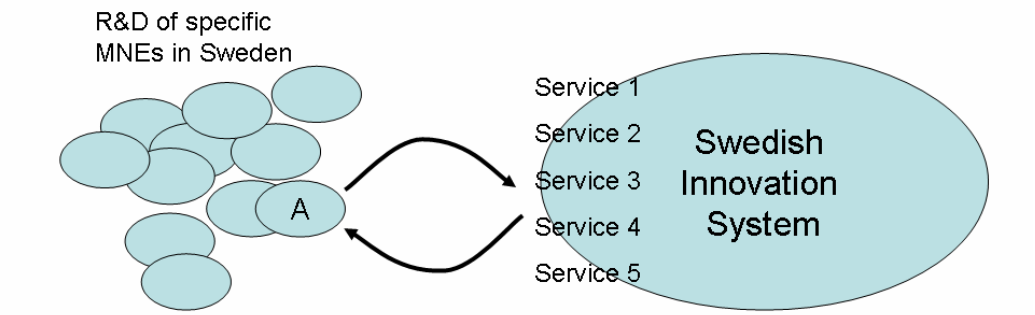


*Figure 1: Illustration of a research problem with services*

To illustrate the interaction between an individual firm and the system of innovation, we provide an example inspired by comments from two respondents in our case study.

> **Example:**
> The respondents at firm A (AstraZeneca) fear a weakened competitiveness of service number four (supply of highly skilled labour) for 'Swedish' IS relevant to its Södertälje plant, as compared to comparable innovation systems. In particular, the Swedish higher education and research system is said to produce less skilled researchers, and in insufficient numbers. If the firm cannot recruit sufficiently well, it may in the long term reduce its R&D activity in Sweden. This action, in turn, will further deteriorate the supply of skilled labour (as the stock of R&D employees of AstraZeneca constitute a significant part of the nation's pharmaceutical competence). For any other pharmaceutical firm, the decreased performance of service number four may lead to a long-term downscale of R&D in Sweden. A vicious circle threatens to be released.

All of the feedback loops of system services are perceived as positive, and thus a change anywhere in the system will trigger virtuous or vicious circles. Balancing forces, i.e. efforts that may break a

vicious circle, come from forces external to the system. As the system is defined above, such external forces may include such important drivers as technological development, the dynamics of markets and multinational management of firms. The role of public policy, from a system services perspective, is to act as a particular type of balancing force.

**Continued example:**
The Swedish government may attempt to interrupt the vicious circle through measures that increase the strength of the relevant parts of the Swedish system for higher education and research. To be fully effective, such measures must also be convincingly communicated to the local firm and, in this case, to the international headquarters of AstraZeneca.

We conclude that the IS services framework has helped us analyse the role of innovation system factors in the processes leading to decision about investments of the most advanced R&D. In particular, three characteristics of the approach have proved valuable for analysis.

1. The approach has served as a useful framework for delimiting the relevant system to study. In the context of our case, the SI-approach helped us to separate the SI-related factors from those related to the market or to corporate management within multinational firms.

2. The approach has allowed systemic insights to enter into the cross case analysis. The SI approach has helped us emphasise that the total impact of innovation system factors on the decisions about locations for advanced corporate R&D hangs upon "the weakest link" in the set of services. For example, the failure of the service "opportunities for collaboration and local out-sourcing" lead Gambro to invest in competing regions of the world. The approach has also enabled analysis of the changing role of innovation system factors over time; in particular, the IS services are as most critical in the face of turbulence in the corporate R&D organisation. Furthermore, the IS services approach has allowed us to discuss the critical role of relations within the IS and the feed-back mechanisms through which corporate strategy and public policy interact in path dependent processes.

3. Applying the approach to our case study has created a number of testable hypotheses that may be subject to further empirical enquiry. IS services carefully defined for an actor-activities nexus are empirically founded hypotheses related to each other in a systemic manner, each one available for further analysis. To take an example from the context of our case, a review of existing studies or new empirical enquiries on the relation between the supply of highly skilled labour (service no 4) and the attractiveness of a certain region or country could be used to test the validity of (one of) the services presented in our case study. Similarly, the importance of service no 4 as compared to service no 5 ("price of highly skilled labour") could be explored.

