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Where did Swedens Top 100 innovations originate?

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Foreword

One of the most important issues when launching an innovation policy should be the determination of what innovation environments are the most prospering. Only when this question is answered, the innovation policy will have rational grounds.

Yet there are hardly any studies providing answers to the the question of where important innovations are developed. One American study presents quite remarkable conclusions. Perhaps politicians should not focus on universities to be the main source of innovation?

For reasons mentioned above, the Reform Institute commissioned Christian Sandström to research the origins of Swedens 100 most prominent innovations.
LIC. Dr. Christian Sandström is uniquely qualified for this task. He researches and lectures at Chalmers University of Technology and the Ratio Research Institute. With his background as a civil engineer in Industrial Engineering and a master in Economics in 2010, he dissertated a thesis on how technology changes affect established enterprises.

The study was funded by the Swedish Inventors association. The initiative was taken by Örjan Strandberg, president of Stockholm Innovators Association, who also contributed with preparation work and substrate material.

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Summary

Swedish prosperity is largely built on pioneering innovations that also have often become export successes. This report investigates where 100 of Sweden's foremost innovations of all time occurred. The object is to determine what proportion of the innovations comes from 1) individual inventors/entrepreneurs, 2) a university, college or research institute, and 3) innovation through employment at a larger company or organization.

The study shows that 47 percent of these innovations have been created by inventors employed by companies, individual inventors have a 33 percent share and academia accounts for the remaining 20 percent. In previous research in the field definitions vary some, but in most cases, other studies have confirmed that the role of universities is less prominent.

One explanation for the results may be that larger companies spend more on research and development than others. Furthermore, they have, at best, the combination of technical expertise, market knowledge and access to capital needed to develope breakthrough innovations. The individual inventor's role has become more prominent in recent decades. Their share amounted to 45 percent of the innovations in the period 1981-2006. Universities play a more marginal role, as explained by their lack of interface to the market and to a lesser extent, engage in applied research.

The results, however, differ across sectors. Universities are key sources of innovation in medicine and health, where they account for 56 per cent of the innovations. In this sector, the research is essential for radical innovations to occur. In sectors such as engineering, construction, telecom and IT, private companies and individual inventors stand for more than 90 percent of the innovations.

The conclusions above have implications for Swedish research and innovation policy. The results indicate that if Sweden is to remain an innovative economy, policy should focus on improving conditions for businesses and individual inventors for realizing the value of their innovations. The potential is greater in industry than in academia, and a policy that puts universities at the heart of the innovation process is likely to end up with a lesser result. A more general conclusion is that the Swedish innovation policy needs to be more evidence-based and less driven by political rhetoric.

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1 Introduction

Innovation is central to economic development. New technologies, products, processes and business models lead to community resources being used more efficiently. Many of today's Swedish export successes started out as groundbreaking innovations. Studies on the origins of innovations therefore provides important insights on how Sweden can remain a competitive economy in a world characterized by high conversion speed, macro-economic turmoil and increasing competition from low-cost countries.

We have seen an increasing focus in the West on innovation issues. As one result, the role of universities has partly changed. The new idea is that they should not only produce knowledge and basic research but that they should also commercialize the results of their research (Etzkowitz, 2003). There is a long tradition of studies on how the very small and large firms contribute to innovations in a country.

In what environments were Swedish innovations primarily created? This report examines where 100 of Sweden's greatest innovations developed. The study investigates the extent to which these have occurred at universities, through established corporate R&D investments, or from independent inventors. The classification is quite similar to the one introduced by Linköping researchers Per Frankelius and Charlotte Norrman in the Vinnova-funded publication ”Inventions importance for Sweden” [1] .

Previous research in this area has shown that universities account for a relatively small share of innovations. Of the 100 innovations that annually were assessed as most outstanding by R&D Magazine only about 6 % came from universities (Block and Keller, 2008). Another study on ground-breaking innovations in the United States during the first half of the 18th century showed that a majority of these came from individual inventors and small companies. This is remarkable, especially considering that contemporary big corporations had built up their own extensive research laboratories (Jewkes et al., 1958).

A study authored by Olof Ejemo (2011) showed that the largest number of inventors were found in manufacturing. Ejemos report shows that during the years 2004-2005, there were 1 567 inventors in this sector and 190 in academy, i.e. less than an eighth compared to manufacturing. The Chalmers scientists Ove Granstrand and Sverker Alänge (1995) studied 100 Swedish significant innovations from the period 1945-1980. According to their data around 80 % of these innovations attributed to large corporations while the other 20 came from small businesses and independent inventors.

There is a relatively large amount of research literature on universities and corporate innovation based on patent data. Within this research the role of universities appears as quite marginal, although it has become more prominent over time. An article from 1998 showed that the university's share of the patents had increased from 1.5 % in 1975 to 2.5 % in 1988 - a large relative increase, albeit from low levels (Henderson et al., 1998) and a similar pattern can be seen in several European countries (Lissoni et al., 2008). Lissoni et al. also show that patent activity tends to be more common in chemistry, biochemistry, medicine and related topics. This study also showed that the universities' share of total patents amounted to between 4 and 6 per cent in France, Italy, Sweden and USA. In a doctoral dissertation from 2013 Evangelos Bourelos at Gothenburg School of Trade estimated that universities accounted for about six % of the patents in Sweden (Bourelos, 2013).

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This study is based on a different dataset that spans over a longer time period. Furthermore it seeks also to appreciate the role of universities in the innovation process. The next chapter discloses how the data has been collected and analyzed. Then there is a brief background to the different sources of innovation, after which the results regarding the origins of the innovation are presented. The report also presents changes over time and differences between sectors. Finally, there is a brief summary of the results.

2 Method

Discussions on what innovations are to be considered most groundbreaking will always contain a certain degree of subjectivity. Current definitions of the term ”innovation” refer to a novelty of commercial value (Schumpeter, 1911). An invention is therefore not an innovation until it has reached a user and thus has created a value. The height of an innovation can be measured both in the degree of technical and scientific development and in what economic value it creates. Even by a strict academic definition, there is still a wide scope for personal interpretation. Is the safety match more technologically innovative than mobile telephony? The access to soap and water has revolutionized human health without being particularly technically advanced.

