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The responsiveness of the universities

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Reflections on R&D, R&D policy and high tech sectors in Sweden and the differences and similarities to the situation in America

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Foreword

One of the assignments of the ITPS is to evaluate innovation policy. This is the first report in this field. It deals with the responsiveness of the Universities, and is a broad overview of R&D, R&D policy and some high tech sectors in Sweden. The situation in Sweden is discussed with America as a backdrop.

The study was the result of collaboration between Professor Nathan Rosenberg at Stanford University and Doctor Hans-Olof Hagén at ITPS who also acted as project manager.

Stockholm in November 2003

Sture Öberg,
Director-General

Innehåll

1 Why should we worry so much about R&D?

The most immediate answer is quite straightforward: There is much evidence to support the view that, for advanced industrial economies (let us say OECD member countries) R&D expenditures can serve as a prime determinant of a country's long-term economic performance. It should be emphasized that the main focus of this paper is on long-term trends and not, for example, the recession of the last couple years. By "economic performance" we mean the standard of material well-being and the ability to generate an abundance of attractive employment opportunities for a country's population. To put the point in a slightly different perspective, there is compelling evidence that the social rate of return to expenditures on R&D - the rate of return to society as a whole, and not just to a few private individuals - can be very high. And there can be little doubt that, as the forward thrust of technological change is to make successful economies increasingly knowledge-intensive, the social rate of return to R&D (as well as the social rate of return to higher education), will continue to rise as a result. [1]

Alternatively put, the penalty that any economy will pay for failing to improve the performance of its R&D system will also rise. Of course, a high payoff to R&D spending is far from inevitable. R&D is a measure of input to economic activity, not a measure of output, and society needs to provide incentives and mechanisms that will assure that these inputs are most effectively allocated among the wide range of possible uses.

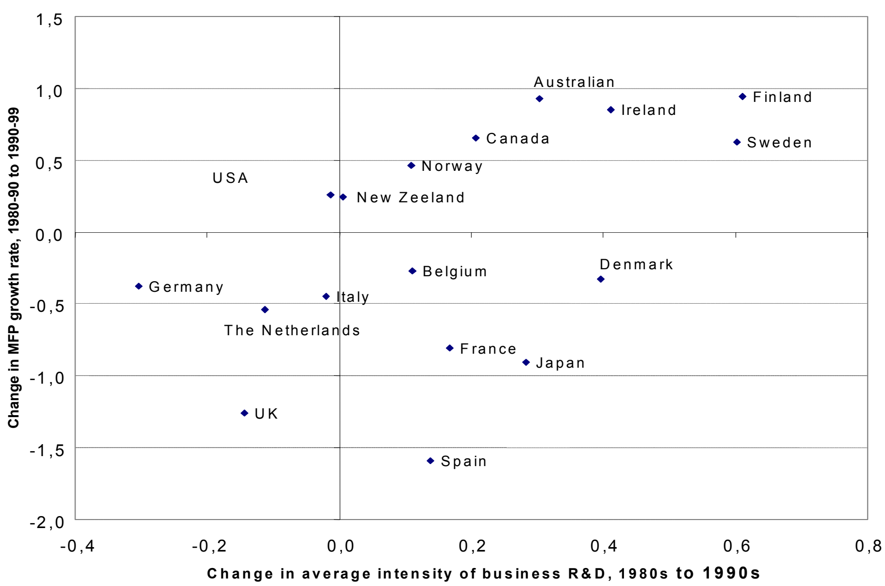
One piece of evidence of the relation between one measure of output (the change in multifactor productivity growth from the 1980s to the 1990s) and an input (the increase in business R&D) is shown in figure 1. Sweden's result comes out as normal in productivity terms, and higher than most other countries on both input and output. That means that the increase of the R&D intensity of its Swedish business sector from the 1980s to the 1990s is larger than in most other countries and that Sweden also is one of the countries that have the largest increase of its multifactor productivity growth rate. But this is only a measure of the changes in the 1990s compared to the 1980s, and not a measure of the benefits that Sweden derives from its absolute high level of R&D inputs.

In English-speaking countries we now routinely use the term "high tech" to refer to those industries that make intensive use of scientifically-trained personnel – semi-conductors, computers (hardware and software) information and communication technologies, aircraft, instrumentation, medical diagnostic technologies, pharma-

[1] *We want to express our gratitude to many experts who have given us information and comment on our manuscripts. They are of course not responsible in any way for the factual mistakes that still are left or to the conclusions. Among these experts we want to especially mention Dr Anna Sandström who is a biotech expert at the IVA (The Swedish Academy of Engineers) , former Professor Jan Odhnoff at KTH, Dr Carl Jacobson head of the Analyse department at The Swedish Research Council), Lennart Ståhle head of the* University Chancellor's secretariat at the *National Agency for Higher Education and Gunnel Dreborg deputy head of the Innovation System Analysis Division at VINNOVA (Swedish Agency for Innovation Systems)*

ceuticals, biotechnology. In the present context, however, the term "high tech" may be misleading because some of these industries, especially computers and information and communication technologies, have become indispensable in raising the productivity of *other* industries that we do not ordinarily think of as high tech.

FIGURE 1
CHANGE IN R&D INTENSITY AND MFP-GROWTH IN THE OECD-COUNTRIES, DURING THE 1990S.



Source: OECD

Computers, for example, are now widely used in textiles, banks and department stores. Most new cars in recent years contain a couple dozen computers: they regulate the flow of gasoline into the carburettor; they regulate the transmission, traction control, and anti-lock braking to increase traction and to reduce the dangers involved in skidding. And it has become increasingly common in the US for garage mechanics to undertake the diagnosis of mechanical problems in automobiles by first turning on a computer, then lifting the hood of the car, and only then reading the computer printout.

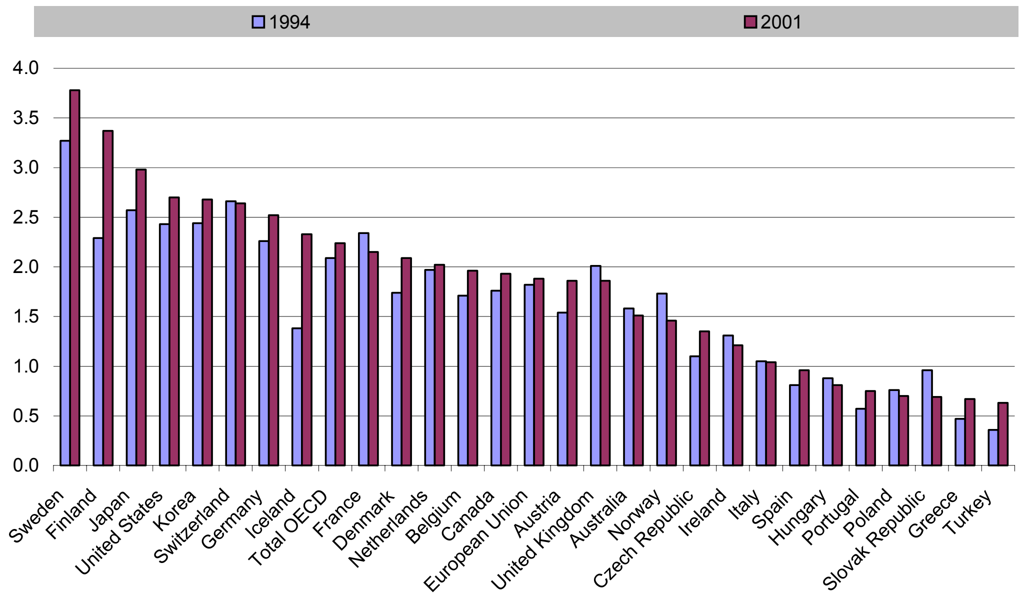
So, a key point about high tech industries is that their products are being widely diffused and their adoption and use have become crucial to raising the productivity and improving the performance of a wide range of more "traditional" industries. Thus, R&D is now essential, not just for improving the products of the high tech industries, but also for applying the new high tech products to the more traditional sectors of the economy.

Suppose that we grant the potentially high rate of return to R&D expenditures that has been suggested by the discussion so far. Why can't the whole question of R&D simply be left to the normal workings of the market place? The question is an important one, and an immediate answer is that, in most OECD countries, the bulk of expenditures on R&D are, in fact, left in the hands of private industry. Nevertheless, public expenditures remain critical.

To explain why, it is necessary to "unpack" the concept of R&D and examine its main component parts. The "R" of R&D refers to research, the sort of things that scientists do, and the "D" refers to development, the sort of things that engineers do. The R consists of Basic Research and Applied Research. It is generally agreed that Basic Research is not something that can ordinarily be left to market forces, although, in the US today, more than 30 per cent of Basic Research has recently been financed by private industry. In fact, over the years a number of scientists working in private industry have won Nobel Prizes for the very fundamental nature of their research findings. In the year 2000, for example, the Nobel Prize in Physics was awarded to Jack Kilby, who won that great distinction for research that culminated in his invention of the integrated circuit. Kilby conducted his research, not at one of America's well-known research universities, but at Texas Instruments, a private firm that was awarded the patent for Kilby's invention. Nevertheless the essential argument remains that, if Basic Research were left entirely to private industry, society would not get nearly enough of it. This is, in other words, a case of market failure.

FIGURE 2

R&D AS A PERCENTAGE OF GDP, 1994 AND 2001[1]



[1].Or nearest available years.

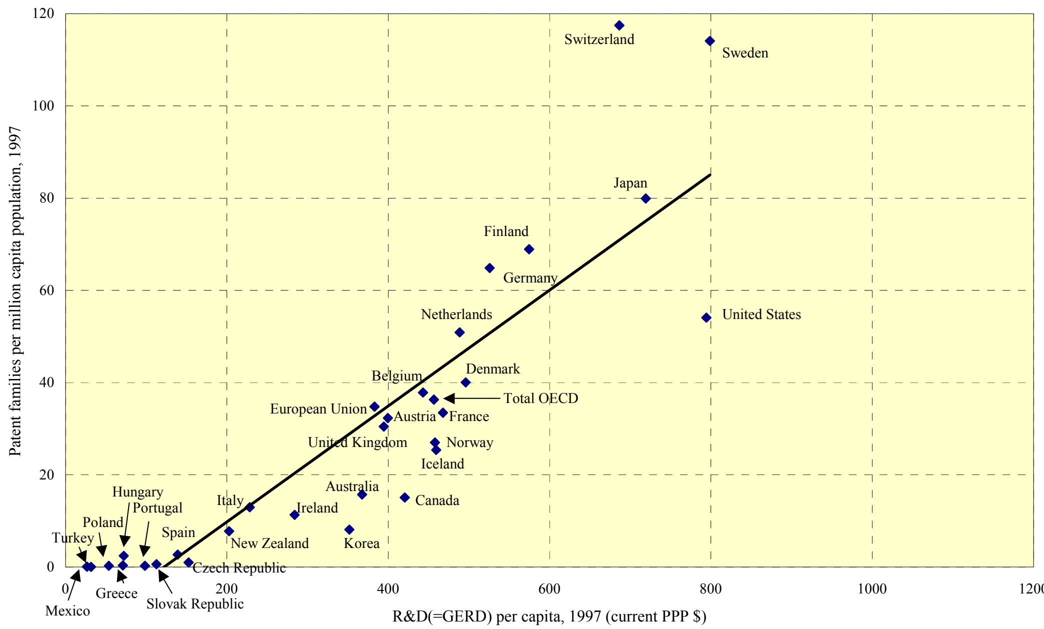
Source: Science, Technology and Industry Outlook 2002, OECD, MSTI database, May 2002.

Normal market forces would not generate the socially optimal amount of Basic Research. There is an appropriability problem ("Free Rider"). That is, the findings of Basic Research are ordinarily published very quickly. They are generally made available to one and all, including to firms that had made no expenditures whatsoever on this research. If sources of financial support, beyond those that were based upon calculations of private profit, were not provided in one way or another, society would not get nearly as many of the sorts of scientific breakthroughs that occasionally win Nobel Prizes.

