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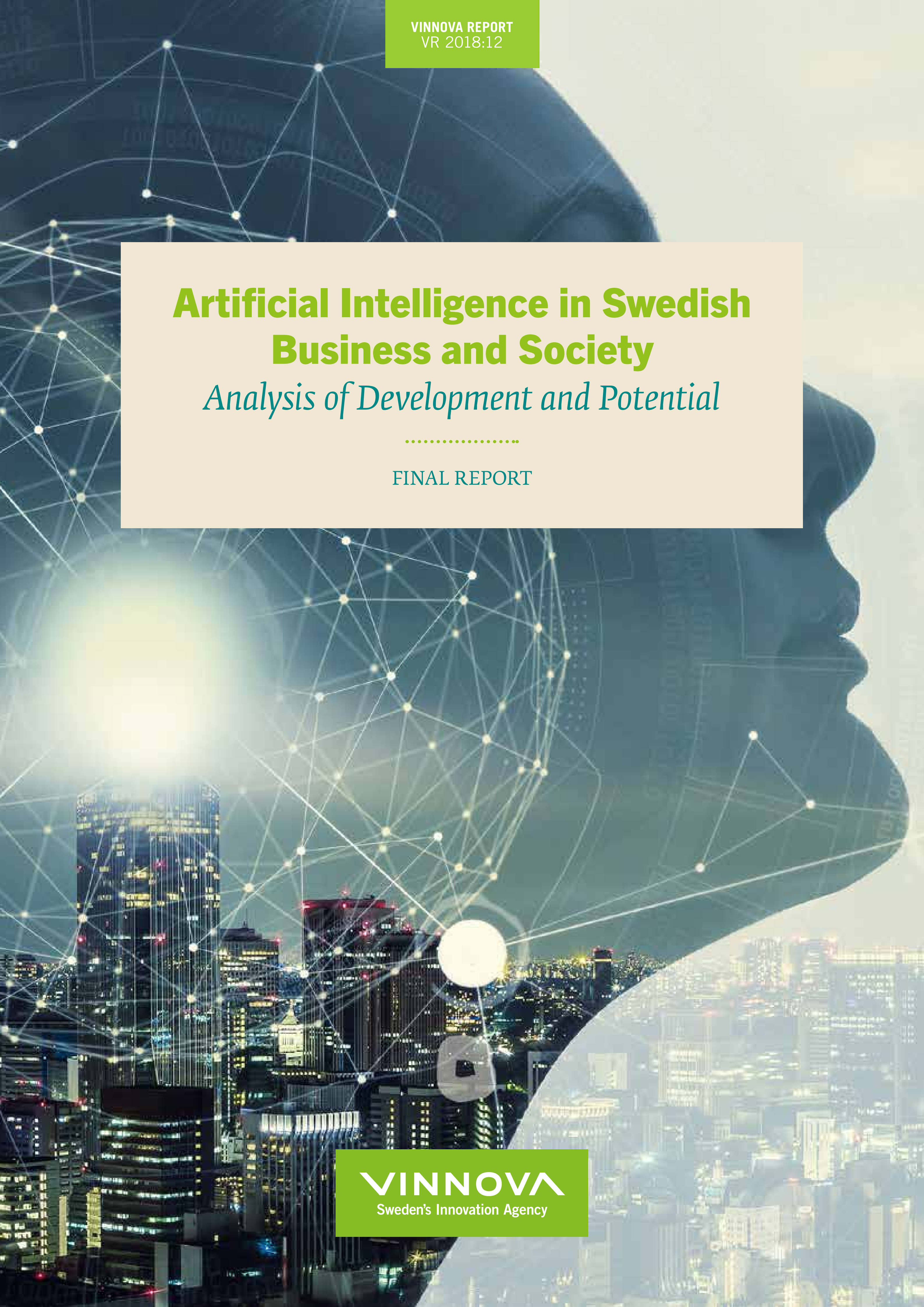

Artificial Intelligence in Swedish Business and Society

Analysis of Development and Potential

FINAL REPORT

VINNOVA
Sweden's Innovation Agency

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Short about Vinnova

Our vision is to strengthen Sweden as a country of research and innovation.

Vinnova's vision is for Sweden to become a leading global player in research and innovation, and a country that is attractive for investment and entrepreneurship.

Vinnova is Sweden's innovation agency. Our mission is to contribute to sustainable growth by improving the conditions for innovation. We do this mainly by funding innovation projects and the research needed to develop new solutions. We also invest long term in strong research and innovation environments.

We stimulate collaborations between companies, universities and other higher education institutions, public services, civil society and other actors. Our activities also focus on strengthening international cooperation.

Each year, Vinnova invests around SEK 3 billion in fostering innovation. Most of these funds are allocated via calls for proposals in which companies, public sector actors and other organisations apply for funding. All investments are continuously monitored and evaluated and we regularly analyse the impacts of our investments.

Vinnova is a government agency under the Ministry of Enterprise and Innovation, and the national contact authority for the EU Framework Programme for Research and Innovation. We are also the Swedish Government's expert authority in the area of innovation policy. Vinnova employs just over 200 people and has offices in Stockholm and Brussels. Acting director general is Leif Callenholm.

The **Vinnova Report** series includes evaluations, analyzes and reports about our programmes, funded projects or assignments we've given others.

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Artificial Intelligence in Swedish Business and Society

– Analysis of Development and Potential

FINAL REPORT

Government commission to conduct mapping and analysis of the effective application of artificial intelligence and machine learning in Swedish industry and in Swedish society

Ref. no. 2017-05616

N2017/07836/FÖF

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Preface

On 22 December 2017, the Government commissioned Vinnova (N2017/07836/FÖF) to conduct mapping and analysis of the effective application of artificial intelligence (AI) and machine learning in Swedish industry, the public sector and Swedish society and the potential that can be realised by reinforcing its use. The commission involves:

- mapping and analysing the potential of using AI and related technologies in Swedish industry in particular and in Swedish business and the public sector in general,
- mapping and describing the current position of Sweden within the field of AI, especially in terms of availability to and provision of competence through education and further training, but also with regard to research and public initiatives to implement AI in different industries and social sectors,
- analysing how far Sweden has come in terms of utilising the possibilities of AI and highlighting bottlenecks that may constitute limiting factors for its use.

A commission report shall be submitted to the Ministry of Enterprise and Innovation by 30 April 2018. Vinnova submitted an interim report to the Ministry of Enterprise and Innovation on 12 February 2018. This report constitutes Vinnova's final report.

Firstly, Vinnova would like to THANK all those who contributed with supporting documentation, proposals, opinions and comments during the process of producing this report. The list is long: public actors, business representatives, academia, research institutes, research financiers, strategic innovation programs, trade associations, networks within the AI arena, and many more. A special thanks to Governo, Teqmine, KTH's bibliometric group, the Swedish Research Council and Statistics Sweden, all of whom have contributed analysis data in collaboration with Vinnova. In addition to data, Governo has provided an analysis of AI within the public sector, and the Finnish company Teqmine has, in addition to patent data, assisted in the analysis of this data.

At Vinnova, Lennart Stenberg, Annika Zika-Viktorsson, Rolf Nilsson, Jonny Ullström, Josefin Lundström and David Jonasson have produced data and analysis documentation and have also analysed data and material from many different sources. Cecilia Sjöberg, Erik Borälv, Linda Swirtun and Ulf Öhlander have contributed their essential expertise within the field of AI with regard to the different areas of application for AI, the role of AI in Vinnova's initiatives, and international developments within AI. Hanna Mittjas and Ingelore Djurheden contributed communications skills and layout. In addition, many others at Vinnova have contributed with supporting material, viewpoints and initiatives. Karin Stridh coordinated the government commission and has worked on the report. Göran Marklund was the project manager and has been responsible for the writing of the report.

Vinnova in May 2018

Göran Marklund
Deputy Director General external matters
Head of Operational Development

Summary analysis

There is no clear-cut definition or generally accepted demarcation of artificial intelligence (AI). In this analysis, artificial intelligence is defined as the ability of a machine to imitate intelligent human behaviour. Artificial intelligence also denotes the area of science and technology that aims to study, understand and develop computers and software with intelligent behaviour.

The purpose of this analysis is to identify and analyse:

- Opportunities in the use of AI within business and public services in Sweden.
- Development to date of Sweden's use of AI.
- AI skills for business and public services.

A central part of the analysis is to create an understanding of driving forces, opportunities, obstacles and links between significant factors for AI-based value creation in business and the public sector.

The issues dealt with by the assignment are wide-ranging, and many different aspects of the development of business and society are significant in relation to these issues. Accordingly, this analysis cannot claim to be comprehensive. This summary describes Vinnova's assessments and conclusions of the studies, data and expert opinions on which the analysis is based.

Sweden's AI capability

Applications of AI have already been of great importance for the development of internet platforms, information retrieval, image recognition and automated translation, but the practical impact of AI has been limited in large parts of business and in public activities in Sweden. However, during the last decade, access to data in electronic form and computing power has increased very quickly, which has considerably improved the conditions for AI applications in various activities.

Opportunities and challenges

In order to assess the AI potential for value-creation and to use this potential, it is important to understand the possible areas of application in various industries, since it is in these that the value-creating potential lies. Possible applications also provide the driving force for AI development in companies and public activities.

The potential lies in:

- Automating functions in established value chains, operations and functions.
- Developing new business models, products, services and system solutions.
- Transforming value chains and sectors for brand new development tracks.

Sweden's value creation potential in the use of AI within business and public services is great. Most assessments identify a growth potential that is twice as fast with large AI utilisation in the economy compared with a low AI utilisation.

The potential for improved quality and efficiency in the public sector is great. Additionally, there is very considerable potential in developing and implementing AI solutions for environmental and social challenges in society. Accordingly, artificial intelligence can contribute to Sweden's possibilities of achieving the goals in the 2030 Agenda for Sustainable Development.

A considerable increase of AI applications in business, the public sector and society has not only a potential to improve the quality and efficiency in various operations, as well as increased growth and improved welfare; AI developments will also generate new challenges through the development and adjustment processes that will become necessary. The following challenges will become important as a consequence of increased AI utilisation:

- **Leadership and adaptability** in companies, public operations and policy systems
- **Labour dynamics and unemployment** due to rapidly changing job descriptions
- **Data ownership** and challenges in relation to privacy, ethics and trust
- **Data and business monopolies** for a small number of technology-based companies
- **Risk of application of immature AI solutions** based on incorrect data and algorithms
- **Security risks** through conscious harmful data usage and data manipulation

Innovation leadership in all sectors and at all levels will become very significant for the AI development in Sweden. The dynamics in the labour market will increase considerably as the AI applications in business and public operations become more frequent. **Adaptability** of individuals and operations will become increasingly important. This will place very high demands on leadership skills for business development and the ability to support individuals in readjustment and upgrading of skills. Therefore, the momentum, skills and other requirements for such adaptability must be significantly strengthened.

The net effects of labour dynamics for the economy are largely very uncertain. Based on historical development and new scenarios, there is no reason to assume, however, that the creation of new jobs will be slower overall than the pace of the jobs that will disappear.

Regulatory developments and the rules regarding data and **data access** will be crucial for the development of AI. Such rules must strike a balance between the fundamental needs for **privacy, ethics, trust and social protection** and data access necessary for the development of value-creating AI applications. This requires that drivers and competences to participate in innovation processes are significantly strengthened among public authorities and experts in charge of regulatory and regulatory monitoring. One important aspect is that such public authorities and experts should cooperate directly with other stakeholders in the R&D and innovation processes where new AI applications are developed.

Leadership and governance for a safe and value-creating transformation of society as a whole must be strengthened considerably. Knowledge about how increasing AI usage may affect the development of society and what measures may contribute to minimizing the risks of adverse effects of AI are deemed highly undeveloped. Competence development in relation to social aspects of AI therefore needs to be strengthened. The ability to prepare **system analyses** that create understanding of how different drivers, factors and processes affect each other are very significant in this context. However, analyses that form the bases for various policy areas are often conducted with a systems perspective that is too narrow, linked to specific areas of policy and based on narrow questions. Often, they are also based on a method repertoire for necessary systems analyses that is too narrow. While initiatives are taken to promote the utilization of AI, research, analytical capacity and processes for system analyses need to be developed significantly.

Important areas
Artificial intelligence will be important for Sweden's future competitiveness and innovative strength in all sectors and industry branches, that will all be affected by the development of AI. Therefore, it is difficult to identify areas of application for AI where Sweden is particularly well-placed. However, the following broad and mutually dependent areas of application for AI are expected to be particularly important for the development of both Swedish business and society:

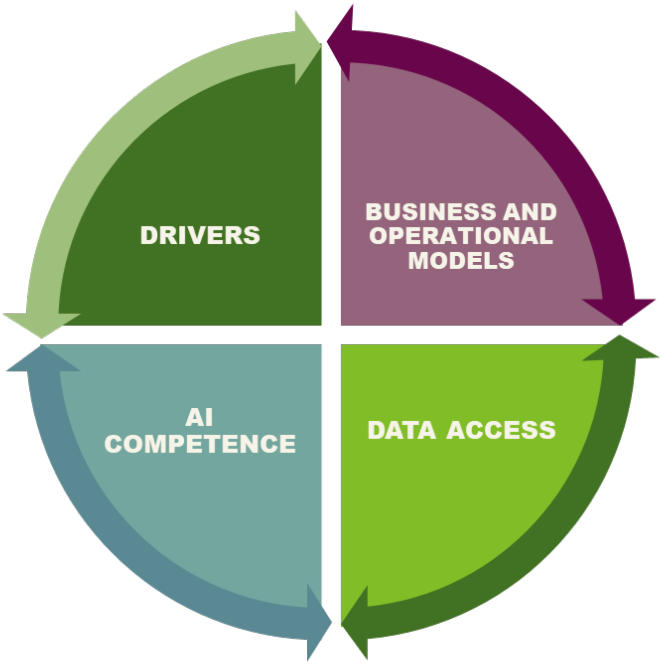
- **Industrial development** - development of products and services and manufacturing and service processes
- **Travel and transports** - autonomous vehicles, logistics and transport infrastructure
- **Sustainable and smart cities** - transport systems, energy and waste, education and healthcare systems
- **Health** - products, services and processes for diagnostics, drugs, and healthcare
- **Financial services** - service development in finance, insurance and payment systems
- **Security** - defence, civil contingency, police and customs

The opportunities for AI applications are different in different areas. Many different factors will be important in the development and these will be strongly mutually dependent on each other. The following factors and the interaction between these will be important in all activities:

- **Business and operational models** - for some companies and public operations the value creation potential of AI is apparent, while others cannot yet perceive a benefit as clearly.
- **Drivers** - for some companies AI is already a significant competitive factor, while others still lack clear drivers, and the drivers are generally weak in the public sector.
- **Data access** - in most areas, lack of data access is a crucial limit on the development of business and operational models are based on AI applications.
- **Competence** - limited AI skills in companies and public activities, among both managers and employees, hampers the development of AI in most operations.

Business and operational models, data access and competence are mutually dependent and therefore heavily affected by each other in companies and public operations. Without clear prospects of business benefits, the drivers of AI-based investments are inhibited. If the business benefit is not clear, AI competence is also not viewed as an important factor for value creation and efficiency, affecting recruitment patterns and competence development. Limited AI competence, at managerial level and among employees, makes it difficult, in turn, to develop AI based business and operational models. Data access and possibilities of combining different data will be fundamentally significant for purposes of identifying the applications that can be developed. Data restrictions that inhibit or eliminate the development of AI-based products and processes weaken the drivers for AI investments, Figure 1.

Figure 1. Mutual dependencies among important factors for the development of AI applications



Important prerequisites for a positive development of the interaction between the above factors will include:

- **Innovation leadership** for the development of AI applications and the ability to lead business restructuring and to support individuals in readjustment and upgrading of skills.
- **Labour market models** that give individuals drivers and favourable terms for labour dynamics and life-long learning lay the foundation for continuous adjustment in the labour market.
- **Data regulations** for many AI applications restrict the development considerably. Such regulations often have strong links to privacy, ethics, trust and ownership rights.
- **Social solutions** for digital security, integrity, ethics, trust and safety, striking a balance between the fundamental needs for data access for AI development and social development needs.
- **Critical mass** and international attractiveness in environments for research, education and innovation that are characterized by efficient cooperation among different functions and market participants.
- **Collaboration** among companies, public operations, research institutes, universities and university colleges will be crucial in realizing Sweden's AI potential.

Leadership in relation to innovation and operational development will be of crucial significance, and there are many indications that requirements in relation to this ability in companies, public operations, universities and university colleges as well as in political bodies will increase significantly as the use of AI becomes more frequent. Increased AI applications will have a strong impact on job descriptions, labour organisation and the labour market. This will involve significant challenges in leading restructuring or AI-based operational development and innovation in companies, public operations and in universities and university colleges.

Increased AI usage will also place significantly higher demands on individuals to continuously change tasks and continuously renew their competence. This in turn will require development and adaptation of drivers and social security systems for transitions in working life, presenting new challenges in terms of labour market policies and for the participants in the labour market. Successful AI development in different areas will depend on both specialist and broad competence within AI and domain and organizational competence for different AI applications.

Access to data is closely linked with regulatory conditions relating to data and data management. Data regarding individuals and individual behaviour is of crucial significance for many AI applications. Data access is determined by how companies and public operations develop and safeguard data in their operations and collaboration, and by the development of regulatory conditions for data generation and data access. Therefore, society's regulatory and ethical management of privacy issues, data security and title to data will be very important in the context of AI development.

Internationally strong environments for research, education, and innovation will therefore be important for Sweden's innovative strength and international attractiveness for leading AI competence and corporate AI development. Cooperation to achieve a critical mass in such environments will be crucial. Cooperation will also be important to link regulatory development and labour market development with innovation processes for AI applications. It is difficult to identify any area that is as dependent on cooperation between different stakeholders and across sectoral borders as AI. A positive AI development in Sweden thus demands efficient cooperation among many different actors and functions in society.

Sweden's AI capability

There are many different factors that are significant in relation to Sweden's ability to develop and use AI. Different factors also play roles of different magnitude within different sectors and different branches of industry. Table 1 is an overall analysis of Sweden's Strengths, Weaknesses, Opportunities and Threats (SWOT).

Table 1 Overall SWOT-analysis of Sweden's AI capability

STRENGTHS	WEAKNESSES
Technology-friendly population High level of technological skills Qualified researchers and engineers Good domain competence regarding processes Good data access Excellent IT networks Infrastructure for data traffic Many digitalised processes High level of automation Major international technology-driving companies Efficient public operations Good innovation ability Ability to solve complex problems Long experience in security-critical solutions Culture of cooperation Developed innovation system Efficient value chains and ecosystems Ability to build consortia	AI competence hard to recruit Lack of competence for digital business models Universities and university colleges have weak drivers for flexible professional training Many SME have limited resources and competence Slimmed-down organisations hamper competence development IT infrastructure not always accessible and stable IT maturity varies within value chains Lack of coordinated security initiatives Automation systems are often based on old technology Unclear ownership and data rules Uncertainty concerning future data access regulation Lack of AI standards Difficult to cross-check data Failures in data quality and structure Fragmented municipal sector Poor cooperation among county councils Lack of state control Few and unfocused R&D initiatives in AI
OPPORTUNITIES	**THREATS**
Increased innovation pace with AI Use access to large volumes of data Use our quality register for AI analysis New technical opportunities via system connections New functions and improved quality of products and services Increased efficiency in production and processes System potential in new value chain connections New work methods and new organisation methods New interesting and attractive jobs Improved work environment Sweden could be a test bed for AI development Sweden has a high attractiveness level internationally Develop cooperation around AI-development Develop cooperation around AI-implementation Use the cooperation capacity of the research institutes Train existing AI competence Develop regulations promoting data access Develop policies promoting system development	Regulatory development does not interact with the AI requirements Privacy issues are dealt with differently in Sweden Intellectual property rights could be threatened Poor AI competence at management level Poor AI competence weakens development momentum Regional differences in AI competence AI competence leaving Sweden Fears and unrealistic expectations Long implementation timelines inhibit investment Lack of AI investments inhibits competitiveness The rest of the world invests more and faster than Sweden Sweden will not become a test bed for new AI solutions Large dependence on systems suppliers Increasing vulnerability in systems Poor IT security increases social risks Simple jobs are disappearing and unemployment is rising Trust and confidence in the future is inhibited by the development of AI Distrust as AI failed in the 80s and 90s

Swedish society is characterized by a high degree of digitalisation compared to most other countries. IT infrastructure is well developed and has a high capacity in large parts of the country. Digitisation in working life has come a long way in many sectors, while a majority of the population is connected to the internet and has a high level of IT experiences. This provides an important basis for Sweden's AI capability and for a strong development of AI competence and AI applications.

AI competence will be of crucial significance in order to realize Sweden's AI capability. While computer science skills are important, access to software engineers will be crucial, since successful AI development often requires extensive software development. Access to AI competence will be a significant challenge, since there is a global lack of such expertise. AI applications are expected to increase drastically in the next few decades. Global demand for AI competence will therefore increase sharply, which means that an already significant lack of AI competence is expected to grow further.

How digitisation competence in general and AI competence in particular should be compared between countries is not obvious. In relation to technology and IT competence, Sweden has a relatively good starting position, both for newly graduated and for IT-educated in the labour market. This should mean that there are good opportunities for strengthening AI competence in Sweden through competence development of already well-educated technological competence. However, digital transformation and AI development will change the requirements and conditions for both research and competence development. Technology development increasingly takes place through interdisciplinary science, i.e. through new connections between different areas of technology and competence. In this context, established processes and institutional solutions in research and education are becoming less suitable for this development.