A selection of key innovations can therefore be questioned. The overwhelming majority of the studied innovations, however, are by themselves obvious in this context.Worldwide, successful businesses have been created in areas such as the spherical ball bearings, the milk separator, the tetrahedron and the electric welding. Had the Ericsson Group been around today, had they not developed the AXE system during the 70's? Xylocaine and Losec have become global sales successes of the former Astra company. Furthermore, the basis for the selection comes from a number of credible actors in the field, including the Museum of Technology, The Confederation of Swedish Enterprise, The Swedish Inventors Association and The Swedish Patent and Registration Office. It should also be pointed out that similar methodological approaches have been made by researchers in other countries. An excellent example is the study published by Fred Block and Matthew Keller (2008). Based on award-winning innovations over a 40 year period, they were able to draw conclusions about the universities and the companies' respective roles in the innovation process.

Other prominent innovations are not on the list. For example the Facit calculus machine with only ten keys from 1932, the company was the first in the world with such a product, and grew into a company with more than 10 000 employees before the transition to electronics ended their success story in the early 70's (Sandström, 2013). The Lund-based Axis company was the first in the world to launch a network-based video camera in 1996 - a product innovation that made the company a world leader in the security industry.

The purpose of this report is not to decide what innovations are the most prominent in Swedish history. The idea is rather to examine the inventor's business structure at the time when the innovation was created. This has been done according to the following categorization:

A) Independent/autonomous, without steady relation to a university or college (Universities) or corporate R&D unit
B) Employee/student on research institutes, universities or colleges
C) Employed as a product developer or similar at larger companies

The journey of an idea from concept to finished product is usually long and arduous. In some cases, this study has encountered demarcation problems where some of the innovators have partly moved between the different categories over time and sometimes may have collaborated within all categories. Gustaf de Laval got many of his ideas on steam turbines, separators, etc., during his employment at Kloster Bruk, but developed and completed them on his own. Other inventors such as Nobel Prize winner Allvar Gullstrand was active at a university but worked with companies such as Carl Zeiss. Åke Hörnell did his research at Chalmers University of Technology and then started his own company.

In each of these cases, an assessment has been made regarding where, when and how the majority of the development work took place. In the above cases Ake Hornell has been classified as active at the university [2], as is the case with Allvar Gullstrand [3]. Gustaf de Laval has been placed in the category of independent inventors, even though he was both a PhD and got many of his ideas during

his time as an employee at Kloster Bruk. Secondary sources indicate that a large part of his development work was made as an independent inventor. [4] In the case of Per-Ingvar Brånemark and the titanium screw for dental treatment a different interpretation was made. Although Brånemarks innovation resulted in a large company, the major part of his work with titanium implants was carried out through his employment at the University [5]. Employees in the public sector have in some cases been sorted into the category of college/university or similar and in some cases in the category of employee of a company. Lans' invention of computer graphics was made at a research institute linked to the military. The nurse Barbro Hjalmarsson's innovations were created during her employment in healthcare. She has been placed in the category of employee of a company, she can neither be considered as independent, nor as active in a university-like organization primarily engaged in research.

The method used therefore leaves some room for interpretation. Definitions of when, where and how innovation occurs over a longer period of time, however, is virtually impossible to do without a certain degree of subjectivity. Within the framework of this study, mainly secondary sources have been used. The sources has been deemed credible by this reports author. The Museum of Technology, trade magazine Ny Teknik and the Swedish universities' official websites are some of the sources mostly consulted (see Appendix). In some border cases, the inventor in question has been contacted for a direct confirmation. The combination of subjectivity and secondary data means that there may be a margin of alternative interpretations in some cases. It is, however, limited by ambiguity to the overwhelming majority of inventions and the conclusions of this report should not be affected by the above.

In the classification above, inventors who received funding from a company founded by themselves are regarded as independent, as they can be said to have solved the issue of financing on their own. The list of the top 100 innovations is found in the Appendix.

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3 Background - How do successful innovations occur?

Based on the perception of an innovation as an novelty of commercial value, it is understood that a number of factors contribute to the emergence of an innovation. To begin with, a degree of novelty is required, either in the form of technology or ways to earn money (business model).
For this to be possible, some form of specialization and expertise is needed, for example in a product or a scientific discipline. Some kind of insight into the markets demands is also necessary. Although innovations require a context, it is also important that the development work may be relatively autonomous. This arises a potential conflict since the work on the one hand requires a degree of independence and at the same time needs to be financed somehow. The uncertainty is by definition large and the financier may never know for sure what return an investment will provide. In summary, the following factors influence the emergence of innovation:

- Technical know-how
- Knowledge of the market
- Autonomy
- Access to capital

These factors have different importance depending on the application. Simpler product innovation do not necessarily require advanced technical skills. Sometimes a unique customer insight is enough. Conversely, developing a new drug requires scientific expertise. Independent inventors, universities, and large companies are associated with a number of different strengths and weaknesses in relation to these four parameters. These are summarized below.

3.1 Independent inventors

The independent inventor obviously has a high degree of autonomy. Many times they will on their own acquire the needed technical knowledge and market knowledge, but this often requires their being in the adequat context. They will often need access to external financing.

3.2 Universities

Researchers working at universities often develop a very specific expertise in a particular field. Furthermore, they often enjoy a high degree of freedom in how they allocate their time. Researchers do however not have a natural interface to the market that would ensura a demand for possible inventions. As a rule universities are basically more engaged in basic research than, for example, product development, and they are therefore mostly disconnected from the market. Academic institutions are also characterized by other incentive structures - scientific publications and the ability to attract research funding is usually rewarded before commercialization of results. Furthermore, researchers like independent inventors do often need to raise external capital.

