Will the R in R&D at large technology corporations disappear?

The demise of the 'R' in corporate R&D: is academia stepping up to the challenge?

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The demise of the ‘R’ in corporate R&D: is academia stepping up to the challenge?

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Abstract

The author has as a practitioner in industry for 25 years seen a shift in the attitude to corporate research. Previously, most established technology firms had substantial departments doing research. Over the years this has changed, and corporate research not seen as short term profitable has decreased.

A number of papers indicate that the amount of in-house science in technology corporations is indeed decreasing. This could be a serious problem, as much of innovation until now has stemmed from the existence of both research and development within one organisation.

There are indications that this work is now being done at universities in cooperation with industry. There seems to be a lack of broad studies to show if this is true.

A literature study and report data mining has confirmed that in-house corporate research has declined over the last decades. However, data does not confirm any increase in university research directly funded by industry.

A common opinion in industry is that instead, the acquisition of start-ups and other small firms have replaced some of the in-house research. This requires a strong strategic technology plan.

A number of paths for continued research are proposed, in order to confirm this opinion.

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Introduction

The author, a long time engineering practitioner in various industry fields and nations, has an experience based perception that the amount of in-house research within large corporations has decreased over the last 25 or so years. Apart from dedicated research divisions within the companies, there also used to exist groups spread out through the corporations which would do research as part of their technical responsibility. In such a group, where the author worked in the mid-nineties, about half the work consisted was company funded research, with no specific requirement of how much should be marketable, and within what time frame. Still, considerable amounts of new ideas were produced, and many were eventually put into production.

When talking to colleagues, such research divisions and research groups within R&D in large corporations seems anecdotally to have disappeared. Is there evidence for this being true?

The paper will attempt to answer the following questions:

Q1: is in-house research in technological corporations decreasing, and

Q2: if so, is there a shift to more cooperation with universities?

The subject will be limited to the situation in Sweden, with data from the United States being included as comparison.

Is corporate research declining?

In their extensive review of the decline of science in corporate R&D in the United States, Arora et al (2018) point to very clear evidence for this, at least in the US. The US NSF Science and Engineering indicators show that the "*share of basic and applied research in corporate R&D*" was 21% in 2009 as compared to 28% in 1985.

Bloom et al (2017) state that "*Our robust finding is that research productivity is falling sharply everywhere we look. Taking the U.S. aggregate number as representative, research productivity falls in half every 13 years — ideas are getting harder and harder to find."* It should be noted, however, that Bloom et al use TFP (Total Factor Productivity) growth as measure of idea production, which is problematic for various reasons. They then define research productivity as the ratio of idea output to research effort.

We will return to the question of whether there has been a corresponding increase in basic and applied research performed in universities and funded by industry during the same time span.

Reasons for the decrease in corporate in-house research

There are several possible reasons for the decrease of research within corporations. Arora et al (2018) list the following:

1. Inventions are becoming less science-intensive, i.e. innovation becomes more focused on new applications for existing science.
2. This corresponds to a possible decrease in the general social value of science.
3. It has become increasingly possible to access new scientific results through the acquisition of small start-ups.
4. General short-termism, i.e. when management will sacrifice long term investments such as maintaining a research division in order to fulfil short term incentives such as quarterly profit targets, has increased.
5. A change in the labour division between actors such as universities, other state institutes/initiatives, start-ups, and major technology corporations.

Some, or all, may valid in parallel or conjunction.

If reasons 1-3 are the dominant, then there should not be a corresponding increase in research being done by universities on the behalf of or at least being used by industry.

However, if reason 5 (and possibly also reason 4) is the main cause, it should be possible to find evidence for this. We will look into publication and funding data.

Findings in the US

As mentioned in the introduction Arora et al (2018) show that corporate R&D has been shifting away from basic and applied research over the last decades. The following definitions of basic and applied research are used by Arora et al, and by NSF:

Applied research: The objective of applied research is to gain knowledge or understanding to meet a specific, recognized need. In industry, applied research includes investigations to discover new scientific knowledge that has specific commercial objectives with respect to products, processes, or services (OECD 2002).