The ability of universities and university colleges in Sweden to adapt the focus of their research and education to the rapid and multidisciplinary changes that AI generates is poor. There are many indications that further education must account for most of the education system's adaptation in catering to the AI requirements of business and society. However, universities and university colleges find it difficult to develop and operate brief independent courses in close interaction with and directly adapted to working life, i.e. for life-long learning in general and AI in particular. The forms of cooperation between universities and university colleges with business and society need to be developed, especially to achieve a faster and improved adaptation of the educational offer to existing needs.

The digitisation of the educational institutions needs to be developed, both at a basic level and in universities and university colleges. This applies both to the use of digital technology and AI in courses as well as the utilization of digitalisation opportunities for management and administration. It is likely that successful education and research institutions will, in the future, have high digitisation rates in both core and support activities. AI will be significant in this context.

Bibliometric data indicate that Swedish AI research has, overall, limited international competitiveness. It is a generally accepted view that development within AI, both in research and commercially, is dominated by the USA, with China being the main contender, while Europe has tended to lose ground, relatively speaking. An analysis of the contributions to the 19 highest ranked AI conferences since 2010 strongly supports this view. American researchers participate in nearly half of all conference contributions. Researchers from China have the strongest increase and their share is nearly one fifth. The presence of Swedish researchers at the same conferences is very modest, with only 0.6 percent of all contributions in 2014-2017 and a downward trend compared to previous years. The participation per capita at the conferences is many times greater for Singapore, Switzerland, and Israel than for Sweden and significantly larger also for Australia, Canada, Finland, and Denmark.

The situation changes considerably if these comparisons are widened to include all the articles published in journals classified as belonging to AI as a subdivision of computer science - mainly by strengthening China's position. The average citation rate for articles with authors from China was indeed just a third of the citation rate for articles with authors from the United States a few years ago. Nevertheless, there were almost as many articles with Chinese writers among the 10 percent most cited as with American writers. For Sweden the wider picture is somewhat more favourable than that for highly ranked conferences. This applies in particular to the average citation rate that gives a positive picture of the quality level of AI research in Sweden. However, when comparing the number of publications among the 10 percent most cited, the distance to Singapore and Switzerland is great.

The great attention that has surrounded artificial intelligence globally in recent years has its background in an increased use of machine learning in various applications. So-called deep learning has yielded particularly striking results. The increased use of AI is reflected only to a small extent in conferences and journals with AI specialists as primary target audience. An analysis based on key words with a close connection to deep learning gives the impression that Sweden, from a relatively favourable starting point at the turn of the century when technology was still in its infancy, failed to join in the growing experimentation with deep learning that has taken place in some other countries and successively lost ground. Fortunately, there is evidence that a positive shift in this trend occurred in 2017.

Patent data is another indicator of Swedish development capability. Since around 2010, AI is a rapidly growing patent area, and today it is one of the largest patent areas globally. AI-related patenting is strongly dominated by major IT companies such as Samsung, Microsoft, IBM and Google, but as the use of AI is widened to new areas, the group of companies applying for AI-related patents is also widening.

Based on data on patent applications to the patent authorities in the USA, Europe and Japan, Sweden's development capability in AI appears neither particularly weak, nor particularly strong. Sweden is ranked 13th internationally in AI patenting and just under 1 percent of all the world's AI patents in recent years have involved inventors from Sweden. In a closer comparison with five other smaller countries, Sweden's AI patenting per capita is a little ahead of Canada, equal with Switzerland and Denmark, a little behind Finland and significantly behind Israel.

In Sweden, as in the other five countries above, the number of AI patented companies has increased significantly in recent years. However, Ericsson strongly dominates Swedish AI patenting with computer networks and the operation of mobile communications networks as special strengths, which also resulted in these areas being the strengths of Sweden, a position that has also been strengthened. Smart transports and vehicles is one of the fastest growing sub-areas for patenting within AI and of particular importance for Sweden with several major vehicle companies in the country. However, in this area of patenting Sweden has been unable to keep up with the development in the rest of the world and seen its share of patenting halved.

Artificial intelligence is still a relatively unestablished research area in the Swedish research system. Within undeveloped research areas, there is often a need to invest with special initiatives in building research expertise and research environments before a strong demand for such skills emerges from business or society. In Sweden, it is difficult for academic institutions to develop internationally strong research environments within AI through their own strategic initiatives.

Concerted effort to boost Sweden's AI development

A successful realisation of Sweden's AI potential requires a targeted and powerful national strategy for AI development and AI utilisation. Several other countries currently have national AI strategies.

> *The goal of a Swedish AI strategy should be to turn Sweden into a leading country for the development and application of AI for sustainable growth and social development.*

Since the correlations and dependencies are strong between different factors that are significant for AI development, it is important that a national policy stimulates cooperation between all significant stakeholders, so that a mutually reinforcing development momentum is generated.

> *Sweden's greatest opportunities for competitiveness within AI lies within a mutual interaction between innovative AI application in business and innovative organization of society.*

This requires a well-developed strategic cooperation among participants in business, the public sector, research and education. Accordingly, not only strategy as such is important, but through the strategy process itself, the necessary knowledge, competencies, leadership and collaborative relationships can be strengthened among the various actors involved in the process.

> *A national strategy based on a broad and inclusive process should be designed and include most areas of policy and public authorities.*

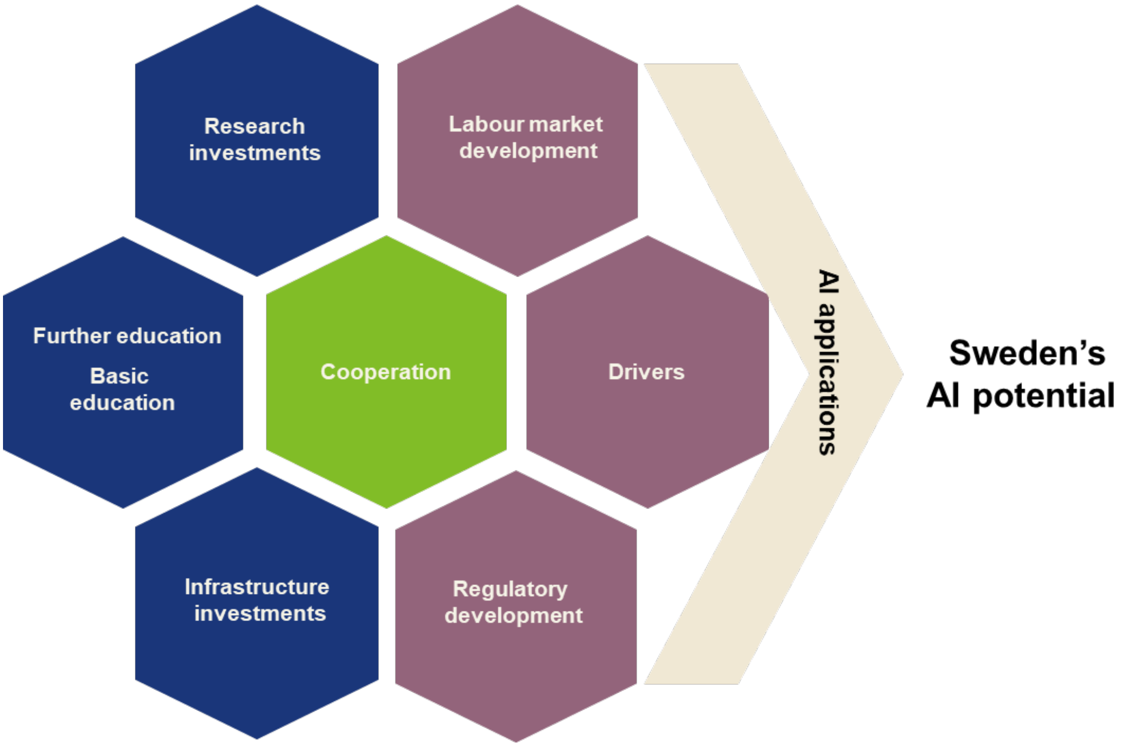
Strategic areas

In a national concerted effort to achieve Sweden's AI potential, it is important to purposefully prioritize the development of each of the following areas so that a mutually reinforcing interaction between them is generated:

- **Drivers** for companies and public operations to streamline and develop new value-creating solutions based on artificial intelligence.
- **Cooperation** in research, development, data access and competence development for AI innovation, linking requirements within different value chains and sectors for a combined development momentum.
- **Further education** and **basic education** for continuous supply of AI skills in the labour force, which requires a renewal of the education system.
- **Research investments** in AI for excellence and internationally leading research and innovation environments for advanced AI research and R & D collaboration.

- **Regulatory development** for data access, data integration and data ownership promoting AI innovation and safeguarding integrity, ethics and data security.
- **Infrastructure development** promoting research, development and testing of AI applications and AI security, integrity and rules in connections between various data, value chains and societal areas.
- **Labour market development** promoting the labour force mobility required by AI, which places significant demands on transition leadership in companies, the public sector and politics.

Figure 2. Policy areas and mutual dependencies in a concerted effort for Sweden's AI-potential



Prioritised initiatives

In the context of a national concerted effort, some government initiatives are particularly important for positive development. These should be initiated before a national strategy is available, while they should also be central parts in such a strategy.

Further education in AI, which is well adapted to the labour market, should be stimulated with special initiatives for a rapid development of such education and processes for these.

Without special policy initiatives, this development will not take place at the pace required to realise Sweden's AI potential. The development of further education in AI and dimensioning of these courses needs to take place in a close dialogue between academic institutions, companies and the public sector.

Internationally leading collaborative environments with a critical mass in research, education and innovation, with advanced data and technology infrastructures, need to be developed.

Without special policy initiatives for this purpose, the necessary concerted effort will not take place. This in turn inhibits the innovation processes for AI-based value creation. As of 2012, the Swedish Foundation for Strategic Research (*Stiftelsen för Strategisk Forskning*) (SFF) has made major investments in cutting edge research within AI. The Swedish Knowledge Foundation (*Stiftelsen för kunskaps- och kompetensutveckling*) (KK Foundation) has also made several significant investments in research and education within AI at Swedish academic institutions and new universities. Wallenberg AI, Autonomous Systems and Software Program (WASP), started in 2015, is a concerted effort for research and education. From and including 2017 a strongly reinforced 10-year investment in AI in the context of this venture will be made. In the cooperative programs financed by Vinnova in collaboration with the Swedish Energy Agency and the Swedish Research Council Formas, there has been a drastic increase of AI projects in recent years. AI has also increased drastically in the innovation projects for small and medium size enterprises (SME) financed by Vinnova. This development is significant because a major part of the challenges in both research and education concern the use of AI methods in real applications.

A state-wide concerted effort for internationally leading collaboration environments for research, education and innovation should be designed to complement the initiatives of WASP, SSF and the KK Foundation. At the same time, it should be designed to complement and efficiently interact with investments in the major government initiatives in 17 Strategic Innovation Programmes (SIP), the Programme for Vehicle-Strategic Research and Innovation (FFI) and the Programme for Challenge-driven Innovation (UDI). In addition, it should relate to the EU investments in AI which are currently planned and which will probably form an important part of the next framework programme for research and innovation in the EU.

Other important initiatives

Apart from the above initiatives, which should be initiated with a high priority, a number of other initiatives should be central parts of a national concerted effort. These will require targeted development efforts, linking different actors' development processes with regulatory development and with the development of infrastructures and test environments.

Access to data for both education and research as well as application-focused development projects in AI should be an important priority in a national concerted effort.

Society's regulatory and ethical management of privacy issues, data security and data ownership will be very important in the context of AI development. To enable several parties to access the same data, in many cases special agreements governing the use of such data will be required.

Test beds for AI development based on access to important data should be an important focus for a critical mass and efficient cooperation in research and innovation environments.

The role of public organizations in making data available is important for AI applications in the public sector, business and societal development at large. Companies should also be encouraged to open their data to promote cooperation and attractive research and innovation environments in Sweden.

The development of basic education and research-level education in AI for width, excellence and cooperation with industry and the public sector should be prioritized.

In addition to further education, the following parts should be included in the development of higher education for stronger AI competence:

- Investment in industrial doctoral students and industrial postdoctoral students for testing AI solutions.
- Appointment of new combined teaching and research positions:
  - with recruitment in Sweden and internationally,
  - of which part with shared positions between institutions, academic institutions and companies.
- Commitment to education by companies, institutions and the public sector, with practical AI experience.
- The educational system should provide basic computer science for students in many areas.

Drivers and conditions for academic institutions to digitize courses, research training and support operations need to be reinforced.

Increased digitisation of academic institutions is an important condition for efficient education and research within AI. This is also needed to achieve the flexibility and ability to adapt in education that will be required of academic institutions in the future. Drivers and conditions can be reinforced in a number of ways. This can be achieved with instructions, regulation letters and allocation of funds or through earmarked appropriations linked to specific assignments.

The Governance and Resource Investigation's Committee (Styr- och resursutredningen, Strut) on how governance and resources for universities should be developed will be important for the development of drivers and conditions for academic institutions. The final report of the Investigation will be presented in December 2018.

Drivers and conditions for individuals to take more responsibility for their own competence development needs to be strengthened to encourage active life-long learning and job mobility.

Such drivers and conditions will be important to stimulate and facilitate individuals' capacity for adaptation and lifelong learning, which will become increasingly important for the future's skills supply. This, in turn, will be of major significance for achieving a labour market dynamics and human trust in the rapid technological renewal and social transformation. In this context, network-based courses, such as MOOCs, which are not time- or location-dependent, should be covered by the study funding system. In addition, tax breaks, incentive programs or subsidies should be considered to create opportunities for individuals to take greater responsibility for their own skills development.

Government control and drivers for an innovative public administration will be very important for a value creating AI development that strikes a balance between business innovation and privacy, ethics and digital security.

For many public operations, the drivers to develop and apply AI are weak. These drivers originate in the governance of state and municipal operations. How such governance stimulates and requires innovation management and adaptation ability will be of great importance for AI development in Sweden. Trust-based governance, investigated by *Tillitsdelegationen* (the Swedish Trust Delegation) is an important part of such developed governance.

Developed state governance will be crucial for the utilisation of AI 's transformative potential in the development of systems solutions to address important social challenges and to achieve the targets in the 2030 Agenda for Sustainable Development.

The drivers of the public sector to develop new system solutions that address social challenges, where AI can play a central role, are even weaker than for an AI-based development in the context of individual public operations. Powerful development that addresses social challenges requires developed administrative governance, creating clear drivers for an innovative and collaborative public administration. Such a developed administrative governance needs to generate innovative drivers that cross policy areas, government boundaries, administrative boundaries and geographical boundaries.

Examples of AI projects

AI improves the life of people in need of care

With a bracelet that alerts if something goes wrong, older people can maintain their independence while carers and relatives do not have to worry.

With a bracelet carried by recipients of home care services, it is possible to see where the bearer is located and how they move. If anything unforeseen happens, such as a fall, the system sends an alarm. The bracelet is combined with a cloud-based AI engine that facilitates smart movement analyses. Other functions include monitoring of whether the bearer has woken up and gotten out of bed, whether the person is eating or taking their medicine.

Aifloo SmartBand – "a self-taught e-health system for home care" was developed by Aifloo in cooperation with Skellefteå Municipality.

Remote controlled vehicles in mines result is safer mining operations

Remote controlled heavy goods vehicles will make mining both safer and more efficient. The project ”Wireless and Remote Operation of Mobile Machines, WROOM” contributes to the vision of the independent mine.

The purpose of the WROOM project is to develop concept solutions for remote controlled loading in big wheeled loaders and remote monitoring of such machines. Machine learning is used to develop autonomous functions, such as automatic loading and proactive maintenance.

There are several advantages with remote controlled vehicles below ground. With the help of remote controlled wheeled loaders, loading can start directly after blasting. As a result, there is no need to wait for the mining sites to be ventilated so that staff can work below ground. This results in an improved work environment for employees.

Luleå University of Technology coordinates the project, with the participation of among others Boliden, Volvo CE, ABB, Oryx and RISE SICS Västerås.

Improve healthcare with AI and image analysis

AIDA is a project promoting research and innovation within artificial intelligence and medical image analysis, with the goal of improving healthcare.

There are great opportunities to improve image examinations using AI. For example, analysis of large data volumes can create a higher accuracy in diagnostics.

We know through research that current AI technology is very powerful, but because it is not adapted to healthcare, it has not yet achieved any notable benefit in this field. In AIDA, academics, healthcare and industry meet to create AI innovations. This cooperation results in decision support that creates patient benefit in healthcare. Cooperation between humans and machines is in focus. By using these respective strengths optimally, healthcare will significantly improve.

The project is led by Linköping University and today includes seven hospitals, five academic institutions, one major company and four small companies.

Deep learning improves the process industry

The Swedish process industry produces huge amounts of data and there is an untapped potential in these data, which can be utilized with new tools. The project "Deep Process Learning" uses data from a board machine at BillerudKorsnäs in Gävle to investigate how analysis of large volumes of data with the help of deep learning algorithms can improve quality and efficiency.

By analyzing large volumes of data, so-called deep learning, there is potential for increasing the competitiveness of the Swedish process industry through increased productivity, quality and flexibility.

Deep learning has the human brain as a model, and with the aid of algorithms, a system builds knowledge gradually, just as humans do. When the system has built knowledge, it can perceive patterns and better control our processes. In the longer term, the project hopes to inspire other industries to use their large volumes of data for development and process optimization. In 2018, the parties in the project will start a new initiative to develop web-based courses to spread knowledge on how these technologies can be used.

The project is a cooperation between BillerudKorsnäs, PulpEye, Peltarion, FindIT and RISE SICS Västerås, who leads the project.

AI improves breast cancer screening

Today's breast cancer screening has reduced mortality, yet about 1,500 women die annually in Sweden of breast cancer. AI could help reduce the number of deaths due to breast cancer by detecting tumors earlier.

By training deep learning with over one million mammography images combined with clinical data from the Breast Cancer Registry, decision support is produced in the "AI for Breast Cancer Screening" project.

The goal of the decision support is to identify easily assessed mammographs and to identify the women who benefit most from a supplementary study. The digital decision support can easily be distributed across the country and reduce regional differences in the screening system. The hope is that this will provide socioeconomic value with safer diagnosis and improve the efficiency of the mammography process in Swedish healthcare.

Karolinska University Hospital coordinates the project AI for Breast Cancer Screening with the participation of among others Regionalt Cancercentrum Stockholm-Gotland and Sectra AB.

Fredrik Strand Karolinska University Hospital, Photographer: Robert Sundberg

The projects were financed by Vinnova.

1 Introduction

Purpose

The purpose of the analysis of artificial intelligence in Swedish business and society is to answer the main questions posed by the government commission to Vinnova. It involves mapping and analysing Sweden's:

- Potential with regard to using AI within business and the public sector.
- Development so far in terms of utilising AI within business and the public sector.
- Skills provision regarding AI competence within business and the public sector.

An important aspect of the analysis is to identify and understand the conditions (obstacles and opportunities) and the driving forces (incentives and interaction), as well as their importance for Sweden's capacity to exploit the potential of AI for value creation within business and the public sector.

Method

The limited time for the commission has made it necessary to base the empirical foundation on existing studies and data. The analysis is based on:

- A review of existing studies
- Statistics and indicators concerning AI developments and AI competence
- Assessments by different experts with an overview of AI development
- An interpretation seminar with leading actors and experts.

Outline

Chapter 2 discusses what is meant by artificial intelligence. Chapter 3 presents growth scenarios linked to AI applications. Chapter 4 presents assessments of the AI potential within the business sector. Chapter 5 discusses the AI potential within the public sector. Chapter 6 discusses risks associated with AI with regard to individuals, organisations and society. Chapter 7 analyses patent data within the field of AI. Chapter 8 analyses bibliometric data linked to AI. Chapter 9 discusses Sweden's AI competence. Chapter 10 discusses the potential for higher education institutions to strengthen education and research within AI. Chapter 11 presents data relating to R&D initiatives linked to AI. Chapter 12 discusses the efforts of other countries to promote AI development.

2 Artificial Intelligence

2.1 What is artificial intelligence?

Artificial intelligence has no clear definition or generally accepted demarcation; there are many definitions. In essence, artificial intelligence is digital technologies and tools that enable automated information processing and decision-making that previously required human mental activity. In this report we will use the following definition of artificial intelligence:

> *The ability of a machine to simulate intelligent human behaviour. That is, the ability of machines that enables them to function meaningfully in relation to the specific tasks and situations they are intended to perform and act within[1] Artificial intelligence is also the field of science and technology that aims to study, understand and develop machines with intelligent behaviour.[2]*

Research within areas that today fall under the collective term artificial intelligence (AI) has been conducted since the 1950s and the term artificial intelligence was coined in 1956 by John McCarthy. The principles of artificial intelligence are considered to have been formed by John McCarthy, Alan Newell, Arthur Samuel, Herbert Simon and Marvin Minsky within the context of the Dartmouth Summer Research Project, 1956. Although AI research has evolved steadily since the 1950s, many hopes have proven to be overoptimistic, leading to reduced funding for AI research in the later decades of the 20th century.[3]

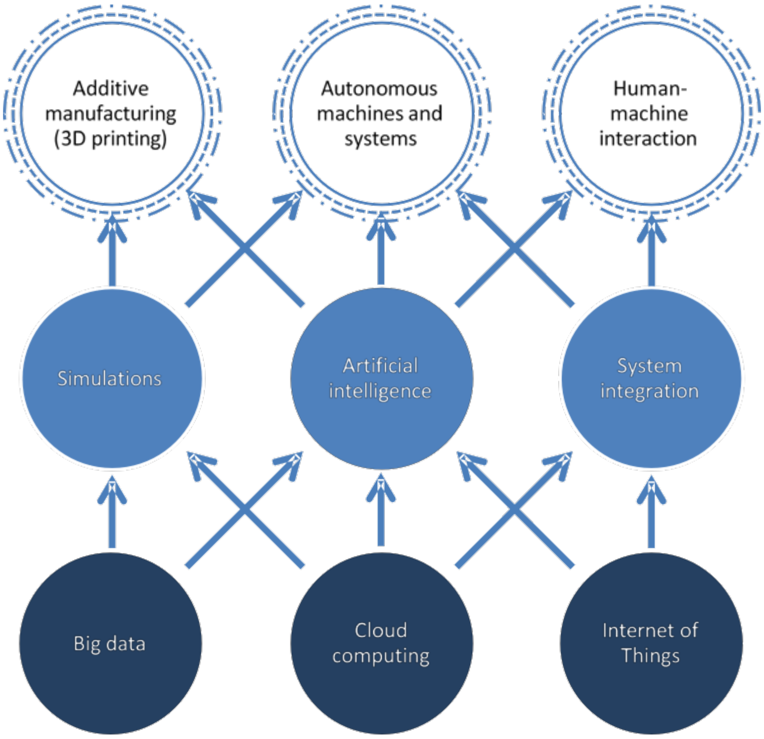
In principle, artificial intelligence deals with cognitive functions while robotics primarily involves motor functions. In practice, however, these delimitations are not sharply defined, as robots require sensory ability and the capacity to analyse relevant environments. Nevertheless, the difference between AI's essentially intangible manifestations and robots' fundamentally physical manifestations is significant.