3.3 Companies

Companies are often relatively specialized regarding both technology and relations to existing customers. At best, this can provide a critical mass of knowledge and creativity within a specific area well connected to the market. A profitable company also has a cash flow that may be reinvested in new development projects. In some instances, companies manage to prioritize breakthrough innovative work ahead of short-term improvements of their existing products. However, it is not unusual for them instead to allocate more resources to existing products and markets (Christensen, 1997). Generally, the autonomy of the employed innovator is generally lesser than that of the independent inventor or the scientist.

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4 The emergence of innovations

Figure 1 below summarizes the contexts in which Sweden's top 100 innovations have emerged.

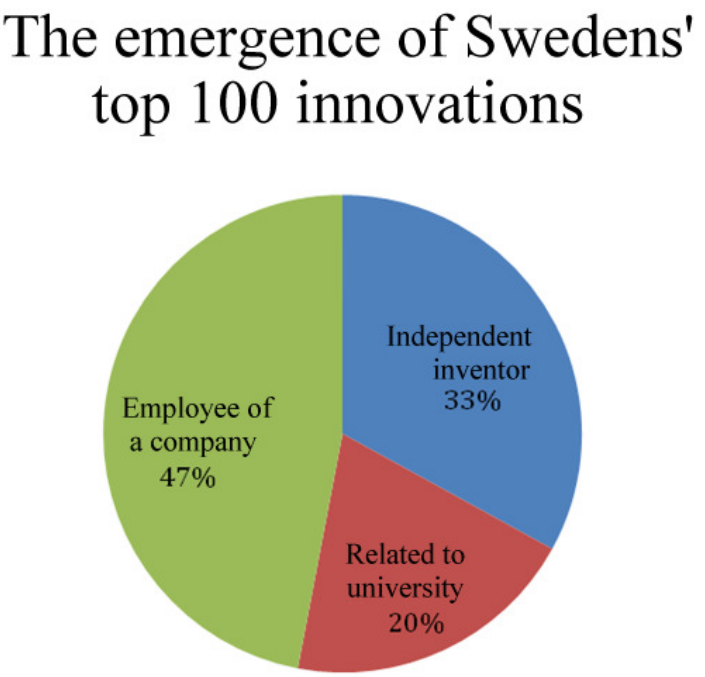

Figure 1, the proportions of the top 100 Swedish innovations from companies, independent inventors or in related to universities.

The figure shows that most of the innovations were created within the context of employment at a company. Companies usually have an established technical ability and specific market knowledge. If these skills are used correctly and the company is able to prioritize the pioneering work, individuals employed by companies are well situated to create radical innovations. At a first glance the above data differs from, for example, the study made by Granstrand and Alänge (1995). Their study, however, have sorted entrepreneurs and independent inventors into the same category, which explains some of the difference. Further, Granstrand and Alänge studied an epoch in Swedish history (1945-1980) when Swedish industry was to a large extent dominated by large corporations, many of which were the product of individual inventors work at the beginning of the 18th century. Alfa Laval (separator) and LM Ericsson (handset) can be seen as illustrative examples of this pattern.

Based on these 100 innovations the universities in Sweden seem to have had a more prominent role than in the USA for example. The data though is too limited to be able to draw any far-reaching conclusions. In relation to Ejemos report (2011) the universities also seem to have a more prominent role in the dataset for this study. Bourelos thesis from 2013 also shows that a significantly lower proportion comes from the universities (six percent).

There are a number of possible explanations for this. The 100 innovations studied in this report are very prominent. Perhaps universities have a more significant role to play for breakthrough innovations in areas such as medicine? It should also be pointed out that government research institutes and other scientifically oriented organizations other than universities have been included in this category. This may explain part of the difference. Moreover, several of the above studies mentioned uses a different method, based on patent data. Although a patent must contain a certain degree of technical height, there is a qualitative difference between a patent and those innovations studied in this report. Previous research indicates that the results from this study probably exaggerates the relative role of universities.

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4.1 Changes over time

In Figure 2 below, the number of innovations having emerged have been divided into three different intervalls of 50 years, illustrating the pace of innovation over a longer period of time.

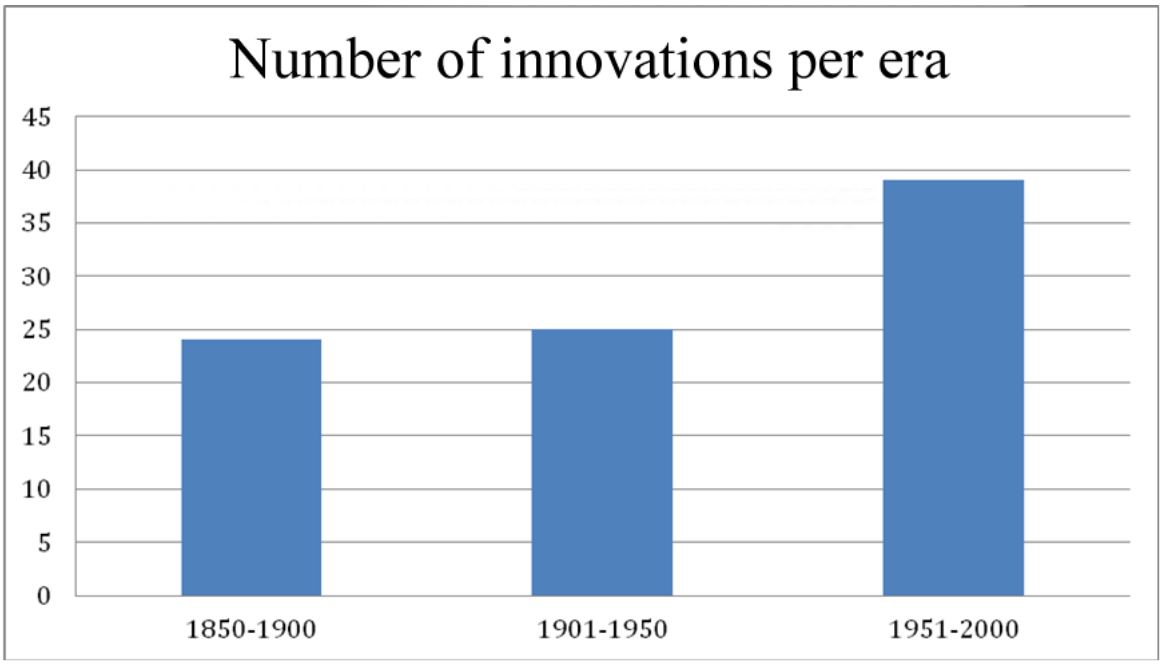

Figure 2, the number of innovations divided into intervals of 50 years.

