LOCAL ECONOMY, 2003, VOL. 18, NO. 1, 80–90

Routledge
Taylor & Francis Group

Universities and Technology-based Entrepreneurship in the Gothenburg Region[1]

Åsa Lindholm Dahlstrand and Staffan Jacobsson

[1] The authors wish to thank MSc Mattias Johansson for valuable help in the data collection and VINNOVA for financial support.
[2] Corresponding author.

ABSTRACT

We trace the relationship between changes in the supply of capabilities from Chalmers University of Technology and the extent and nature of technology-based entrepreneurship in the region of Western Sweden in the period 1975–1993. Changes in the supply of capabilities are approximated by changes in volumes and orientation of graduates at MSc and PhD levels. The knowledge base of 539 new technology-based firms is specified in terms of the different programmes at Chalmers (e.g. mechanical engineering). We argue that the responsiveness to the growing technological opportunities in electronics and computer engineering was weak and that, as a consequence, the volume of technology-based entrepreneurship was probably not only unduly limited but also skewed towards mechanical engineering, the 'traditional' area of specialisation in the region.

INTRODUCTION[3]

In a 'knowledge-based' society, attention needs to be given to the role of universities in technical change and economic growth. The growing pressure for 'accountability' in the public funding for academic R&D has focused much of this attention on the value of practical (commercial) benefits of academic research in terms of information coming out of that research (Pavitt, 2001; Geuna, 2001; Benner and Sandström, 2000). However, as is well known from history of technology, uncertainties abound in both the innovation and diffusion process. Indeed, it is more appropriate to think in terms of 'ignorance' as decision makers simply cannot have access to either the full range of potential outcomes of research, or the probability distribution with respect to those which can be identified (Rosenberg, 1996). In a situation of ignorance, quantifying the expected benefits of academic R&D *does not seem to be possible* (Rosenberg, 1996; Computer Science and Telecommunications Board, 1999).

[3] This introduction is based on Jacobsson (2002).

Åsa Lindholm Dahlstrand and **Staffan Jacobsson** are at the IMIT and Department of Industrial Dynamics, Chalmers University of Technology, Gothenburg, Sweden, Email: asli@mot.chalmers.se[2] and stja@mot.chalmers.se

Local Economy ISSN 0269–0942 print/ISSN 1470–9325 online © 2003, LEPU, South Bank University
http://www.tandf.co.uk/journals
DOI: 10.1080/0269094032000073816

In contrast, leading edge policy research suggests that main justification of academic work lies in generation of scientific and technological capabilities (Pavitt, 1991, 2000, 2001; Salter and Martin, 2001, Scott et al, 2001). As Loasby (1998, 144) argues:

> 'Capabilities are the least definable kinds of productive resources. They are in large measure a by-product of past activities, but what matters *at any point in time is the range of future activities which they make possible*. What gives this question its salience is the possibility of shaping capabilities, and especially of configuring clusters of capabilities, in an attempt to make some preparation for future events, which, though not predictable, may . . . be imagined (our italics).

Hence, in an uncertain world, the main justification for academic research lies in building capabilities, which embody the ability to generate, and eventually, contribute to the realisation of (some of) these options, most of which are unknown at the point of decision to develop a capability.

There are various *mechanisms* by which the generation of capabilities may benefit society, and the influence can be both direct and indirect. Some of these mechanisms are listed below (Meyer-Krahmer and Schmoch, 1998; Pavitt, 1998; Salter and Martin, 2001).[4] The first three refer to the traditional mechanisms of publishing and of teaching. The fourth and fifth emphasise the role of various types of networks, meeting places and markets for sharing of information and knowledge whereas the last two point to the development of products and firms by academics.