Yet in the long term, many of these breakthroughs in fundamental science turn out to be immensely valuable to society, because applied scientific research eventually builds upon those breakthroughs, and product designers and engineers in private industry devise ways of producing new products with the new knowledge. But this process ordinarily takes a long time - so long that private industry normally decides that it cannot wait 10 or 15 years, or even longer, before such expensive research finally begins to generate a cash flow.

But at this point a further question arises, one that is especially pertinent to the Swedish experience in the past couple decades. If we consult the OECD Science, Technology and Industry Outlook 2002 (see figure 2) of R&D spending by member countries, we find that Sweden has, for many years, been at or close to the very top when OECD countries are ranked by the ratio R&D/GDP.

FIGURE 3
THE RELATION BETWEEN R&D AND PATENTING



Source: Science, Technology and Industry Outlook 2002, OECD.

This is well known - certainly to most Swedes. In fact, in most of the 1990s, Sweden was ranked number one, and has been the only country where the ratio stood at well over 3 per cent (A cautionary note. Since we are discussing a ratio, its value obviously depends on the size of the denominator as well as the size of the numerator. Sweden's very high ratio in the early 1990s was due, at least in some measure, to the relatively poor state of the economy during the sharp decline in Swedish GDP during the years 1990-1993). And this development together with the crises in the 1970s and 1980s have led to a relatively low GDP per capita level in Sweden, especially compared to those of the US and Switzerland. This means that in per capita terms, the resources that are put into research are roughly the same in US and Sweden and just a little lower in Switzerland and Japan, (see figure3). The latest figures seem even more impressive since the just published result from the 2001 R&D survey reveals that the business sectors have increased their R&D-spending from 2.74 per cent of GDP in 1999 to 3.32 per cent in 2001. Together with a public spending of well over one per cent, the total level will approach 4 and a half per cent of GDP in R&D investments that year. But we know that Ericsson is cutting its spending to half of their earlier level after 2001. This alone will probably mean a loss of half a per cent of GDP in R&D investment, so the peak of the R&D curve has probably been passed, at least for the time being.

So again, if Sweden stands at the top, or at least very close to the top, in the rankings of the share of GDP devoted to R&D, why should R&D be a matter of deep concern for the Swedish economy especially since Sweden also seems to perform well in terms of patenting activity, a measurement that is often regarded as a useful proxy for successful commercialization (See figure 3).

The most obvious explanation is that there has been a growing dissatisfaction with Sweden's economic performance for many years. If we refer to the most common measure of that performance, its GDP/person (a measure that, in turn, is a consequence of the country's past rate of economic growth), the country's record of deterioration is indeed disquieting. Sweden's slow rate of economic growth since 1970 has had a highly significant impact on the Swedish income level vis-à-vis that of other OECD countries. Using purchasing-power-parity adjusted measures of GDP per capita, Sweden had the fourth highest GDP per capita among OECD countries in 1970, behind only Switzerland, the US, and Luxembourg, with per capita GDP 13 percent above the OECD average and much higher than the other Nordic countries. By 1990 Sweden had fallen to ninth position, 5 percent above the OECD average. In 2002 Sweden was ranked 15^{th}, with a GDP per capita only 7 percent above the OECD average. This means that Sweden is the least prosperous of the Nordic countries and is at the EU average.

In looking for contributory factors in Sweden's relative economic decline, plausible arguments can be made connecting that decline to possible weaknesses in the country's R&D capability, even though the volume of R&D, expressed as a percentage of Swedish GDP, had remained high and the patenting results appear to be quite favourable. The presumption that such a connection may exist is a main motivation for this paper.

1.1 Similarities and differences between US and Sweden

In looking at the organization of R&D in Sweden from a comparative international perspective, it is almost impossible to begin anywhere except with the distinctive role played by the country's universities. It has often been observed that Sweden has, for some time, had a higher ratio of R&D spending to GDP than any other country. But there is another, related observation that is seldom made: If all OECD countries were ranked by the share of their R&D activities that was conducted in universities, Sweden would consistently be found to be at the top of that list as well. If we look specifically at the conduct of scientific research - the R of R&D - the Swedish arrangements are, quite simply, unique.

Let us place this in a larger context. For the countries of continental Europe, scientific research has been heavily concentrated outside the higher educational system; although this has begun to change somewhat in recent years. In Germany the most important institutions for the conduct of scientific research are the various Max Planck Gesellschaften; in France it has been the centralized laboratories of the CNRS and INSERM; in Eastern Europe the national academies of science have been the dominant institutions where scientific research has been carried out, typically, far from the student populations in the universities. In the US, indeed, slightly more than half of the country's scientific research activities are carried out within the university community, around 60 per cent if one includes the FFRDCs (Federally Financed Research and Development Centers). But the concentration of scientific research in Swedish universities has been substantially higher than the American case. In the year 1999 the government and the foundations with public money in Sweden gave 86 per cent of their money for public research to the universities (The Swedish Foundation for Strategic Research), but strict comparisons with the US are very difficult because of substantial differences in the way data are reported.

There are great potential advantages that can be made to flow from Sweden's concentration of scientific research in its universities rather than in separate research organizations such as dominate the European continent:

1. The quality of university teaching, especially at the graduate and professional levels, can be much better when the best researchers play a prominent role in the teaching process, and when they also serve as role models for students. It ought therefore to be a goal of education policy to reduce the separation between teaching and research.
2. The other side of this coin is that the quality of scientific research itself is likely to be improved when the country's brightest students have an opportunity to participate directly in the research process, admittedly in a subordinate role, but in a cultural environment that, at the same time, encourages and rewards informed criticisms.
3. Third, but not least important, new scientific knowledge and methodologies are likely to be transmitted more rapidly into industry, government and medicine by university graduates, when they go on to their subsequent professional employments. The American experience supports the view that recent university graduates are, frequently, the most effective of all diffusers of new science.

The responsiveness of universities to the changing needs of society and the economy is, then, to a great extent shaped by the speed with which the universities can accomplish 3 things:

1. Produce new, potentially useful knowledge through research,
2. Incorporate this knowledge into the teaching curriculum, and
3. Bring about the rapid diffusion of this knowledge through its graduates, in addition to the normal diffusion processes of publication, professional meetings and consulting activities.

There is, however, a critical point in any Sweden/US comparison that needs to be expanded upon in the present context, even though it has already been mentioned. That is, private industry in the US conducts a great deal of scientific research. Indeed, the National Science Foundation, which is the most authoritative source of such information for the US, reports that private industry in recent years has financed and performed over 30 percent of all basic scientific research (as the NSF defines it) in America. This has had enormous implications for the university-industry interface. It means that scientists in private industry are able to interact closely, and to derive benefits, in many ways, from professional contacts with university researchers.

Because private industry in the US has made a major commitment to the conduct of scientific research, private industry in the US has a sophisticated capacity for monitoring university research. Industrial scientists can effectively evaluate university research findings in terms of their potential usefulness for new product development, cost reduction, or performance improvement, because their location inside the firm provides them with a good sense of the firm's priorities, as well as its weaknesses and limitations. And industry scientists can facilitate the transfer of useful knowledge based upon university research. In certain sectors, at least, there is extensive, and increasing, co-authorship between university and industry scientists. Citation analysis indicates, in the biotechnology realm, that the academic quality of papers co-authored with industrial scientists remains very high. Indeed, it is no longer unheard of for university professors to take their sabbaticals with private firms, such as Genentech, Intel or Hewlett-Packard. And many American research universities readily allow extended leaves of absence for faculty who would like to try their hand at starting up new firms, frequently drawing upon recent scientific findings in the university. In fact, in the early years of the emergence of the biotech industry (early1980s) all of the new start up firms had strong, prominent leadership supplied by university faculty (See the valuable study by Martin Kenney, Biotechnology: The University-Industrial Complex, Yale 1986).

It is important to add that university spin offs have also been created by university dropouts. Google, the most widely used internet search instrument, was started by two dropouts from Stanford's graduate program in computer science. These two dropouts were quite clearly drawing heavily upon knowledge acquired during their graduate training at Stanford. And, as is widely known, Microsoft, by far the largest of all software firms, was started by a Harvard dropout.

From the American perspective, then, it appears that communication across the Swedish university/industry interface may be seriously handicapped by the very modest commitment of Swedish industry to scientific research. Another example of this lack of interface is the small commitment of Swedish industry to finance university research. In 1999 they contributed only 4 per cent (The Swedish Foundation for Strategic Research) to the Universities research budget, the same amount that the researchers received from foreign sources (mostly EU). There is, in brief, a high degree of mobility and interaction, taking a variety of forms, between the worlds of academic and industrial science in America that has no close parallel in Sweden.

At the same time, it should be observed that there is a good deal of ongoing concern over the intrusion of commercial values into the pristine world of American academe (In the American context, the use of the word "pristine" should be interpreted as deliberately ironic. American universities have never been pristine!). These concerns focus especially on the extent to which academic research agendas are being reshaped by the pursuit of potentially patentable findings that may generate large royalty flows. It may be of interest to note that a number of distinguished scholars (e.g., Ed Mansfield, Harvey Brooks) have looked for evidence of such reshaping of academic research goals, but they have, at least as of a few years ago, found nothing truly compelling. [See also paper by Mowery et al.].

But perhaps even more serious is the concern, in the US, over possible conflicts of interest, especially in Academic Medical Centres, where most of the lucrative patenting activity has been taking place. Additionally highly controversial is the arrangement in which universities accept sponsored grants from industry that involve any restrictions on access to research findings. Such arrangements most directly offend the traditional academic norms of universities as open institutions. But it seems fair to say that the American academic world is largely reconciled to the inevitability of a more intimate relationship between academe and industry; it is now mainly concerned with limiting abuses. In this respect there now appears to be a large cultural gap between the American and Swedish academic worlds, which is very much relevant to our present concerns. Swedish academics now seem to worry far more than do their American counterparts about a substantial reputational risk that might follow upon their expression of interest in the commercialisation of academic research findings. Having gone this far, it should also be admitted that distinguished American professors in the Life Sciences have been heard to voice the concern that an expression of interest in the commercialisation of their research findings might seriously prejudice their candidacy for a coveted Nobel Prize.

1.2 The reforms of the 1990s

With respect to the D of R&D, the business sector, and particularly a small handful of large multinationals are, of course, the predominant institutions in Sweden. But, even here, Swedish universities conduct a higher proportion of the country's research activities than the other Nordic countries (NUTEK, p. 65) and also, most probably, a higher proportion than other OECD countries. Furthermore, a striking fact, at least to most outsiders, concerning the prominence of Swedish universities in the country's overall R&D system is this: if one focuses upon the total amount of R&D (the Swedish data on research activities at the universities do not distinguish between R and D) that has been conducted specifically by PhDs., more than half of them (52 per cent) were located within the Swedish university community in 1993. The situation in the year 2000 represented only a partial change. Of all research-educated persons (doctors and people with an intermediate degree; this is called lisenciat) who were working in Sweden in this year, in total 36533, 40 per cent were working in the private sector and the same number were working with research and education in the public sector. Of those who made up the remaining 20 per cent who were occupied in the public sector outside the university system, two thirds (12.7 per cent points) of them were in the health sector. In the private sector only one third as many were working in this sector, which means that 4 per cent of all research educated persons are in the private health sector. If we only compare those who are working with research we find that almost twice as many are working in the public sector as in the private, 4614 and 2689 respectively. If we widen our perspective to all with a university degree we find that just over 50 per cent have found a job in the public sector compared with the 60 per cent for those with a research education, still a very high figure.