The figure shows that the pace of innovation has increased, which seems natural given that GDP has gone up and a larger amount of resources in absolute terms are used for development. It is somewhat surprising that the difference between the first two epochs is negligible. In relation to Sweden's economic size the period 1850-1900 is distinguished as very innovative. This is a time when the country is characterized by deep poverty and about 20 % of the population emigrated. In the next graph, the onehundred innovations are divided into intervals of 20 innovations upon which the balance between independent inventors, universities and companies have been studied.

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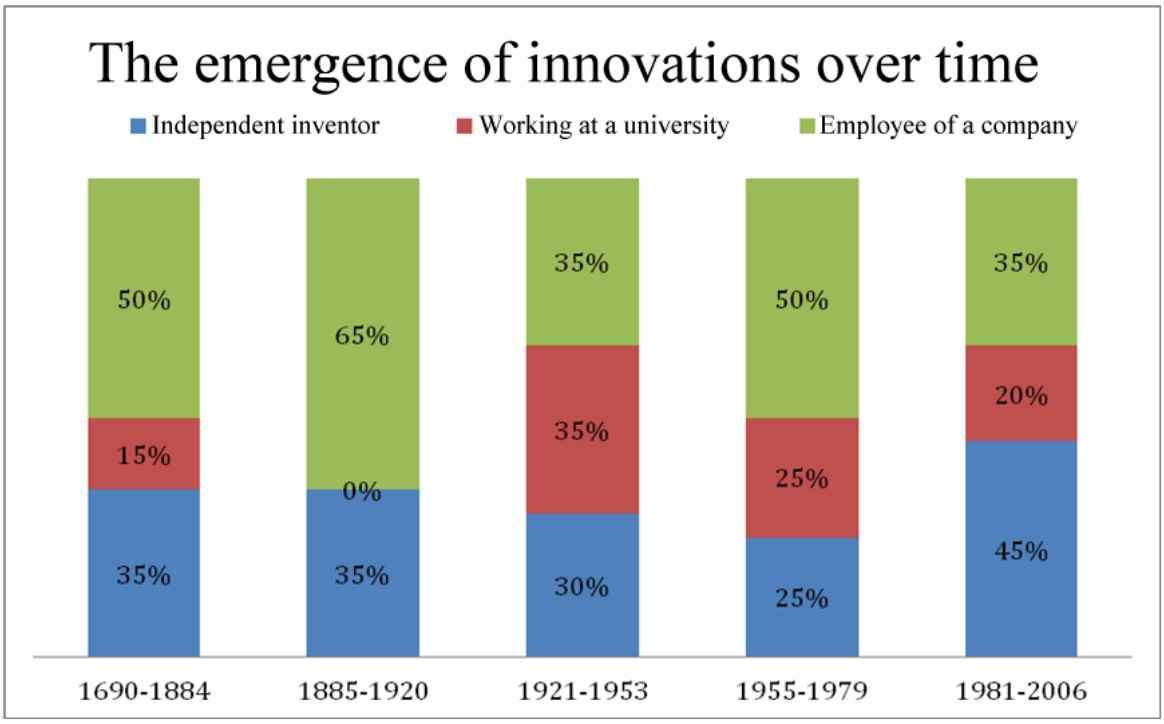

Figure 3 shows how the emergence of innovation has changed over time.

The number of innovations per time unit is in this case more limited and it is difficult to draw conclusions based on the data in Figure 3, where small changes make a huge difference at the margin. However, it is interesting to note how the independent inventors' importance seems to have increased during the past 30 years. Perhaps this is related to how the conditions for starting and running a business has improved during this period. Deregulation of capital markets in the 1980's would probably also have made it easier for individuals to move from the idea stage to reach the market and commercialize.

4.2 Innovation in various sectors

In Figure 4, the innovations have been divided into various sectors. To create a meaningful classification of a limited data set, four different categories were created: medicine and health, consumer products, engineering and construction, IT and Telecom. Of the 100 innovations 78 fit into any of these categories, the other 22 were in other words excluded. The bar in the middle is an average across all sectors and was also presented in Figure 1, page 4.