> *Developing complex motor functions is typically more difficult, expensive and time-consuming than developing complex cognitive functions. Popular examples of the convergence between AI and robotics are self-driving cars and humanoid robots. It is important to highlight that autonomous machines combining advanced AI and robotics techniques still struggle to reproduce many basic non-cognitive motor functions.[4]*

Figure 3 comprehensively illustrates different groups of technologies, which in vital respects are both mutually interdependent for their development, and together generate the conditions for a radical transformation of industrial development based on artificial intelligence.

[1] This definition is similar to and in line with that used by the Ministry of Economic Affairs and Employment of Finland in the report: Finland's Age of Artificial Intelligence, Turning Finland into a leading country in the application of artificial intelligence, Objective and recommendations for measures, Helsinki, 2017, p.15.
2 McCarthy, the Dartmouth Summer Research Project, 1956
3 OECD, Digital Economy Outlook, 2017, p.296
4 OECD, 2017, pp.296–297

Figure 3. Comprehensive links between transformative key technologies



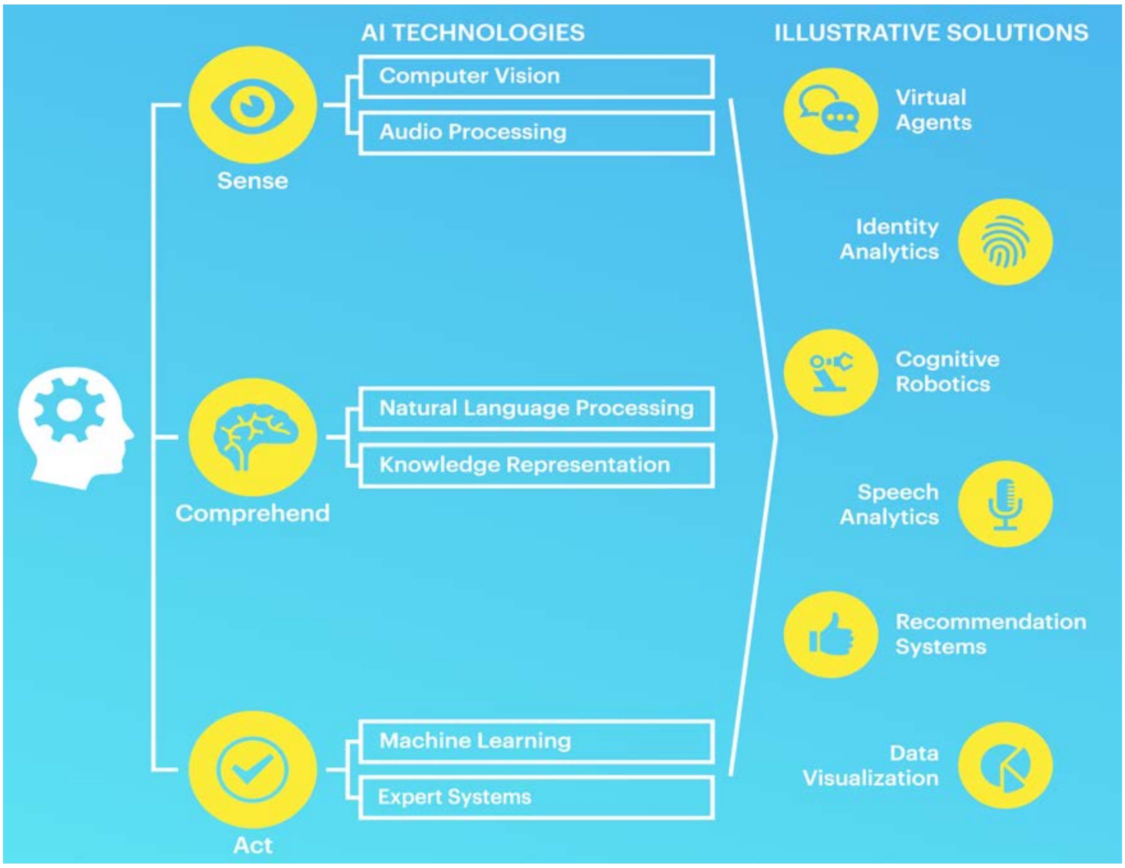
Source: OECD, The Next Production Revolution, 2017, p.78. Modified by Vinnova.
Comment: In the upper right corner, Vinnova has changed Human-machine integration to Human-machine interaction.

> *"Two major trends make digital technologies transformational for industrial production: the reduction of the cost of these technologies, enabling their wider diffusion, including to SMEs; and, most importantly, the combination of digital technologies, enabling new types of applications. The figure depicts the key ICTs which are enabling the digital transformation of industrial production. The technologies at the bottom of the figure enable those at the top, as indicated by the arrows. The technologies at the top of the figure (in white), which include additive manufacturing (i.e. 3D printing), autonomous machines and systems, and human-machine integration, are the applications through which the main productivity effects in industry are likely to unfold. In combination, these technologies could one day lead to fully automated production processes, from design to delivery."*[5]

In order to understand the potential of AI for value creation and to exploit this potential, it is necessary to understand potential applications within different industries. It is in the areas of application that the value-creating potential lies. Potential applications also generate the basic business and operational incentives for companies and public entities that determine the willingness and prerequisites for investment in AI development and in AI investments. Figure 4 illustrates basic features of emerging AI technologies and basic functional areas of applications.

[5] OECD, The Next Production Revolution, 2017, p.77

Figure 4. Features of emerging AI technologies and functional applications



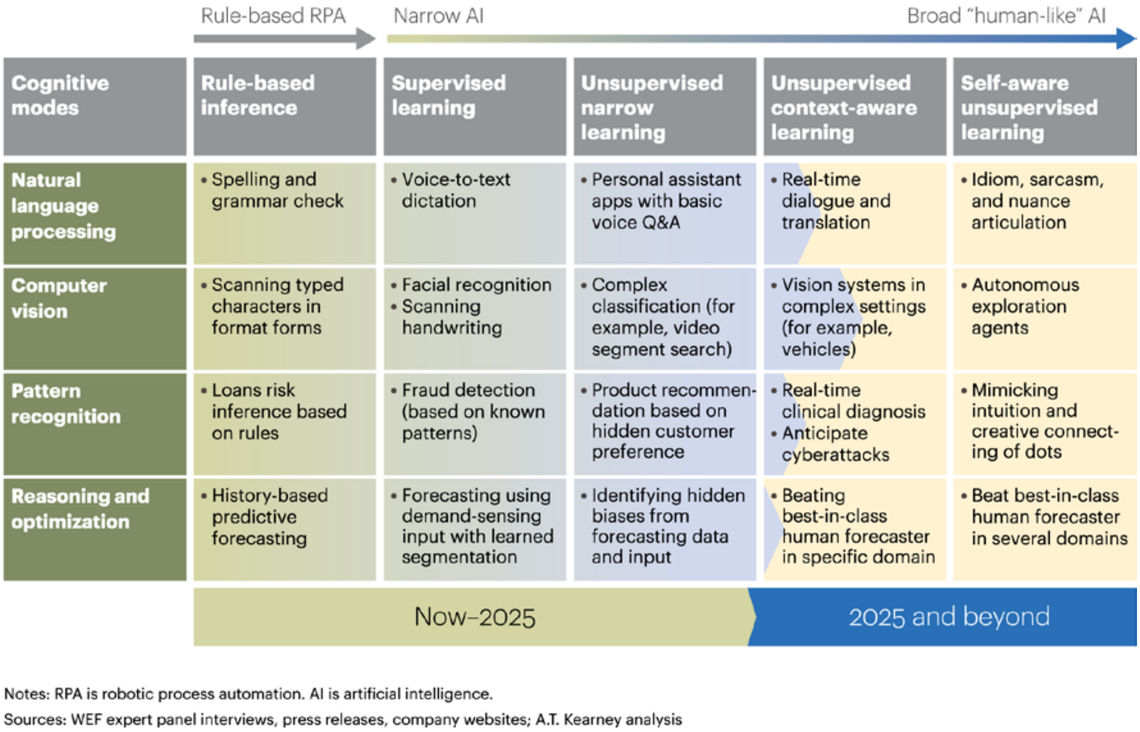
Source: Purdy, M. and Daugherty, P., Why Artificial Intelligence is the Future of Growth, Accenture, 2016, p.11

Although applications of AI have been of great importance within internet platforms, information retrieval, image recognition and automatic translation, the practical impact of AI has been limited within large parts of the business sector and public sector. However, due to the rapidly expanding access to data in electronic form and increased computing power, the AI methods developed in the past few years have begun to gain practical importance and have been a decisive factor in the rapid development of recent years.

In a report to the Ministry of Finance in 2017, the assessment suggests that AI in the coming years will be used to enhance humankind rather than replace it. In this way, the quality and efficiency of different tasks will increase and enable people's work to become less routine, thus creating space for more creative work tasks for humans.[6] This assessment is shared by most experts whose opinion is therefore that the development of AI over the next few decades will generate technology that supports and enhances human skills and abilities. The time horizons for this wave in the application of *narrow AI* are rarely discussed explicitly, but several analyses indicate that applications in the form of *broad AI*, i.e. with more human-like features, could gain momentum from about 2030. An attempt to illustrate these developmental perspectives is provided in Figure 5.

[6] Lindsjö, G., En AI-redo statsförvaltning [An AI-ready public administration], Stockholm, March 2017, p.9

Figure 5. Development perspective for applications of AI



Rule-based RPA → Narrow AI → Broad "human-like" AI

Cognitive modes	Rule-based inference	Supervised learning	Unsupervised narrow learning	Unsupervised context-aware learning	Self-aware unsupervised learning
Natural language processing	• Spelling and grammar check	• Voice-to-text dictation	• Personal assistant apps with basic voice Q&A	• Real-time dialogue and translation	• Idiom, sarcasm, and nuance articulation
Computer vision	• Scanning typed characters in format forms	• Facial recognition • Scanning handwriting	• Complex classification (for example, video segment search)	• Vision systems in complex settings (for example, vehicles)	• Autonomous exploration agents
Pattern recognition	• Loans risk inference based on rules	• Fraud detection (based on known patterns)	• Product recommendation based on hidden customer preference	• Real-time clinical diagnosis • Anticipate cyberattacks	• Mimicking intuition and creative connecting of dots
Reasoning and optimization	• History-based predictive forecasting	• Forecasting using demand-sensing input with learned segmentation	• Identifying hidden biases from forecasting data and input	• Beating best-in-class human forecaster in specific domain	• Beat best-in-class human forecaster in several domains

Now–2025 | 2025 and beyond

Notes: RPA is robotic process automation. AI is artificial intelligence.
Sources: WEF expert panel interviews, press releases, company websites; A.T. Kearney analysis

Source: A.T. Kearney Analysts, Evans, H., Hu, M., Kuchembuck, R., Gervet, E., Will you embrace AI fast enough?, A.T. Kearney, 2017, p.3

The time perspective in Vinnova's analysis extends to around 2030. It also entails focusing on the development and application of so-called *narrow AI* and its value-creating potential, through increasing quality and efficiency within business and public sector activities.

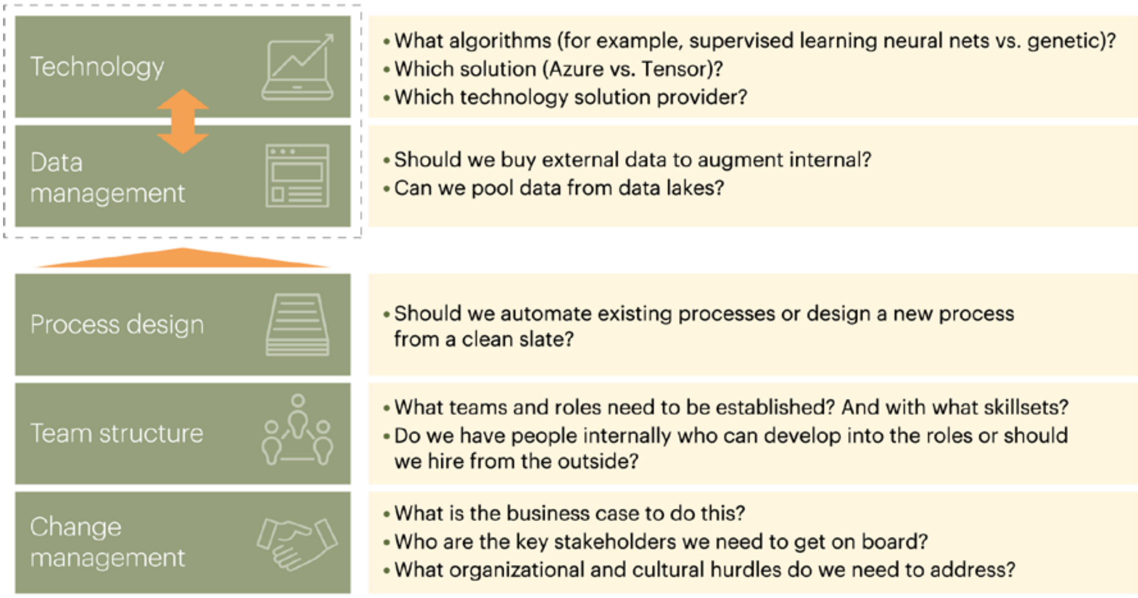
2.2 Driving forces and conditions for artificial intelligence

For different actors, companies and public entities, it is important to understand the interplay in AI development and AI applications between business opportunities and value creation on the one hand, and technological and organisational opportunities on the other. Such understanding is also important to develop the conditions and driving forces for AI using various policy measures. An illustration of this interplay is given in Figure 6.

The basic conditions for the application of AI are access to data in digital and otherwise appropriate form. In pace with increased digitalisation in society, an increasing amount of data is available in digital form. This not only applies to data created directly by human hand (economic and administrative data and texts, images and audio produced for a purpose). It also applies to data that is automatically collected through different types of sensors regarding the status of, for example, machines, buildings and physical environments, as well as data collected automatically from sensors on and inside humans. This includes data concerning geography (maps), weather, companies, real estate, healthcare, public statistics etc.

Unlike data collected through leading digital platform companies, the digital data produced in society is usually not standardised in such a way that it can be easily combined and processed together. Instead, extensive work is often needed to render data useful. Such work needs to be done both in the short term, to use the available data, and more strategically, in order for data to be uniformly produced in terms of both content and format, which enables it to contribute to value creation with the help of automated processing, i.e. using AI. To enable and thereby create driving forces for AI development and AI applications, it will be important to standardise semantics, formats and annotations based on common ontologies that make the information processable for computers.

Figure 6. Interplay between strategies for business models, organisation and technology development linked to AI applications in companies and public entities



Note: AI is artificial intelligence.
Source: A.T. Kearney analysis

Source: A.T. Kearney Analysts, Evans, H., Hu, M., Kuchembuck, R., Gervet, E., Will you embrace AI fast enough?, A.T. Kearney, 2017, p.3

Competence within AI and data science are necessary conditions for truly useful AI-based solutions to be developed. However, the introduction of AI-based solutions in those operations that are not primarily digital in nature requires major changes in the organising and running of operations. The competence required to adequately and resource-efficiently implement such adjustments is based on combining knowledge within AI and data science with operation-specific knowledge and skills in organisational development. It is very important that this type of hybrid competence is developed within different fields of activity in parallel with the strengthening of specialist competence within AI and data science.

3 Growth scenarios

This chapter discusses scenarios regarding the potential for value creation and efficiency in business and public sector activities. These also compare Sweden with a number of other countries in terms of potential.

Investments in AI applications are essentially driven by expectations of increased value creation through:

- Increased competitiveness in established business models and business activities or,
- Development of completely new business and operational models that challenge the established system.

The use of AI in the context of established business models aims at improvements in the goods and services produced or for increased efficiency in the development, production or trading of these goods and services. In such development, the reality often entails various forms of automation of functions in these operations. AI to an increasing extent also enables the development of brand new, or radically modified, business models and operations to address different needs. This development enables new solutions for different needs and also challenges established value chains, while at the same time facilitating new solutions to societal challenges.

There is a strong indication that the rapid digitalisation in general and the increasing use of AI in particular will transform business and society in many different respects and within most areas. Developments and transformations within different areas are likely to fundamentally impact the opportunities and challenges of AI development and value creation through AI within other areas. From this perspective, assessments of the AI potential for business and society are genuinely difficult. Even more difficult is quantifying AI potential in the form of value creation in economic terms, as well as in the context of addressing societal challenges linked to environmental and social challenges.

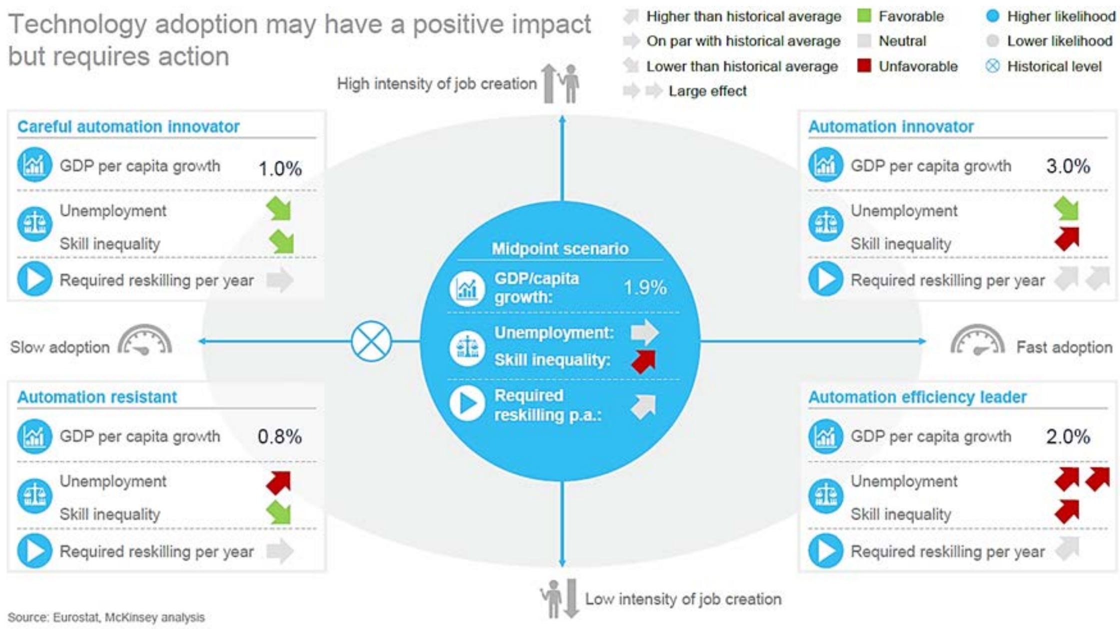
In order to exploit the potential of AI and broach the challenges that AI development and its transformative effects can generate on value chains and operations, as well as on social structures and institutions, it is important to understand the development force of AI. This entails an understanding of the driving forces, connections and interplay between different actors, value chains, technologies and social structures that influence the direction, power and conditions of development, application and effects with regard to AI.

3.1 Growth potential in AI applications

As noted above, quantitative assessments of the potential for value creation through applications of AI are genuinely difficult. However, based on certain assumptions about economic and social development, a number of scenarios regarding economic growth potential have been created. These growth scenarios are presented below.

In a 2017 analysis of the economic potential of digitalisation and AI in nine countries, "digital front-runners" (Belgium, Estonia, Finland, Ireland, Luxembourg, the Netherlands, Norway and Sweden), McKinsey & Company has created scenarios of economic growth potential via automation. The time horizon for these scenarios is 2030. Figure 7 describes the overall growth scenarios and labour market scenarios in this analysis.

Figure 7. Overall growth scenarios 2017–2030 for nine countries with different degrees of automation



Source: McKinsey&Company, Digitally-enabled automation and artificial intelligence: Shaping the future of work in Europe's digital front-runners, October 2017, p.36
Comment: The nine countries the growth scenarios concern are: Belgium, Estonia, Finland, Ireland, Luxembourg, the Netherlands, Norway and Sweden.