Basic research: The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind. Although basic research may not have specific applications as its goal, it can be directed in fields of present or potential interest. This is often the case with basic research performed by industry or by mission-driven federal agencies (OECD 2002).

We will now discuss the five possible reasons for the decrease, as listed above.

1. In Arora et al (2018) the opinion that it is not true that "Inventions are becoming less science-intensive" is put forward. Although this corresponds to the author's opinion, no data that proves it has yet been found.
2. If there is a decrease in the general social value of science, that should be visible in figures. However, as shown in Figure 1, the quota between R and D for the US society in general, has been astonishingly stable for the last decades.
3. The availability of start-ups or other acquirable sources of ready-made science has meant that in the US, corporate research has moved away from long term strategies with or without university participation altogether, and has been replaced with constant searching for mature ideas. This can be compared with incubators driven by universities, cities or other, in that there is no common long term technical strategy other than the individual evaluation and support for stand-alone inventions. Arora (2018) point out that after 1980, it became easier for US universities to patent and license inventions actively, which has also improved availability. Is this part of a more entrepreneurial approach by large corporations?
4. General short-termism, i.e. when management will sacrifice long term investments such as maintaining a research division in order to fulfil short term incentives such as quarterly profit targets. Is there proof that this really exists?
5. A change in the labour division between actors such as universities, other state institutes/initiatives, start-ups, and major technology corporations. Does this work in real life?

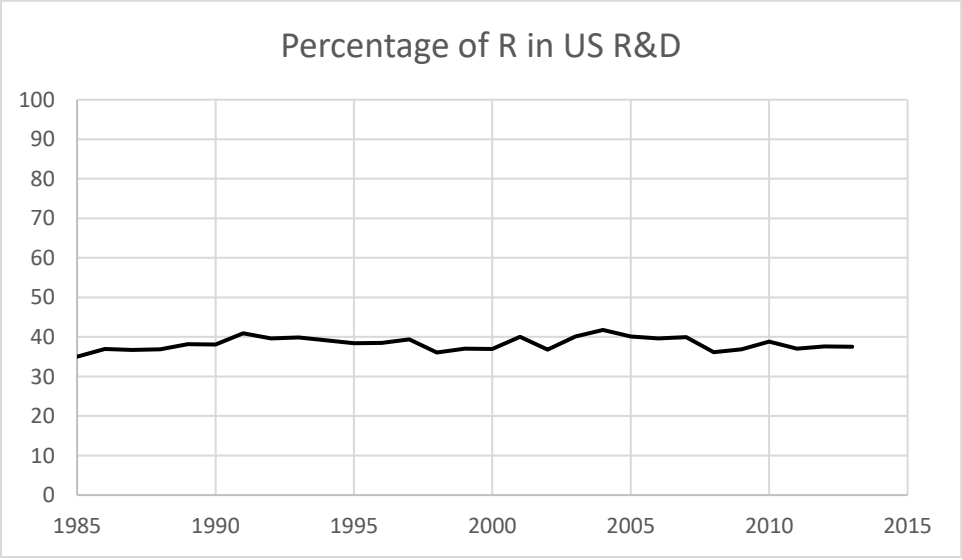

Figure 1. Basic + applied research for all performers and funders as percentage of total R&D expenditure in the US. Source: National Science Board (2016) – Appendix Table 4.

Measuring research

The National Science Board provides enormous amounts of data regarding the US. Similar sources of data do unfortunately not seem to be openly available for countries such as Sweden. Therefore, other ways of estimating the amount of basic and applied research within corporations must be employed.

We start with an assumption: *since basic and applied research provides innovations, trends in innovations should be very similar to trends in basic and applied research.*

This assumption has some problems, related to definitions of research and of innovations. A typical example is combustion engine efficiency, where a motor manufacturer may spend huge sums on what it considers research, slowly improving certain attributes of the engine, but not through what would necessary be defined as innovations. However, by looking at trends rather than absolute numbers, in this paper we consider the assumption valid.

Measuring innovation is an established field. It has long been in the interest of both nations and companies to measure this. In general, it is the output which is mostly measured. A number of different approaches have been applied.

a. Patents applied for.
b. Patents approved.
c. Published papers in technical journals.
d. Products brought to market.