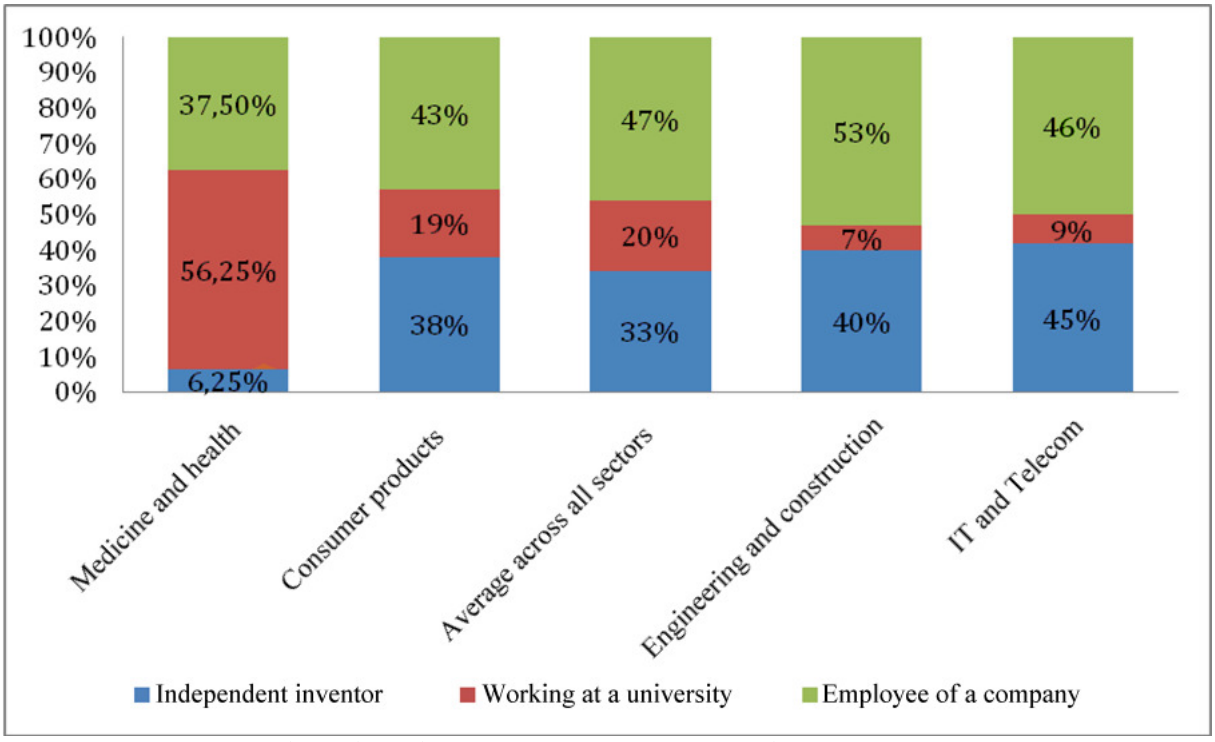

Figure 4 shows how the emergence of innovations differs across sectors.

Medicine and health

In medicine and health, it is unusual for pioneering innovations to have been created by individual inventors. At the same time, universities are heavily over-represented relative to the average.

	Innovation	Inventor	Year
Independent	The Respirator	Carl Gunnar Engström	1950
University	Ophthalmology equipment	Allvar Gullstrand	1889
	Xylocaine for local anesthesia	Nils Lofgren, Bengt Lundqvist	1941
	Titanium for dental treatment	Per-Ingvar Brånemark	1952
	The Heart-lung machine	Åke Senning	1952
	Ultrasound	Carl Hellmuth Hertz, Inge Edler	1953
	Levodopa	Arvid Carlsson	1958
	The Gamma Knife	Lars Leksell	1968
	Map of human protein	Mathias Uhlén	2002
Company	Gel filtration	Jerker Porath	1957
	The Pacemaker	Rune Elmqvist	1958
	Genotropin	Bertil Atkins	1987
	The Artificial kidney	Nils Alwall	1965
	Losec	Ivan Östholm, Sven-Erik Sjöstrand	1988
	ESR measurement	Barbro Hjalmarsson	1994
	Nicotine chewing gum	Ove Fernö	1995

Table 1: The major innovations in medicine and health

The explanation for this is probably fairly simple. Pioneering innovation in medicine and health often requires research skills. Scientists are generally operating either at universities or corporate R&D departments. The Xylocain was developed by a number of researchers. However, Astra acquired the patent and had a decisive role in its commercialization. Further, research is often capital intensive in medicine and health, individuals usually have problems solving the funding issue. In some cases, it appears the link between universities and businesses have given individuals a relatively high degree of freedom that may have been decisive. Although Arvid Carlssons discovery of L-dopa appears to have been made in the context of his research at the University, he had strong connections to the companyAstra. During the development of Losec, Astra also had close ties to the Sahlgrenska University Hospital.

The above results should not be interpreted as if individual inventors or entrepreneurs in healthcare are unimportant. It needs to be emphasized that innovations in this dataset are not representative of the development potential in medicine and health. It is possible to develop products and services for care that does not give the Nobel Prize and this is done all the time, creating large economic values. These products are not included in this dataset covering the top 100 innovations in the history of Sweden, but the cumulative effect of all these minor innovations is probably still huge.

Consumer Products

The category 'consumer products' follows almost exactly the average of the top 100 innovations. In this case, individual inventors may have an advantage because they understand the market as consumers. Of the four innovations that come from the universities, two of these were graduate projects that were commercialized in other contexts. polkagris

It is not clear how the single-lens reflex camera should be classified. Victor Hasselblad was a self-employed entrepreneur but had also inherited a business. Since he owned and developed the company and the camera, this author has chosen to categorize him as an individual inventor.

	Innovation	Inventor	Year
Inventor	Sparkling mineral water	Torbern Bergman	1775
	The Candy Cane	Amalia Eriksson	1859
	Synthetic adhesives	Axis Karlsson	1920
	The spinning reel	Göte Bergström	1937
	The Single-lens reflex camera	Victor Hasselblad	1948
	The Frame backpack, thermal tent	Åke Nordin	1950
	A Colour-coded plug in nylon	Oswald Thorsman	1957
	A Newspaper without price	Pelle Anderson, Monica Lindstedt Robert Braunerhielm, Jorgen Widsell	1995
	C-pen, wand	Christer Fahraeus	1996
University	Patents on safety match	Gustaf Erik Pasch	1844
	Refrigerators with no moving parts	Malmo von Platen and Carl Munters	1921
	Rear-facing car seat	Bertil Aldman	1963
	Peepoo disposable toilet	Anders Wilhelmson	2005
Company	The Safety match	Janne Lundström	1855
	Västerbotten Cheese	Ulrika Eleonora Lindström	1872
	The Paraffin stove Primus	Frans Lindqvist	1888
	The zipper	Gideon Sundbäck	1910
	Marketing of vacuum cleaners	Axel Wenner-Gren	1912
	The Coca Cola bottle	Alexander Samuelson	1915
	Dried milk	Ninni Kronberg	1912
	The disposable diaper	Molnlycke	1955

Table 2: The main innovations in consumer products

Engineering and construction

Within the category of engineering and construction we find product and process innovations for industrial use. The end user is in other words not a consumer but a business or an industrial enterprise. The innovations may therefore involve new manufacturing methods or clever inventions that facilitate a particular work. The milking machine states a good example in this category because it is sold to farmers for their commercial use. Odhners calculus machine may also be seen as an industrial product since such machines almost exclusively were sold to businesses until the advent of electronics by the end of the sixties.