- Scientific publications which expand the technological opportunity set of firms
- Training of engineers and natural scientists
- Training of PhDs with its essential provision of background knowledge, skills and personal networks
- Participating in common informal networks, joint R&D projects, research funding and contract research with an associated sharing of explicit and tacit knowledge (gained through research and being members of national and international professional networks)
- Linking national firms to international networks and providing access to explicit and tacit knowledge from a wider range of sources
- Development of instruments and engineering design tools
- Spinning off technology-based firms

It would seem reasonable to divide these into primary, secondary and tertiary mechanisms. The primary is research, the secondary is teaching at PhD and undergraduate levels, while the tertiary mechanisms refer to the remaining ones. Taken jointly, it is through all these mechanisms that academic research increases the rate of return of private, more applied R&D.[5] Without high quality

[4] Faulkner and Senker (1994) specify additional mechanisms.

[5] See Dasgupta and David (1994) for a discussion of this overall function of academic R&D.

capabilities in research, as revealed in, for instance, scientific publications, academics will not be able to provide such a meaningful contribution to industry and society, even if the remaining mechanisms are employed.

A science policy where the generation of capabilities is the central issue clearly needs to be concerned with the speed and strength by which universities explore new fields. The 'response' capacity has implications not only for the generation of specific options and capabilities in the form of e.g. PhDs, but also for the ability to develop new undergraduate programmes and to expand them as and when a new knowledge field has matured enough to be applied widely in society. Indeed, *the main challenge for Science and Educational Policy is to make sure that capabilities are built in terms of volume,*[6] *variety and quality.*

In what follows, we will analyse the responsiveness of Chalmers University of Technology in Gothenburg, Sweden in terms of volume and variety of capabilities, i.e. we will analyse how rapidly the University reacted, in terms of *both* research and education, to the growth in importance of 'new' knowledge fields. A particular focus will be on capabilities in electronics and computer engineering as they represent the knowledge base in the rapidly growing field of information and communication technology.

The supply of capabilities will be related to the size and orientation of local technology-based entrepreneurship in the Gothenburg region.[7] In an earlier study of the region, it was shown that a tenth of the firms were direct spin-offs from Chalmers (Lindholm Dahlstrand, 1999). Another 21% were indirect university spin-offs in that they were based on university research, but not established until the founder(s) had gained additional knowledge in a private employment. Hence, for about one-third of the technology-based start-ups, there was a clear relation between university research and firm formation. This relationship had a strong spatial dimension in that firms were spun off locally (Lindholm Dahlstrand, 1999). This benefit of capability formation was therefore not reaped only or even mainly through direct spin-offs (the last of the mechanisms outlined above).

Most of the new technology-based firms exploited knowledge gained through working in private firms. These firms, which provide a training ground for potential entrepreneurs, rely largely on the *local* labour market for engineers and scientists (Lindholm Dahlstrand, 1999). This market is, in turn, greatly influenced by the responsiveness of the University, in this case Chalmers. The extent of the local availability of specialised labour, e.g. electronic engineers in microwave technology, has a direct bearing on the size of industrial activities in fields demanding such specialised labour, e.g. design and production of antennas for mobile phones systems. The responsiveness of Chalmers is therefore expected to influence, via its influence on the labour markets, the 'size' of the training ground, and therefore, the potential number of technology-based entrepreneurs. To the extent that this potential is realised[8] there is, again, a

[6] It is particularly important that the university sector is able to train a sufficiently large volume of students with a knowledge/technological profile appropriate for both established organisations and new firm entry, and especially so in high-growth sectors of industry.

[7] The role university graduates play for the transfer of university research into industry is often ignored or excluded in earlier studies of academic entrepreneurship (see e.g. OECD, 2001).

[8] Large firms provide a training ground but for many reasons the propensity to spin off firms from these may be generated, leaving few to be exploited in the form of new start-ups.

strong spatial dimensions in that firms are spun off in close geographical proximity to the parent firm (Lindholm Dahlstrand, 1999). In here lies an indirect relationship between the responsiveness of Chalmers and local, new firm formation.

Hence, we suggest that there is probably a relationship between local formation of capabilities and local formation of NTBFs, although this is mainly an indirect one. In the subsequent exploratory analysis, we will simply map the formation of capabilities, in the form of PhDs and MScs in different programs at Chalmers and the formation of technology-based firms in the region of Western Sweden in the period 1975–1993.