Each of these metrics come with corresponding problems. These are discussed briefly:

a. Not all innovations are patented. There may be a number of different reasons for a company to decide not to apply for a patent. These could include the cost being prohibitive for small companies, short product cycles making patenting unnecessary, and others.
b. A patent application may fail because someone else has already put forward a similar idea. You could argue that in that case the runner up had not produced an innovation. That is sometimes unfair since in some fields several actors will work in parallel without open knowledge of each other. Also, the innovation eventually not being patentable should in my opinion not invalidate the research that resulted in it. It is still research.
c. Some companies have no tradition or no interest in publishing inventions or other results from their research.
d. Statistics for products coming to market is generally unreliable as a measure of innovations or research. A new product may consist of several new innovations, but innovations may also be introduced into an existing product to make it simpler or cheaper, without necessarily informing the market about this. Also this metric does not necessarily include innovations in the manufacturing process.

In general, there are also sectors where publishing details of inventions, whether as patents or as technical papers, is directly detrimental to the business practice of a company. In the defence industry, there is a constant race between threats and countermeasures, and neither customer nor producer wishes the technical details to be fully known to competitors.

Experience in Sweden

Hallonsten and Slavcheva (2017) point out that

"While the general performance of the Swedish R&D system on the supply is very good, there is a long-lasting debate concerning the alleged inefficiency of turning the heavy investments in R&D into innovation-based economic growth."

Hallonsten and Slavcheva point to some structural reasons for this. An unclear role for the universities in the innovation system, as well as an insufficient entrepreneurial climate makes exchange between academic and private R&D difficult.

According to a 2019 report from the Swedish Research Council, Sweden, although starting from a very strong position, and spending large sums on R&D, is falling behind on research quality. This is particularly worrying as Sweden as a very small country has been depending on research and engineering quality and productivity for inventiveness for the last century (Swedish Research Council, 2019).

Kander et al (2019) examine trends in innovation output for two highly ranked innovative countries: Finland and Sweden (1970–2013).

In the paper, they show that Finland and Sweden, both with R&D to GDP ratios over 3% (in 2014), are ranked among the most innovative economies in the European Union, and indeed in the world.

A question that has been discussed is whether new innovations add to growth, or if they just replace previous innovations, thus not providing growth.

In the Kander paper, examples point to a steady decline of innovations from the 1870s and onward. This, however, indicates that the definition of innovation may have changed throughout the centuries. There have been various suggested years for "peak innovation", but it can be argued that this depends heavily on the definition of what an innovation is.

At stated previously, there are several ways to measure innovation as well as research activity.

Some of the more common measures are:

- R&D expenditure. This metric contains a major problem: most companies do not share what the split between research and development is. In this paper we are concerned with research and not with development.
- Published scientific papers. This should theoretically be an excellent metric. In practice, many firms will not publish their results for various reasons.
- Number of patent applications. Data for patents applied and accepted are easily acquired. The main problem with using patents as a metric of research is however that many innovations are never patented. There are several reasons for this: the innovation may be of such a technical nature that the corporation prefers to not make it public, or, when the innovation is a service or a new application of an existing technology, it may not be possible to patent it.
- Eurostat Community Innovation Survey (CIS), and other surveys. There is an inherent problem with surveys, as it is in the interest of the participating firms to make a good impression.

There are several other alternative metrics of research and also of innovation available. Kander et al use the literature based innovation output method (LBIO).

According to Kander et al, "*The LBIO method is based on the identification of an innovation in the editorial section of valid publications. Hence, the unit of observation is the innovation and not the innovating firm, which is often the case in other survey approaches."*

An important point is that LBIO, similarly to patents and generally published papers, measure output rather than input such as R&D expenditure.

A general problem with LBIO is that it requires in-depth studies of journals and papers, and the method is therefore heavily resources dependent. Therefore it is probably mainly useful to use LBIO for finding detailed results, such as in the Kander paper. When the purpose is to identify general trends, more simple statistics will likely be sufficient.

Still, the LBIO suffers from the same fundamental problem as any analysis based on statistics of published papers. A firm may very well choose not to publish any research. There are two main reasons for this

- There are commercial reasons for not publishing the results
- There is no tradition in the company culture to publish research in scientific journals

From experience, I would argue that the second reason is the most common one.