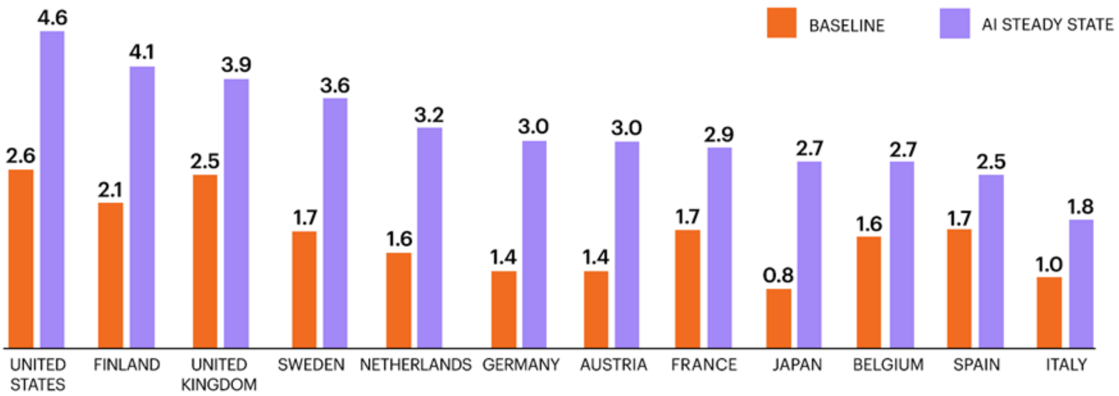
In 2016, Accenture, in conjunction with Frontier Economics, produced an analysis of the growth potential of AI. The basic perspective of these scenarios is that AI represents a new production factor that will transform the foundation for economic growth on a global scale.

> *"With the recent convergence of a transformative set of technologies, economies are entering a new era in which artificial intelligence (AI) has the potential to overcome the physical limitations of capital and labor and open up new sources of value and growth."*[7]

Accenture's analysis comprises 12 countries, including Sweden, and the time horizon is 2016–2035. The analysis concludes that the economic growth potential for Sweden and most other countries in the study is twice as great if AI is applied, in line with the expected general AI development, than without AI applications, Figure 8.

[7] Purdy, M. and Daugherty, P., Why Artificial Intelligence is the Future of Growth, Accenture, 2016, p.3

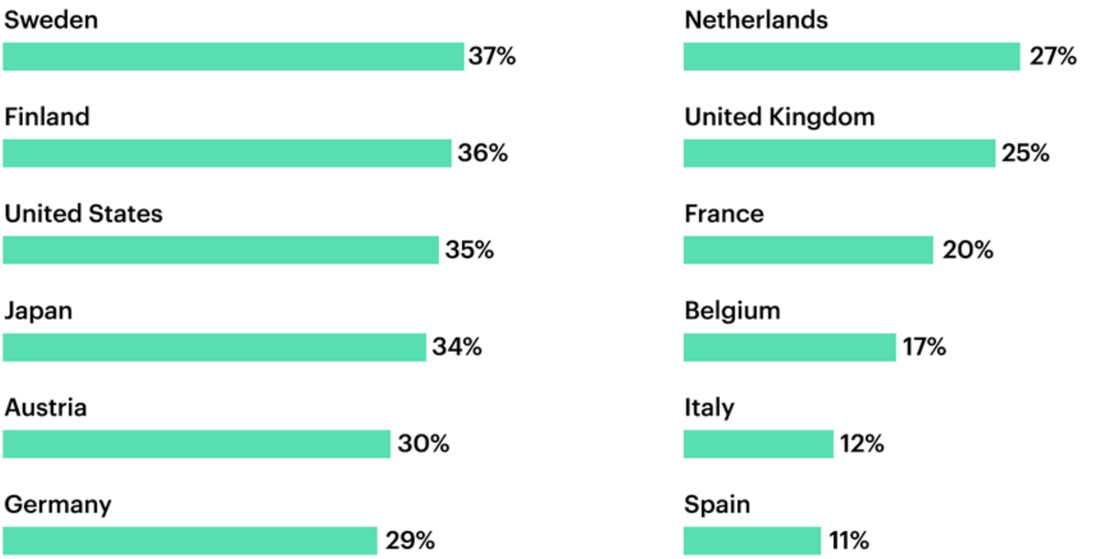
Figure 8. Scenarios for real gross value added 2016–2035 in different countries with and without the utilisation of AI



Source: Accenture and Frontier Economics, Purdy, M. and Daugherty, P., Why Artificial Intelligence is the Future of Growth, Accenture, 2016, p.16

In such a development, the potential for labour productivity is estimated to be almost 40 per cent higher in 2035 if AI is applied than without AI applications, Figure 9.

Figure 9. Scenarios for labour productivity development 2016-2035 in different countries with and without the utilisation of AI

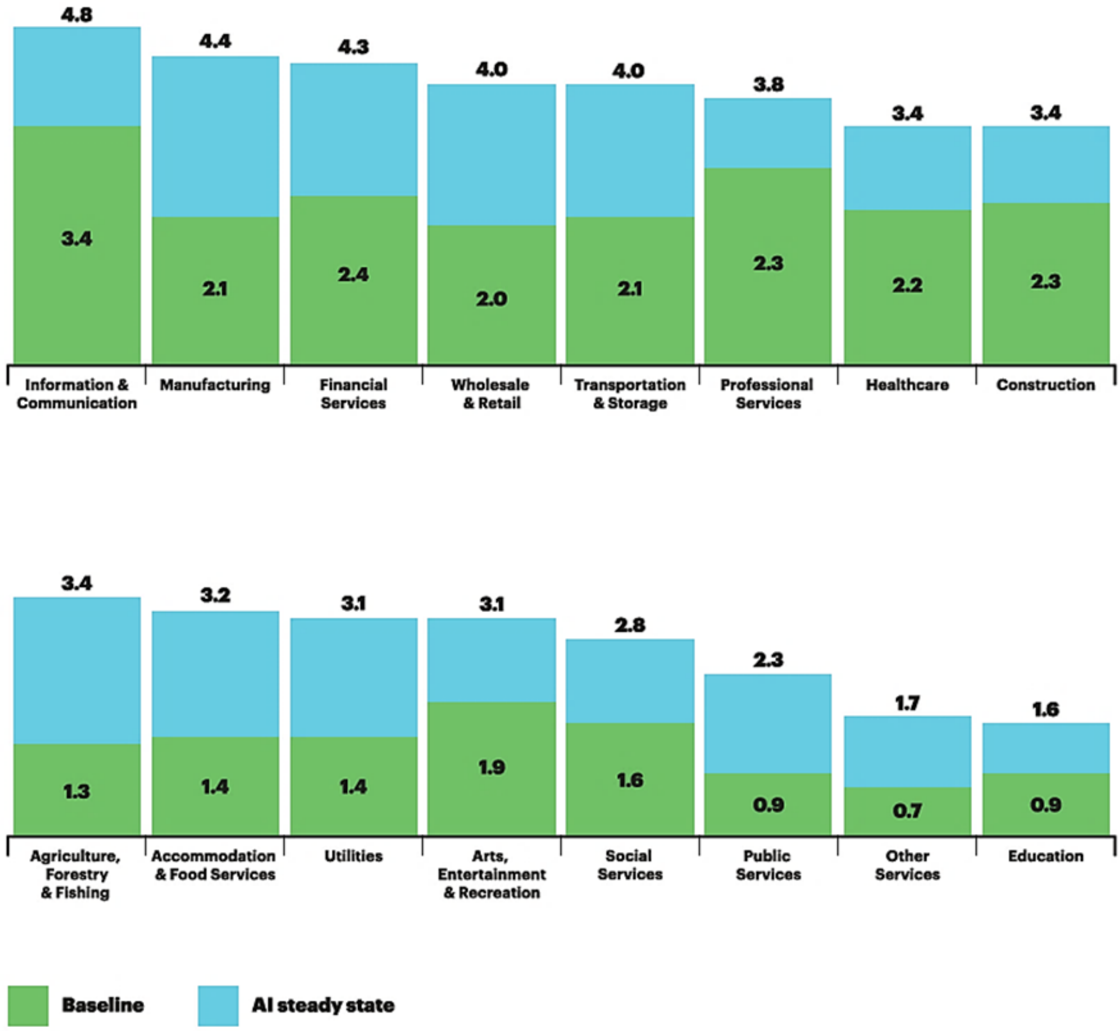


Percentage difference in labour productivity in 2035 between "baseline" and "AI steady state" in 2035.
Source: Accenture and Frontier Economics, Purdy, M. and Daugherty, P., Why Artificial Intelligence is the Future of Growth, Accenture, 2016, p.17

3.2 AI potential in different industries and sectors

AI is expected to have a big impact in more or less all industries and social areas. In 2017, Accenture, in conjunction with Frontier Economics, conducted an in-depth analysis of the analysis from 2016. In the 2017 report, AI's growth potential and potential for innovation within various industries were analysed, based on data for the same 12 countries included in the 2016 analysis. As in the 2016 report, the time horizon extends to 2035. Accenture's scenarios indicate that growth potential is high in all branches of industry, within the private and public sectors, in the manufacturing industry and in service production, Figure 10.

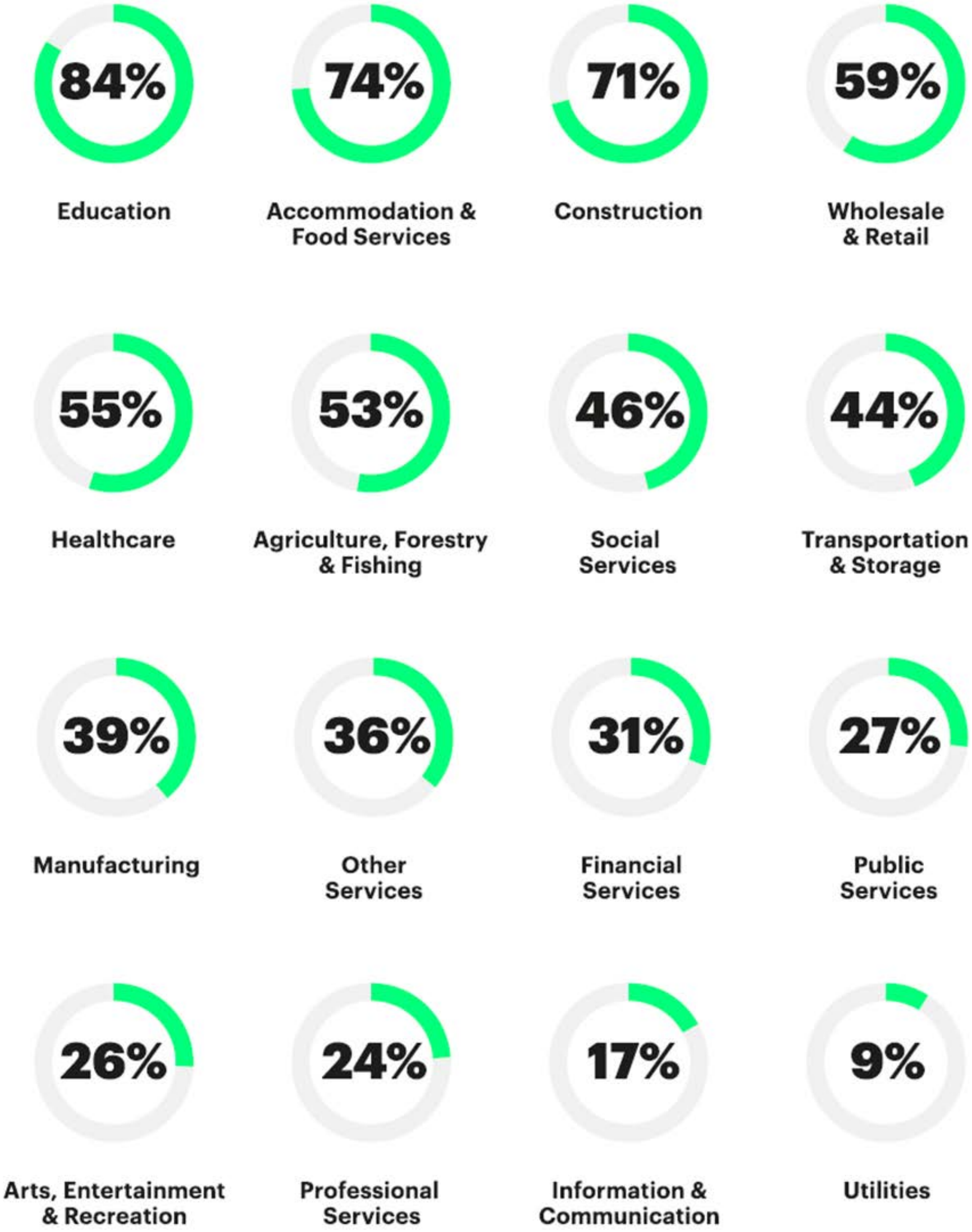
Figure 10. Scenario showing the impact of AI application on economic growth in different industries



Source: Accenture and Frontier Economics, Purdy, M. and Daugherty, P., How AI Boosts Industry Profits and Innovation, Accenture, 2017, p.10

Scenarios of profitability in the same report point to very high profitability potential in most industries, especially in various service industries, Figure 11.

Figure 11. Scenario of the impact of AI application on profitability in different industries



Source: Accenture and Frontier Economics, Purdy, M. and Daugherty, P., How AI Boosts Industry Profits and Innovation, Accenture, 2017, p.17

Service companies that build their business on information exchange with consumers via internet-based digital platforms have thus far had the greatest opportunities to use AI. In such cases, information is provided directly by consumers in a format defined by the platform-based companies, which then provide information services to consumers and to other companies based on this information. The processing of information for these services is largely done using different methods within AI.

Within a number of service industries, such as the financial sector, digitalisation is already extensive, which means that the effects in this sector may become significant in the near future. AI is also extensively applied in e-commerce, which is growing at the expense of traditional trade. In other areas, the application of AI methods is more complicated and requires development in a number of other areas. The development of self-driving vehicles and related transport services is one example. Another is applications within health, medical care and social care.

National defence and the defence industry, primarily in the United States, were among the first to use AI applications. Today, not only do the largest countries invest major resources in research and development in applied AI for their respective defence systems. There are also several intercountry initiatives. One example of this is recent cooperation between India and Japan. Military AI applications have also started a lively debate on different ethical aspects. Some examples of existing applications or applications under development[8]:

- Prediction of the course of events
- AI-controlled missiles that can be directed to new missions
- Smart uniforms
- Data collection and decision support in real time
- Surveillance of airspace
- Autonomous vehicles and drones for, e.g., surveillance
- Autonomous warships

Platform-based companies have access to immense amounts of information in electronic, and thus mechanically processible, formats from consumers. They also have a high level of competence and organisational ability to develop AI methods (algorithms, etc.). The processing of this information has been shown to give these companies growing competitive advantages.

Data access and development of AI methods grow in interaction with each other and lead to increasing market dominance for companies like Google, Facebook, Apple, Amazon, Alibaba, Tencent and Baidu. Due to high profitability and rapid growth, these major platform companies have gradually gained ground in new business areas where they are challenging established companies. The dominant role that a few leading technology companies, primarily in the US and China, have assumed in the development of internet-based services is rapidly beginning to influence the conditions for the development of society and business in almost all areas.

[8] Governo (2018), Artificiell intelligens i offentlig sektor. Hur realiserar vi potentialen? [Artificial intelligence in the public sector. How do we realise the potential?], p.20

4 Sweden's AI potential in business

This chapter discusses Sweden's opportunities and obstacles (bottlenecks) with regard to exploiting the AI potential for increased value creation (quality and efficiency) in different industries. The chapter is based entirely on surveys and interviews with leading business representatives, as well as on SWOT analyses from Strategic Innovation Programs (SIP) and various actors. Different actors' responses, SWOT analyses and quotes have been anonymised.[9] Vinnova has summarised different actors' assessments. Thus, the interpretations or assessments presented in this chapter are not Vinnova's own.

4.1 Company surveys and interviews

At the beginning of 2018, Vinnova sent out a survey to a selection of representative companies to get their company's and industry's views on AI. Some answers have subsequently been supplemented with interviews. Below is a summary of the material, as well as quotes and examples from survey responses.

AI companies

The growth potential for AI-developing companies is estimated to be very good, at least as positive in Sweden as in other countries. An important area where AI has great potential and which, in turn, has great potential in applications within many areas is automatic image recognition.

> *"The greatest driving forces are to use automatic image analysis to develop products and services that would be economically inconceivable without AI. There is a huge difference in the cost of a full-time employee compared with a computer + a camera, and a huge difference in scalability. If you successfully develop good automatic analysis, you can directly insert this into several [facilities] in parallel with very little overheads. Although development costs are often high, this is the right direction in the long term."*

Important development challenges include making AI development easier and more robust for other companies and solving concrete problems with customers and partners. The potential for AI applications within Swedish industry is considered good, but

> *"Swedish industry unfortunately is lagging behind in the automation and use of intelligent processes to increase flexibility and quality assurance. We can digitalise manufacturing processes further and become more efficient and profitable in our production."*

Access to AI competence, at the master's and third-cycle level, is an important development factor for AI companies.

> *"To build tools to work with AI models, we need to find staff who both understand machine learning in great detail and who are exceptional developers. These have been difficult to find... Google, Microsoft, Apple, Facebook, Baidu, etc. have employed most of the people with an academic background who would be interested in working with the industrialisation of AI... If we*

[9] Quotations in the text have in some cases been marginally edited for linguistic reasons.

could get some "crowd pullers" to the universities (renowned/skilled professors), more research would be done here, more students/doctors would be trained and there would thus be more potential staff with strong profiles."

"In Sweden, there is a great deal of knowledge in terms of data-driven processes, and there are talented data scientists. However, the companies that have adopted modern machine learning are too few and too late, and the educational programs have also been late in catching on to the developments. This means that there are very few experienced experts within machine learning in the country compared with the needs that have arisen."

When compared to other companies, AI companies more strongly emphasise the importance of AI specialists with a high academic background. They perceive the lack of such competence as a major shortcoming in Sweden.

"As a result of all of that has been written on competence deportations, we as a small company are hesitant to recruit internationally. We don't have the resources required to feel 100 per cent confident that some rule somewhere won't go unnoticed. Employees have a long start phase with us, and the risk of losing an employee because of bureaucratic complications is too great for us to go that way."

Telcos

In the telecom industry, the potential of AI is estimated to be very great.

"AI is absolutely crucial in telecom. Partly because the infrastructure itself can become more automatic and autonomous, in order to reduce production costs for service providers, and partly because AI will make objects and equipment more communicative. Sweden has more potential than other countries, as we typically work higher up in the value chain than other countries."

"[The telecom industry] represents one of the mainstays in applying AI to other industries. With mobile connectivity it becomes possible to represent the real world with data. Data, separately or together with real knowledge, constitutes the foundation for AI."

The main driving forces are increased efficiency (automation) but also the ability to create new services. Key conditions include:

- Open source software.
- Access to data.
- Open Application Interfaces (APIs).

Effective collaborations between companies and academia are an important development factor. Both as a driver to propel technology forward and as a basis for recruitment. Effective industrial partnerships, i.e. collaboration between different companies are also important. In this context, an important factor is an open climate in which to share data in order to create new values together.

Healthcare, pharmaceuticals and medical technology

Health services are increasingly making a shift to data, and the potential for using AI within healthcare is assessed as being very great, even groundbreaking.

> *"Fresh market research takes into account international market development [within medical technology] of about 65–70 per cent per annum over the next few years. Sweden is well positioned in the international context."*

Major potential effects within healthcare are noted in the good prospects to work preventively using AI so as to identify health problems early on through AI-improved diagnostics, via:

> *"Measurements that are currently too time consuming (and thereby expensive). But there is also a potential to save money by automating time-consuming methods that are currently part of the clinical routine."*

> *"Our care mission is facing an uphill struggle with an ageing population, and efficiency must increase significantly if we are to retain the quality level we have today. Higher efficiency also counteracts prevailing shortages of specialist physicians. In addition, there are great opportunities to increase quality by introducing assessments/analyses beyond human ability."*

The potential of care lies in increased quality and efficiency at several interacting levels:

- *"Improving operational performance and efficiency of workflows. AI-enabled solutions can support clinicians to optimize their workflows.*
- *On a departmental and enterprise level, AI can help hospital administrators to optimize performance, drive productivity, and improve the use of existing resources.*
- *Supporting high-quality and integrated clinical decision-making. AI-enabled solutions can help to combine large amounts of medical data to a more holistic view of patients.*
- *Empowering patients and consumers to proactively manage their health. AI offers tremendous opportunity as it gets embedded in solutions for home care and healthy living.*
- *Enabling population health management. Based on predictive insights in patient populations, healthcare providers will be able to take preventative action."*

The trend towards increased AI applications is likely to go through different phases:

> *"You can divide the use cases into three areas, sometimes called AI-A, AI-R, and AI-X, which can each make a huge difference. AI-A stands for Assist, where mechanical analysis can help the doctor to become faster or more accurate, but the doctor is still in control of the diagnostic conclusion. This is the great potential in the near future. AI-R stands for Replace, where manual steps can be completely replaced by mechanical analysis. This possibility is often exaggerated today as the work of a diagnostician is usually too complex. However, with smartly designed tasks, one can benefit greatly without the negative consequences of an incorrect mechanical decision being too great. AI-X deals with tasks that are not manually handled today. The challenges can be difficult, but the benefits are reaped long before the algorithms are perfect, because the alternative is to do nothing at all."*

The potential within medical technology is also assessed to be very significant. Here, the main drivers linked to research and product development are found, where AI is expected to play a major role in research to develop products. One reason for this is the Medical Device Directive, which states that one needs to be able to demonstrate how results have been achieved. The customer needs are derived from the business strategies that the health services, i.e. the customers, are developing:

"Data and interoperability are absolute prerequisites for artificial intelligence to work. Fortunately, a large proportion of Swedish healthcare organisations have an electronic healthcare system (EHR) in place. But interoperability is still lagging behind. Investments in these electronic systems have come at a considerable cost and have resulted in massive quantities of new data and information. Healthcare providers are looking for these tasks as a way to unlock valuable information, a reimbursement in the form of new data-driven services that create efficiency and help them to compete and become successful."