Despite its simple nature, the analysis is useful. We will be able to argue that the responsiveness to growing technological opportunities in electronics and computer engineering was weak in that period and that, at least in part a consequence of this, that the volume of technology-based entrepreneurship was not only unduly limited but also skewed towards mechanical engineering, the 'traditional' area of specialisation in the region.

The paper is structured as follows. In the next section, we will present our databases and make some methodological notes. The following section presents data on both the formation of capabilities and new technology-based firms. The final section contains a concluding discussion.

■ METHOD AND DATA

We had earlier developed a database on new technology-based firms (see e.g. Rickne and Jacobsson, 1999). In addition to elaborating on this, we collected data on the volume and profile of MSc and PhD graduates at Chalmers University of Technology. In both cases, 1975 was our starting point. Below our two databases will be described.

With 'new technology-based firms' (NTBFs) we do not only refer to firms in 'high tech' but to all firms where natural science, medical or engineering skills are central to achieving a competitive edge. These include not only manufacturing firms but also firms in industry-related services. When creating the original database, we used three criteria to identify the population of NTBFs. The Swedish Bureau of Statistics (SCB) provided us with data on all establishments which: (1) were classified in a selected set of industries and industry-related services in which we included the categories incorporating the bulk of engineers and natural scientists in Sweden[9]; (2) had at least one employee with a minimum a bachelor's degree in any of these fields; and (3) had at least three employees, which means that we excluded a 'tail' of very small firms. The period involved reached to 1993. Our total sample of new technology-based establishments includes 6,889 organisations. Out of these, 1,054 were found in the Gothenburg region.[10] By excluding those established before 1975, and those that were clearly large firm establishments/subsidiaries (Swedish or

[9] The industries included are ISIC (rev. 2 from 1968) 341, 35, 37, 38, 6112, 72002, 8323, 83249, 83292, 83299 and 932. This is a subset of the manufacturing and service sector.

[10] We used the postal area code/zip code to identify firms in the Gothenburg region.

foreign) we ended up with a sample of 539 NTBFs. For these, we have data on e.g. the time of entry and the educational profile of staff with a minimum of a Bachelor's degree. With the latter information, we were able to classify the establishments according to their dominant knowledge fields, e.g. mechanical engineering or computer engineering.

Chalmers University of Technology is one of the older and largest institutes of technology in Sweden. Chalmers offers Master of Science degrees and doctoral degrees. Research is carried out in the main engineering sciences as well as in technology-related mathematical and natural sciences. Some 2,500 employees work in more than 100 departments organised in nine schools. The turnover is around SEK 1.9 billion a year; more than two-thirds of this sum relates to research.

The Chalmers-database has two subgroups: (A) Chalmers' MScs and (B) Chalmers' PhDs. We use MSc graduates as an indicator of university education, and PhD graduates as an indicator of university research. Since MScs and PhDs are awarded within comparable technological areas, this measure allows for a comparison between research and education.

To create the Chalmers-database we collected data from the Chalmers administration registers on graduation.[11] It includes 17,641 MScs and 1,496 PhDs graduated between 1975 and 2000. For the years 1975 to 1993 (i.e. the years we measured NTBFs establishment) the corresponding figures were 11,776 and 828. We have information on year of graduation and program followed (i.e. mechanical engineering or computer engineering). In the period 1975 to 1993, Chalmers offered 10 different MSc programmes, four of which did not exist in 1975. None of the six other programmes existing in 1975 terminated during the period studied. In 1985 came the first graduate from a new program, computer engineering.

[11] Register information from Chalmers Administration has been complemented with interviews at Chalmers. A few personal interviews were made at Chalmers Administration, but we have also interviewed representatives from Chalmers different technological programmes and schools. This helped to control errors in the data and, also, our understanding of some irregularities in the data.