Before the 1990s the Swedish university system could have been fairly described as a "top-down" form of organization, with a high degree of centralized control, at the Ministry of Education, over the multidisciplinary universities, the technical universities, The Karolinska Institute (now a medical university), and the various university colleges. This could be sharply contrasted with arrangements in the US, a decentralized, "bottom-up" form of organization which was market oriented, with no centralized decision making body, and also, it should be emphasized, with no centralized government agency which composed, and delivered, an annual budget to its various constituent parts. American universities have been market-oriented because, historically, they had little alternative [See Rosenberg, "America's Entrepreneurial Universities", forthcoming].

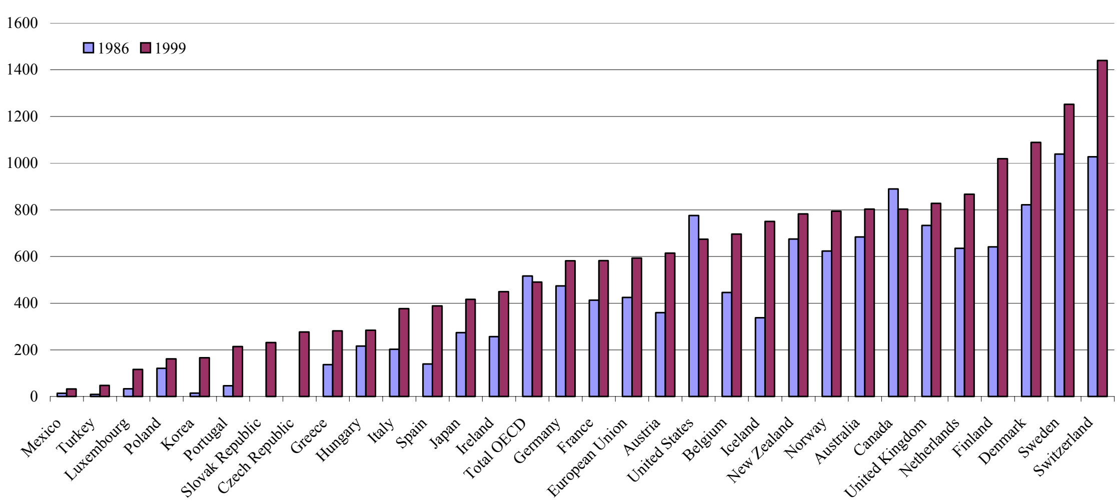
In the course of the 1990s, but mostly as a result of the reforms in 1993, a number of substantial, decentralizing changes were introduced into the organization of the Swedish higher educational system. The central thrust of the reforms was to provide a considerable increase in the degree of autonomy at the level of the universities. This was to involve greater freedom of decision making for universities, for example with respect to hiring practices and the introduction of new course materials, at least within the limits of their budgetary constraints. There are now considerable salary differentials across departments within a given university, and salary differentials now exist in the same discipline at different universities. At the same time, universities are now free to compete for financial support from the various foundations to expand the research activities of their faculties. It appears, however, that substantial reallocations of funds are still in practice very hard to achieve within the Swedish higher educational system, even if the universities have more freedom nowadays to reallocate (more about these changes are presented at page 23).

It would also be valuable to learn more about the extent to which a “two-tier” system still prevails in the teaching of students. That is to say, what fraction of university teachers without PhDs lecture to students? It is not currently possible to answer that question, but, at least according to the official statistics of all the teaching personnel, less than 40 percent have passed the PhD exam. If one tries to adjust for the fact that the professors, assistant professors, and the research students teach less than lectors, junior lectures and extra teachers, it probably adds up to almost the same numbers. And since the proportions between the different categories have not changed very much during the last five years, the proportion of the time students meet teachers with PhDs has been roughly the same. In the humanities and social sciences the categories with higher percentages of PhDs is a little lower, but the difference is not great. This means that the proportion probably is around 30 in these fields and around 40 in the others. It is very clearly a two-tier system, since it is not very feasible for associate professors and junior lectors with heavy teaching loads to aspire to move up the academic ladder, even if there are some differences between different fields**.**

2 The Life Sciences

We turn now to measures of Swedish academic performance in research. Here, as would be expected, one finds impressive measures. If one employs a broad gauged measure, for example, the number of publications in internationally-recognized professional journals (expressed as numbers per billion US dollars of GDP), Sweden ranked second only to Israel in 1995, while the US ranked 20th at less than half the Swedish level (National Science Board, 1997). Clearly, when one considers such highly aggregated measures of Swedish scholarship, the results are highly favourable. This is also the case if we compare the number of scientific publications per million of population within the OECD. In this context Sweden comes out second only to Switzerland (Israel is not included in this material) in 1986 as well as 1999. Additionally, in 1999 the US reaches only half the score of Sweden.

FIGURE 4
NUMBER OF SCIENTIFIC PUBLICATIONS PER MILLION POPULATION, 1986 AND 1999



Source: Science, Technology and Industry Outlook 2002,OECD, based on NSF (2002); ISI-SCI.

If one looks, as one must, at more disaggregated numbers, one finds that Sweden has consistently ranked very high in the biology-based disciplines, including especially clinical medicine and biomedical research generally (European Science and Technology Scoreboard, 1999, pp. 34-35). Indeed, Sweden's prominence in the scientific research fields on which the biotech industry has been based is quite remarkable in view of the country's small size and geographic isolation. At the same time, this small population base must render Sweden's position rather precarious with respect to both the country's research capabilities as well as its commercial prospects in this burgeoning, research-intensive field. The departure of Pharmacia and Astra (once entirely Swedish companies), even if there still is a lot of activity in Sweden inside the AstraZeneca group, are surely matters of very serious concern. These departures deprive the country of financial resources and marketing capabilities to support the later development and commercial exploitation of new products emerging from small start up firms.

Sweden's biotech industry in the year 2001 included some 183 companies of less than 500 employees each, with a total of about 4000 employees and a turnover of about 4.4 billion SEK in the year 2000. There were four companies with more than 500 employees each; one with 550, one with 1400, AstraZeneca with at least 5000 of their 11,000 in Sweden and Pfizer, formerly Pharmacia&Upjohn, with perhaps a 1000. This placed Sweden's biotech industry as the fourth largest in Europe in terms of the number of companies, after Great Britain, Germany and France – surely a very considerable achievement for a nation with a much smaller population.

Recent research and data collection now make it possible, using bibliometric techniques, to calibrate Sweden's performance in the Life Sciences through international comparisons. The Life Sciences, in these exercises, have been broken down into the following seven categories:

1. Biochemistry and Biophysics
2. Biotechnology and Applied Microbiology
3. Cell and Developmental Biology
4. Immunology
5. Microbiology
6. Molecular Biology and Genetics
7. Neurosciences and Behaviour

Sweden's overall performance in these selected fields can be summarized as follows: (We thank Dr. Anna Sandström, of IVA for allowing us to draw upon her recent study (see below), but she bears no responsibility for any inferences that have been drawn from her data). The years drawn upon vary between 1986 and 2001, depending upon availability.

1. Expressed on a per capita basis, Sweden ranked first, second or third in terms of the number of publications in each of the 7 subject fields.
2. In 5 out of the 7 fields Sweden showed an increasing share of the world's total volume of publications 1987-2001.
3. In 4 out of the 7 fields Sweden showed increasing citation levels 1987-2001, with a five-year citation window.

It can be argued that the frequency of citations to an article is a more sensitive index of the quality of research than the number of publications, since citation provides a measure, or at least a good proxy of how important - how influential - a given publication has been in the estimation of other qualified researchers in a given field. In that respect, the "flip side" of the third observation, that 4 out of 7 fields showed increasing citations, is that 3 of the 7 fields showed declining citations. Those fields showing declining citations are of great importance since they include Immunology and Neuroscience.

The data [in a newly released biotech report, VINNOVA Analysis; VA 2003:2 by Anna Sandström and Lennart Nordgren] suggests that Sweden has a strong, but weakening, position with regard to the science base in fields relevant to the biotech industry. The most important measure of performance is perhaps not the volume in relation to population, but rather the relative citation levels, which can be regarded as a measure of quality. It seems clear that Sweden is losing ground to other countries if the quality of science is measured in terms of citation levels. It is worrying that many countries, both within Europe and elsewhere, have overtaken Sweden in the statistics for the two largest fields Neuroscience & Behaviour and Biochemistry & Biophysics. In four of the seven fields, the analysis indicates that Sweden, in terms of scientific quality, is being passed by a number of countries.

The decline in citations in these fields might well be regarded as a sort of "early warning" measure that calls for further examination. The reasons for these declines are not yet clear. Three possibilities suggest themselves: (1) As the pool of researchers expands because of growing awareness that this will be an attractive field, Sweden may be moving down the quality gradient of potential new recruits to the field: or (2) As other countries move into a field where Sweden has been an early research pioneer, an expanding group of countries that have been more recent arrivals may be narrowing the citation gap between their own performances and that of Sweden. (3) A third explanation could be the recent reform of the Swedish higher education system. This reform is intended to speed up the time for the completion of PhD studies, and it has diminished the average time by half a year. This could mean that the quality of the theses has deteriorated since the authors now spend less time on them. That means that they may be less original and thus will not be cited to the same extent as before. Since the PhD theses account for a large proportion of all Swedish research papers, this can also have had an influence.

What measures is it possible to use with respect to the biotechnology industry (as well as to clinical activity generally), where Sweden has demonstrated such high levels of research competence? This is a very important question because Sweden clearly has huge research capabilities in this burgeoning new field but has, as yet, hardly any firms that have started from scratch and that have subsequently "made it big." The vast majority of biotech start-up firms seem to be very small "research boutiques" with little demonstrated capacity for growth. In other countries, especially the US, the large, traditional pharmaceutical firms have been playing a significant role, in various ways, to expedite commercialization of technologies that are being nurtured by these numerous "research boutiques." In this respect, again, the departure overseas of Sweden's large pharmaceutical firms should remain a matter of considerable concern. But it is particularly a cause for concern because Swedish start-up firms in this sector seem never to grow. The departure of Pharmacia and Astra renders even more urgent the development of policy measures that will encourage the future growth of biotech start-ups. The industry has grown, although not sufficiently to become one of great importance to the national economy, at least so far. Some numbers from the biotech report mentioned above;

- The number of companies increased by 35 per cent between 1997 and 2001 to 183.
- The number of employees increased by 48 per cent between 1997 and 2001 to about 4000.
- The turnover (fixed prices) increased by more than 30 per cent between 1997 and 2000 and amounted to about 4400(?) MSEK in 2000.
- The equity/assets ratio increased but so did aggregated net losses for 95 companies present during the entire study period.

There is an interesting contrast between Swedish and American policy concerns that is relevant in this context. Historically, the US has always been concerned about barriers to entry into an industry, a concern that goes all the way back to the passage of the Sherman Antitrust Act in 1890. In Sweden the larger problem, at least in recent years, seems to be barriers, not to entry, but rather to the growth of new firms after they have already achieved entry into some new market. This slow-growth phenomenon in Sweden seems to be even more pronounced for university spin-offs than for commercial spin-offs. See the research findings of Lindholm Dahlstrand The economics of technological-related ownership relations: A study of Innovationness and Growth through acquisition and Spin-offs. A PH. D. Diss at Chalmers Technological University 1994)**.** This is a highly cited research result but it is not based on a large-scale study and it is obviously somewhat dated by now. Still there are no new results that contradict the findings that university spin-offs in Sweden consistently grow much more slowly than other spin-off firms. Considering the prominence of universities in Sweden's R&D system, this finding should be a matter of great concern. Of course, if a new technology is not being commercialized by some university spin-off that was started with the specific intent of commercializing a particular new technology, this does not mean that commercialization is not being achieved by some other means. Still, the failure of university start-ups to achieve some greater degree of success is a subject that calls for more critical examination (See Henrekson and Rosenberg in Journal of Technology Transfer 26, 207-231, 2001).