The patients' expectations are an important fundamental driving force:

"The performance of the health and medical care system becomes clearer. Patients look at cost and quality measures and decide where they will receive care. This is happening at a time when competition for patients is increasing. In this new era of consumerisation of care, patients – especially younger "millenials" – will expect a healthcare experience [in line] with other online services that will bring about their recovery (on their own or) faster."

AI also has a great potential within the Biopharma area:

"Being able to use self-learning systems in the research and development of biodrugs will have a major impact on how quickly these can be made available to the population. As regards Sweden, there is a lot of cutting-edge competence within protein research here, and through this one can definitely imagine that AI will be able to take a foothold, not only in Sweden but also in the world at large."

There are strong driving forces to design better services and systems, but also brand new business models that are based on and use data, but the direct incentives are often missing.

"In, for example, the UK and the USA, they are working to prevent diabetes by way of Diabetes Prevention Programs. The companies that offer clinically verified DPPs are reimbursed in the amount of USD 2,000 per year as a diabetic costs UDS 6,000. No equivalent business model is available in Sweden today."

The industry is highly regulated and the application of new technologies and processes often takes a long time to reach acceptance. Important systemic challenges for the use of AI in this sector lie in regulatory barriers and uncertainties and undeveloped business models where AI could be utilised. At present, there is great uncertainty about what the new General Data Protection Regulation (GDPR) will entail.

"The regulatory systems are a major obstacle for smaller companies. The CE marking of a medical device is becoming increasingly complicated without leading to higher quality in the products. The only thing it leads to is longer and more expensive development processes, which hinders, in particular, small businesses that would otherwise have been able to compete through their fast processes."

The lack of developed business models is partly explained by regulatory challenges, which in turn have a strong link to data access, something that represents a fundamental challenge.

"It's difficult to obtain ethical approval to use the images available and it's hard for doctors to find time for the time-consuming annotations that are required. In this respect, the regulations aimed at protecting personal privacy get in the way a bit. Even anonymous medical data is in short supply. The impression I get is that it is easier in some other countries to obtain data."

There is a very large amount of data that could potentially be used in AI systems:

> *"Diagnosis is increasingly dependent on the combination of multiple data sources, such as general patient history combined with imaging, laboratory responses, and genetic data. AI is an essential component for realising this 'integrated diagnostics'."*

However, the availability of important data is limited for large-scale interconnection, it is "kept in silos". A basic reason for this is regulations, policies and practices to avoid privacy risks.

> *"Modern AI, not least "deep learning", requires access to large amounts of data. The models can be trained to achieve great complexity, but training data must contain enough examples of each aspect that the model is to cover. In addition, it's a huge challenge to generalise the models so that they function in a robust manner despite the unique variations that appear at each new site where they are used. In terms of healthcare data, the ultimate vision is for all data within healthcare to be available to train and provide AI analyses. Instead of analysing laboriously extracted subsets of clinical data in slow cycles, clinical data could be analysed in rapid cycles simultaneously as it appears. In other words, healthcare where 'precision medicine' is fully applied."*

The patient's privacy must be maintained for this sensitive data. Public confidence in increased data access and developed data connections lies in people's control over their own data. Important lines of development to achieve this may be identified in developments of so-called "block chain" solutions.

> *"In terms of competence, I feel that Sweden is in a favourable position in relation to comparable countries, although we cannot compete with the USA and the UK, probably because these countries have the ability to import competence from around the world."*

Collaboration between different actors and competencies will be of great importance to development.

> *"Sweden is quite ineffective in terms of collaboration between researchers in medicine (who often also work clinically) and those who are knowledgeable in AI. Machine learning and AI are ultimately almost more about data than about skilled engineers. To be able to teach a computer to analyse medical images requires access to large amounts of medical images that has been manually annotated by doctors or other medically competent staff. At this point, collaborations concerning AI and health often collapse."*

> *"Close collaboration between hospitals, academia and industry. [This] is... a necessity to be able to carry out clinical studies to test new technology, which often requires the involvement of the academic sector."*

As AI has such high data requirements, support for researchers and innovators will be needed to balance a good level of privacy protection with effective innovation.

> *"For successful technology development, knowledgeable clients need to be in charge of the work with good requirement-setting based on actual needs. At the same time, AI methods involve major changes in working methods. Therefore, the client needs to possess significant innovation power, which can question existing processes and, where evidence is found, keep pushing to secure the new process. The remit of the healthcare service includes innovation, but it very often lacks the ability and resources to systematically do this in a way that impacts at a foundational level."*

Developments in the simplification of mechanisms and large-scale clinical data extraction, in respect of AI development, will require extensive development investments in collaboration between different actors, with domain knowledge from the healthcare service, technical knowledge from AI companies and IT infrastructure companies, as well as cooperation with actors with regulatory responsibilities and competencies. The development of new technologies and new working methods requires financing. AI competence will represent an important development factor, but it needs to be combined with competence regarding the application domains.

Automotive industry

The potential for AI within the automotive industry is assessed as being very great.

> *"The potential for AI in Sweden is among the highest in the world, as we develop and produce system-related goods and services with many sensors and high automation. In addition, Sweden has many unique data sets (insurance data, accident data, healthcare data, power production data, etc.) that enable companies and higher education institutions around the country to attract talent and produce world-leading research, products and results – if the staff involved act fast enough."*

> *"We estimate that Sweden has the same potential as many other countries with, for example, a strong domestic industry where a significant impact can be achieved already in the short term."*

> *"Sweden as a nation has fallen behind. The leading countries are the USA and China. And those possessing the highest level of expertise are a few big American companies."*

There is great potential in using AI within the automotive industry. The main driving forces are efficiency, optimisation of internal processes, improved customer understanding and developed customer relations.

> *"One driving force is automation and the road to self-driving vehicles. Even in our production activities there is a need for AI, such as real-time imaging. There is also a need in the what we call the aftermarket. It can involve collecting large amounts of data and determining whether a vehicle needs to be taken for service, etc. Another driving force is international competitiveness, where AI is expected to become increasingly important for industrial products and services."*

> *"[The features contained in] the software that control self-driving vehicles, as well as driver support software... would not be possible to realise without AI, and if we don't have this capability, eventually the Swedish automotive industry will turn to foreign suppliers or lose its market share when competing vehicle manufacturers [launch] self-driving vehicles. In addition, the business model within the car industry will change due to mobility-as-a-service, ride-sharing, the ability to update software over-the-air, etc. The car's connectivity means that large amounts of data will be available, and cutting-edge expertise with AI makes it easier to find new business and business models."*

In the aviation industry, the main driving force is improved system performance. Internal networks, organisation, methods, tools and processes will be crucial in successfully exploiting the potential of AI. In this connection, the availability of competence is of major importance and appears to be the biggest challenge for AI development in the automotive industry today.

> *"[An important factor is] the possibility[possibilities] of further education and training for professionals within, for example, technology development and business development... [There*

is, however,] a limited number of competent teaching staff within university education [which] limits the volume of students as well as continuing professional development."

It is important for the automotive industry to be able to recruit students from master's programs specialising in AI and conduct research in the field of AI, often in collaboration with academia and industry research institutes, and to be able to further educate existing staff (both managers and specialists).

Data access and data collection pose another development challenge. In this context, the ability to record and store data for the development and training of algorithms is an important factor. Access to data from the traffic system, parking areas, dynamic speed limits etc. is another.

Regulatory challenges are another important development factor. The new General Data Protection Regulation (GDPR) may limit the possibility of storing data where it would be possible to identify persons or vehicles. There is already a ban on recording video in city environments due to applicable privacy laws. In addition, it is difficult to get the opportunity to conduct product tests in a real environment. In the defence-related automotive industry, a large proportion of the data generated is also classified. In these contexts, the handling of sensitive military data is crucial.

"The automotive industry will be affected by new international and national laws, regulations and standards. It is very important that we as companies and Sweden as a country actively participate in the development of these, firstly, so that we are at the forefront and know what's coming, and secondly, to ensure that Swedish industry it not at a disadvantage compared to competitors in other countries."

Mining and metal industry

The potential in the industry is assessed as being high.

"There is a special need within the mining industry. It's a rather complex environment where you work in materials that are largely unknown. It then becomes difficult to simulate and plan with other methods, rather you need some kind of self-learning system to succeed in full. Since a large proportion of the world's mining equipment is being developed in Sweden, the need should be extra pronounced here, in any case with regard to the mining industry. Sweden is generally a leader in many other areas, such as robotics and digital solutions, which is why a high competence level within this area should be a priority in Sweden."

Understanding how AI can be used to develop business models and processes is an important challenge. There is great uncertainty regarding what AI actually is, the technologies that are available and how it can be used.

"We need to educate many more people on what AI is, what is possible today (and what is NOT possible). It is not sustainable that a small group of data scientists understand it but business people or the larger engineering community does not - because the data scientists have a hard time understanding where the business value is (this is why you will hear a lot of talk about 'use cases' but little about value generation from this community)."

Access to AI competence is an important challenge, but also understanding how to use the technology. When a technology is new, it takes a while to understand how best to use it.

Pulp, paper, cellulose, packaging and fibre

The potential for developing and using AI is considered to be good within the areas of pulp, paper, cellulose, packaging and fibre. Sweden's potential should be somewhat greater than in other countries due to very good network coverage, both fibre and 4G, across the country. In many places outside of Sweden, the ability to get good bandwidth is difficult, expensive or impossible.

Key drivers for AI applications in this industry include quality assurance, operational reliability in production, simulation and optimisation of processes, more efficient logistics and customer demand forecasts. Another driving force lies in the challenge of finding younger labour, inter alia, due to the fact that production facilities are often located in rural areas at the same time as the existing labour force has a relatively high average age. These labour patterns and recruitment challenges apply both in Sweden and abroad.

However, the industry is generally lagging behind in the case of AI application. One reason for this is that operational support and production management systems are often relatively old, often from the 1990s, and developed and adapted for this industry. The renewal of these systems is now rapidly taking place, mainly in Europe, where many are replacing their older systems. An important question is whether, how and if so what role AI can play in this system support renewal.

> *"My assessment is that AI can be developed and used within small selected components for a plant where we see the greatest value creation to then be distributed and scaled up."*

> *"The easiest way is to view opportunities in the form of continued automation where automation is already implemented. In the process industry, all participants, including operators, are trained to think in terms of automation, which facilitates implementation. In this respect, the driving force is financial savings, streamlining, and the elimination of monotonous tasks."*

Standards and regulatory uncertainties regarding access to and use of data are important challenges for developing AI solutions. National and international standards and regulations are important for the development force.

The development of the technical infrastructure is of great importance to this industry, which is largely located outside the largest cities. In this context, the development of 5G and fibre expansion in all parts of the country will be of great importance.

> *"A test bed 'in a neutral location' for related learning and testing cognitive algorithms (we are currently referred to providers) [is important]."*

Competence development within AI, which is flexible and adapted to the needs and capabilities of business and individuals, is an important development factor.

> *"Access to competence, in terms of cognitive algorithms, but also general IT (insofar as data transfer and integration will be needed for virtually all new applications)."*

AI courses that facilitate training without having the staff missing from the production site for a long time will be important, both for companies' opportunities to invest in the courses and for the staff's opportunities to receive training in AI in direct connection with the work's development.

Collaboration between industry companies, technology companies with AI skills and academia will be important for the development and use of AI within the industry.

> *"The prerequisites are that those who can explain and show the potential of the new technologies can meet people in the business who are either dealing with known problems, where the new technologies can be a new solution, or who can see new opportunities within their area using the new technology. It is an obstacle if no space is created for these meetings and to test ideas, or where demands for fast/secure ROI are set as requirements."*

Construction industry and construction materials industry

The potential to exploit and use AI within the construction industry is considered good. Sweden is judged, in this industry, to be neither better nor worse than other countries. In all countries, the construction industry is at the beginning of the journey to applying AI.

The main driving forces for AI applications are to:

- Increase profitability by minimising risks.
- Automation (primarily replace administrative tasks).
- Increased occupational safety.

The development of business models based on AI is an important challenge. The industry is "traditional" in terms of lines of development and technology. There is a significant lack of insights in terms of the potential benefits with AI. Insights are also lacking to some extent regarding the fact that everyone will be affected by the AI development, and there is therefore no state of preparedness in this respect.

For the development of AI applications in the construction industry, collaboration with companies well versed in AI technology will be essential. The construction industry possesses knowledge on the "problems" of the construction sector and also has some important data, but the industry largely lacks the technical knowledge regarding AI.

The labour challenges will be significant when AI applications gain momentum within the construction sector. Extensive practical experience from work in the industry can be rapidly transferred to newly graduated technical college students, with AI competence. The latter can also quickly do the work with a higher level of quality. This means that increased AI applications will lead to major changes in workplaces and throughout the industry. Many people will need to find new work duties and be trained for other tasks and professions. For individual employers, it will be a big challenge to find qualified jobs within their operation with the short time adjustments that are likely to be required. It is therefore likely that this development will meet with resistance. In order for this to work, legislation must be developed and the social partners need to have the appropriate knowledge and ability to handle this development.

Energy sector

The potential for AI applications in the energy sector is considered to be high.

> *"Sweden is [however] an economy limited in size, with a limited number of customers from which to collect data and recover costs, and it is doubtful that Sweden has any advantage when it comes to access to cutting-edge competence in the area."*

Key drivers for AI applications in the energy sector include opportunities for the following:

- Better offers for and interaction with customers in existing business.
- Increased internal efficiency, both in terms of higher performance and higher resource efficiency.
- Development of new business models.

Regulatory, ethical and security-related uncertainties regarding data access and data usage are important challenges for developing AI-based solutions. Partly linked to this, access to effective technical platforms for AI, which integrate and assure the quality of data, is of great importance. However, the development of such technical platforms is hampered by regulatory uncertainties surrounding data.

Change management will be of great importance if the transformative power of AI is to be exploited. An important part of this change management is the development of value-creating applications, "use cases", and the development of business models for these. It is in this development that the business-related driving forces lie, and which can motivate AI investments of both a technical and organisational nature. Another important aspect is in dealing with the significant changes in production processes and work tasks entailed by AI applications, which in turn will lead to organisational changes that affect many employees. This places demands on organisational change management and requires close collaboration with employees and union representatives. Access to AI specialists and specialists in related areas will be significant in order to enable the development of AI applications.

4.2 SWOT analyses from Strategic Innovation Programs (SIP)

Vinnova, the Swedish Energy Agency and the Swedish Research Council Formas fund seventeen strategic innovation programs. Collaboration within areas that are strategically important for Sweden creates the conditions for sustainable solutions to global societal challenges as well as increased international competitiveness. Within these programs, companies, academia and organisations together develop the sustainable products and services of the future. Today there are 17 Strategic Innovation Programs, Figure 12.

Figure 12. The seventeen strategic innovation programs (SIP)

Vinnova has asked the seventeen strategic innovation programs to perform an analysis of the strengths, weaknesses, opportunities and threats (SWOT) they see in their respective areas relating to AI. Below is a summary of the material that has been produced. These SWOT analyses are summarised in Table 2. In the text below, different aspects of the SWOT analyses are discussed in more detail.

Table 2. Summary of SWOT analyses from SIPs regarding Sweden's AI potential

STRENGTHS	**OPPORTUNITIES**
Good data access Good technical starting position Experience in policy development and strategy work Good collaborative competence in the innovation system Effective ecosystems for the development of AI	The technology and potential of systems New features as well as improved quality and increased efficiency in products and services Opportunities to increase the pace of innovation and new investments in research Improved work environment and new working methods
WEAKNESSES	**THREATS**
A lack of standards A lack of policies and regulations Uncertainties with regard to ownership of data Technical shortcomings and unfulfilled technical needs A lack of research and development investments A lack of resources and competence	Reduced competitiveness due to a lacking sense of urgency and shortage of investments Scarcity of jobs and brain drain High vulnerability and security risks Scarcity of expertise Exclusion from international contexts due to a lack of investments Missed opportunities due to insufficient insights on AI Technical shortcomings and data problems

Strengths

Good data access

Access to data is described as good, owing to the systems for both manufacturing and production and for administration generating large amounts of data. In addition, the databases within the industrial sector are maintained in good order. Particularly in the process industry, data has been collected for many years. There are also large amounts of data found in the automotive industry. This is due, inter alia, to the use of dynamic parameters and data generated by interaction between human, vehicle and infrastructure. The fact that production systems, machines and robots generate large amounts of data makes the manufacturing industry very suitable for machine learning and AI. All patient data available in the healthcare sector also represents a great opportunity.

Good technical starting position

There is already a high degree of automation in parts of the industrial sector and there is a great potential for further development. Advanced measurement and control systems are used and many processes are already digitised (e.g. information and control). The development of cheaper sensor solutions can for example lead to increased opportunities for distributed wide-range data collection.

The competence is high within many of the related technology areas (e.g, sensor technology), which also includes good domain competence concerning processes. Sweden also has prominent researchers in the field of security who work with cloud solutions and physical security in products.

Sweden has a well-developed infrastructure for data traffic in both fixed and wireless networks and good geographical distribution, which is a prerequisite because AI and machine learning will entail an increase in transmitted data.

There are already many AI applications (such as the many map applications, decision support, simulation tools, etc.) that facilitate further development. This applies to several of the strategic innovation areas but is specifically highlighted in the field of transport where AI and machine learning are already included in many applications and technical solutions. Smart city technology also has great development potential due to the advanced technical applications that are already being applied. For example, it is possible to develop visualisation of measurement results in real time and data-driven allocation and optimisation of resources. In the community planning sector, there has been a sharp increase in the use of technologies such as BIM (building information modelling) and generative design, which can be linked to AI and thereby further enhance the sector's working methods.

The Swedish chemical industry is described as being in a favourable position compared to its competitors abroad. There is a high degree of automation and many information and control processes are already digitised. Large parts of today's forestry production are largely automated with advanced measurement and control systems. With new knowledge, these systems will be able to develop significantly and offer completely new opportunities. Large volumes in the flows provide development resources when a step towards AI is chosen. Technical competence in regard to connections between technology and material is needed to enable data collection for AI systems.

Experience in policy development and strategy work
It is important that leading actors within digitalisation and automation also continue to take a leadership role in terms of the development of AI. Within the aviation industry, there is substantial experience and competence when it comes to developing policies and designing complex critical security solutions (including certifications). In addition, the industry has solid competence within strategic development and continuous improvement work.

Good collaborative competence in the innovation system
Among the stakeholders represented by the innovation programs, there is extensive experience of international and national partnerships as well as habitual cooperation across industries. There are several established collaborations between the business sector and academia. A strong tradition of collaboration between companies, academia, institutes and society exists, and according to the Triple Helix model. There is a high degree of openness between companies. The strategic innovation programs describe themselves as potentially important bases for collaboration on AI development.

In the field of aviation there is experience from international cooperation in developing technical solutions and regulations, which provides competitive advantages and can support applications within other civil transport systems. Here, there are also established collaborations within academia to promote competence building in the area of AI.

Effective ecosystems for the development of AI
Geographic regions that can offer support to all parts of a value chain at the same time as proximity to science are described as a Swedish strength. There are ecosystems that can offer collaboration and interdisciplinary knowledge necessary to build AI into a value chain.

Interdisciplinary and multidisciplinary project teams are essential when working with analysis and AI. The strategic innovation programs are described as an excellent basis for conducting collaborative projects for the development of AI. Each program can also serve as a cross-industry solution platform.

The opportunities for experience exchange across national borders are also included because many of the innovation programs work with general needs and solutions the world over. The community building program describes the existence of a huge experience bank from which to draw.

Weaknesses

A lack of standards
There is a lack of standards, which makes it difficult to develop AI solutions through the collaboration and across the boundaries required. The lack of industry standards for information sharing and the use of AI in transport systems is indicated as being a major bottleneck for development.

A lack of policies and regulations
The lack of policies and regulations – or uncertainty surrounding such – risks delaying or obstructing developments in the field of AI. This applies to different product areas, but it also covers the ethical, legal and security-related aspects of certain AI-based solutions. This applies, for example, to the mapping of human and vehicle movements or the use of drones for the transport of goods. Sweden is a small player, which limits the opportunities to influence regulations and certification in all areas.

A lack of ethics and transparency risks preventing the development of trust in AI as a tool. A lack of control, overview and transparency prevents clarity regarding accountability as well as the capacity for system troubleshooting. It is also important to consider how (and with what time perspective) different suppliers of AI solutions will control and influence usage, data collection and calculations.

The issues concerning policies, rules, ethics, privacy and security need to be handled individually as well as jointly, not just from a technical perspective. Discussion on ethics and security is far too limited today.

Uncertainties with regard to ownership of data
Linking data from different sources can cause difficulties in terms of keeping track of ownership. When data comes from both public and private sources, it is usually very unclear who owns the collected data.

Managing issues that concern the control of data is very complex and can easily be misused by someone who has a knowledge advantage and extensive resources.

Technical shortcomings and unfulfilled technical needs
The IT infrastructure is not always accessible, stable and secure. Some systems are based on old technology and the data generation occurs in systems that are not linked (systems for process automation are often based on structures and technology from the seventies). Traditional systems (e.g., cars, aircraft, manufacturing units) are designed for long life, whereas flexibility and development require a modular design where life cycles can run in parallel.

Poor quality in sensors (and other data collection) is likely to cause distorted applications. Generally, there is a risk with low-quality data because it leads to distorted applications. Distortion may also arise through bias in the selection or collection of data. Data also needs to have sufficient variance for the AI models to make reliable predictions.

One prerequisite for AI is digitisation, and the actors who are lagging behind within this area risk also losing out on the opportunities with AI. In supply chains, IT maturity and data capacity can vary, which complicates the application of AI.