Kander et al also notice that there is a bias in what innovations will be published. Most firms tend to publish results related to new products. However, this potentially excludes innovation related to application, method, and process. Also, innovations regarding services will risk not being visible, which is a problem as many new innovations are within the services field, and this field is certainly gaining importance.

It is obviously important to measure whether the achieved innovation output is reasonable regarding the amount of funds being invested in research. As opposed to the United States (National Science Board), figures for the basic and applied research, i.e. the R in R&D, is not readily available for Swedish firms. However, we can compare the innovation output to the total R&D expenditure.

Results such as presented in figure 2 below, clearly point to a falling innovation output relative to investment in R&D. Here opens a very interesting discussion: for most people, there is a clear distinction between Research and Development. Unfortunately most companies in Sweden and other Nordic countries avoid presenting separate figures for R and D. Considering that D in a product developing firm can include everything from new ideas to recurring rework of already produced solutions, this does not help to understand how much, if any, research is done.

Therefore we cannot tell, from expenditure only, if the amount of research in corporations has dropped.

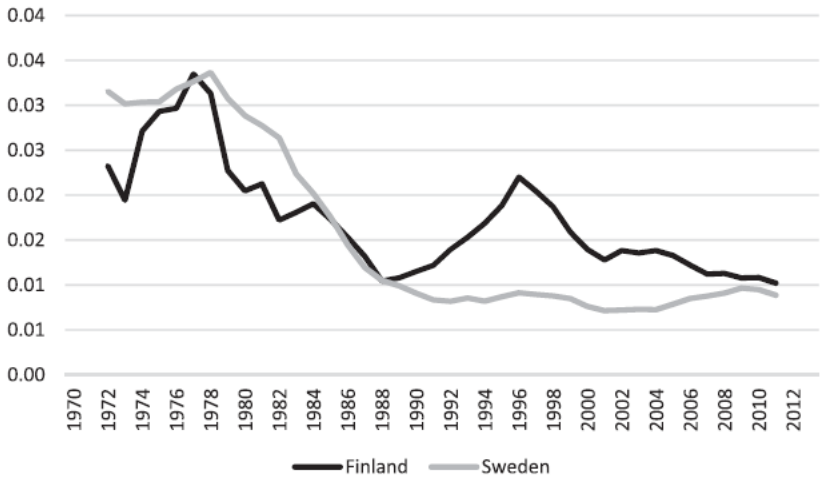

Figure 2. Ratio of innovations to R&D (million US dollars 2010) in Finland and Sweden, 1970–2013 (five year centred moving averages) (from Kander et al, 2019)

It is noticeable that, although the ratio of innovations to R&D in Sweden dropped by two thirds from the early seventies to the late eighties (Figure 2), after that (the period we are focusing on in this paper) it has been relatively stable. As noted by Kander et al, the innovation output as measured with LBIO includes even very small firms. This means that if we accept LBIO as a measure of innovation, this could support that the overall national levels are stable, but that the work load split is changing; someone else is doing the research for the big corporations.

Kander et al also observe that the large corporations are not behind the changes in the innovation figures.

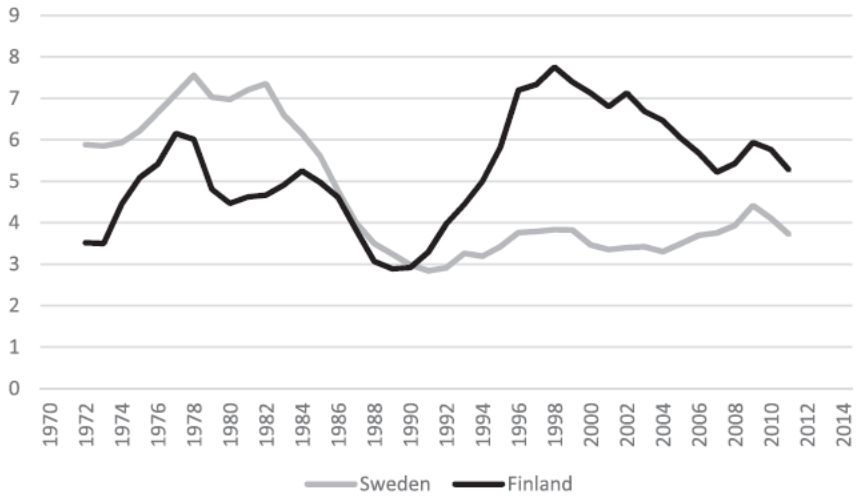

Figure 3. Innovation intensity in Finland and Sweden 1970–2013 (innovations/constant million dollars of GDP, 2007 year prices), five year centred moving averages. (from Kander et al 2019)