One measure worth monitoring, then, is university patenting activities in biotechnology, since a large fraction of all biotech firms in Sweden have in fact been university spin-offs. How did the invention (or idea) come about? Are the patents being commercialised? Who is commercialising them? If they are not being commercialised, why not? What are the main barriers to expansion? (See Henrekson and Rosenberg "Akademiskt entreprenörskap", SNS 2000).

When one turns, then, from measures of Swedish scientific research output to measures of commercialisation of new biological entities, the picture changes quite drastically. Intellectual property rights are strongly enforced and constitute a powerful legal protection in the pharmaceutical industries of OECD member countries. Moreover, the US constitutes, very roughly, almost one half of the total world market for higher tech, health-connected products, and the FDA(=the American Food and Drug Administration) is well known for maintaining rigorous standards for safety and efficacy before approving a new product for sale in the American market. Additionally, taking out a patent at the US Government Patent Office is not cheap. Consequently, the extent of a country's patenting activity in the US is now widely accepted as a useful proxy for that country's commercialising capabilities in a given product line.

Using the criterion of "Inventor origin for biotechnology patents in the US patent system 1987-2001," the Swedish measure is, at best, distinctly unimpressive (Here again the data cited were kindly made available by Dr. Sandström).

A few facts concerning the Swedish shares of patents granted in the US patent system:

- The Swedish share in Pharmaceuticals is 1.3 per cent, corresponding to a 40 per cent increase comparing 1999-2001 with 1987-1989.
- The Swedish share in Biotechnology is 0.8 per cent, corresponding to a 17 per cent increase comparing 1999-2001 with 1987-1989.

Even if there has been a substantial increase the absolute numbers are not high.

2.1 University Intellectual Property Rights

We turn now to consider Intellectual Property Rights as they may affect Sweden's prospects for commercial exploitation of potentially patentable university research findings. We draw primarily on the much more extensive American experience over the past 25 years. At first glance it appears, somewhat surprisingly, that Sweden still remains more heavily committed to a narrowly individualistic interpretation of private property rights, as compared to the present situation in the US that, in some respects, reflects a considerable departure from earlier definitions of property rights, especially with respect to universities.

The Anglo-American tradition, going at least as far back as John Locke's Second Treatise on Civil Government, was that the incentive to undertake inventive activity is maximized by assuring the potential inventor of the full fruits of his inventive efforts, in the event that those efforts should result in a valuable patentable invention. Though alterations are currently being considered in the Swedish system, the dominant arrangement is still the presumption that a professorial inventor is the sole owner of the patents that may issue from his university research.

TABLE 1

OWNERSHIP OF IPRS AT PUBLICLY FINANCED RESEARCH ORGANISATIONS (PROS)

	Ownership of patentable inventions		
	PRO	Inventor	Government
Australia	♦		
Austria[1]	♦ (P)	♦ (U)	◊
Belgium	♦		
Canada	♦	♦	
Denmark[2]	♦		
Finland[3]	♦ (P)	♦ (U)	
France	♦		
Germany	♦		
Hungary	♦ (P)		
Iceland	♦ (P)	♦ (U)	
Ireland	♦		
Italy	♦ (P)	♦ (U)	
Japan[5]		♦	◊
Korea[4]			
Mexico	♦		
Netherlands	♦		
Norway	♦ (P)	♦ (U)	
Poland	♦		
Russia			♦
Sweden		♦ (U)	
United Kingdom	♦		
United States[6]	♦	◊	◊

(P) = Non-university PROs (public labs, academies, etc.)
(U) = University-based PROs
♦= General rule or common practice ◊= allowed by rule but less common

1. In Austria, the government owns inventions by employees at universities, but in practice transfers ownership to the individual inventors.

2. In Denmark, the university or PRO claims ownership but inventors have a right of first refusal.

3. In Finland, ownership of inventions at non-university public research organisations must be transferred from the individual to the institution provided the latter can exploit the invention.

4. In Korea, ownership is dependent on the research contract and source of funding. Researchers at both universities and PROs own title to invention for privately funded research.

5. In Japan, ownership of inventions at the national universities devolves to the government through university invention committees. If an invention is not classified as a national invention, the individual inventor retains title.

6. In the US, universities to have the first right to elect title to inventions resulting from federally funded research. The Government (e.g. federal agency) may claim title to if the performer does not claim title. In certain cases, the inventor may retain rights with the agreement of the university/federal partner and the government.

Sources: Science, Technology and Industry Outlook 2002 OECD Questionnaire on the Patenting and Licensing Activities of PROs, results; Benchmarking-Industry Science Relationships (OECD, 2002b).

This is not unique internationally since there are five other countries that have employed this model according to table 1, one of which, Italy, has recently introduced this model. But after only a year, Italy is now in the process of changing back to the other principle with the university having some of the IPR. Norway has also completed a change at the turn of the year. So the great majority of countries are now opting for essentially the same system as the US. Beside Austria, Iceland and Finland, which are discussing a change, Sweden is alone.

Of course there are some strong arguments for the earlier situation. The most basic is that it is morally right for the inventor to reap the full return from his effort. One counter argument to this is that the inventor in the universities system has used the resources of his employer and perhaps also his colleagues to the same extent as an inventor in a private firm. And according to Jan Odhnoff and Inga Hamngren, in a report from a government committee (SOU 1996:70 page 158-159) there has been a clear anti entrepreneurial opinion pressure on potential entrepreneurs in the Swedish university system due to the fact that the institutions do not receive any income from the proprietary rights.

But it is also true that most players in the biotech industry and academia maintain that the teachers' exemption should not be changed. The reasoning behind this is that it is less bureaucratic to attract investments and start a new business or to licence out an invention if the university is not involved. This makes it a competitive advantage for Sweden. This is also often stated by US- and Japanese investors. It is also advocated that it increases the incentives for the most important person in the starting of an innovation process, the inventor, to try to get the innovation commercialised. The universities today have very little experience concerning commercialisation of academic research.

It is also argued that if the teachers' exemption was to be removed that must be combined with other initiatives and changes at the universities, e.g. the support system to patenting and licensing must become much more efficient and professional and supply better legal and other services as well as networking with commercial players such as VC companies. Also, a way to include a scientists' success at patenting and commercialising his/her research in the academic qualification system could be investigated.

Many also point to the fact that it is already possible today, in principle, for the universities to draw up agreements with their scientists concerning sharing potential profits from university inventions. Also well functioning holding companies or technology licensing offices at the universities can offer help with the commercialisation of a scientists' invention in return for ownership shares of the project to the holding company or a technology licensing office as a way to work around the teachers´ exemption.

One example of a venture capitalist who expresses the view mentioned above is found in an article in “Nature” (supplement, December 2002). He thinks that it is easier to deal with a lone academic inventor than with a university. No doubt this is sometimes the case. But it is not obvious that the ability of a venture capitalist to "swing a better deal" for himself, when dealing with a weaker negotiating partner, necessarily translates into a "bad deal" for Swedish society as a whole, although it might. But it is also possible that, if a university technology transfer office was able to provide services that led to the successful commercialization of a socially valuable product that might otherwise have "withered on the vine," society might be a substantial beneficiary. And surely examples of such cases are not hard to find. Indeed, this was the basic rationale for the passage of the Bayh-Dole Act of 1980.

In the US the possibilities for commercial exploitation of university research findings were strengthened by the passage of the Bayh-Dole Act of 1980, which allowed universities to appropriate the property rights to an invention that resulted from university research that was supported by federal grants. As a result, American universities can now, in effect, develop contractual arrangements for “profit sharing” between individual faculty researchers, their departments, and the university. Within the American decentralized framework, the final arrangements will be made by each university (bottom up). Moreover, universities now have strong incentives to set up their own offices of technology transfer. These offices, and there are now more than two hundred of them, operate on a fully professional basis with staffs of lawyers, technology specialists, marketing specialists and accountants, who facilitate the commercial exploitation of potentially valuable research findings. The constructive feature of the Bayh-Dole Act, from the point of view of encouraging the commercialization of university research, is that, by providing for university ownership, it also provides university administrators with a strong incentive to support commercialization.

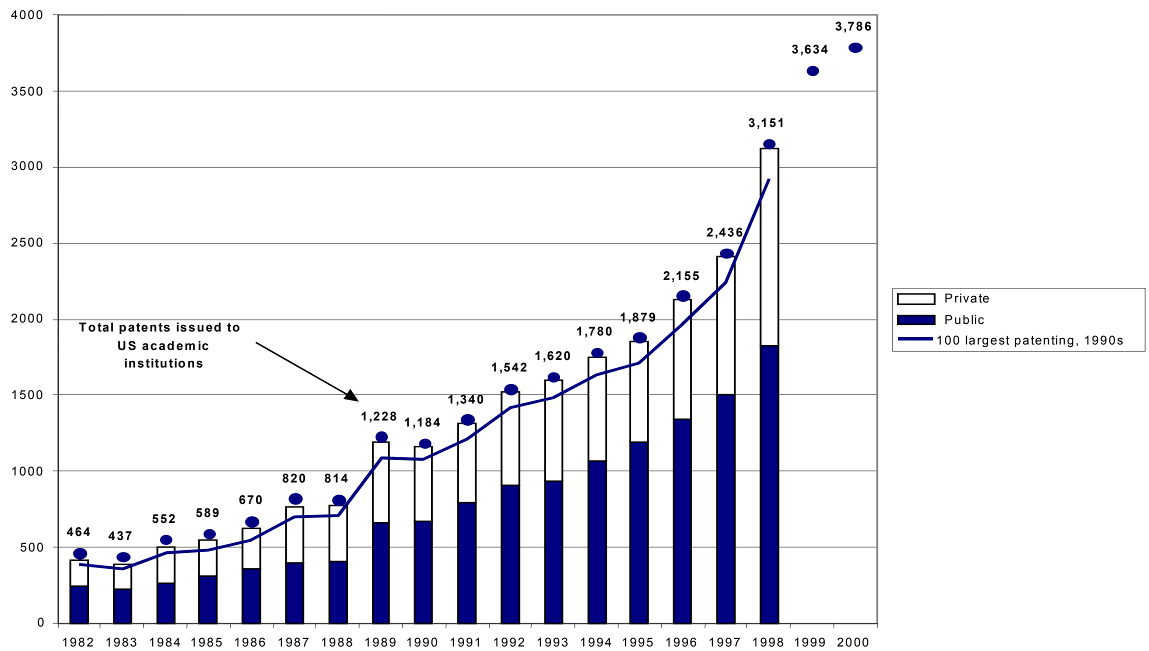
At the same time, however, it is possible for universities to distribute license revenues in ways that strengthen the incentives to perform academic research. A common arrangement at many research universities, in the years since the passage of the Bayh-Dole Act, is that each of 3 parties receives roughly one-third of the patent revenues: the academic inventor, the inventor's department (or laboratory), and the school within which the department is lodged. In practice, this is likely to mean an increasing concentration of research support for the fields where the patent revenues have been generated - the biomedical realm (especially biotechnology) and certain engineering disciplines (especially electrical engineering and computers).

But the influence of the Bayh-Dole Act by itself should not be overstated. The US was probably already moving in the direction of university offices of technology licensing even before the Bayh-Dole Act was passed in 1980. The massive increase of federal financial support for biomedical research, after 1960, was clearly increasing the attractiveness of university patent licensing. In fact, the most important breakthrough in the emergence of the biotechnology industry, the development of Recombinant DNA, had already been patented, by Stanford and UCSF, in 1974. More generally, the number of all patents taken out by American universities shows a distinct acceleration before the passage of Bayh-Dole. But the increase afterwards is still impressive (see figure 5). With respect to academic patenting in the US today, it is fair to state that this patenting is totally dominated by the biomedical sciences. [For a valuable overview, see David Mowery et al., "The growth of patenting and licensing by US universities: an assessment of the effects of the Bayh-Dole act of 1980," Research Policy, pp. 99-119, 2001.

As a result, the incentives within the US university system now encourage active participation, not only by faculty, but also by university administrators - department chairmen, deans and knowledgeable specialists available through the offices of technology licensing - all of whom now have distinct financial interests in successful commercialisation.