A lack of research and development investments
In Sweden, investments in R&I projects are too few and too unfocused for it to be possible to meet the development needs driven by AI (although WASP is an example of a coordinated initiative). The initiatives are too scattered and too temporary in nature without a strategic plan. Coordinated investments in security are indicated as being particularly expansive.

Some industries or sectors are large and have many players where digital maturity is also low – which means there is a great need for a general increase in knowledge regarding AI at all levels. The fragmentation for the development is slow. The absence of major players also poses a risk that nobody is driving the change.

A lack of resources and competence
The lack of competence is a weakness that is constantly highlighted. Both in terms of access to own internal competence and the opportunities for recruitment. In addition, many companies who need AI are small and have limited resources to work with development. The available human resources must focus on day-to-day operations, and it may be difficult to take part in continuing professional development and experimentation with AI. Major players with extensive resources have an advantage.

Acquiring new knowledge can be complicated by the fact that the industrial sector does not really have the time to further train its staff, and maybe there is also reluctance regarding the potential of AI for the business in question. In addition, there is a risk of the prospects associated with AI being somewhat negatively perceived due to previously failed attempts at this technology in the 80s and 90s.

Access to competence outside the field of pure process management/automation is indicated as being limited within several of the innovation areas. In particular, there is a lack of "digital business" competence, which leads to a shortage of initiatives to develop and test new and alternative business models. Many people would like to use AI, but the lack of in-house knowledge means that there is an over-dependence on costly consultants. Client competence is also lacking in many areas.

The Swedish chemical and plastics industry estimates that they are lagging behind some of the end customers. The access to IT competence with an understanding of the process industry is a narrow sector. It makes it difficult to start important projects, even if they are profitable and funding is available. With regard to the forest industry, there is a reported difficulty in implementing the new opportunities that AI can offer because there is a desire to avoid the risk of interruptions in the complex production systems, interruptions that can cost a lot of money. In the textile companies, players are unaccustomed to creating new data points in logistics chains, which is otherwise said to be an opportunity for the textile industry.

Opportunities

The technology and potential of systems
AI is a tool that enables major changes. The potential for automation and efficient and optimised processes is huge. Planning and follow-up can be done with great precision and maintenance can be carried out proactively. The actual technology development is not described as advanced – AI is simply a new tool in the toolbox, but with huge potential and the ability to identify previously undiscovered links. Efficiency and increased productivity apply not only to production but also to administrative processes to a high degree. AI can also be efficiently scaled up, meaning that AI technology that works for a machine or system can easily be scaled up to a global level, for example in a global manufacturing group.

For the process industry, great opportunities are identified in the form of better predictions for supply and demand, and thus more efficient business processes. AI models can be trained in relation to users' subjective experiences. AI also provides opportunities for predicting quality characteristics that can be difficult to measure. Improved production planning and the potential to solve previously insoluble optimisation problems are additional opportunities.

With regard to the potential for lightweight materials, it is indicated to be found in the possibility of new lightweight structures being generated and realised faster industrially. Among other things, due to simplification of the product optimisation of lightweight solutions. AI enables autonomous vehicles which in turn allow the weight to be reduced by removing multiple functions.

For the forestry industry, there is a great potential in improving existing systems and the possibility of streamlining and optimising the entire value chain from forest to finished product. Different forms of Big Data approaches to systematically utilise the huge amounts of data generated by forestry and the forestry industry are important.

The mining industry is undergoing development of its instrumentation that is streamlining production (throughout the mineral value chain) through a complete and total extraction and recycling of both primary and secondary resources.

For the textile industry, there are possibilities for the sorting of textiles in all stages of reuse. AI can be used for automated analyses, such as spectral analyses for recycling, damage analysis for refurbishing, design analysis for remaking and fashion analysis for reusing. It is also possible to coordinate geographically dispersed clothing and furniture for collection despite the lack of identity in products. Analysis of transport chains for fashion products is another possibility.

New features as well as improved quality and increased efficiency in products and services
AI entails great potential for reforming businesses, products, services, and optimising internal and external processes in almost any kind of operation. AI can be used to optimise processes, ensure better sustainability and integrate value chains. Cooperation within industries is needed for sharing development costs and risks.

AI is a tool that is of great importance in order to truly benefit from the Internet of Things (IoT). AI represents an opportunity to process and present all data collected through IoT.

For the metal industry, there are great opportunities in tailor-made products for different needs based on existing data. This data also allows for adaptation to shorter product life cycles and a changing market, as well as identifying brand new uses for the materials. Other possibilities include brand new businesses (spin-offs) where systems and solutions can be sold to other similar industries. That is, the development of entirely new business models. AI also makes it possible to integrate the ability for simultaneous documentation and continuous improvements as well as the simulation of processes in order to work with process development in virtual environments.

The fact that buyers and customers can use AI for marketing and sales functions is stated as an opportunity for the forestry industry. AI will also ensure that the design of factories, as well as the management and control of these, will become more effective, with lower capital requirements for investments and operations. To an increasing degree, it will be possible to let a control room run factories remotely. It will also be possible to automate the lab work for research and development.

An important opportunity for the aviation industry concerns the broadening of the product portfolio by adding applications for manned and autonomous craft that can interact in large and complex systems-of-systems. Other possibilities created by AI in terms of transport systems involves cloud-based services for intelligent line transport. Developed mobility services based on the complex links between offers, customer needs, logistics and traffic predictions are another possibility. Smart traffic signals and maintenance prediction are other potential aspects.

On the material side, more reliable manufacturing processes, for example, for additive fabrication of lightweight materials are suggested. As far as the graph is concerned, the material can enable important properties in the sensors and hardware that will be required to ensure the functionality of the AI.

AI represents opportunities for more sustainable urban environments, among other things, through reduced car traffic and the transition to transport as a service. The new technology can also attract innovators who want to contribute to urban development. For social planning, AI will be able to optimise solutions in relation to many criteria, such as energy, climate, integrity and economy. Solutions can also verify links to current regulations and laws. Furthermore, AI provides the opportunity to predict complex scenarios regarding demographic development, traffic flows and climate impact.

Increased resource efficiency through the use of AI is described as a great opportunity for the transport sector. In addition, the productivity of transport infrastructure can be improved through better design, construction, operation and maintenance, traffic management, traffic monitoring, etc. Decision support can be greatly improved thanks to AI and machine learning. New services and more skilled jobs can be created within the sector, which is another opportunity.

Opportunities to increase the pace of innovation and new investments in research
Although development is at an early stage, AI can be important in terms of increasing the pace of innovation. However, focused initiatives are needed that ensure research and drive innovation forward.

Increased data volumes in networks and the need for storage options require new solutions for transmission, memory and storage, which opens up the field for disruptive, or radical, innovations.

Data. Within city administration, but also at the national level and via companies (which can also operate across national borders), new data sets are now being collected. AI methods like data mining can be used to identify previously undiscovered links between different measurable phenomena.

Improved work environment and new working methods
AI can offer new and improved ways of working. Risky work environments no longer need to be manned by people and heavy work can be done by autonomous machines. Repetitive and simple routine work (including within administration) can also be reduced and provide additional time for more advanced and stimulating tasks.

New types of automated machines and so-called cobots can be used for special jobs. AI makes it possible to prevent human exposure to noise, harmful particles, gases, etc. while eliminating the "human factor" by avoiding different types of errors. In the mining industry, new AI-driven machinery (e.g., electric autonomous vehicles and digitised mining) means improved working conditions and increased production.

Another possibility with AI is that elusive and experience-based knowledge can be transferred from individuals to systems, which facilitates the transfer of knowledge and generational development.

Threats

Reduced competitiveness due to a lacking sense of urgency and shortage of investments
The current economic prosperity gives the false impression that there is no urgency. Inactivity along with a lacking competence, in addition to outdated work methods and leadership, imply a risk that we in Sweden are lagging behind, that the competitiveness of Swedish industry is decreasing.

Other countries are making major investments and global technical development is moving at a fast pace. Among other nations, China and South Korea have invested heavily and implemented coordinated initiatives in pursuit of rapid development.

Scarcity of jobs and brain drain
Work tasks and jobs are disappearing and the creation of jobs is dwindling. Many existing jobs will disappear, not only within production but also within administration. This will in turn lead to problems regarding the provision of skills, especially in smaller towns.

High vulnerability and security risks
Vulnerability is likely to increase as systems become more advanced and with more connections. There will be an increased risk of data theft and attacks. Especially against the autonomous systems. There is a risk that security aspects will not develop at the same rate as the systems, which leads to security risks. The uncertainties are not only dangerous in and of themselves, but they also reduce trust in AI. New products and services based on AI will entail major benefits to society, but only if the users can feel confident that the systems are reliable and do not threaten our security or the individual's democratic rights and freedoms. Transparent management of algorithms and data processing becomes an important factor.

Scarcity of expertise
New technologies can make some industries very attractive to work in, and there is a risk that employers who cannot apply new technology or work with rapid development may find it difficult to recruit cutting-edge competence. Access to competence is a narrow sector and

scarcity of expertise represents a serious threat. There may be hesitation in companies when it comes to further training if there are doubts that AI will have an impact and an expectation that the development will follow the trend seen in the 80s and 90s. A lack of domain skills in companies causes them to become too dependent on consultants, which in turn reduces flexibility and innovation and the opportunities for unique solutions.

Exclusion from international contexts due to a lack of investments
If Sweden is falling behind when it comes to investments in the development of AI, we risk becoming internationally irrelevant. The Swedish system-building industry needs to participate in the rapid international development in order to be competitive in the long term.

Missed opportunities due to insufficient insights on AI
The general knowledge regarding what AI is and can be must increase in order for Swedish companies not to end up in a weak position in terms of global competition. Industrial companies risk lagging behind or being forced to adapt to developments in the industries leading the development (finance, telecom and high tech companies). In addition, many companies that work with AI have little or no experience of industrial production and the special conditions prevailing in a process industry, which implies difficulties in developing truly customised solutions.

Both the over-confidence in AI and excessive distrust may represent a threat. Unrealistic expectations as well as fears can create difficulties and obstacles. Over-confidence in AI and machine learning risks giving these technologies a bad reputation when predicted effects are not achieved fast enough. Data collection can take a long time and require large investments, which means that it may not gain momentum as quickly as might be expected. Excessive distrust in AI and machine learning means that the technologies are not used to solve the problems to which they are suited.

Technical shortcomings and data problems
All AI is based on the availability of data which is used to train AI models. Most production equipment requires continuous maintenance where machinery, components and sensors are replaced or rebuilt during scheduled maintenance shutdowns. Automation systems are designed to compensate for this, but an obvious risk of AI models is that they become invalid after a maintenance stop and require a calibration that is actually only possible when sufficiently long data series have been collected.

Rapid changes in products and materials (e.g., in the fashion industry) entail data changes at a rate that makes the learning process of AI systems difficult due to the constant addition of new data, which can result in diminished precision in new products.

Another threat that is highlighted is the misaligned optimisation and control of complex learning systems. Optimising a current specific traffic flow is not always the best approach. Cost functions that are incorrectly formulated, in a context where many different types of AI systems interact directly with each other (such as in a city), can have consequences that are virtually impossible to predict.

Data management requires knowledge and accountability. Shared data is in demand in many sectors, but there are major challenges regarding ownership and control. Poor accessibility to data is another threat. There are large quantities of 'legacy data', unstructured data or data in outdated media or formats, for which common data models and APIs do not exist. In many cases, a single supplier owns the data and may not have an incentive to share it.

Immaturity concerning open and shared data is another problem. Much of what is open data today will not be so in the future as it can be correlated to other data and thus threaten the privacy of individuals, organisations and infrastructures. Shared data can provide great opportunities, but responsibility and ownership will pose new challenges.

5 Sweden's AI potential within the public sector

This chapter conducts an in-depth analysis of Sweden's opportunities and obstacles (bottlenecks) with regard to exploiting the AI potential for increased value creation (quality and efficiency) in the public sector. The analysis is based entirely on a study conducted by Governo on behalf of Vinnova.[10]

5.1 AI in the public sector

To get a picture of the current situation in the Swedish public sector, a survey has been sent out to government agencies, municipalities and county councils/regions (totalling 560 respondents). The response rate was 60 per cent, corresponding to a total of 337 responses, of which 171 were from government agencies, 145 from municipalities and 19 from county councils where the survey was sent to both the county council director or regional director and to the health care director. The survey addressed the following areas:

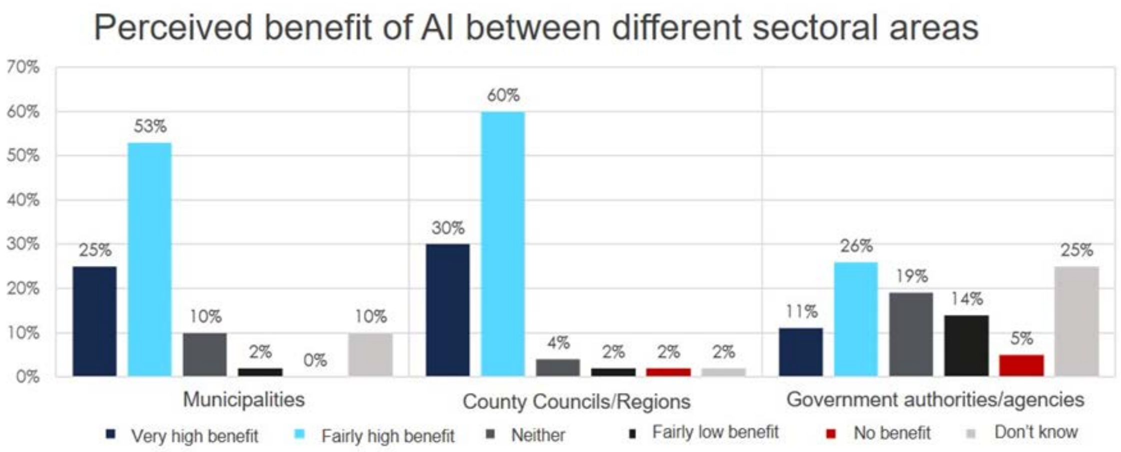
- Implemented, ongoing or planned projects using AI technology.
- Current knowledge and work with skills development.
- Strategic work with AI.
- The potential of AI based on assessed benefits, driving forces and obstacles.

In order to get a more detailed overview, parallel in-depth interviews were conducted with senior executives (director-general/municipal chief executive/county council director or digitalisation manager/IT manager) in some of the largest organisations where great potential for AI is assumed. The intention was to gain insight into the current use of AI, planned projects, driving forces and obstacles for AI, etc.

Overall, there is a positive view of AI in the public sector and the benefits that the technology could bring to the organisation and its activities. About 60 per cent of the respondents believe that AI would contribute fairly significant or very significant benefits in terms of improved service to citizens and businesses, quality of work done and efficiency. Many also state that they feel the work environment for the employees could improve with the support of AI, Figures 13 and 14.

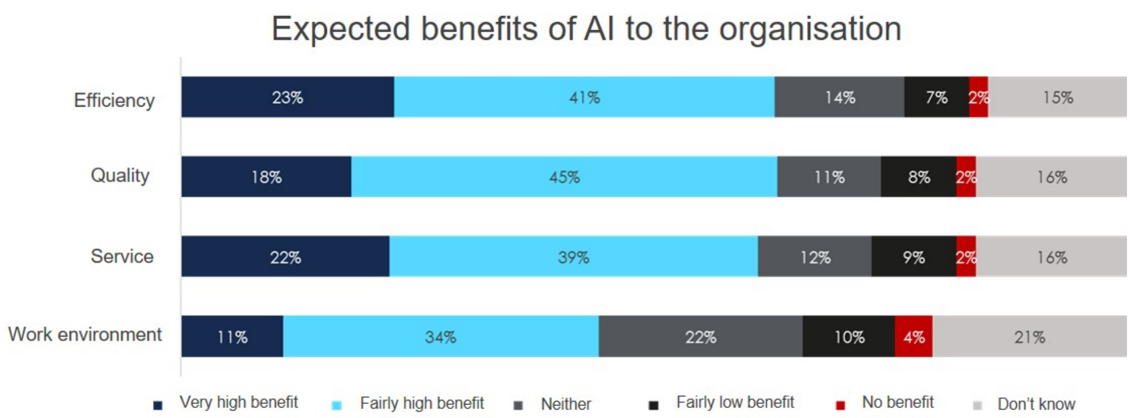
[10] Governo (2018), Artificiell intelligens i offentlig sektor. Hur realiserar vi potentialen? [Artificial intelligence in the public sector. How do we realise the potential?].

Figure 13. The benefits of AI are assessed as being possible within the areas of improved service for citizens and businesses, quality, efficiency and work environment for the employees. Government agencies are more divided on AI's potential operational benefits.



Source: Governo AB

Figure 14. Results from the survey question "What benefit do you think AI can provide your organisation in relation to improved service for citizens and businesses, quality, efficiency and work environment for the employees?"



Source: Governo AB

In order to get started with AI and capitalise on expected benefits, directives/steering from management are an important driving force. Of those who have a plan or strategy for AI, 13 out of 19 respondents state that directives from management are a reason why they started their work. It is also stated in the open answer field in the last survey question that AI is not yet on the political agenda and that there is an absence of commissions and external pressure. Furthermore, a large number of respondents indicate a need for a unified, national approach to the issue.

Government agencies

The survey responses indicate that government agencies are those who assess that they have not progressed very far in their work with AI at a strategic level. In this respect, 53 per cent say that they have not even begun, and only 6 per cent state they are currently in the process of implementing projects with AI technology, that is, only 10 of the 171 government agencies that responded to the survey. Some of these projects are mentioned:

- Use of AI for booking meetings and interpretation services.
- Classification and review of texts.
- Pattern recognition and clustering for assessment.
- Machine learning, for example, tracking behaviour abnormalities.
- Forecasting precipitation with deep learning/neural networks.
- Self-driving buses.
- Customer service – chatbot.

In comparison with municipalities and county councils/regions, government agencies are also more divided on what level of operational benefits AI is expected to contribute to their organisation. In this regard, only 37 per cent of the government agencies indicated in the survey that AI would contribute to improved service, quality, efficiency and work environment for the employees to a fairly high or very high degree, which is significantly less than the average in municipalities and county councils/regions, which indicated 78–80 per cent. In other words, it is concluded that the government agencies currently do not see the same potential in AI as municipalities and county councils do. This could, however, be due to the fact that a number of the government agencies that responded do not have contact with citizens to the same extent as other agencies or as municipalities and county councils.

The Swedish Migration Agency has begun work with a few pilot projects in the area. Opportunities are identified both in the processes that engage with the customer, and in purely internal processes. One area is processing, where the benefits of automation are observable within some parts, while other parts require human interaction. Interpreting and translation services represent an area where there is a scarcity of expertise and where focus is turned to various services available on the market. The agency has prepared an action plan which includes issues relating to AI. There is also work being done with an idea bank where various development proposals are included, as well as the introduction of new roles (innovation coordinator, innovation team). One challenge is that resources for investment in development are scarce, both in terms of finance and staff. In addition, there is a scarcity of expertise within AI. At the same time, the specific driving forces are to reduce both lead times and costs, wherein it usually takes a few years before any savings are realised.

Statens servicecenter, which today manages wage and finance administration for a large number of government agencies, expects AI to radically change its duties. Robotic Process Automation (RPA) is already being used to eliminate recurrent and routine elements in parts of the support processes handled by the agency. This is expected to increase to a large extent and ultimately encompass the entire processes. The driving forces for AI are to become more cost-effective and ensure the quality of the processes. In the long term, when as much as possible of the government agencies' wage and finance administration has been transferred to the agency, only a few employees would be needed to manage and monitor the processes (currently 450 employees). The obstacles mentioned firstly allude to financial constraints with regard to the investments needed and secondly to the difficulty in finding and attracting the right technical competence within the area. There is also an observed need for government investments in the area, as well as a common mindset for developing competence within AI.

The Swedish Companies Registration Office has a number of planned pilot projects within the area, and has recently conducted a preliminary study to identify potential in different areas. The IT budget is growing (today close to 40 per cent of business volume), while at the same time the agency needs to secure savings and implement cost reductions (based on lower revenues in the fee-funded operations). In order to achieve this, digitalisation and AI are absolutely crucial, which has meant that cost calculations linked to the pilot projects are also now being performed. Large parts of what the agency is doing today is based on data, and where other solutions for both collection and analysis are conceivable in the future (including new services). There is a need to increase the rate of digitalisation and level of competence, which is not restricted to the agency itself but also includes collaboration with others. The Swedish Companies Registration Office is very active in eSam, where for example issues concerning basic data and information provision are addressed, as well as in a Nordic partnership (Nordic Smart Government) with its sister agencies. In the near future, a lab and a development team will also be established with, inter alia, a focus on AI. The driving forces thus include the need to rethink a whole new business model based on AI (including benefit realisation) and the fact that employees have a positive attitude toward digitalisation. Obstacles may entail a lack of employee competence, low trust among society, and legislation. The biggest obstacle, however, is the Swedish management model, where “drainpipe policy” hinders digitalisation.

Municipalities

The survey responses indicate that both knowledge regarding AI and the practical work with technology are most limited at the municipal level, although this does not differ significantly between municipalities and government agencies. However, there is greater potential for AI within the municipal sector with regard to the estimated benefits of the technology. More than 80 per cent of all municipalities state that they believe that AI would entail fairly significant or very significant benefits in terms of efficiency, quality and service in operations. As in the rest of the public sector, competence and time constraints are the two main reasons why the work with AI has not commenced. The lack of financial resources is also reported to a greater degree among municipalities; 7 per cent higher than in government agencies and county councils. Some ongoing projects at the municipal level:

- Management of income support.
- Digital employee in the form of a chatbot.
- Competitive intelligence.
- Intelligent security cameras.