	Innovation	Inventor	Year
Inventor	The Screw propeller	John Ericsson	1836
	The Hand operated milk separator	Gustaf de Laval	1877
	The Steam turbine	Alfred Nobel	1875
	The Action Song turbine	Gustaf de Laval	1888
	The Adjustable wrench	Johan Petter Johansson	1889
	The Wrench	Johan Petter Johansson	1893
	The Milk machine	Gustaf de Laval	1896
	The Truck Crane	Eric Sundin	1946
	The Backhoes	Goran and Birger Lundberg	1951
	The Building Elevator	Alvar Lindmark	1962
	The Construction Crane/Tower Crane	Elis Lindén	1970
University	The frame loop	Alfred Holm	1935
	The Welding helmet	Ake Hornell	1981
Company	The Match making machine	Alexander Lagerman	1873
	The Series Made Calculator	Willgodt Odhner	1878
	The Dynamo Machine	Jonas Wenström	1882
	The blowtorch	Carl Nyberg	1882
	The Measurements combination kit	CE Johansson	1894
	Electric welding	Oscar Kjellberg	1904
	A Cutting apparatus for gas lighthouses	Gustaf Dalen	1905
	AGA mass.	Gustaf Dalen	1906
	The spherical ball bearing	Sven Wingqvist	1906
	The Solar valve for gas lighthouses	Gustaf Dalen	1907
	The Ljungstrom turbine, double rotation steam turbine	Birger Ljungstrom	1908
	The Ljungstrom turbine, rotary air preheater	Fredrik Ljungstrom	1908
	Kanthal	Hans v. Kantzow	1926
	The KaMeVa propeller	KMV Karlstad	1937
	The seat belt (with three points)	Bengt Odelgard, Per-Olof weman, Stig Lindgren, Nils Bohlin	1957
	Retractable seat belt for cars	Hans Karlsson	1962
	CARB bearings	Magnus Kellström	1995

Table 3: the major innovations in the engineering and construction

Table 3 shows clearly that the role of universities is negligible. Most of Åke Hörnells development of the welding helmet seems to have taken place at the Chalmers University and his invention is therefore placed in this category. It should be emphasized though that Hörnell developed and commercialized the product through the starting of his own business. The main reason for the limited role of universities is likely that almost all innovations in this category are based on applications of known physical laws. The milk separator is the application of mechanics and laws of centrifugal force, the building elevator, the construction crane and the turbine should also be considered as applications of existing knowledge.

IT and telecom

Just as in the engineering and construction category, universities have a very limited innovative role concerning IT and telecommunications, mainly because these are examples of applied science rather than basic research. Håkan Lans developed computer graphics during his time as an employee at the Swedish Defence Research Agency, that is, an environment where science was not the main focus. Apart from this, all innovations in this category have been developed either by independent inventors or by companies.

	Innovation	Inventor	Year
Detached	The telephone handset	Lars Magnus Ericsson	1884
	An application of GPS for positioning	Håkan Lans	1991
	Audio compression, AAC	Lars Liljeryd	1997
	Skype, Kazaa	Niklas Zennström	2003
	Spotify	Daniel Ek, Martin Lorentzon	2006
Institute	Computer Graphics	Håkan Lans	1981
Business	The integrated telephone handset (Ericofon)	Ralph Lysell and Gösta Thames.	1940-56
	The first mobile computer game	Göran Sundqvist	1960
	AXE system.	BG Magnusson / Goran Hemdahl	1970
	Mobile telephony; NMT and GSM	Östen Mäkitalo	1989
	Bluetooth	Sven Mattisson, Jaap Haartsen and Örjan Johansson	1998

Table 4: Innovations in IT and telecom

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5 Conclusion

This study has investigated how 100 of the most important Swedish innovations have emerged. As stressed earlier, there are some methodological challenges around determining when and in what form an innovation occurs. Nevertheless the report gives interesting insights in the creation of cutting-edge Swedish innovations.

The results indicate that 47 percent of the top one hundred innovations were created by inventors as employees of companies, while individual inventors and entrepreneurs have contributed 33 percent and university finally accounts for the remaining 20 percent. Companies and individuals often have a combination of technical expertise and market knowledge that allows radical innovations to emerge. Companies often may have a cash flow that sometimes can be used for funding extensive development.

An important conclusion is that the independent inventors' role has become more prominent in recent decades. Of the twenty major innovations during the period 1955-1979 25 percent of those emerged from independent inventors. Of the 20 innovations between years 1981 to 2006 no less than 45 percent came from this category. The independent inventors in other words have become increasingly important in Sweden.

The report also shows that the emergence of innovations seem to vary a lot between different sectors of society. Universities and research institutes contribute to a larger proportion of innovations in the areas medical care and health. In the fields of engineering, construction, telecom and IT, they have a much more limited role. The results from this study should not be seen as controversial or dissenting from previous research in this area.

Although the figures presented are in line with similar earlier studies, they present political implications. If an overwhelming majority of Sweden's pioneering innovations are created by individual inventors/entrepreneurs and individuals employed by companies, the Swedish innovation policy ought to focus primarily on these. Even though the role of universities in society has been redefined in recent years and the commercialization of research has become prominent, the majority of cutting-edge innovations emerge from the industry and individual inventors.

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About the author

LIC. Dr. Christian Sandström is a researcher and a lecturer at Chalmers University of Technology and the Ratio Research Institute.With a background as a civil engineer in Industrial Engineering and Master in Economics in 2010, he dissertated a thesis on how technology changes affect established companies. The empirical reserach material was among other sources collected from the digitization of the camera industry field and the transition to electronic calculators. The thesis was awarded with Handelsbanken's Wallander scholarship that provides three years of funded research. Sandstrom has in recent years been a guest researcher at ETH Zurich and the University of Cambridge. His research has focused on how technology changes alter customer behavior and political institutions, among other things related to 3D Printing and the digitization of the financial markets. In 2009, he received the I-engineers' award as the best lecturer.