# 5. System services and system functions

The SI "services" approach presented in this paper is conceptually closely related to the SI "functions" approach of Rickne (2000), Johnson (2001), Bergek and Jacobsson (2003), Jacobsson and Bergek (2004), Alkemade et al. (2007) and Bergek et al. (2008). Just as the functions approach, the focus on services emphasises heterogeneity among actors and path dependency, and does in this regard fit within the settings of evolutionary economics (Nelson, 1991; Eliasson, 1991; McKelvey, 1997). Just as the functions approach, the services approach 1) provides a tool for setting analytically motivated system borders, 2) facilitates evaluative judgement of the innovation system and the identification of present bottle-necks or weaknesses and 3) provides the focus necessary for analysis of the dynamics of the system (see also Johnson, 2001). In fact, the services discussed here can be understood as the set of SI functions that relate to a particular activity of a particular group of actors (actors-activities nexus). We argue that this specification allows for two further important features that allow us to come closer to an operationalisation of the SI approach. The services approach 4) allows a more direct relation between empirical investigation and the abstract level of the "system". While the functions presented in e.g. Johnsson (2001) all are theoretically justified, abstractions such as a system function that may "facilitate the exchange of information and knowledge" or "stimulate / create markets" will remain difficult to operationalise in empirical studies. The focus on a particular actors/activities nexus allows us to come up with operationalised measures of services to that nexus, either as experienced through the opinions of relevant respondents, as in this study, or as measured in econometric analysis. A related virtue of the services approach is 5) the connection to public policy. The literature linking the SI-approach to rationales for policy rationales identify different "systemic failures" or, since comparisons between an existing system and an ideal or optimal system are not possible (Chaminade & Edquist, 2006) "systemic problems" (for a review, see Woolthuis et al., 2005). These problems include some that are applicable to a system service framework, and others that are more difficult to apply in our setting. In the IS service framework, attention is focused on the failure of services. It can be argued that the focus on services available to the firm entity removes the necessity of superior information on behalf of the policy maker needed to remedy the more abstract "systemic problems" described in previous SI literature (Woolthuis et al., 2005). This more limited approach recognises the significant difficulties of predicting the reactions of the economy to public policy (Eliasson, 1991) and may better correspond to the true scope of innovation

policy than the more optimistic views on the opportunities for policies building strongly on systems analysis presented by e.g. Chaminade & Edquist (2006).

# 6. Conclusion

This study has argued that the systems of innovation (SI) approach provides a valuable general framework for the study of innovation activities, but that this framework seems to lack the focus necessary to translate into a tool for scientific analysis. We suggest that the necessary focus can be supplied by defining an innovation system from the point of view of a particular set of activities of a particular group of actors. The concept of innovation system services, defined as the set of factors that have a significant potential influence on the opportunities of the actors to perform the activities efficiently, is defined. This set of system services is suggested to constitute the relevant innovation system for the actors-activities nexus at hand. Thus, the system services approach entails a reorientation from previous SI approaches focusing on nations, regions or sectors. Examination of this analytical framework in a case study on R&D investments of multinational enterprises in Sweden illustrates the benefits of the system services approach. The approach facilitates analysis of central system dynamics, it serves as a useful framework for delimiting the relevant system to study and it creates a number of testable hypotheses that may be subject to further empirical enquiry. Further studies could help determine the usefulness of the approach by investigating system services in a different case setting. Furthermore, quantitative evaluation of the power of the five services identified in this study would provide an interesting opportunity to test and further develop the system service concept.

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**Appendix 1: Respondents**

| Respondent # | Firm |
|---|---|
| | **Alfa Laval** |
| 1 | NilsOlof Björk, Vice President, Responsible for Technologies |
| 2 | Tommy Noren, Manager, Technologies, Corporate Development |
| | |
| | **AstraZeneca** |
| 3 | Hans Hultberg, Head of Global Discovery Alliances |
| 4 | Christer Köhler, Global Vice President, Discovery Research Areas CNS & Pain Control |
| 5 | Sverker Ljunghall, Director of Science relations |
| | |
| | **Ericsson** |
| 6 | Ulf Wahlberg, Vice Director, Ericsson Research |
| 7 | Magnus Madfors, Director R&D Policy |
| | |
| | **Gambro** |
| 8 | Maris Hartmanis, Senior Vice President and Chief Science Officer |
| | |
| | **Saab Automotive** |
| 9 | Ingemar Nilsson, director Advanced Technical Work |
| 10 | Martin Elliot, manager of hybrid-electric vehicle integration for GM-Europe |
| 11 | Lillemor Lindberg, Project coordinator, Saab hybrid technology initiative, Innovatum |
| | |
| | **Sandvik** |
| 12 | Ulf Rolander, Manager of Västberga plant |
| 13 | Jan-Olof Nilsson, Senior Researcher, special responsibility for external R&D relations |
| | |
| | **SKF** |
| 14 | Ulf Sjöblom, Director of Manufacturing Development Center |
| | |
| | **Volvo Cars** |
| 15 | Christer Lundblad, Vice President VCC Engineering Support |
| 16 | Jon Mikaelsson, Researcher |