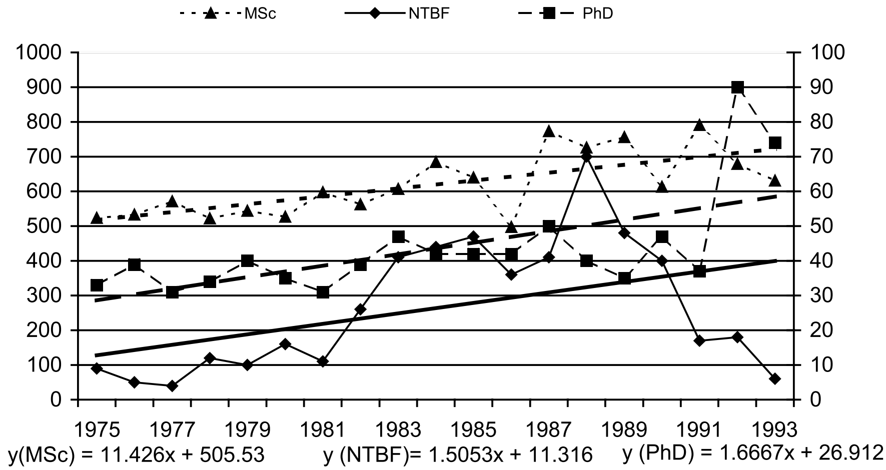
[12] This section is based on Lindholm Dahlstrand (2002).

■ CHALMERS' 'RESPONSIVENESS' AND NEW TECHNOLOGY-BASED FIRMS IN THE GOTHENBURG REGION[12]

Figure 1 contains aggregate data revealing the broad relationships between the graduation of MScs and PhDs and the number of new technology-based firms. There were approximately one NTBF established for every twenty MScs. The trend-line suggests that the number of MSc graduates increased with 11.4 persons each year, while the corresponding annual increase in NTBF formation was 1.5. The relation between the number of NTBFs and the number of PhDs was approximately two NTBFs for every three PhD and the trend line indicates that the number of PhDs increased with 1.67 persons each year.

Whereas broad figures like these reveal the orders of magnitude involved in the relationship between the supply of capabilities and firm formation, an analysis of 'responsiveness' requires a comparison between the supply of

Figure 1. The number of graduated MScs, PhDs and newly established NTBFs 1975–1993



Note: 1st y-axis= number of MScs; 2nd y-axis= number of Gothenburg NTBFs and PhDs
Source: Elaboration on the Chalmers-database (as presented in the previous section).

capabilities from specific programmes (e.g. computer engineering) with the formation of NTBFs with the same knowledge base. This is done in Table 1.

The number of NTBFs with an *electronic engineering* base accounted for more than 25% of the total of such firms formed in the period studied (column II). The flow of NTBFs with an electronics knowledge base increased with 0.55 firms each year (column III), which was the highest growth in the sample. In contrast, the flow of capabilities at the MSc and PhD levels was nearly constant (columns V and VIII), in spite of an initial research strength in some fields of electronics, e.g. high speed electronics (Holmén, 2002) Indeed, the annual increase of PhDs with an electronic engineering base was less than 1 per cent of Chalmers' increase. Thus, while the increase of NTBFs in electronic engineering constituted over a third of new firm formation, the increase in graduates in this knowledge field was considerably lower (i.e. for MScs three per cent and for PhDs one per cent of the expansion at Chalmers).

Mechanical engineering was the technology-base in 30% of the NTBFs, the largest group of the sample (column II). The rate of increase in the formation of such new firms was, however, only 0.21 firms per year (column III), which is considerably lower (less than half) than that for firms with a knowledge base in electronic engineering. This means that the new firms with an electronic engineering base are on average younger (or more recently established) than the firms with a mechanical engineering base. In contrast, the flow of capabilities increased quite a lot at both MSc and PhD levels, in particular for the latter (columns V and VIII). While there was almost no increase in the annual PhD graduation in electronic engineering, PhDs in mechanical engineering increased

Table 1. The number and share of MSc and PhD graduates and NTBFs in different technological fields, 1975–1993