FIGURE 5

US PATENTS AWARDED TO ALL US UNIVERSITIES AND TO TOP 100 PATENTING UNIVERSITIES, 1982-2000



Source: Science, Technology and Industry Outlook 2002, OECD. NSF 2002, AUTM 2002.

By contrast, the Swedish system that placed property rights emanating from university research entirely in the hands of individual faculty members has the result that the universities themselves have had little incentive to become involved in technology transfer to the commercial world. The fact that, under the American system, some portion of patent revenues may be, and often are, fed back into the research lab that spawned the invention, is also likely to lead to a more supportive view on the part of departmental colleagues, department chairmen and deans. With respect to equity considerations, the American arrangement is, in a very real sense, more collegial, as well as more likely to lead to successful commercialization.

Under the Swedish system the university authorities have had little financial incentive to become involved in technology transfer to the commercial sector. For example, it appears that the procedures and practices for obtaining academic leave on the part of Swedish faculty are not as easy to arrange as in the US. The high degree of academic mobility in the US, and the competition on the part of US universities for highly talented researchers who may want to go on leave, have led to liberal practices, and greater permissiveness generally, for faculty who want to pursue commercial opportunities. So, for example, if the MIT authorities were known to be dragging their feet in the case of a distinguished geneticist or immunologist who wanted to go on leave, it would not be totally surprising if the professor soon began to receive attractive offers from Harvard or UC San Diego, offers that just happened to include generous arrangements for going on leave. The general point, of course, is that university ownership of patents in the US has been as successful as it has because of the particular set of incentives generated under the autonomous and competitive nature of institutions of higher education in America. Handing over such property rights to universities under Sweden's present state-owned system would be likely to generate a quite different set of consequences. And some observers suggest that the Swedish universities are not sufficiently business oriented to be competent actors in this field. But it is a widespread experience that if the financial incentives are changed, there is a greater likelihood that organisations - even universities - may change their behaviour. Furthermore, an increase in university patenting activity, through offices of technology transfer, may serve to strengthen the presently-weak links of Swedish universities to the needs of the business community. Such an outcome may ultimately create an environment in which the universities may ultimately be of greater service to the needs of the larger civil society.

TABLE 2
TOP 25 US UNIVERSITIES RECEIVING PATENTS, GROSS LICENSE INCOME RECEIVED

TOP 25 Private Universities	**FY 2000**	**FY 1999**	**FY 1995**	**FY 1991**
	Million dollars	Million dollars	Million dollars	Million dollars
University of California System	268	81	57	19
Columbia University	149	96	34	11
Dartmouth College	68	0,5	0,4	0,1
Florida State University	67	57	10	0
Stanford University	37	40	39	26
MIT	31	17	5	4
Washington University	30	28	10	3
University of Pennsylvania	28	3	1	0,5
University of Florida	26	22	6	4
Michigan State University	26	24	15	11
California Institute of Technology	24	7	3	1
University of Minnesota	23	6	2	0,5
University of Wisconsin	23	18	12	12
Harvard University	17	14	7	2
SUNY Research Foundation	17	14	0,6	0,7
Johns Hopkins University	15	10	2	1
Emory University	13	16	3	0
Baylor College of Medicine	10	13	2	0,9
University of Texas Southwest. Med. Ctr.	9	5	3	0,9
Washington University	8	7	4	0,9
Tulane University	7	8	5	4
Rutgers, The State University of NJ	5	4	3	2
Brigham Young University	5	4	3	0,7
University of Iowa Research Fdn.	5	4	0,9	0,4
University of Cincinnati	5	4	2	0,5
1-25 Top Universities	**916**		**229,9**	**106,1**
26-60 Top Universities	**58**		**30**	**20**
Total for the 60 Top Universites	**974**		**261**	**122**

A change of policy is of course not necessarily a successful way to create funding for the universities; since even in the US there are only a handful of universities that have generated a sizeable, positive net income from this activity. The activity is quite concentrated in a few leaders, which is apparent from table 2 as well as from figure 5. It is also an instrument to create an expanded awareness of the surrounding society in the university community. In this sense it is a way to strengthen the linkages to the business sector and thereby to shape inventive activities in ways that may ultimately be of greater service to the needs of the civil society.

A final precautionary note. As already stated, there are more than 200 offices of technology licensing at American universities. The Association of University Technology Managers (AUTM) provides the most extensive data source on patenting and related activities by American universities and colleges, although its coverage is not complete. For the fiscal year 2000 their survey population included 221 universities and colleges. Gross license income received for the top 60 universities, ranked in descending order in that year, amounted to $974,040,000.

Several observations are appropriate. The percentage change from 1991 to 2000 was just short of 700% (the subsequent years, when the data become available, will of course tell a very different story). Fiscal year 2000, as the note attached to the table indicates, was most unusual (increasing 77% beyond 1999) because it included certain "high one-time payments." For individual universities there was a great deal of year-to-year variability (It should be noted that the numbers for the University of California, which sits at the top of the rankings, represents a total for 9 separate campuses throughout the state). Perhaps most important, although not particularly surprising, the distribution of patent revenues among universities is very highly skewed. For the fiscal year 2000 the gross license income of the 5 top universities were more than 60% of the gross revenues that accrued to all 60 of the universities in the AUTM survey. For the top 10 universities the comparable figure was 77%. Moreover, the financial "home runs" have come primarily from the realm of biomedical innovations, which also account for the occasional unexpected prominence of universities that are not commonly regarded as major centres of research - as in the case of Florida State University's anti-cancer drug, Taxol.

There are only limited data on the cost side, mainly in connection with legal fees, which are far from trivial, so the net figure can only be a matter of speculation. What is reasonably clear, however, is that, with just a few exceptions, patent licensing has provided a sizeable source of revenue for only a limited number of America's major research universities.

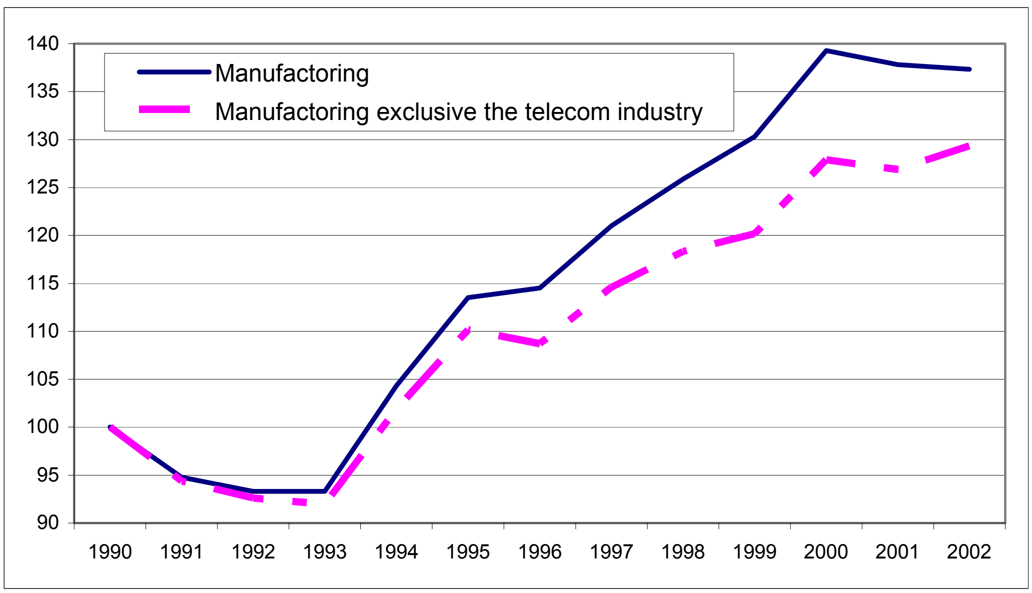
3 The IT Sector

Sweden is consistently ranked as one of the most advanced IT-countries in the world, in all the ranking lists that have been published during the past 3-4 years.

The use of IT is widely believed to be one of the most important potential contributors to economic growth in a country, even if it has been difficult to provide rigorous quantitative evidence of the extent to which a large IT-sector provides value to society. This sector is not only one of the most important knowledge intensive sectors; it is also by far the industry that has had the highest productivity growth rate of all industries during the 1990's. The development of the IT-sector has had a substantial impact on the whole economy long before the recession that has had such devastating effects on this sector in the past few years See figure 6.

FIGURE 6

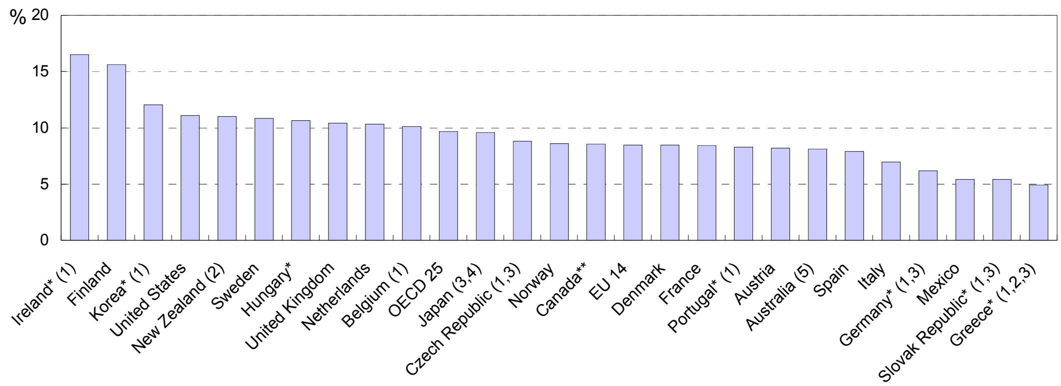
THE DEVELOPMENT OF THE SWEDISH MANUFACTURING SECTOR 1990-2002 WITH AND WITHOUT THE IT-INDUSTRY.



The Swedish IT-sector is somewhat larger than in most OECD-countries. In the majority of the countries it varies from 8 to 12 per cent of the non-farm business sector in the year 2000.

Source: SCB and ITPS

FIGURE 7
SHARE OF THE ICT SECTOR IN VALUE ADDED, NON-AGRICULTURAL BUSINESS SECTOR, 2000

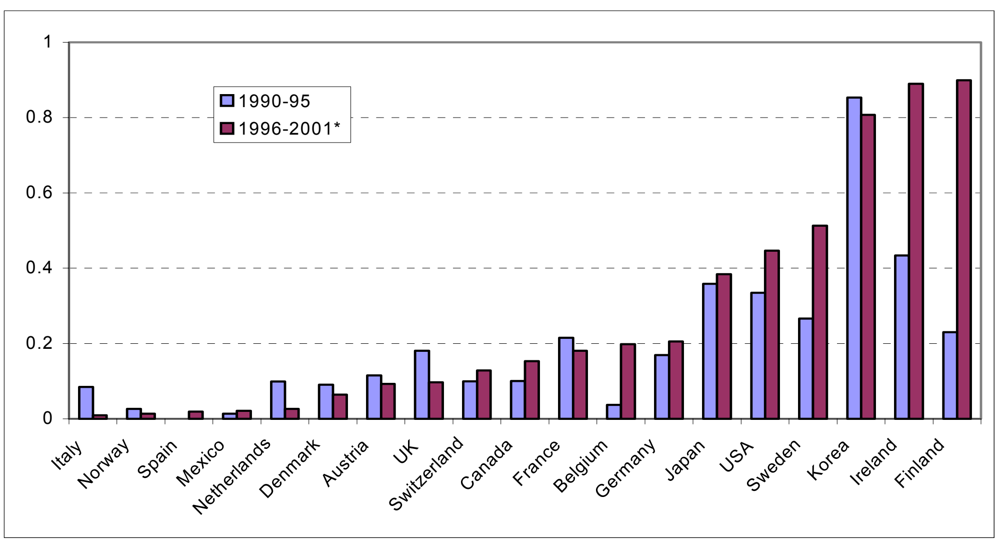


*Notes: * 1999 ** 1998 (1) Excludes rental of ICT (ISIC 7123); (2) Includes postal services; (3) Excludes ICT wholesale (ISIC 5150); (4) Includes only part of computer-related activities; (5) 2000-2001.*

Source: OECD (2002a), Measuring the Information Economy, www.oecd.org/sti/measuring-infoeconomy.