The LBIO data, when broken down into industrial sectors, shows that there has been a structural change in Sweden, where innovation intensive sectors have increased more than others.

Interestingly, Kander et al point to that there is no trend of consistently falling trends of innovation in either Sweden or Finland.

Kander et al find that the data points to a general increase in innovation activity over time. This is in absolute numbers, not related to who is doing the work, or to the general investments in R&D.

As discussed by Kander et al, in some research areas, research is becoming more and more expensive in that it requires more research funding for the same output (Bloom et al, 2017, in Kander 2019).

As stated above, the data for dividing R from D is not readily available for countries outside the US. When looking at Swedish corporations we must use other metrics.

A common method is to look at the number of published papers in peer-reviewed journals. The problems with this metric is discussed above, but we argue that it is still sufficiently correct to show the trends. Figure 4 shows the percentage per year of all papers published, where at least one of the authors is an employee of a major Swedish corporation, as compared to all papers published within the Web of Science main category Technology for the same period. The corporations included are Ericsson, SKF, Saab, Scania, and Volvo. The first three have been relatively stable in size over the time period, whereas Saab has both split from subsidiaries and later acquired new companies, and Volvo has split in two bodies, both still keeping the name Volvo.

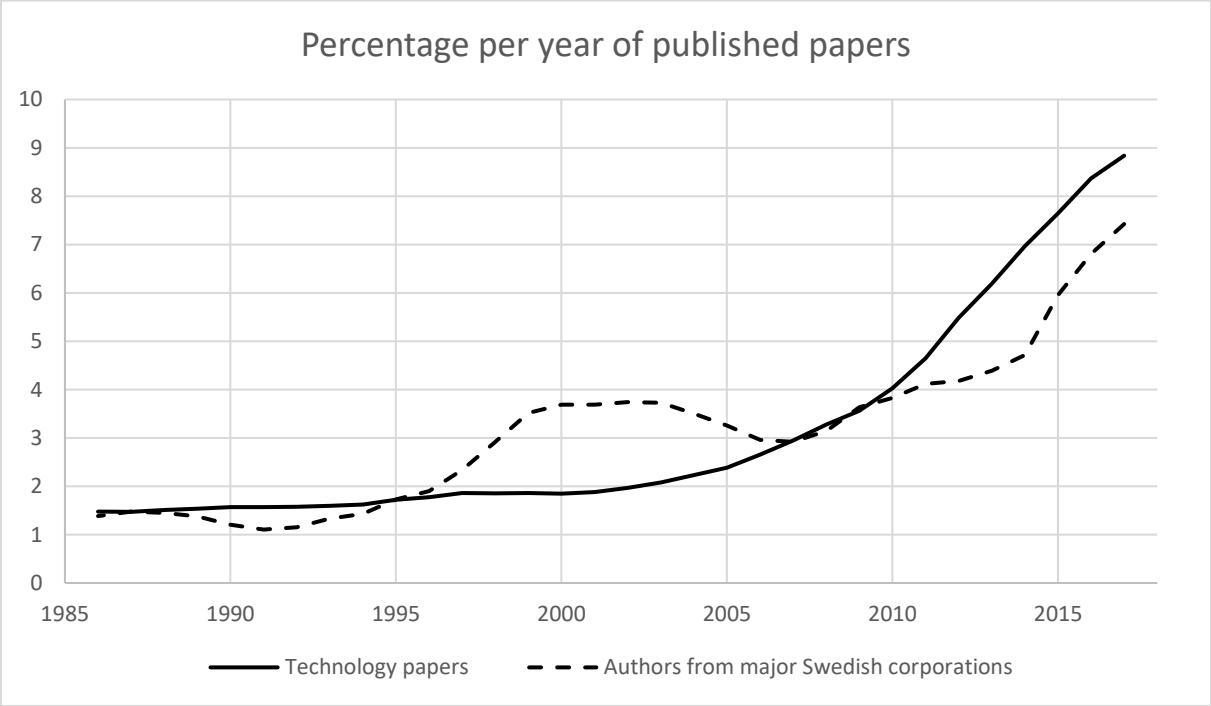

Figure 4. Three year rolling average of papers published by employees of five major Swedish corporations, presented as percentage per year of the total number published, as compared with all papers published worldwide under the field of Technology; retrieved from Web of Science Core Collection.

In figure 4, a three year rolling average is presented to provide clear trends. The diagram shows that after 2007, the corporations being studied have constantly been producing less scientific papers than previously, in comparison with the average of the scientific community in general.