I (1965–1993)	*II* Number of NTBFs (share, %)	*III* Annual increase 75–93*	*IV* Number of MScs (share, %)	*V* Annual increase 75–93*	*VI* Relation (NTBF/MSc)	*VII* Number of PhDs (share, %)	*VIII* Annual Increase 75–93*	*IX* Relation (NTBF/PhD)
Electronic engineering	146 (27.1%)	0.5526 (36.71%)	2,943 (25.0%)	0.33737 (3.27%)	0.050	173 (20.9%)	0.014 (0.84%)	0.844
Mechanical engineering	164 (30.4%)	0.2140 (14.2%)	2,950 (25.1%)	1.4035 (12.28%)	**0.056**	153 (18.5%)	0.3596 (21.57%)	**1.072**
Chemical engineering	31 (5.8%)	0.0965 (6.41%)	1,323 (11.2%)	0.9333 (8.16%)	0.023	155 (18.7%)	0.3439 (20.63%)	0.200
Computer engineering	98 (18.2%)	0.3719 (24.71%)	408** (3.5%)	4.1737 (36.53%)	**0.240**	26 (3.1%)	0.1158 (6.95%)	**3.769**
Other technology base/degree	100 (18.6%)	0.2702 (17.95%)	4,152 (35.3%)	4.5421 (39.75%)	0.024	321 (38.8%)***	0.8333 (49.99%)	0.311
Total	539 (100%)	1.5053 (99.98%)	11,776 (100%)	11.426 (100%)	0.046	828 (100%)	1.667 (99.98%)	0.651

Notes: * Annual increase 1975–1993 is calculated as the increase in absolute terms since 1975. The percentages (shown in parentheses) illustrate the corresponding share of the total increase 1975 to 1993 (i.e. share of total increase of NTBFs in column III, and share of Chalmers' total increase, columns V and VIII).

** first graduation 1985.

*** PhDs physics = 130 (15.7%), PhDs civil engineering = 97 (11.7%).

Source: Elaboration on the NTBF-database (as presented in the previous section).

with approximately 1/3 PhD each year. This represents over 20% of Chalmers' total increase of PhDs graduated in the period studied. Thus, if PhDs are used as a measure of academic renewal one could argue that Chalmers has focused relatively much on mechanical engineering.

NTBFs with a knowledge base in *computer engineering* was the third largest category in the sample, i.e. after mechanical and electronic engineering (column II). This was also the category demonstrating the second highest (after electronic engineering) rate of increase in NTBF formation, (i.e. around 25% of the increase in NTBF formation can be found in this group (column III). In the period, graduates from the programme in computer engineering accounted for about 37% of the total growth in the supply of capabilities at the MSc level (column V). However, at the PhD level, the increase was modest (column VIII), only in electronic engineering was it lower. Thus, at that higher level, the poor growth in electronic engineering was not balanced by an increase in computer engineering.

A striking feature of computer engineering is the large number of NTBFs formed, set in relation to the number of graduates at both levels. This ratio (columns VI and IX) was about five times greater than in mechanical and electronic engineering. While it took 20 MScs (or 1.2 PhDs) in electronic engineering for one NTBF to get founded, the corresponding figures in computer engineering were 4 MScs and 0.26 PhDs!

We have also compared the formation of NTBFs and the supply of capabilities in *chemical engineering* as well as in a remaining category we have called 'other'. NTBFs with a knowledge base in chemical engineering were relatively uncommon, only six per cent in the sample, and the rate of growth in firm formation was low (column III).[13] The increase in the number of MScs and PhDs in chemical engineering was, however, quite substantial, in particular at the PhD level. In chemical engineering, therefore, one new firm was established for as many as every 43 MScs (or 5.0 PhDs) that graduated. These figures are almost as high for the 'other' MSc and PhD categories (most of which are physics and civil engineering). Hence, much of the expansion of capabilities took place in knowledge fields, which are less likely to form the bases for the formation of NTBFs.

[13] This figure is even lower for NTBFs with a technological base in Physics or Civil engineering.

■ CONCLUDING DISCUSSION

Four main conclusions can be drawn from the data in the period 1975–1993. First, a large part of the supply of capabilities, and of the increase in that supply, was in knowledge fields that were not much reflected in the knowledge base of NTBFs. This should, of course not be interpreted as something inherently negative, as the formation of NTBFs is only one out of many mechanisms through which academic work is made socially useful. Yet, the profile of the University would clearly be an important factor influencing the number of start-ups.