But this sector also provides an increasing share of productivity increases in most OECD countries. This is especially true for the manufacturing part of the sector. See figure 8a and b.

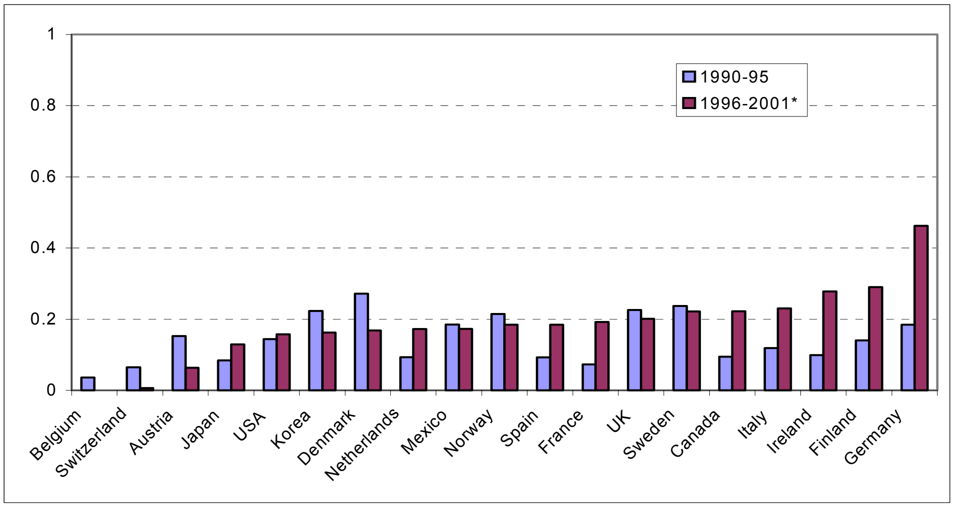
FIGURE 8 A
THE CONTRIBUTION OF ICT MANUFACTURING TO AGGREGATE PRODUCTIVITY GROWTH



Note: 1991-1995 for Germany; 1992-95 for Italy and 1993-1995 for Korea; 1996-98 for Japan, Spain and Sweden, 1996-99 for France, Korea, and the United Kingdom; 1996-2000 for Belgium, Canada, Germany, Ireland, Mexico, Norway and Switzerland.

Source: Pilat, Lee and Van Ark (2002), forthcoming, based on OECD STAN database.

FIGURE 8 B
THE CONTRIBUTION OF ICT-PRODUCING SERVICES TO AGGREGATE PRODUCTIVITY GROWTH

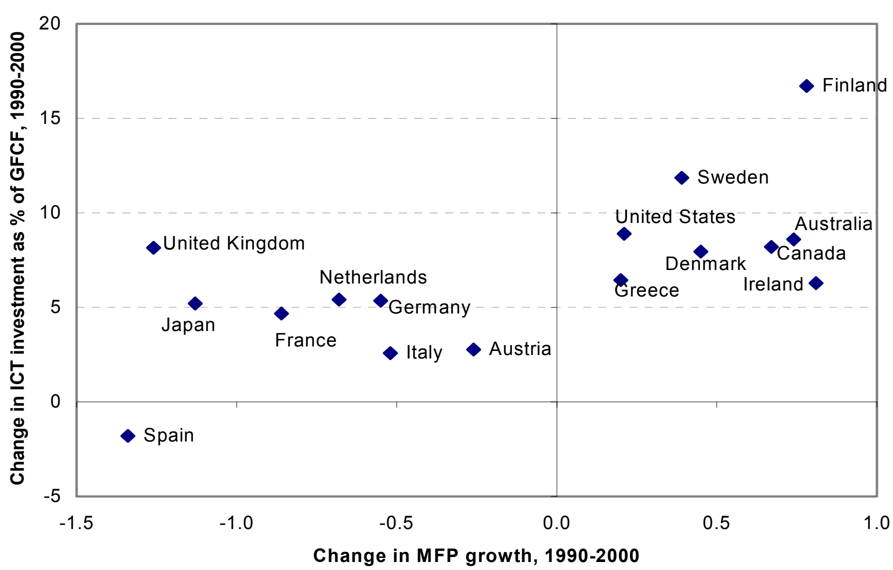


Note: See Figure II.2 for period coverage.

Source: Pilat, Lee and Van Ark (2002), forthcoming, based on OECD STAN database.

As already mentioned, it is harder to get proof of the impact of the IT-usage in the other sectors, but two indications are: the impact of the IT investments and the relation between the increase in multifactor productivity and the increase in ICT-investments, see figure 9.

FIGURE 9
PICK-UP IN MFP GROWTH AND INCREASE IN ICT INVESTMENT



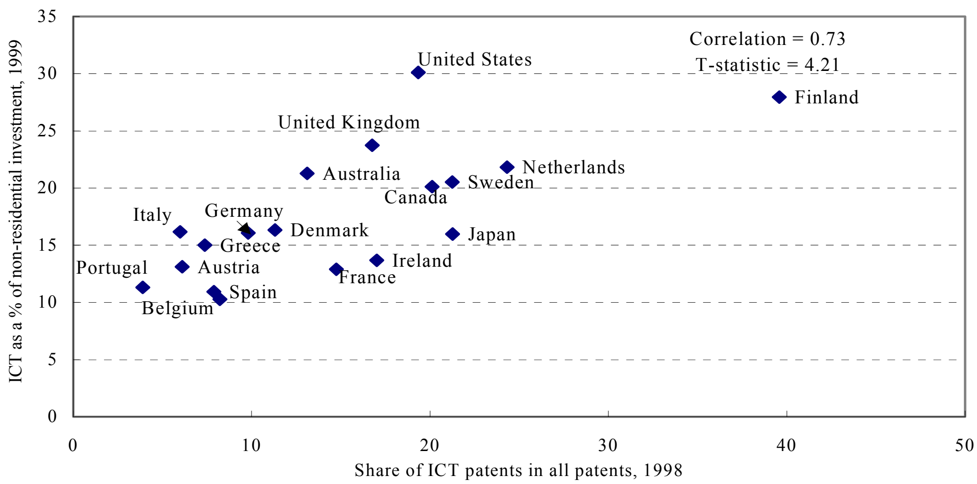
Correlation coefficient = 0.64; T-statistic = 3.15.

Source: ICT investment from OECD (2002a), MFP growth from OECD (2003b).

It is therefore a matter of great national importance to understand better the knowledge production and knowledge flow of relevance to the IT-industry in this country. And there seems to be some relation between ICT-investment and the innovation activity in the sector as measured by patents (see figure 10).

FIGURE 10

ICT INVESTMENT IS ACCOMPANIED BY RAPID INNOVATION IN ICT



Source: Science, Technology and Industry Outlook 2002, OECD. ICT investment from Figure II.1; ICT patents from OECD (2002), Measuring the Information Economy.

But perhaps even more important are the competence and absorptive capacity for stored and new knowledge, and thus the quantity and quality of IT-experts. If one compares the development of both the research field and the education capacity during the last 30 years in Sweden with American development, one comes up with a substantial difference. The IT sector is very different in many ways from the Biotech sector that has already been discussed. It is, for example, much older and more developed commercially.

A recent publication by Jan Odhnoff and Inga Hamngren deals with the responsiveness of the Swedish university system to the challenges of the Internet development, from the IT-commission ["Hänger högskolan med i Internet?", IT-kommissionen 2002]. They have studied the old, big institution KTH and the smaller younger institutions in Luleå and Blekinge. Their conclusion is that on the whole the responsiveness was not very impressive, at least not at KTH. An important fact is that KTH, as a large as well as old organisation, did not receive a very substantial increase in its resources during these years. They also believe that this, together with the collegial organisation and the conflicts in outlook between the different institutions, have created severe management problems.

They also think that this problem was not addressed in a proper manner by the management. Here lies the basic explanation to KTH's lack of response during the Internet revolution. Odhnoff and Hamngren conclude that it is necessary to govern KTH differently. The smaller organisations have, on the other hand, according to the authors, functioned in a more responsive way. They were much easier to manage due to their small size, but their main advantage lies in that they were in an expansion phase. It is of course much easier to direct new money to new fields than if you first have to take away old money from old subjects. The smaller organisations were also managed more dynamically. . Another reason for the lost position is of course the small scale of the Swedish market, which must have been an important disadvantage when the rapid growth in this sector in the US really took off. In the IT sub sector telecom on the other hand, two small countries (Finland and Sweden) have proved to be big enough to foster companies that are the major players in this market world wide. But the computer industry is by far a much larger sector.

The telecom part has become the dominant part of the Swedish IT-sector, especially on the manufacturing side. Both the manufacturing part as well as the service part is now important. Two big companies, Ericsson and Telia, have, respectively, traditionally dominated these two parts. Ericsson is still dominant on the manufacturing side; even though it has been in very serious trouble for some years and has substantially cut down its activity. The reasons for Ericsson`s crises are difficult to establish. They are of course both of internal and external nature. Ericsson made a very important strategic choice when they went for the revolution and started to develop 3G instead of a more gradual development of the GSM. This made them much more vulnerable then the market fell in a historically unprecedented way. This combination was probably the major factor for the crises, although Ericsson's relative position in the crumbling market for terminals remained strong. But the situation in the cellar phones market had became catastrophic. According to some analysts Ericsson was used to doing business with state owned telephone companies, so when the penetration of the mobiles made them a consumer product Ericsson was landed in an unfamiliar territory. The later move to cooperate with Sony, which knows the consumer market, and to sell the technology as such seems to be a quite reasonable action. It has though taken some time; it has proved to be successful but the first positive signs have only come quite recently.

In the past, these two big companies, Ericsson and Telia, cooperated in a jointly owned development company. Most of the development work was done by this company, and with little cooperation with the Universities. Currently, Telia as a network company, is not very R&D intensive, like their foreign competitors. Ericsson, on the other hand, had by far the biggest R&D budget of all the Swedish companies, and most of it has been carried out in Sweden. In 1999 the total research budget for the business sector in Sweden was 57 billion SEK, of that the big Swedish multinationals counted for 26 billions (and foreign owned 21 billions). They also spent another 19 billions abroad. In the same year Ericsson had a research budget of 33 billions SEK, of which the majority was carried out in Sweden, with US as the biggest foreign concentration. The increase of the research budget during the 1990s has, however, mostly been allocated abroad. Ericsson's R&D budget has, of course, been almost entirely spent on development. This development has been carried out by both in house staff and by consultants. Ericsson's own research personnel consist mostly of engineers with a master's degree in electrical engineering or computer science, and researchers with a Ph.D. degree have been relatively few. Personnel with PhDs are more abundant in the consulting firms which work for Ericsson.