The City of Stockholm has undergone a major transformation in its operations based on digitalisation, where the focus was initially on bringing together the city’s IT environment as a group with uniformity and standardisation as a priority. In parallel, work has been done with e-services within different areas of operation, and in recent years these have gathered in the form of a common e-service platform. The city’s current strategy “Smart and Connected City 2040” lays the foundation for next generation digitalisation, where AI plays a prominent role.

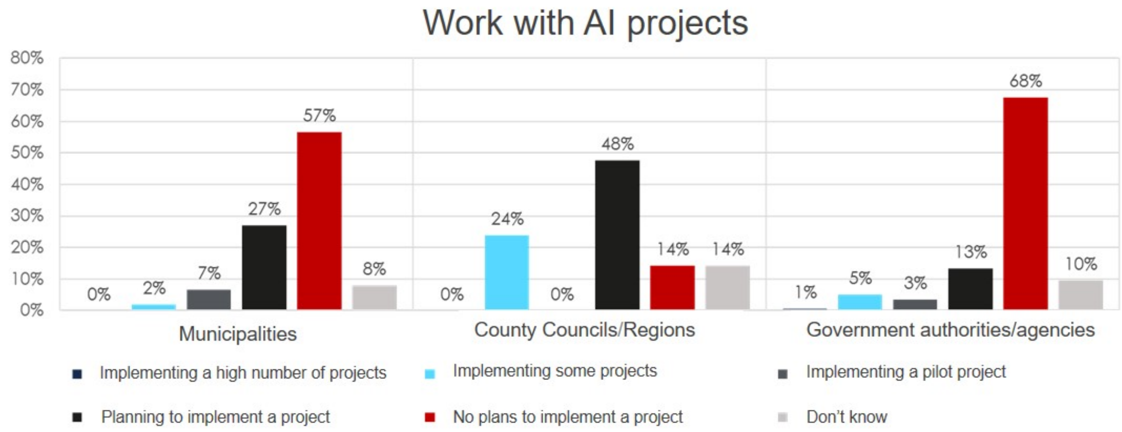
Through the Digital Demo Stockholm initiative, the city works together with Stockholm County Council and various actors within the business community in a number of innovation projects focusing on the smart city. The city and county council have identified a number of challenges to which the business community proposes solutions (for example, intelligent water supply and sewerage systems). Here, however, it has been difficult to work with large, complex areas with a long-term perspective in mind – this places high demands on the city and other parties. There are also a number of internal projects within, for example, the Traffic Administration Office and the Stockholm Environment & Health Protection Administration. A report has been produced by the city's Department of Digital Development which focuses on AI, robotisation and automation within various areas. Here, early pilot projects are described, for example, with RPA within the city's economic system UNIT4 Agresso, but also within the customer service. Some examples of more operational applications include AI for the early detection of reading and writing difficulties, and intelligent waste containers that signal when they need to be emptied. The greatest potential moving forward can be seen within welfare, where there are new and better ways of managing citizen interaction and utilising the city's population statistics.

The City of Malmö's AI work is based on the strategy "Digital Malmö". This document describes the overall digitalisation journey based on four focus areas. The city identifies a large number of areas that could be improved with AI support, such as the Internet of Things in traffic management and urban planning (for example, sensors to measure air quality and water flow), automated processing (such as RPA in financial assistance, school choices and financial management), robots in customer service etc. AI is regarded as critical in order to provide services in a better way in the future and thereby deal with the challenges of welfare. In order to do this, competence is required – both technical competence within AI and competence in change management. Obstacles can include both a lack of competence as well as scepticism within the organisation, but also laws and organisational structure that hinder new ways of working. At the same time, digitalisation and AI are considered critical to being a modern employer and thereby attracting the best employees.

County councils and regions

In the survey, the responses from the county councils/regions are remarkable in relation to those of the municipalities and government agencies regarding the organisation's knowledge of AI, strategic work and the proportion of planned or ongoing projects. In this respect, the county councils and regions are relatively speaking at the forefront of the Swedish public sector, although knowledge is predominantly considered low and the work is primarily at the planning stage. The areas within which AI technology has begun to be used include decision support and, to a limited extent, within triage, i.e. sorting/prioritising patients based on severity of condition.

Figure 15. The figure shows that the county councils/regions have on average a higher proportion of ongoing and planned projects with AI technology in comparison with both municipalities and government agencies.



Source: Governo AB

Region Östergötland uses AI within several areas, including within image diagnostics, e.g. digital pathology, where world-leading research is conducted in cooperation between the region, companies and Linköping University. Another AI area where decision support is broadly implemented in the region is in the journal system. The first application (whose results have been published scientifically) issues reminders and provides active support in order to, through correct medication, prevent stroke in individuals with atrial fibrillation. Work is ongoing together with the supplier of the journal system to introduce more applications within other diagnostics for this technology. There is also focus on automation/robotisation within customer engagement, both internally and externally in relation to patients/residents, to provide smoother and faster processing of cases. There are a number of projects in progress within other areas as well, but these cannot be mentioned here due to intellectual property rights. The driving force behind the digitalisation work is both the new technological possibilities and the population challenge – it will not be possible to deliver the same quality of care using current resources as the population is growing, and it is already difficult to find and attract the right competence. Management is in agreement on this issue, and through the willingness of the staff and access to research, it has been easy to launch various initiatives. The region has had a development strategy in which AI is included. There has also been a willingness to work together with the suppliers. The challenges are that the work requires a long-term perspective, not least with regard to the provision of skills and funding. It also requires consideration of where machines and people are needed most, and how they can best work together in new ways to become better than just a machine or just a person.

Stockholm County Council (SLL) has a number of different AI projects, all of which are run out in the field (i.e. not centrally). SLL has no overall strategy for AI, and probably does not see the need for such. It is rather a case of identifying smart working methods out in the field and ensuring that technical conditions are in place. Examples of areas with potential include diagnosis, analysis, decision support, counselling, customer service, remote care, etc. In public transport there is a pilot project that manages smart, data-driven maintenance where AI can be linked to the operating system that controls the traffic facility. In this way mistakes can be prevented, trends of disruptions can be identified, and useful data for investment decisions can be obtained. A number of obstacles to AI are observable that primarily centre around difficulties sharing data, in terms of legislation, patient safety, etc. which can prevent projects from being carried out or causing delays. It can also be difficult to calculate the benefits and thereby secure funding for projects.

5.2 Strategy, governance and leadership

One aspect that characterises countries with successful AI development is that they have formulated national goals and strategies for AI. It is important to remember that these countries not only see AI as part of digitalisation, or a trend within this field. AI is instead regarded within the context of the data-driven society where the national AI strategies are intended to impact an entire country's policy, focusing on welfare, business and employment.

Sweden currently has no overall national strategy for AI. The Government's digitalisation strategy from 2017 mentions AI and contains areas where AI may pose a prerequisite but also a solution. SALAR's[11] strategy for eSociety does not mention AI. As far as national governance of AI is concerned, wording in this respect is absent from appropriation directions and municipal budget documents.

The survey responses clearly indicate that the work with AI at a strategic level within the public sector is very limited; only 5 per cent state that they have a strategy or plan for their work. However, about 10 per cent of the respondents state that they have begun work on projects that to some extent involve AI. Current activity within the area primarily involves preliminary studies and early pilot projects rather than broad implementation. However, the majority state that they have no plans to implement projects involving AI technology at present.

In those countries that have worked longer and more expansively to yield the benefits of AI when compared to Sweden, it is often pointed out that a crucial factor is commitment from management. In Sweden and in our region, we have a long tradition of relatively prominent elements of delegation and internal consensus. This is a proactive leadership style that has often served us well. However, attention is required with regard to how this is combined with the high demands on speed and competence evident in the business world, where there are actors quick to exploit continuous new achievements within AI.

Public sector management can be expected to face increased demands when it comes to handling the rapid and radical changes that AI generates and enables. If too much responsibility is placed on digitisation or IT managers, there is a risk that business opportunities will not be utilised sufficiently. In the interviews and in the survey, there is a tendency to see AI as only a part of or a trend within digitalisation, which may hinder the exploitation of its full potential.

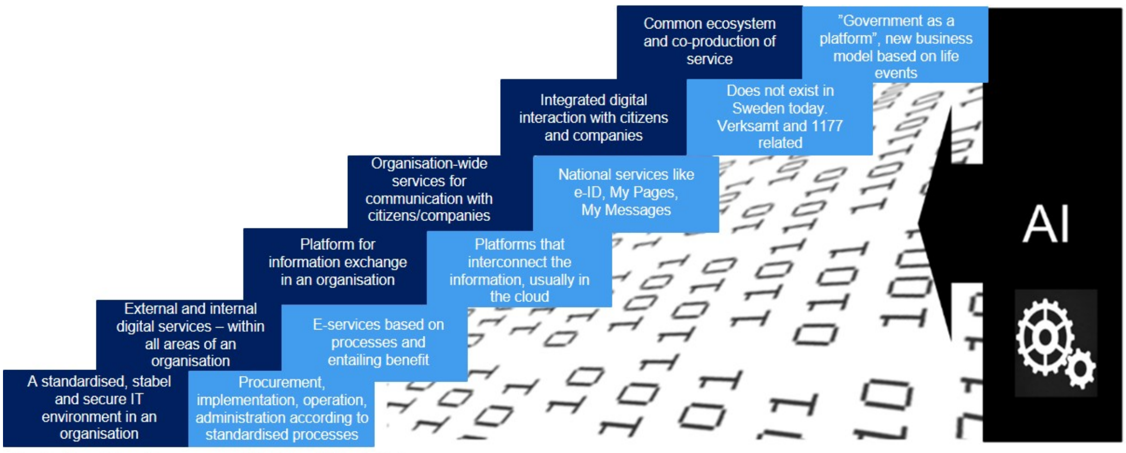
The Swedish government agencies can be said to be semi-autonomous. They are governed, inter alia, through instructions and appropriation directions. Controlling an authority's operational activities is more complex than steering the goals of the authority. This is

[11] Swedish Association of Local Authorities and Regions.

particularly evident when agencies need to collaborate and where the immediate conditions for such collaboration do not exist. A multifaceted issue like digital maturity can be taken as an example. It has proved difficult to increase digitalisation, enhance digital competence, and create clear processes for value-creating effects of digitisation using the usual means of control, such as appropriation directions and dialogue with government agencies. Corresponding difficulties can be expected with regard to increasing AI applications in government activities.

In municipalities, county councils and regions, the governance situation is further complicated by municipal self-government, while at the same time the completed survey shows a strong willingness to collaborate and develop common solutions. A fundamental challenge for many municipalities is to develop an adequate level of digitalisation in their operations. This means that the step towards AI applications can feel immense and maybe even insurmountable. At the same time, it is also true that developments within AI are unlikely to require the same step-by-step development as more traditional digital development, Figure 16.

Figure 16. Traditional digital development journey – the difference with AI is that AI can be applied at different levels and in parts of systems



Source: Governo AB

In the case of joint ventures in municipalities and county councils, high hopes rest on SALAR (including Inera and Kommentus), currently the only central municipal actor that could contribute to joint, essential projects being implemented and managed in subsequent management. If development is to originate from each individual actor with differences between solutions and with that a lack of investment drive from the market, there is a risk of there still being 290 shades of IT[12], leading to restricted interoperability at a number of different levels.

5.3 Competence

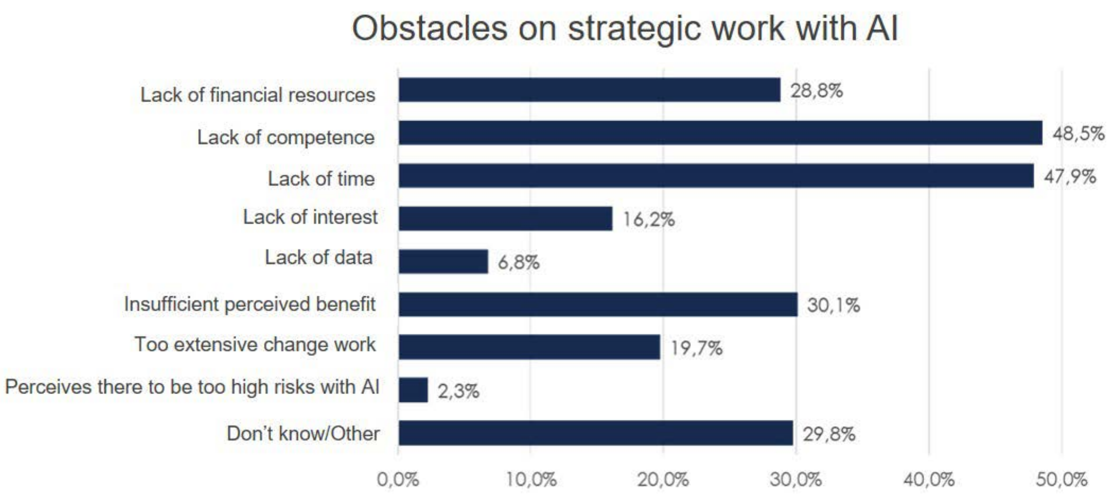
In order to benefit from AI, different kinds of competence are required for different roles in an organisation, as well as at the national level (Government/Government Offices/Swedish Association of Local Authorities and Regions). For an organisation about to embark on its AI journey, it is

[12] Sweden is divided into 290 municipalities.

probably managerial competence that is the most important according to the reasoning above, i.e. management within government agencies, municipalities, county councils and regions.

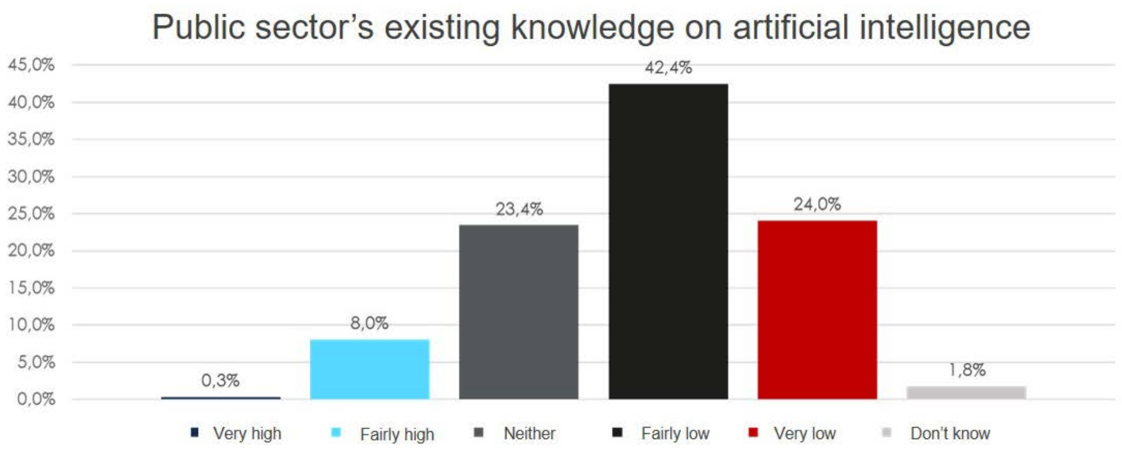
The fact that both strategic work and the implementation of AI projects are only being pursued to a limited extent in public sector operations can be explained by the lack of relevant knowledge currently found in the area. Despite over 70 per cent of survey respondents considering themselves to have a relatively good understanding of AI (over half of them indicate that they are IT managers, digitisation managers or the like), they also indicate that the organisation's overall knowledge level concerning AI is predominantly fairly low or very low, Figure 17. Here, respondents state in the open answer fields that they "basically do not know anything about what this concerns", that they feel that AI is "unfocused" and that the term is not very well defined. Overall, it appears that there are challenges to understanding what AI really involves and the uses that may be relevant to the organisation.

Figure 17. Results from the survey question "Provide the main reason/s for why there is no strategy/plan for AI in your organisation? (Multiple answer options are possible)



Source: Governo AB

Figure 18. Results from the survey question "How do you judge your organisation's existing knowledge of AI?"



Source: Governo AB

At the same time, a number of respondents indicate in the open answer fields that other activities within digitalisation have higher priority, and that they feel they must prioritise the base requirements or other more basic digitisation issues before AI. They feel that they have “a long journey within digitalisation” and that “AI needs to feature in phase 2”. In relation to the survey question about various obstacles facing the organisation’s strategic work with AI, almost half of the respondents mention that the scarcity of expertise and time constraints as reasons why they have not begun their strategic work.

Since the possibilities for support and automation offered by AI are so varied, a very broad range of diverse applications have emerged. This means that all the different parts of the organisation require knowledge on the possibilities of AI within their respective areas of responsibility. It is not only the organisation’s main processes but also its support functions such as finance, HR and IT. In addition, there is a need to access cutting-edge competence within AI at a strategic and technical level. This is in short supply in Sweden today.

An organisation with a high degree of digital maturity finds it easier to exploit the opportunities that AI entails. This is clear when studying how fast the digitally born businesses have yielded a return from their investments in AI. An organisation that has developed, broad and in-depth experience of an agile working approach and is used to valuing effects has an easier time getting results from AI investments.

In the various studies conducted by the Swedish National Financial Management Authority in recent years of major Swedish government agencies, it appears that there is still great untapped potential regarding digitalisation in many agencies. There is reason to believe that the situation in many smaller government agencies and within several municipalities and county councils is at least as inadequate. It is not only problematic for the general development of public sector activities but also hampers opportunities to exploit the full potential of AI in society.

There is also a gap in relation to Sweden’s population, which in various measurements is considered one of the world’s most digitally mature populations[13]. Sweden is often used as a test market for new digital services. At the same time, it is expected that improved customer service from, for example, banks and insurance companies will also entail increasing demands on public sector activities. If, for example, a complicated bank matter is handled in a matter of seconds, expectations concerning case management will also increase in the public sector.

In addition, private companies may, in some cases, create services that affect public sector activities. It may be a healthcare company that offers an AI robot that provides medical advice, or citizens who are professionally competent in law or economics and use ready-made AI applications vis-à-vis a municipality. This can very quickly change the conditions for contact with citizens. An early example of this is the “robot lawyer” created by a student at Stanford University to appeal parking fines that, in a few days, overloaded the New York City Department of Transportation with qualified complaints.

[13] Inter alia in the Global Information Technology Report (Insead, World Economic Forum and Samuel Curtis Johnson Graduate School of Management at Cornell University.)

According to the World Economic Forum, 2 out of 3 children starting school today will work in professions that do not yet exist. Most likely, these professions will be digital and based on AI. Many of us will probably need to be retrained during our professional life, which also places new demands on further training based on lifelong learning.

In Finland, there has been programming on the curriculum for almost 10 years, and the next step towards AI in schools is now being taken. This contrasts sharply with Sweden, where the schools are wrestling with declining knowledge outcomes and digitalisation that has primarily focused on access to technology rather than a broad implementation of digital education. The strategic analysis indicates very good potential for improved and individualised learning. However, this requires extensive development work at many different levels – nationally, municipally and in the individual school.

The Swedish public sector is a small market for digital services and systems. Due to the relatively small market, stakeholders' willingness to invest is limited, especially in the municipal sector where customers' willingness to pay is limited. All in all, this has led to under-investment in IT in large parts of the public sector, which of course also affects future investments in AI.

In addition, many of the systems are tailor-made based on specialised processing and legal requirements. Many systems have been in place for a good few years and the suppliers of these systems generally have a monopoly within their niche. Furthermore, the public actors have different requirements, which has led to a large number of variations of the same solution. This, in turn, has led to major challenges when information is being exchanged and there are a number of standardisation projects under way to address this.

5.4 Adjustment and innovation capacity

AI allows for rapid changes, which means increased expectations from citizens and politicians when it comes to public organisations exploiting these opportunities. In order to do this, it is necessary that control mechanisms, organisation and processes are adapted to ensure a high adjustment capacity. This will be a challenge in the public sector, which needs to counter this with other requirements, not least linked to legal certainty.

Since many of the earliest applications of AI could be associated with a high degree of innovation capacity, this has partly remained a feature in many other organisations now using AI. You sometimes see the applications that you start to use as something innovative and therefore something that requires special handling with regard to processes and organisation. There is probably no reason for this anymore when using finished products. On the other hand, the more commercial and strategic use of AI is likely to continue to require a high degree of business innovation capacity.

The potential with regard to the export of social AI solutions within, for example, welfare should also be noted. The combination of AI and Swedish expertise within the welfare sector can yield very high potential for the export of services. As the systems in the welfare sector are usually too complex to be described using simple rules, AI is particularly well suited to support different works elements and to automate others.

From an AI perspective, healthcare has been identified as the vertical industry with the greatest gap between what can be done with existing AI technology and what has already been done. To a certain extent, existing and future specific AI products can be used to support the welfare sector, but in order to solve more complex problems within, for example, healthcare, powerful general tools are best suited. This means, in turn, that collaborations with the major platform suppliers within AI at an initial stage can provide significant efficiency gains and increases in quality. At a secondary stage, such cooperation can lead to high export potential for packaged services. This may require discussions to begin early with these companies to discuss the potential in Sweden as a test bed. One of the first such embryos for collaborations is at Inera AB, where different possible environments for the updated Healthcare Guide 1177 are being developed.

The completed strategic analysis also shows that we can learn from the bigger national projects where the public sector, together with companies, has taken on some of the greatest welfare challenges and developed solutions using combined competence. This is unusual in Sweden, probably because of how the Public Procurement Act (LoU) is handled and the relatively strict application of the EU procurement directives. In addition, government investments in digitalisation have been comparatively small. The State's main strategy has been the one that emerged in the 1990s broadband policy, where the market forces shall govern while the State intervenes when the market is insufficient. This has meant that the most important projects have not been run nationally, but rather certain projects that have dealt with the conditions for digitalisation (e.g. e-ID). The Swedish management model has continued to be used in parallel, while many other countries have opted to organise into increasingly larger organisational units.