Second, Chalmers substantially increased its supply of capabilities in mechanical engineering, in particular at the PhD level. This might seem odd in times of the 'electronics and software revolution' but may well reflect the traditional strength of Sweden in that field. Sweden's revealed technological comparative advantage (as measured by patents and R&D) was as high as 1.55 and 1.95 respectively in the end of the 1980s (Jacobsson and Philipsson, 1997). The specialisation in Western Sweden was even more oriented towards mechanical engineering (Holmén and Jacobsson, 1997). Thus, it is no surprise that Saemundsson et al (1997) found that this region demonstrated an above average (related to other Swedish regions) specialisation of NTBFs towards mechanical engineering. The educational and research profile could, therefore, be interpreted as being responsive to the needs of current dominant mechanical engineering industry (e.g. SKF, SAAB, Volvo). This should not be interpreted as saying that Chalmers strengthened its position in dated sectors. Mechanical engineering is still a scientific and technological area which exhibits vitality, for instance through the development and use of new materials.[14]

[14] Simplistic classifications of sectors in 'high' and 'low' tech fail to capture the dynamics of some knowledge fields which are relevant in sectors other than 'high tech' (Laestadius, 1998).

Third, although there was a substantial increase in the supply of capabilities in computer engineering, there was stagnation in the graduation of electronic engineers. Moreover, the supply of capabilities at the PhD level hardly increased in these two fields. One reason behind this poor responsiveness (with hindsight) is related to the centralised nature of the Swedish Higher Educational System in the 1980s where the Department of Education controlled the volume and specialisation of undergraduate education in great detail. When Chalmers wanted to start a program in computer engineering, the university therefore had to apply for permission and bargain about funding with the Department of Education.

Since computer engineering had earlier been part of Chalmers' programme in electronic engineering, policy makers saw the two programmes as related. This affected not only funding, which was based on marginal costs, but probably also that the formation of a programme in computer engineering was made at the expense of an expansion in electronics. In part, this was due to a belief that the establishment of a MSc programme in computer engineering reduced the need for an increase of MSc in electronic engineering. Hence, a somewhat weak response capacity to growing technological opportunities was probably influenced by the beliefs of the future among central policy makers. With today's knowledge of industrial development after the early 1980s, it is clear that this belief was not correct and, with all likelihood, detrimental to technology-based entrepreneurship in the Gothenburg region. Indeed, it comes as no surprise that the region's specialisation in NTBFs with a knowledge base in electronics and computer engineering is below the national average (Saemundsson et al, 1997).

Fourth, the great differences between electronics and computer engineering in the relationship between firm start-ups and the supply of capabilities (it was five times higher for computer engineering) underscores the negative impact of stagnation in the supply of capabilities in electronics on local technology-based entrepreneurship. This substantial difference may, of course, be argued to reflect greater opportunities for firm formation in computer engineering, but this is not plausible. Instead, we would suggest that it is due to a demand for MScs in electronic engineering from established employers, which is so large that it absorbs most of the capabilities. For electronics engineers, the local labour market has always been dominated by Ericsson Microwave, which was established in the region decades ago as a supplier of military electronics. The firm received a strong impetus to grow with the expansion of civilian mobile telephony in the 1980s and it is very plausible that technology-based entrepreneurship has suffered from the absorption of much of the capabilities by this large firm. Hence, the volume and renewal of education and research alone cannot explain the development of regional technological entrepreneurship – we need to consider also the demand for electronics engineers by the existing industry.

References

Benner, M. and Sandström, U. 2000: Inertia and change in Scandinavian public-sector research systems: the case of biotechnology, *Science and Public Policy*, Vol. 27, December, 443–54.

Computer Science and Telecommunications Board 1999: *Funding a Revolution*. Government support for computing research, National Research Council, National Academy Press.

Dasgupta, P. and David, P. A. 1994: A new economics of science, *Research Policy*, 23, 487–521.