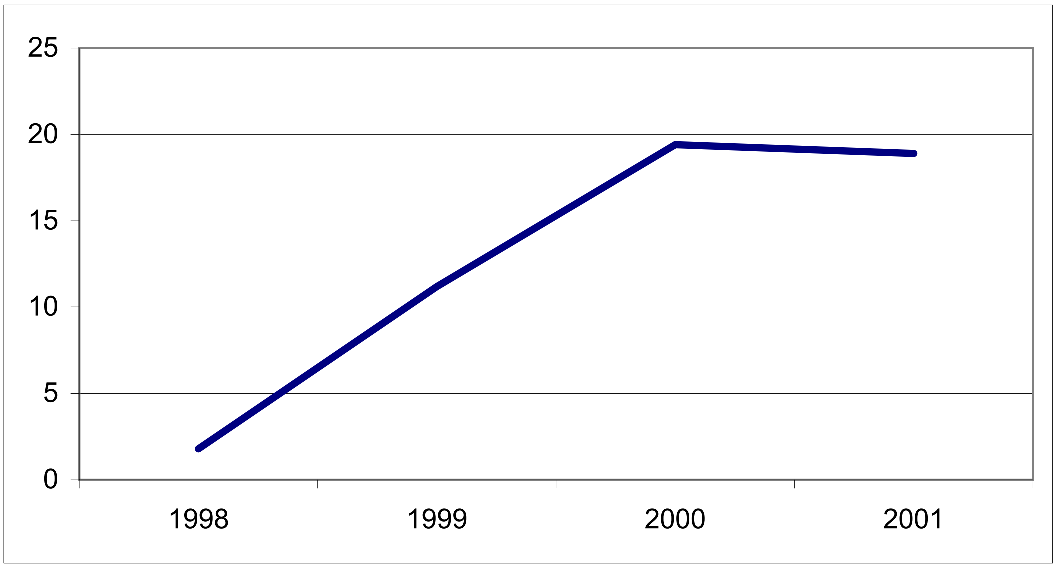
The Ericsson system works in close cooperation with numerous big and small companies both in manufacturing and consulting. This arrangement has been the backbone of the IT-development in Swedish Telecom and thus in the IT-sector as a whole. Even if Ericsson, like many other big multinationals in Sweden, is very much less interested in financing university research than their US-competitors, they have had direct access to much of the research capability that resides in the technical universities. A revealing example of this is that about two thirds of the patents that come out of the research in KTH became the property of private companies, in spite of the fact that these companies had contributed less than a fifth of KTH's research budget (According to an interview with Peter Holmstedt head of the foundation companies of KTH. These companies are created in order to improve the commercialization of the research results). And probably more important, the American multinationals have their own research departments since they do a lot of their research themselves so their understanding of university research is, in many cases, more profound.

Even before the recent crises, Ericsson started to streamline and focus its operation on its core businesses, which meant that its importance as a partner for cooperation with small and medium sized companies in Sweden declined. During the recent crisis this has been very much accentuated. This will have a substantial impact both on the IT-companies and the university research in the telecom and related fields

An important question is what might be the loss to Ericsson and Telia resulting from the sizeable reduction in their interactions with the universities? Even if these two have together been very successful in the development of the NT-mobile phone system and then Ericsson on the GSM, they have also been rather slow to respond to new developments outside their line of thinking - for example with respect to the Internet protocol. So one reason for the apparently slow response of the universities may be the lack of demand for Internet-related research during the 90s from the industry, dominated by these two organisations. According to Odhnoff and Hamngren, KTH and the other Swedish technical universities would have fallen even farther behind the emerging developments in the Internet world had it not been for the direct linkages to ongoing developments in the US that were provided by connections to Stanford University. Had KTH relied solely on its contacts with Ericsson and Telia, it would have been seriously out of touch with new findings at the frontiers of Internet R&D. Ericsson has also been the principal "buyer" of students in their fields from the technical universities during the 1990s, but their demand varied very much according to the company's performance on the world market. It sent out quite different signals during the years according to its own level of performance. In some years it told the universities that it had to expand outside Sweden due to the extreme shortage of people with the right competences and in other years it stated that the production of students in the technical universities was far too excessive. This is of course nothing special for this company, since almost all companies have very short planning horizons, but due to its size in the national labour market it has had big consequences. It also did take some time for them and other big companies to understand the competence of a new category of university educated specialists; computer-engineers.

FIGURE 11

INVESTMENTS IN VENTURE CAPITAL 1998 – 2001. IN BILLION SEK



Source: EVCA

Generally speaking, it has been a continuous problem for the development of the Swedish IT-industry that it has functioned with so few players. They have been too dominant. This is changing but, at best, only partially. During the hype, that is the extreme boom in the IT-sector 1999-2000, we saw many new start-ups, and some did grow substantially. During those years there also seemed to be no lack of risk capital in the Swedish market. As seen in figure 11 the increase in available venture capital for the Swedish market during the hype was very substantial. Even if a high proportion of the venture capital was used for financing buyouts, about half during the period 1998-2001, it was almost as much as 1 per cent of Swedish GDP in both 2000 and 2001. The figures for US 1998-2001, with the buyouts excluded, were 0.4 per cent of its GDP. This suggests that, adjusting for the differences in size between the two economies, the Swedish figures compared quite favourably with the US for these two years, at least in terms of shares of national income.

But in the post-hype period, reality finally struck most of the dotcoms and other IT-companies, with critical evaluations of sales and costs and other hard facts. Investors suddenly started to value companies according to traditional rules and looked for profits instead of burn rates (the new expression for how fast the new companies could spend the investors' money) Of course, a substantial number still survive, and may prove to have been quite sound, but the majority do not currently generate any profit. According to the Swedish daily business newspaper "DI" only 6 of the 55 public IT-companies that had reported in the middle of February, 2003 had been able to show black figures. But now, 2003, it seems that there is very little risk capital available for IT-companies. It is to a great extent, no doubt, a sound correction of the earlier valuation of risk; but it appears, as is normally the case, that financial markets are at least partly overreacting, which is, in turn, harmful to the development of the sector. The "bottom line" is that the risks eventually came to be perceived as being too high.

During the first year of the slump the traditional firms, the IT-users, absorbed those who were laid off, but for almost a year now, many of the IT-experts who have lost their jobs have had difficulties in finding new ones in their old specialties. This has had a huge impact on the potential IT-students who have gone to other fields en masse. The numbers of students who have wanted to get an IT- education (both hardware and software) at one of the technical universities, and made it their first choice, have dropped from 7116 in 1998 to 5378 in 2002. The same numbers for other universities are even more dramatic: from 9468 to 3693 applicants. The number of acceptances has been much more stable. They were actually somewhat higher in 2002 than 1998, but down from their peaks which were reached in 2000 by technical universities and 2001 by the others (they decreased from 4575 year 2000 to 4141 in 2002 for the technical universities, respectively from 3402 in year 2001 to 2760 in year 2002 for the other universities.

Of course new start-ups in this field are of great interest, especially with respect to their ability and willingness to grow. But what Sweden needs is many big players in the industries where Sweden has some relative advantage. But the maintenance of Sweden's position in highly competitive international markets is most unlikely to be shored up by start-ups, at least not in the short-run. The exchange between nations in goods and services are dominated by the large companies and in Sweden more than in many others. This exchange is necessary for specialisation and division of labour between nations and regions, and thus for the creation of wealth.

Many of the small companies live in a tight relationship to the big ones in the role of subcontractors to developers, and in many other roles. Thus their products and services are, to a large extent, exported indirectly as inputs to the big companies' products. It is normally necessary to have access to these international networks and brand names in order to be able to sell in many foreign markets. Thus, unfortunately, many new small companies cannot really compensate for a loss of the big ones without, themselves, growing to a much larger size.

On the other hand it is very risky for a small nation such as Sweden to be dependent on just a handful of multinationals, since they can fail in the international competition because of mistakes made by single management groups. Yet a small nation cannot hope to develop international competence in very many fields. The ideal situation is that where the nation has developed a competitive specialisation it is also able to attract a number of big players. Then the small nation depends on how well the conditions for this field develop, but is rather independent of how well single players succeed. To be able to attract these companies, it is necessary that they can be offered good possibilities to recruit competent staff and, of lesser importance, access to an interesting research community. It is thus somewhat disconcerting that, even after the 1993 reforms, the responsiveness of the university system to the increasing demand for IT education was so slow that there was almost no increase in the number of students who could start their education for the years1992-96, irrespective of the fact that both students and employers were very keen for that to happen. The number of students who had the IT as their first choice increased from 6 000 to 13 000 during these years at the same time as the number of acceptances increased only marginally from 5 000 to 6 000. This meant that the number of specialists that left the universities did not exceed that of 1987/88 (2300) by more than a few hundreds until a decade later [NUTEK: Swedish Industry and Industrial Policy 1997 and Swedish Industry and Industrial Policy 2000].

4 The possibility of greater responsiveness to market forces

The responsiveness of the university system to market forces is, as we have already indicated, of great importance to their contribution to the growth of the Swedish economy. The traditional Swedish system (pre-1993) was quite isolated from market forces. There were two main reasons for that situation. About two thirds of the research budget was channelled through the university system in a traditional way. This meant that the professors controlled much of the research budget themselves. Of course there was competition for the outside money, but this competition was far less fierce since the number of participants in the competition was much smaller in those days. Under these circumstances, money from the business sector was not so attractive. The second reason was that the general public regarded money from the business sector as inherently corrupting, and this opinion was shared as well by many members (perhaps most?) of the Swedish university research community.

This situation has changed dramatically, in part because of the new funding system and because there are many more faculty who are competing for the funding, not least faculty from the regional university colleges. So nowadays money from the business sector looks a good deal more attractive than was once the case, and there is now a much greater demand for such money. Moreover, public opinion is much more positive toward the business sector in general. Of course this is not unconditionally true, as the scandals in US business, which have been revealed lately, as well as the drastic fall in the stock markets have had a significant negative impact.

The greater decentralisation of power in the university system has also meant that universities can now create professional positions themselves, subject only to the availability of funds, without consulting the ministry of education. This means that the business sector can now be a potentially important source of financial support to universities. Some firms have already proven to be willing to provide such support, but typically only for a few positions and primarily for the technical and medical faculties. But the numbers of business people who have become part time (in most cases 20 per cent of a full time position) professors have grown to a substantial number. Another force for change is a related one; many university researchers are now interested in starting up new businesses of their own. The main factor behind this is probably a change of mindset. An example was a course in business administration for start-ups offered to the faculty of the Karolinska University in the middle of the 1990s that had been proposed but did not take place because of a lack of interest. Nowadays many are interested. One reason for this change of mindset is probably due to the general change in the public climate mentioned above; but there has also been the interest from the financial sector in the IT-business that had an influence in that sector and set an example for other sectors. The work by the management at the Karolinska University and the exodus of Pharmacia could have been other factors in the biotech field, according to the article in Nature Supplement, 12 December 2002. The management at the

Karolinska University has among other things created institutions such as Karolinska Innovation to increase technology transfer, and Karolinska Fund to attract Venture Capital. During the last two years they have formed and found external investors to 10 new biotech companies and has also closed 10 license deals with companies in the Pharmaceutical & Biotech industry.

This interest in start-ups by the faculty makes them also more interested in business connections in general and more responsive to the needs of this sector. The bursting of the IT-bubble has of course seriously weakened the incentives for students to pursue a professional education in technical fields, at least in the short run. But prospects in the medical field appear to remain attractive.

During the same period, the funding-system for education of students has also changed twice, in 1993 and in 1996. Previously, that is before 1993, the universities received money from the government for the number of students the government had decided that they should have. That meant that the universities' resources were not affected either by the number of students that they could recruit nor of how many of them that did take their exam. At present they receive their money according to both the number of students who do register and to the number of students who pass a course exam. These two criteria are on average of the same importance since most universities get half of there money for each. The laboratory disciplines though get a little more for the enrolments, since they have higher fixed costs in the form of buildings and inventories.