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Appendix

Year	Inventor	Invention	Independent	University	Company
1690	Christopher Polhem	The Polhem Knot	X		
1742	Anders Celsius	Thermometer Scale		X	
1775	Torbern Bergman	Sparkling mineral water, soft drinks		X	
1836	John Ericsson	Screw propeller	X		
1844	Gustaf Erik Pasch	Patents on safety match		X	
1855	Janne Lundström	Safety match			X
1858	Göran F Göransson	Bessemer (Järnframst).	X		
1859	Amalia Eriksson	Polkagrisar	X		
1864	Alfred Nobel	Efficient cap-			X
1865	Alfred Nobel	The dynamite.			X
1872	Ulrika Eleonora Lindström	Västerbottensost			X
1873	Alexander Lagerman	Matchstick Production Machinery			X
1874	Daniel Carl Ekman	Sulphite cellulose			X
1875	Alfred Nobel	Blasting Gelatine			X
1877	Gustaf de Laval	Hand operated milk separator.	X		
1878	Willgodt Odhner	Series Made calculator.			X
1882	Carl Nyberg	The blowtorch.			X
1882	Jonas Wenström	Dynamo Machine.			X
1883	Gustaf de Laval	Steam turbine	X		
1884	Alfred Nobel	Nobel gunpowder.			X
1884	Lars Magnus Ericsson	Handset.	X		
1888	Frans Lindqvist	Paraffin stove Primus			X
1888	Gustaf de Laval	Action Song turbine	X		
1889	Allvar Gullstrand	Ophthalmology equipment		X	
1889	Johan Petter Johansson	Adjustable pipe wrench.	X		
1891	Jonas Wenström	Trefasöverföring AC	X		
1892	Johan Petter Johansson	Wrench	X		
1894	Carl Edvard Johansson	Measurements combination kit			X

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1896	Gustaf de Laval	Milk machine.	X		
1904	Oscar Kjellberg	Electric welding			X
1905	Gustaf Dalen	Cutting apparatus for gasfyrar.			X
1906	Gustaf Dalen	AGA mass.			X
1906	Sven Wingqvist	The spherical ball bearing			X
1907	Gustaf Dalen	Solventilen for gasfyrar.			X
1908	Birger Ljungstrom	D ubbelroterande steam turbine			X
1908	Fredrik Ljungstrom	Ljungstrom turbine, rotary			X
1910	Gideon Sundbäck	The zipper			X
1912	Axel Wenner-Gren	Marketing Method for vacuum cleaner			X
1915	Alexander Samuelson	Coca Cola bottle			X
1920	Axis Karlsson	Synthetic adhesives	X		
1921	Baltazar von Platen and Carl Munters	Refrigerators with no moving parts		X	
1926	Hans von Kantzow	Kanthal			X
1933	Ninni Kronberg	Dried milk			X
1935	Alfred Holm	The frame loop		X	
1937	Göte Bergström	The spinning reel (fishing)	X		
1937	KMV Karlstad	KaMeVa-propeller with controllable pitch.			X
1940	Fredrik Ljungstrom	Extraction of shale oil, etc., etc.			X
1940 -56	Ralph Lysell and Gösta Thames	Integrated telephone handset (Ericofon)			X
1941	Nils Lofgren and Bengt Lundqvist	Xylocaine for local anesthesia		X	
1944	Erik Wallenberg	Tetrahedrons			X
1946	Eric Sundin	Truck Crane	X		
1947	Erik Bergstrand	Geodimeter		X	
1948	Victor Hasselblad	Single-lens reflex camera	X		
1950	Carl Gunnar Engström	Respirator	X		
1950	Uno Lamm	High-voltage DC			X
1950	Åke Nordin	Frame backpack and thermal tent	X		
1951	Goran and Birger Lundberg	Backhoes	X		
1952	Per-Ingvar Brånemark	Titanium for dental treatment		X	
1952	Ake Senning	Cardiovascular lungmaskinen		X	

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1953	Carl Hellmuth Hertz and Inge Edler	Ultrasound			X	
1955	Libero	The disposable diaper				X
1957	Bengt Odelgard, Per-Olof weman, Stig Lindgren and Nils Bohlin	The seat belt (with three points)				X
1957	Jerker Porath	Gel filtration			X	
1957	Oswald Thorsman	Colour-coded plug in nylon	X			
1958	Arvid Carlsson	Levodopa			X	
1958	Rune Elmqvist	Pacemaker				X
1960	Göran Sundqvist	First mobile computer game				X
1961	Per Oscar Persson / Göran Lundahl	Freezing of food				X
1962	Alvar Lindmark	Building Elevator	X			
1962	Hans Karlsson	Retractable seat belt for cars.				X
1962	Per-Oskar Persson	Flofreeze				X
1963	Bertil Aldman	Rear-facing car seat			X	
1965	Nils Alwall	Artificial kidney			X	
1968	Lars Leksell	Gamma Knife			X	
1970	Bengt-Gunnar Magnusson / Goran Hemdahl	AXE system.				X
1970	Elis Lindén	Construction Crane / Tower Crane	X			
1974	Lundblad, Leif	Sedelutmatningssystem	X			
1975	Stone Engwall	Geothermal	X			
1976	Bengt Gunnar Magnusson	the first AXE exchange put into use				X
1979	Sven Erik Sjöstrand, Astra	patenting his invention Losec				X
1981	Håkan Lans	Computer Graphics			X	
1981	Ake Hornell	Welding helmet that blocks automatically			X	
1983	Klas Stoltz, Stoltz and Bo Kjell Gustavsson.	Färgklämman (theft protection for clothes with color coding)	X			
1985	Jack Gustavsson	Ski Binding	X			
1987	Bertil Atkins	Genotropin				X
1988	Ivan Östholm and Sven-Erik Sjöstrand	Losec				X
1989	Östen Mäkitalo	Mobile telephony; NMT and GSM				X