Faulkner, W. and Senker, J. 1994: Making sense of diversity: public-private sector research linkages in three technologies, *Research Policy*, 23, 673–95.

Geuna, A. 2001: The changing rationale for European university research funding: are there negative unintended consequences?, *Journal of Economic Issues*, Vol. XXXV, No. 3, September, 607–32.

Holmén, M. 2002: Regional industrial renewal: the growth of antenna technology in West Sweden, *Technology Analysis and Strategic Management*, Vol. 14, No. 1, 87–106.

Holmén, M. and Jacobsson, S. 1997: Characterising the competence base of a region: the case of Western Sweden, in Eskelinen, H. (ed), *Regional Specialisation and Local Environment – Learning and Competitiveness*, NordREFO, 3.

Jacobsson, S. 2002: Universities and industrial transformation. An interpretative and selective literature study, SPRU Electronic Working Paper Series, No. 81 and *Science and Public Policy*, Vol. 29, No. 5, 345–65.

Jacobsson, S. and Philipsson, J. 1997: Sweden's technological profile, in Carlsson, B. (ed.), *Technological Systems and Industrial Dynamics*, Kluwer Press, 61–92.

Laestadius, S. 1998: The relevance of science and technology indicators: the case of pulp and paper, *Research Policy*, 27, 385–95.

Lindholm Dahlstrand, Å. 1999: Technology-based SMEs in the Gothenburg region: their origin and interaction with universities and large firms, *Regional Studies*, Vol. 33, No. 4, 379–89.

Lindholm Dahlstrand, Å. 2002: A pilot study of university renewal and business creation in the Gothenburg region, in Lindholm Dahlstrand, Å. and Jacobsson, S. (eds.), *Renewal of Academic Research and Education: The Role of Universities in the Emergence of New Innovations Systems*, VINNOVA Report, March.

LOASBY, B. 1998: The organisation of capabilities, *Journal of Economic Behaviour* and 38; Organization, Vol. 35, 139–60.

MEYER-KRAHMER, F. and SCHMOCH, U. 1998: Science-based technologies: university-industry interactions in four fields, *Research Policy*, 27, 835–51.

OECD 2001: Fostering high-tech spin-offs: a public strategy for innovation, *STI Review* (special issue), Vol. 2000, No. 26, Issue 1.

PAVITT, K. 1991: What makes basic research economically useful?, *Research Policy*, 20, 109–19.

PAVITT, K. 1998: The social shaping of the national science base, *Research Policy*, 27, 793–805.

PAVITT, K. 2000: Why European Union funding of academic research should be increased: a radical proposal, *Science and Public Policy*, Vol. 27. No. 6, December, 455–60.

PAVITT, K. 2001: Public policies to support basic research: what can the rest of the world learn from US theory and practice (and what they should not learn), *Industrial and Corporate Change*, Vol. 10, 761–79.

RICKNE, A. and JACOBSSON, S. 1999: New technology based firms in Sweden. A study of their impact on industrial renewal, *Economics of Innovation and New Technology*, Vol. 8. No. 2, 197–223.

ROSENBERG, N. 1996: Uncertainty and technological change, in Landau, R., Taylor, T and Wright, G. (eds), *The Mosaic of Economic Growth*, Stanford, California: Stanford University Press, 334–55.

SAEMUNDSSON, R., RICKNE, A, LINDHOLM DAHLSTRAND, Å. and JACOBSSON, S. 1997: *Regional Industrial Renewal: Technological Specialization and Employment in Swedish New Technology-based Firms*. Paper presented at the conference on 'Industriell & Teknisk Utveckling', Fågelbrohus, Sweden.

SALTER, A. and MARTIN, B. 2001: The economic benefits of publicly funded basic research: a critical review, *Research Policy*, Vol. 30, 509–32.

SCOTT, A., STEYN, G., GEUNA, A., BRUSONI, S. and STEINMULLER, E. 2001: *The Economic Returns to Basic Research and the Benefits of University–Industry Relationships*. A literature review and update of findings, Report for the Office of Science and Technology, mimeo, Science and Technology Policy Research Unit, University of Sussex.