Why publish?

Why would corporations want to publish their innovations in scientific journals?

To publish helps and encourages research staff within the corporation to keep connected to the scientific community, which in turn enables being à jour with the development in relevant fields. It

can also help finding external partners whom it would be beneficial to include in the company sphere in some manner.

In addition, it might be beneficial for a corporation to demonstrate its technical knowledge and innovativeness to a potential market.

There is intrinsic value for corporations to cooperate with universities. There is ample evidence that companies that engage with the academic world will become more likely to produce new R&D projects.

Is there a corresponding rise in research in universities?

We now look at the second research question. We start by examining if there is a change in the amount of university research being directly funded by industry.

The Science and Engineering Indicators (National Science Board, 2016) is an extensive report, which includes current and historic data. By extracting data from the records for basic and applied science, funded by business and performed by universities and colleges (NSB 2016, Appendix tables 4-3 and 4-4), we create the following figure.

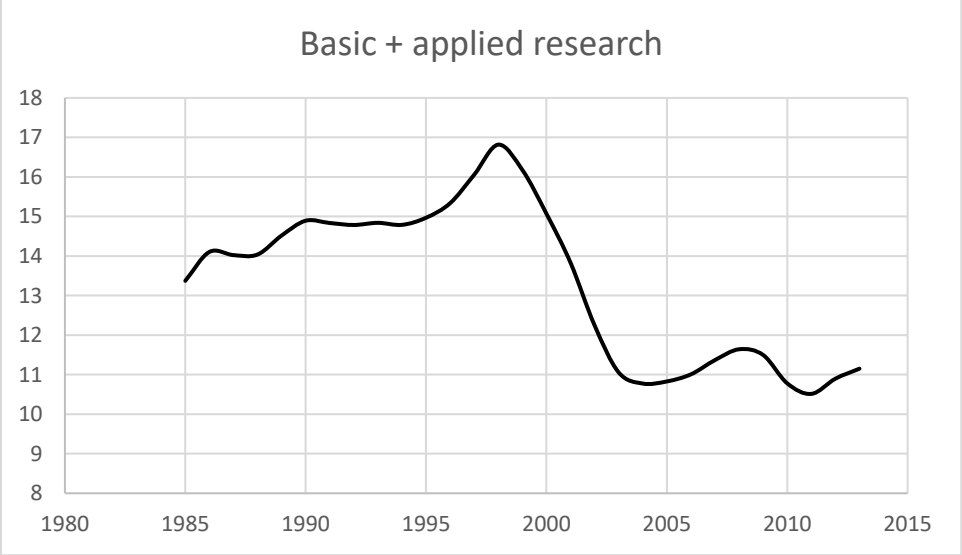

Figure 5. The percentage of all basic and applied research performed by universities, that was funded by business. Source: National Science Board (2016) – Appendix Table 4.

Interestingly, it seems that although there is a slight increase in business funded university research during the nineties, there is a sharp drop from the late nineties and onward. This seems to disprove the idea that business corporations are actively moving research out of the corporations into universities.

To compare this with Sweden, we also look at the data for scientific papers that have been funded by one of the five major Swedish corporations mentioned earlier, but where no employees of the same corporation are among the authors.