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1991	Håkan Lans	Application of GPS for positioning	X			
1994	Barbro Hjalmarsson	ESR measurement and Triomix / blood analysis				X
1995	Magnus Kellström	CARB bearings				X
1995	Ove Fernö	Nicotine chewing gum				X
1995	Pelle Anderson, Monica Lindstedt Robert Braunerhielm and Jorgen Widsell	Newspaper without price for distribution in tulllbanor (Metro)	X			
1996	Christer Fahraeus	C-pen, wand	X			
1997	Lars Liljeryd	Audio compression, AAC	X			
1998 approx	Sven Mattisson, Jaap Haartsen and Örjan Johansson	Standard for local communication, Bluetooth				X
2003	Mathias Uhlén	Map of human protein			X	
2003	Niklas Zennström	Skype, Kazaa	X			
2003	Petra Wadström	Clean water from sunlight	X			
2005	Anders Wilhelmson	Peepoo - disposable toilet			X	
2006	Daniel Ek and Martin Lorentzon	Spotify	X			

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Sources

Below are the sources used to determine the various innovations emergence.
The right column also indicates the date of any sources used.

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Thermometer Scale m the freezing and boiling point as ref	University of Uppsala	http://www.astro.uu.se/history/celsius.pdf	2014-04-29
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Screw propeller	National Park Service	http://www.nps.gov/joer/historyculture/people.htm	2014-04-29
Patents on safety match	Technical Museum	http://www.tekniskamuseet.se/1/1901.html	2014-04-29
Safety match	Företagsamheten.se	http://www.foretagsamheten.se/Entreprenorer/Entreprenorer/Janne-and-Carl-Lundstrom/	2014-04-29
Bessemer (Järnframst).	Technical Museum	http://www.tekniskamuseet.se/1/1906.html	2014-04-29
Polkagrisar	Technical Museum	http://www.tekniskamuseet.se/1/1909.html	2014-04-29
Efficient cap-	Technical Museum	http://www.tekniskamuseet.se/1/1910.html	2014-04-29
The dynamite.	Technical Museum	http://www.tekniskamuseet.se/1/1910.html	2014-04-29
Västerbottensost	Företagsamheten.se	http://www.foretagsamheten.se/Entreprenorer/Entreprenorer/Ulrika-Eleonora-Lindstrom/	2014-04-29
Matchstick Production Machinery	The National Archives	http://sok.riksarkivet.se/sbl/Presentation.aspx?id=10925	2014-04-29
Sulphite cellulose	Technical Museum	http://www.tekniskamuseet.se/1/1911.html	2014-04-29
Blasting Gelatine	Technical Museum	http://www.tekniskamuseet.se/1/1910.html	2014-04-29
Hand operated milk separator.	Technical Museum	http://www.tekniskamuseet.se/1/1915.html	2014-04-29
Series Made calculator for general use.	Technical Museum	http://www.tekniskamuseet.se/1/1913.html	2014-04-29
The blowtorch.	Sundbybergs museum	http://www.museet.se/historik/persona/nyberg/sida1.htm	2014-04-29
Dynamo Machine.	Technical Museum	http://www.tekniskamuseet.se/elkraft/snilleblixtar/wenstrom.htm	2014-05-03
Steam turbine	Technical Museum	http://www.tekniskamuseet.se/1/1915.html	2014-05-03
Nobel gunpowder.	Technical Museum	http://www.tekniskamuseet.se/1/1910.html	2014-05-03
Handset.	Technical Museum	http://www.tekniskamuseet.se/1/1916.html	2014-05-03
Paraffin stove Primus	Technical Museum	http://www.tekniskamuseet.se/1/1924.html	2014-05-03
Action Song turbine	Technical Museum	http://www.tekniskamuseet.se/1/1915.html	2014-05-03

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Adjustable pipe wrench.	Technical Museum	http://www.tekniskamuseet.se/1/1921.html	2014-05-03
Trefasöverföring AC	New Technology	http://www.nyteknik.se/popular_teknik/kaianders/article227039.ece	2014-05-03
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Measurements combination kit	Technical Museum	http://www.tekniskamuseet.se/1/1926.html	2014-05-03
Milk machine.	Technical Museum	http://www.tekniskamuseet.se/1/1915.html	2014-05-04
Electric welding	Technical Museum	http://www.tekniskamuseet.se/1/1777.html	2014-05-04
Cutting apparatus for gasfyrar.	Technical Museum	http://www.tekniskamuseet.se/1/1930.html	2014-05-04
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Ljungstrom turbine, rotary air preheater	Technical Museum	http://www.tekniskamuseet.se/1/1932.html	2014-05-04
The zipper	Rawr Denim	http://www.rawrdenim.com/2014/05/history zippers-talon-universal-gideon-sundback/	2014-05-04
Marketing Method for vacuum cleaner	IDG.se	http://www.idg.se/2.1085/1.225735/pojken-with-gold pants	2014-05-04
Coca Cola bottle	Coke	The Coca Cola Company, link here .	2014-05-04
Synthetic adhesives	Elmer's glue	http://www.karlsons-klister.se/indexx.html?historia/historia.html	2014-05-04
Refrigerators with no moving parts	Swedish Inventors - museum	http://svensktuppfinnaremuseum.se/baltzar-von-Platen-and-carl-munters/	2014-05-04
Kanthal	Science Graph	http://sv.sciencegraph.net/wiki/Hans_von_Kantzow	2014-05-04
Dried milk	Technical Museum	http://www.tekniskamuseet.se/1/1933.html	2014-05-04
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Geodimeter	Technical Museum	http://www.tekniskamuseet.se/1/1938.html	2014-05-05
Single-lens reflex camera	Hasselblad Foundation	http://www.hasselbladfoundation.org/the-history/sv/	2014-05-05
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CARB bearings	Chalmers University of Technology	http://www.chalmers.se/sv/om-chalmers/akademiska-hogtider/promotion/hedersdoktorer/Sidor/magnus-kellstrom.aspx	2014-05-07
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