This means that universities must now compete on the recruitment of new students and by assuring that their students take their courses and exams. There is however a very severe restriction on this competition. A university could up to 1996 only get funding for a limited number of students split into broad categories, such as technical fields and the humanities. Now there is only a restriction on the total budget of the university and they get paid depending on the number of students and in what fields they are studying. Fields like humanities and the technical fields have for example different price tags. If they receive more applications than their budget limit allows it is not possible to absorb the excess, since they will not receive any money for the extra students. But they can of course have more students if a higher proportion is taking less expensive courses and visa versa. On the other hand they are not guaranteed a certain number of any students. So the terms of this competition are such that the universities might run the risk of incurring financial losses if they are not successful in recruiting students, since they have to at least partly prepare beforehand with facilities and teachers. On the other hand they must not exceed their budget restriction. But there is some softness in the system since, if a university gets too few applicants in a certain year it can save these places a few years ahead if they get more applicants at such time. The new model has been in place for some years, but still a too short time to make a big difference in the educational situation, but it probably will, since it is a whole new set of incentive structures that has been launched. But already some universities that have had problems with attracting students have had their budget limits lowered and some others that have been more popular have had their budgets increased. But this is not in any way an automatic system and the adjustments to new rules will take some years, and there is of course no extra money for those who have exceeded their budget afterwards.

In the competition among the universities, a higher quality of education is in the long run probably a superior weapon in the competition among universities - certainly better than the multicoloured brochures that have been widely distributed. A better reputation for offering students a superior education is more likely to improve a university's competitive position in the struggle for both enrolling the students and motivating them to take their degrees. A socially better way to improve the incentives for the universities to attract more, and better, students is to improve the quality of the education that they can offer to prospective students.

In the pursuit of a better education, which might attract students and induce them to take their exams on time, there are other means, not least in the pedagogical field. And one way to improve the quality of teaching and to enrich the curriculum would surely be to strengthen the link between research and teaching. A significant step in this direction would be a strengthening of both the incentives and the financial resources for prospective university teachers to complete a doctoral degree in their field of teaching. It is also important to strengthen the students' interests in natural sciences and mathematics at very early ages, with a special respect to girls whose interest in more technical subjects had in the past unfortunately been insufficiently encouraged.

4.1 Is it possible to evaluate the responsiveness of the Universities to market forces and social needs?

As we have emphasized, a very important aspect of the Swedish innovations system is the extent of its ability to respond to change. The world changes continuously and the speed of change appear to increase dramatically. The innovations system is in itself a very important force for change, but the question here is: what is the ability of the system itself to change? We firmly believe in the importance of education as a crucial link between research and society. So it is the responsiveness of both the research and the education system, and the combined research-education-system that needs to be addressed. A clear example of the lack of response inside the system is that when the high school education of engineers began to be phased out (1987/88), it took more than a decade before the examination of new engineers came up to the same numbers as in year 1987/88("The Swedish Industry and Industrial policy 2000",[NUTEK]. And this was a disturbance that had been created inside the system itself.

In order to be able to evaluate the responsiveness of these systems we first have to clarify what we mean by the market forces and social needs, and how we can measure their changes. This is by no means a simple or straightforward undertaking.

Market forces can be partially measured if we believe that the students' interest in a certain field, and preference for a particular university, constitutes a reasonable measure of demand, at least to a first approximation. But if it is believed that the market simply reflects the business sector's demand in the near or more distant future, the situation becomes much more complicated. One measurement of this is of course different indicators of the labour market, such as unemployment, wage differentials, or use of surveys to employers concerning their demand for specific kinds of labour. In many fields there are of course other countries that are at a more advanced stage of development than Sweden. In some field that is important to the Swedish society it could be useful to study how development in the business sector has been supported by the educational system in general, and by the universities in particular. A close and critical analysis of this development, where the many differences between these countries and Sweden are taken into account, could lead to the conclusion that it is the responsiveness to this development that is critical.

The indicator of the responsiveness of the university education sector is, naturally, the number of students the universities are prepared to accept in different courses and the speed with which they are able to modify their course offerings while maintaining high intellectual standards. On the research side it is the expansion of the fields that need to be strengthened which is the important indicator, along with the capacity to reallocate financial resources away from fields that are now judged to be of lower priority. In this respect it is quite positive that the educational reforms of a decade ago have moved the higher educational system in directions that have place increased decision making authority in the hands of the universities themselves, since this should increase their responsiveness.

4.2 Education

The most effective method of diffusion of research results and of improving the methods of diffusion of these results resides in the higher education system. A large number of students leave the universities every year and bring their knowledge, their ability to find and absorb new knowledge, and to develop new ideas, to the business sector.

The single most numerous groups of students who leave the university for the business sector are students with bachelor and master degrees, since these students dominate the human output of higher education in quantitative terms. How effectively the universities are able to provide these students with important parts of the corpus of stored knowledge and to develop their abilities to expand their stock of knowledge and eventually to use it in a developing process is therefore crucial. Of course the number and the competence of students who have been trained to perform research of high quality are of the greatest importance. It is thus highly desirable that the researchers take an active part in the education of all students from the undergraduate to the doctoral level. In this sense the research is more of a means to get access to both fresh and older stored knowledge in order to improve the education of different categories of students, than an objective in itself. And our examination of the two high tech sectors - The Life Sciences and Information Technology - makes clear that different sectors of the economy are likely to impose very different demands upon the university system. A successful education policy needs to pay very special attention to these differences. [See Nathan Rosenberg, "America's University-Industry Interfaces, 1945-2000].

4.3 Publications, patents and prototypes

The traditional mechanisms of the diffusion of stored knowledge from the scientific and engineering communities are publications, patents and prototypes. Of course, publication is the channel that has been regarded as the most important one in the traditional linear research model. And it is very important, indeed increasingly important, for the business sector. But it is far from the only link, and many of the links go in the opposite direction, i.e. from the business activities to research activities, most of which is in the public sector.

University patenting might play an important role in the relationship between the business sector and the universities. It is not only a way for the universities to interact with private firms, but it may also accelerate the commercialisation of university research findings. This was precisely the announced intention of the Bayh-Dole Act passed by the US Congress in 1980. The incentive for both the universities and some categories of academic researchers to be involved in the patenting process appears to be increasingly useful in achieving the successful commercialization of certain kinds of university research findings.

Evaluation of the more formal channels of information is more easily measurable. Publications can be expressed in quantitative terms. Scientific quality can also be measured in terms of the frequency of citations. But it may be equally useful to look into citations that appear in patent applications.

Patents that are coming out of the universities are another important indicator of the intensity of the connections between the universities and the business sectors. In Sweden this indicator is currently most relevant for research in the life sciences, but it is also useful in the IT field and in some other sub sectors.

The start-ups that emerge from university research which are made by university researchers are another important linkage between business and universities. Here it is easy to find relevant indicators, but, as suggested earlier, we believe that it may be even more relevant to measure the subsequent growth of such start-ups. [For further discussion, see Henrekson and Rosenberg, "Designing Efficient Institutions for Science-Based Entrepreneurship: Lessons from the US and Sweden," Journal of Technology Transfer, 2001].

4.4 Personal exchange

Direct human contacts, or personal exchanges, are also of great value to the exchange of information and new ideas; indeed, they are often indispensable. This can take place in a variety of different ways, and in more or less formal forms. What really matters is that people from the universities and the business sector need to communicate and meet more extensively. Different forms of networks between public researchers, industry and business can be of great value. Among the more organised forms of this exchange are scientific parks and liaison offices and other technological transfer institutions. Of course these forms can be organised so they work well or less well. It is thus important to take great care in forming them, and it is necessary to evaluate them to see how they are performing. It will, of necessity, be a trial and error process where the lessons from other countries need to be consulted.

The more organized forms are of course more easily measured and the possibilities of finding different indicators are much greater. The development of the companies that are located in the science parks or are helped by the liaison office can be compared in a sophisticated way with other firms outside the park. Although this can be quite tricky, it should be possible. In principle, the performance of companies that have a history before they locate in a science park can be compared with similar companies that have not taken up a location in the science park. If their relative performance is not improved after the relocation in the science park compared to the control group, the park apparently is not providing them with a substantial advantage. For start-ups it is even more difficult and the best way would be to create an experiment where half of the interested start-ups, picked at random, are allowed to locate in the park. However, each of these possibilities clearly suffers from serious, and perhaps even fatal, feasibility difficulties. And the more indirect forms of interchange can only be measured very tentative with interviews and questionnaire.

But the most important part of the personal exchange is of course determined by the mobility of individuals between the universities and the business sector. And we have already pointed out the importance of the major stream, which consists of the undergraduates and masters who leave the universities for jobs in the business sector.

Indicators of mobility are relatively easy to find. Here there exist clear-cut and easily available measurements, since there are databases which can be used to measure the flow of people between different organizations. It is also possible to distinguish between people who are on different academic levels and have different specialties and whose age and gender are usually readily available.

With respect to the role of industrial parks, it is worth pointing out that the evaluation of the American experience is decidedly mixed. The apparent success of the Stanford Industrial Park, often cited as a model that is well worth emulating, was due in no small measure to Stanford's huge landholdings and to the profitability of its extensive real estate developments. Perhaps even more important was its early establishment (1951) and its attachment to an aggressive, and eventually highly successful drive on the part of Stanford's administration to achieve pre-eminence as a major research university. Finally, timing was crucial to the success of the Park, which owed much to the early expansion of Silicon Valley industry, and the huge growth of the electronics industries that were emerging in Santa Clara County in the 1950s and 1960s. The Stanford Industrial Park may be said to have been heavily driven by the truly spectacular growth of local private industry. By the 1980s, which was the great boom period in the establishment of industrial parks in the US, it may fairly be said that "the train had already left the station" and, with very few exceptions, outside evaluations were distinctly on the negative side for these latecomers. [See the manuscript by Roger Geiger, "Universities and the Production of Knowledge for Industry," 1993, unpublished, for a careful, distinctly lukewarm assessment of the contribution of industrial parks in the US].

4.5 Cooperation

Finally, we have the formal forms of co-operation between public researchers and the private business sector. The most important forms are consulting and research contracts. Consulting activities carried out by individual researchers have, of course, less impact on the larger research community than do research contracts, if one simply compares a single consultancy assignment with a research contract, not taking into account the frequency of the respective activity. Nevertheless, consulting can still provide the individual researcher valuable contact with, and insights into, the business sector, at the same time as it brings useful knowledge from the university into the business world. This point is likely to be particularly relevant to the engineering disciplines, since much of the time of engineers is devoted to the design of new or improved products for the private sector. And the consultancy of the academic is sometimes so frequent that this is a major linkage between research and business. The consultancy firms which have expanded substantially in recent years have highly educated personnel. They could thus also be another important but admittedly more indirect linkage between research and business. We would like to insist here that, for reasons discussed earlier, university consultants are, in many contexts, unlikely to be good substitutes for in-house research capabilities.

The eventual usefulness of business consultants is likely to depend very much on the overall attitude within the research community. If the general feeling is that it is inappropriate or even disreputable to be directly involved with the business sector, very little will be known about it and the benefits will be small. A negative attitude will make research contracts infrequent, and the positive effects of such contacts as still exist will be reduced. A more positive attitude can, on the other hand, be of great value for both research and education at the universities.

The best way of acquiring data on forms of cooperation is probably that the research foundations should ask for this kind of information when they follow up on their grants.

4.6 Is evaluation really possible?

In spite of what was stated at the beginning of this paper concerning the importance of R&D for the economic growth of a developed country, it is not easy to determine whether an increase in the research budget for the Swedish university system will have a sufficient incremental impact on economic growth in Sweden that will be large enough to compensate for the increased burden to the taxpayers. The reason for this is due to the complex interactions between research and business, both nationally and internationally, and the amount of time this process is likely to take. In a small country such as Sweden, with about half of the population of Greater Los Angeles, and with the free flow of knowledge internationally, it is even harder to trace the impact. Many of the benefits of Swedish university research, for example, may be captured by residents abroad, just as Swedish universities and Swedish firms may capture some of the benefits of research carried out in other countries. The most important effects of an increase in the R&D budget, as we have emphasized, will probably depend on the increase in the absorptive capacity of many well-educated students, along with good channels for acquiring stored knowledge as well as new knowledge, which is available worldwide. And there are also many other important channels between universities and business. It is thus meaningful to develop indicators and to examine different mechanisms, as we have suggested, since this increases the possibility of determine the effect of a bigger public research budget on the Swedish economic growth.

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