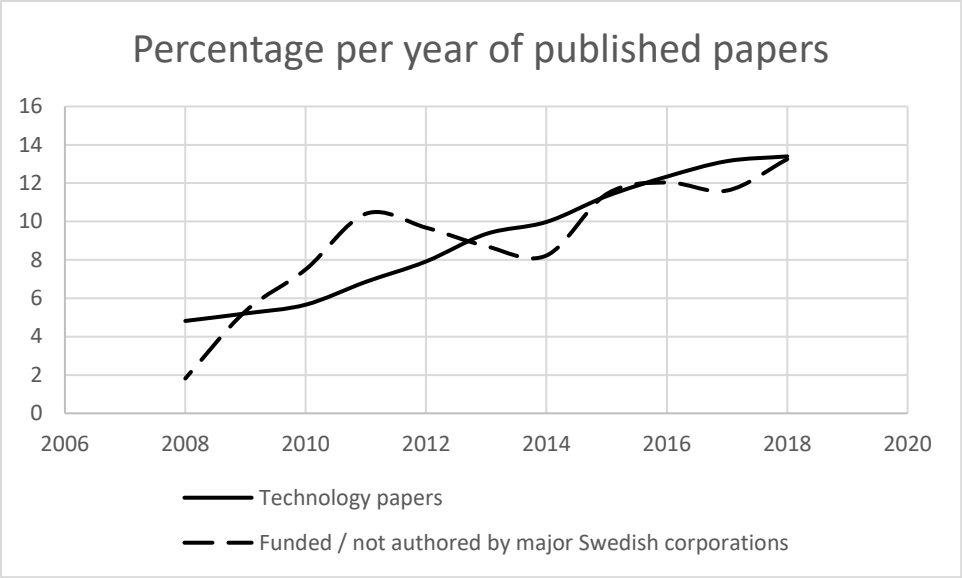

Figure 6. Papers funded by five major Swedish corporations, but with no employees among the authors, presented as percentage per year of the total number published during 2008 to 2018, as compared with all papers published worldwide under the field of Technology; retrieved from Web of Science Core Collection.

Unfortunately insufficient data was available for years before 2008. Interestingly, the same picture emerges as in the US. There is no significant increase in papers being funded by corporations but being authored by academics. Again, if the publication of papers maintains a relative correlation to the amount of research being done, there seems to be no significant change in research being done by academia and directly funded by industry.

Is business-university research cooperation possible?

Could university cooperation be a functioning replacement for in-house science/research?

Farina et al. (2016) argue that in order for a company to prepare and maintain an R&D investment plan, university collaboration is an essential part of the technology strategy work.

The first problem appears when business and academia try to agree about what research really is. This requires recurring discussions, and possibly a detailed contract, to ensure common understanding of whether it is basic or applied research you wish to cooperate on.

There is also a question of time scales. Whereas a research project at a university can last for several years (e.g. a Swedish doctoral project is supposed to last for at least four years), few frontline technological companies have the patience or the possibility to wait that long for results. A way to handle this would be organize the projects so that results will be available at recurring intervals.

The above indicates that some kind of translator framework is needed.

Olander Roese and Batingan Paredes (2015) discuss in detail the barriers that endanger successful collaboration. Among these are the differing institutional norms, as well as a mutual lack of understanding regarding each other's practices. They also propose that a common language should be adopted, in order to improve the exchange between business and academia, where according to Hallonsten and Slavcheva (2017), the current situation is not ideal.

Arora et al (2018) also point out that the decline in basic and applied research is mainly present in big corporation in-house research. It is certainly possible that in-house research is replaced with either funding university research, or other small research-intensive ventures. The acquisition of science, research and innovations through mergers and acquisitions is not only another possibility, but a reality. It is rapidly becoming a major strategy for many corporations world-wide.

Is triple helix a possible enabler?

Can business and academia be coerced into cooperation? Triple Helix Innovation is a term for the synergistic collaboration between actors in government, academia and industry.

According to Etzkowitz and Leydesdorff (2000), "*the common objective is to realize an innovative environment consisting of university spin-off firms, tri-lateral initiatives for knowledge-based economic development, and strategic alliances among firms large and small, operating in different areas, and with different levels of technology, government laboratories, and academic research groups. These arrangements are often encouraged, but not controlled, by government.* "

In Sweden, as in many other countries, there are agencies specifically charged with enabling research cooperation. The chief Swedish agency is Vinnova (Sweden's innovation agency).For specific triple helix initiatives, other agencies may take the government role. An example is the Swedish Defence Materiel Administration and the Swedish Defence Research Agency, who both assume the government research role in triple helix cooperation such as SMaRC (the Swedish Maritime Robotics Centre). In the latter case the min governmental funding organisation is yet another agency - SSF - the Swedish Foundation for Strategic Research.

A particular interest of the government has been to use these collaborations as vehicles to cross the gaps in norms, language, and time scales described in the previous section.

There has been a lot of hype for triple helix, in Sweden as in many other countries. It is difficult to find actual figures to determine if triple helix initiatives have been efficient and have provided results in relation to the investments.

One possibility would be so search for papers where industry, academy, and government authorities have collaborated. That output data could then be combined with the input in the form of funds allocated to the related triple helix programmes.

However, there are also problems inherent in including university research in commercial or near-commercial projects.

"[..] researchers and policy makers in recent years have increasingly argued for the establishment of innovation in the academic world: an effort that can be understood as a struggle to produce entrepreneurs in a way that will benefit regional social and economic growth. The policy makers orchestrating such strategies are thus trying to hybridize universities with society by connecting them to the government and to the world of business". This was expressed in a recent paper by Friberg and Englander (2019), where they also argue that for social scientists, there is a conflict between researchers' critical, scientific stance and the inclusion in commercial activities.

The situation could be complicated for the university scientists if the government, which in Sweden provides the majority of university funds, also expresses a wish that the universities should also participate in cooperation with private corporations. The risk for conflicts of interest is always present.

Start-ups as the future source of "useable" technological research

Arora et al (2018) suggest that when small high-tech firms are acquired by large corporations, their research output drops and eventually disappears.

Many start-ups are the result of ideas generated by university students or staff, and thereafter matured in incubators within or near the universities.

A new division of labour could be

Unis->start-ups->acquisition by established companies

Short interviews with R&D managers in major Swedish/international corporations indicate that the previously heavy reliance on a large internal research department is not efficient anymore. There has to be a combination; some technical areas which are still key to the success of the firm should be maintained, whereas in parallel, the corporation needs to be prepared to pick up good ideas from start-ups or even students, in order to find new ground.

Kander et al (2019) state that the LBIO captures also research done by small or very small firms.

Conclusions

Returning to our research questions – can they be answered?

Q1: is in-house research in technological corporations decreasing, and

- That in-house research is declining in major corporations is a fact, on both sides of the Atlantic.

This has going on for decades, and seems to be the case in all industries.

Q2: if so, is there a shift to more cooperation with universities?

- It seems that there is no proof that in-house research is generally being replaced by university research being directly initiated by and funded by industry

The new way of getting research into production seems to be by looking for and picking up innovations by acquiring start-ups, which are the results of incubators and other initiatives, often within or close to universities.

According to managers in some major corporations, there has to be a combination:

- Key technical competencies that may be unique selling points should still be the subject of research in-house
- Technical areas that are still strategically relevant but less critical could be future by funding research projects at universities and/or within triple helix projects
- A corporation that wishes to be fully prepared for what the future may throw at it should keep a constant watch on the start-up community. Any new ideas, innovations or applications that could expand the business model of the company should be discovered and considered

Future research

A number of fields look promising for continued examination.

It would be beneficial to look into the data used by Kander et al (2019) to see if a further analysis supports the assumption that research is moving away from big corporations to start-ups and other small firms. In addition, it would be interesting to take a detailed look at local research productivity before and after small Swedish firms are acquired by larger corporations.

How should a corporation set up the ideal mix of in-house research – participation in external programmes – and just picking up ideas on the open idea market? This requires a strong strategic idea of what must stay and what could go in terms of technical areas. A sub-area of this could be to study the corporate decision-making when changing the amount and direction of in-house research.

Is triple helix efficient? As described above it would be possible to compare the input of funds to the output in terms of e.g. published papers.

Are inventions in general becoming less science-intensive? Here, the LBIO method could possibly be used to spread some light on this question.

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