5.5 Realisation of AI potential within the public sector

If Sweden as a nation and every government agency, municipality and county council is to see AI as the next phase of social development, clear strategies are required that clarify the focus as well as governance that ensures that development is moving in the right direction.

- **Governance**. The various government instruments in the form of appointments, appropriation directions and dialogue with government agencies should be utilised to ensure that AI potential is achieved. For municipalities and county councils, SALAR or other national actors need to take an active role in running the most important joint projects with a focus on joint information sharing. Furthermore, governance is needed in the form of funding for the most important projects and in terms of increasing competence at all levels.
- **Leadership**. In order for Sweden to be successful in the field of AI application, leadership needs not only to launch and monitor initiatives at different levels. It also needs to set a good example by using AI at the management level, for example, through decision support, effective meeting management or other applications. It is also about signing off on pilot projects where different applications are developed, even if these fail.
- **Competence at the management level.** The knowledge regarding AI's possibilities and consequences for business-critical processes should be disseminated within different management functions in the public sector. Here, initiatives corresponding to Decoding X (SSE Executive Educations) can be an option to quickly boost knowledge in this target group. One way to raise awareness among politicians

can be to build on SALAR's initiative Smarter Welfare [Smartare Välfärd] with additional modules targeting AI.

- **Schools and education.** AI and automation already affect the need for different workplace skills and abilities in many countries. There are good reasons for further analysing what this means for the entire education sector and how today's schools, supported by AI, can create future jobs in Sweden. In this respect, the World Economic Forum has defined the skills that will be needed in the society of the future. These skills must be developed in Swedish schools, where digitalisation and AI can offer individualised learning. In order to effect this change, the Government needs to use all the instruments available, where the Swedish National Agency for Education, the municipalities' education administrations, the respective schools and, not least, teacher training colleges, play central roles. In addition, analyses need to be conducted on how further education and other skills development can be achieved for employees in organisations that need to change.
- **Cutting-edge competence within AI.** Sweden is likely to find it very difficult to compete with regard to cutting-edge competence within AI. This applies inter alia to technical, legal, ethical and business competence within AI. This may mean that even the largest public organisations can find it difficult to carry out important projects. Therefore, various measures to address this scarcity should be implemented. Measures may, for example, include short courses, specialist visas for AI experts, or collaborations with major suppliers and universities. Here, there may be reason to consider a significant education effort in the near future, with inspiration from, for example, MOOCs (Massive Open Online Courses). It may also involve, as seen in countries such as Canada, concentrating the research at bigger universities to achieve critical mass and attract researchers and companies from other countries. There may also be opportunities to establish a policy or lab centre with a specific focus on AI in the public sector, where public actors, research and industry can meet and jointly develop services and analyse this area.
- **Data management.** Sweden has a long tradition of managing public data. Much of this data may be used for various AI applications. In order to enable this, both the quantity and quality of date should be secured. Much of the work can be done within each organisation, but the AI perspective also needs to be included in the ongoing projects that exist in the field of information exchange, for example within healthcare. One challenge here will be the public sector operating systems that today encapsulate the information, thus hampering information exchange. This is especially true in the municipalities, which, on the other hand, use a limited number of systems in their respective areas, entailing that joint initiatives, for example, through SALAR or another national actor, can be initiated. Driving forces, methodologies and knowledge of potential applications should also be disseminated centrally, for example from the policy lab proposed above. Even the possibilities of anonymising data for the purpose of being used in different applications should be analysed. For local actors, it is important to map current information management and data access to be able to utilise this in future service development, and to gain in-depth insights.
- **Technology**. Many technical solutions for AI already exist, both through major international players like Google, Amazon, Microsoft and IBM, but also through niche solutions from smaller players. Here it would be interesting to see how cooperation between these players and some of the larger government agencies and county councils can be developed, in the form of both broad and niche projects. For local players, there may be a point in testing both simple and cost-effective solutions, as well as reflecting on various alternative platforms for the organisation's core processes. The technology also creates opportunities for data to be used in inappropriate and sometimes illegal ways. We have recently seen applications that publish disinformation, influence elections and in other ways threaten democracy. There are thus a number of threats inherent in AI that should also be analysed in an in-depth study.
- **Algorithms** are becoming increasingly important in our lives. Credit assessments, diagnoses, choice of news and suggestions for products to buy are just a few examples. In an increasing number of cases, AI is being utilised. The technology most commonly used is not adapted to provide explanations because

it is not based on explicit knowledge. At the same time, the demands of the public and politicians for transparency in these systems are increasing. In this area, there is an inherent conflict of goals between the quality of recommendations, forecasts, diagnoses and decision support on the one hand, and transparency on the other. What this goal conflict means for the public sector should be analysed and weighed for different situations within, for example, healthcare, consumer information, grants and control.

- **Synergy effects with other related technologies.** As indicated in the survey, there are various activities within the Swedish public sector using, inter alia, blockchain technology, the Internet of Things, RPA and other automation technologies. There may be reason to analyse the synergy effects these activities can yield together with AI in Sweden.
- **Adjustment and innovation capacity.** In order for the public sector to benefit from AI, a very high degree of adjustment capacity is required. Because many tasks are fundamentally affected and some tasks are fully automated with AI, this not only requires further training and other staff adjustment but also the entire organisation's structure is affected, including processes and forms of control. Not least, this implies great demands on human resources departments. AI can help to handle the population challenge indicated by SALAR among others, where an increasing number of elderly people will need healthcare, support and social care in the future. This area requires closer analysis based on an employment perspective.

Another important consideration is the national adjustment capacity. The public sector today is adept at ongoing administration, and in many cases dealing with crisis situations. However, it is challenged when it comes to making major system changes that affect organisational boundaries and brand new ways of working. Part of the adjustment capacity consists of active competitive intelligence. In Europe and Sweden, public players invest relatively little time and resources in competitive intelligence, which is due primarily to scarce resources, but also to the fact that there has been no development area in the past that has impacted an organisation so widely and rapidly as AI is now doing. Important areas for competitive intelligence and comprehensive system analyses include:

- **Collaboration within the Swedish public sector.** In several cases there is reason to analyse the possibilities of common applications. This applies, for example, to customer services and chatbots, but also to large parts of the municipal and county council-municipal services. On the one hand, there are probably economic and quality reasons for bringing together several organisations, but in particular, citizens can benefit from the simplicity that this can entail. Here, national-level governance is needed to instigate the most critical projects, as well as an initial clear idea of how to handle the make-or-break issues in both the project and management phases.
- **International cooperation.** Since most of the developments within AI occur outside Sweden, international cooperation should be sought by the Swedish side at different levels (e.g. government level but also in constellations of different parties). This may include bilateral and multilateral cooperation and agreements within AI, but also between different organisations with the same mission in different countries (e.g. tax authorities). In addition, the Swedish public sector should have close collaboration and exchange with both Swedish companies in AI and the major players in for example the USA and China. Joint learning trips can be a good first step towards such collaborations.

6 Societal challenges with AI

A sharp increase in AI applications in the business sector, public sector and society at large not only has the potential to provide increased quality and efficiency in different businesses and increased growth and economic prosperity in society. Such a development will also generate societal challenges in the development and adjustment processes that will be necessary to achieve these positive effects.

Important societal challenges will be related to:

- Unemployment through a rapid change in work duties and jobs in society.
- Ownership of individual data and challenges with personal privacy and ethics.
- Leadership and adjustment capacity in companies, public sector operations and policy systems.
- Risks associated with applying immature AI solutions based on incorrect data and algorithms.
- Risks of a business monopoly for a small number of technology companies, inter alia, based on a data monopoly.
- Risks of conscious data manipulation to adversely affect businesses and societies.

The knowledge about how increasing AI usage may affect societal development and what measures can help minimise the negative effects must be considered to be very undeveloped. Analyses that form the basis for different policy areas are often produced with too limited a system perspective linked to specific policy areas along with narrow problem formulations. They are also usually based on analytical competencies with too narrow a method repertoire to produce the necessary system analyses.

While efforts are being made to promote the use of AI, research, analysis capacity and analytical processes for system analyses need to be developed considerably. Competence development regarding societal aspects of AI also needs to be greatly enhanced. Leadership ability and the capacity for operational adjustment in different organisations and in society as a whole will in this context need to be strengthened significantly. This applies both to the driving forces and competence of leading representatives of various public and private actors.

6.1 Job scenarios linked to automation and AI

The net effects of greatly increased AI applications for the economy at large are very uncertain, but based on past historical developments and updated scenarios, there is no reason to believe that the creation of new jobs will overall be slower than the pace at which work duties and jobs disappear.

This conclusion is also drawn by Van der Zande et al., Stockholm School of Economics, in a report from January 2018. Based on a review of different studies, the authors conclude:

> *"Many activities can currently not be substituted by machines, and machines are not capable of performing several types of activities in an integrated way (Manyika et al., 2017; Autor, 2015). Hence, they are generally not capable of substituting labor for entire jobs, which usually include*

many bundled activities. Rather, to determine the substitution potential of a particular job, it is better to focus on the substitution of the individual activities within that job. A large body of research aligns with this approach and suggests that technology will take over significant parts of every job across all industries and levels of society (Manyika et al., 2017; Arntz et al., 2016; OECD, 2016)."[14]

Although overall employment development would be neutral, job dynamics will increase significantly in line with increased AI applications in business and the public sector.

"What is certain is that technology will cause large labor displacements, especially in high-routine occupation categories. Organizations and employees will need to increase their focus on education and training in order to be able to keep up with the increasing pace of change." [15]

Many work tasks will thus be affected. This will significantly increase the requirements and capacity for adjustment for individuals and businesses, Figures 19 and 20.

Figure 19 describes a scenario where total employment development is expected to be neutral

Source: McKinsey&Company, Digitally-enabled automation and artificial intelligence: Shaping the future of work in Europe's digital front-runners, October 2017.
Comment: The nine countries the growth scenarios concern are: Belgium, Estonia, Finland, Ireland, Luxembourg, the Netherlands, Norway and Sweden.

[14] Van der Zande, J., Teigland, K., Siri, S. and Teigland R., Substitution of Labor, From technological feasibility to other factors influencing job automation, Innovative Internet: Report 5, Stockholm School of Economics, Jan. 2018, p.38
[15] Ibid p.43

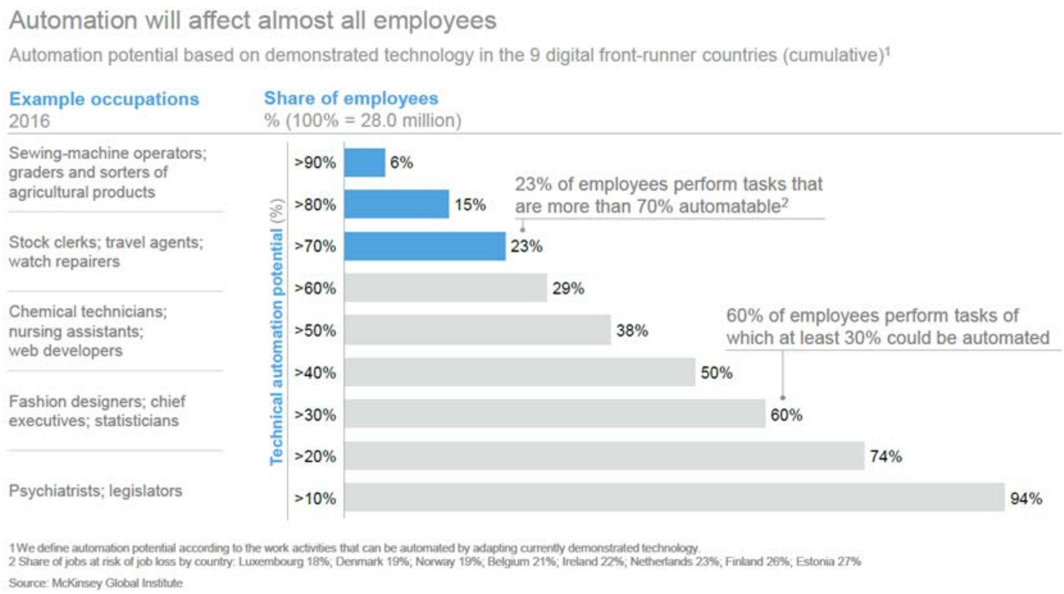
Figure 20. Overall labour market scenario 2016–2030 linked to automation and AI

Labor force impact	Historic trend 1990-2016, %	Baseline without automation 2016-2030, %	Economy with automation[3] 2016-2030, %
Reskilling need	1.4%	1.4%	2.7%
Skill inequality[2]	5%	2%	13%
Share of digital jobs[4]	8%	8%	19%
Share of tasks less prone to automation	39%	39%	49%

Source: McKinsey&Company, Digitally-enabled automation and artificial intelligence: Shaping the future of work in Europe's digital front-runners, October 2017.
Comment: The nine countries the scenarios concern are: Belgium, Estonia, Finland, Ireland, Luxembourg, the Netherlands, Norway and Sweden.

The expected job dynamics will affect different industries in different ways and to different extents, Figure 21.

Figure 21. Scenario of different types of work tasks affected by automation



Source: McKinsey&Company, Digitally-enabled automation and artificial intelligence: Shaping the future of work in Europe's digital front-runners, October 2017.
Comment: The nine countries the scenarios concern are: Belgium, Estonia, Finland, Ireland, Luxembourg, the Netherlands, Norway and Sweden.

This development will place very high demands on innovation leadership, the capacity for operational adjustment and the ability to support individuals in adjustments and upgrading competence. It will therefore be crucial that driving forces, competence and other conditions for such adjustment capacity are significantly strengthened. Van der Zande et al. notes:

"… the adoption of labor-substituting technology often leads to short-term unemployment and subsequently a period in which people need to re-educate themselves. However, as the pace of technological change and adoption is increasing, the question is whether the educational and training systems can keep pace. This is particularly difficult for people at the low-end of the skill spectrum." [16]

In a study of Sweden, Manyika et al. draws the conclusion that a total of 46 per cent of all work tasks in Sweden could be automated, which would affect about 2.1 million people in the labour force. According to these authors, four branches of industry have the greatest potential for automation of work tasks in Sweden[17]:

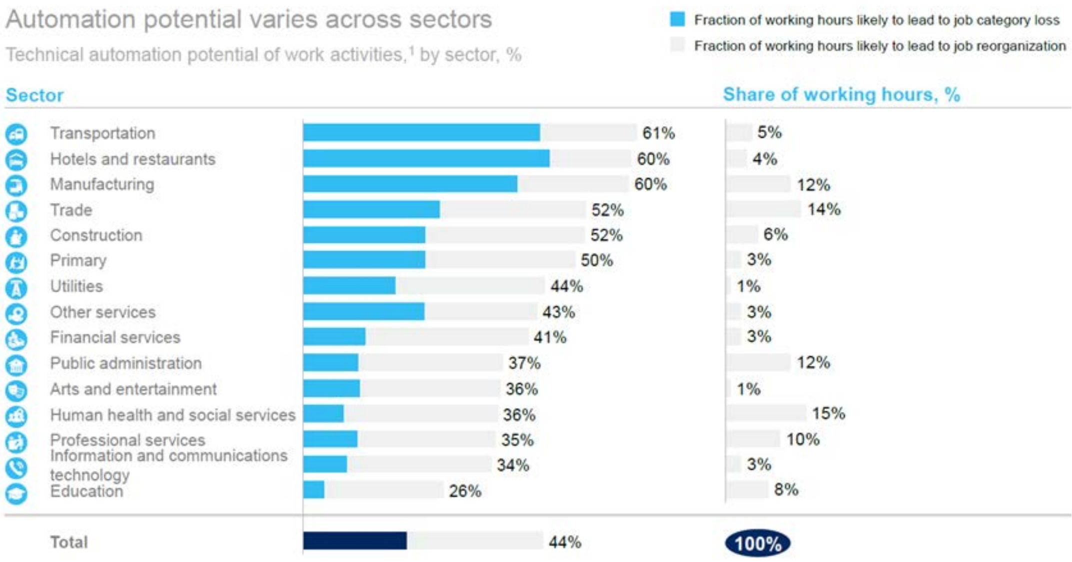
- Manufacturing
- Mining
- Transport
- Warehouse services

Branches of industry with the lowest automation potential according to Manyika et al. include:

- Education
- The information sector
- The arts sector
- Entertainment
- Recreational services

McKinsey & Company make a largely similar but not identical assessment, Figure 22.

Figure 22. Scenario of the impact of automation on employment in different branches of industry



Source: McKinsey&Company, Digitally-enabled automation and artificial intelligence: Shaping the future of work in Europe's digital front-runners, October 2017.
Comment: The nine countries the scenarios concern are: Belgium, Estonia, Finland, Ireland, Luxembourg, the Netherlands, Norway and Sweden.

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[16] Ibid, p.51
[17] Manyika, J., Chui, M., Miremadi, M., Bughin, J., George, K., Willmott, P. and Dewhurst, M., (2017), Harnessing automation for a future that works. [online] McKinsey & Company. Available at: <https://www.mckinsey. com/global-themes/digital-disruption/harnessing-automation-for-a-future-that-works> [Accessed 6 April. 2018]

6.2 Societal risks linked to abuse of AI

Data is a fundamental factor in AI development and AI applications. Data access, data quality and the ability to draw conclusions from data become crucial in this context. In this context, there are risks relating to incorrect conclusions and conclusions based on incorrect data, among other things, due to limited data sets and the inability to handle non-stationary phenomena that change over time. The almost unlimited resources available at leading technology companies in the USA and China, and the apparently growing market dominance and dominance in terms of data access that these exhibit, is perceived in most countries as a threat and has given rise to national initiatives to try to strengthen the country's position.

While AI can be used for value creation, efficiency and addressing societal challenges, AI can also be exploited to damage businesses, individuals and society at large. There are significant risks of data being deliberately manipulated so that wrong conclusions are drawn. It is very difficult to predict how different negative uses of AI may manifest themselves. Artificial intelligence and machine learning, however, significantly change the security landscape for individuals, organisations and societies. Conscious abuse of AI may seriously threaten:

- Digital security
- Physical security
- Political security

A thorough analysis of the challenges that may develop and the principles that should guide the management of such risks has recently been carried out by Brundage et al. in cooperation between a wide range of institutions[18]. The authors identify the following overall risk tendencies associated with increased AI usage:

> *"Expansion of existing threats. The costs of attacks may be lowered by the scalable use of AI systems to complete tasks that would ordinarily require human labor, intelligence and expertise. A natural effect would be to expand the set of actors who can carry out particular attacks, the rate at which they can carry out these attacks, and the set of potential targets."*
>
> *"Introduction of new threats. New attacks may arise through the use of AI systems to complete tasks that would be otherwise impractical for humans. In addition, malicious actors may exploit the vulnerabilities of AI systems deployed by defenders."*
>
> *"Change to the typical character of threats. We believe there is reason to expect attacks enabled by the growing use of AI to be especially effective, finely targeted, difficult to attribute, and likely to exploit vulnerabilities in AI systems."*

The root causes of these risks with AI are basically observable in the same characteristics as those underlying AI's potential for value creation and efficiency. The risks lie in the following characteristics of AI and AI development:

> *"**AI is a dual-use area of technology**. AI systems and the knowledge of how to design them can be put toward both civilian and military uses, and .... toward beneficial and harmful ends.*

[18] Brundage, M, et. al. (2018), The Malicious Use of Artificial Intelligence: Forecasting, Prevention and Mitigation: Forecasting, Prevention and Mitigation.

> ***AI systems are commonly both efficient and scalable.*** *An AI system is "efficient" if, once trained and deployed, it can complete a certain task more quickly or cheaply than a human could.*
>
> ***AI systems can exceed human capabilities.*** *In particular, an AI system may be able to perform a given task better than any human could.*
>
> ***AI systems can increase anonymity and psychological distance.*** *AI systems can allow the actors …. to retain their anonymity and …. psychological distance from the people they impact.*
>
> ***AI developments lend themselves to rapid diffusion.*** *Many new AI algorithms are reproduced in a matter of days or weeks. [And], the culture of AI research is characterized by …. openness.*
>
> ***Today's AI systems suffer from a number of novel unresolved vulnerabilities.*** *These include data poisoning attacks …. flaws in …. autonomous systems' goals."*

The authors provide the following comprehensive policy recommendations[19]:

> *"Policymakers should collaborate closely with technical researchers to investigate, prevent, and mitigate potential malicious uses of AI.*
>
> *Researchers and engineers in artificial intelligence should take the dual-use nature of their work seriously, allowing misuse-related considerations to influence research priorities and norms, and proactively reaching out to relevant actors when harmful applications are foreseeable.*
>
> *Best practices should be identified in research areas with more mature methods for addressing dual-use concerns, such as computer security, and imported where applicable to the case of AI.*
>
> *Actively seek to expand the range of stakeholders and domain experts involved in discussions of these challenges."*

Knowledge on how the increasing use of AI may affect societal development and what measures may help minimise the negative effects must still be considered extremely rudimentary. While efforts are being made to promote the use of AI, research and other knowledge development concerning social aspects of AI must be greatly strengthened.

6.3 Regulatory development linked to AI

Regulatory development with respect to data and data access will be crucial for realising the AI potential in society. Regulatory developments must balance fundamental needs for privacy protection, ethical data management and social protection with the necessary access to data for the development of value-creating AI applications.

> *"Robust mechanisms for addressing risks, benefits and ethical issues are not yet institutionalised (Calo, 2014). This is, in part, because AI is still being developed, and because wide and diverse applications make a comprehensive regulatory framework difficult. Moreover, some view policy interventions around AI with scepticism, arguing that it is too early for AI policy (McAfee, 2015), and that intervention could hamper technological development and the potential benefits to society (Brundage and Bryson, forthcoming)."*[20]

In order to achieve the necessary regulatory developments surrounding AI, there needs to be a significant increase in the driving forces and competencies of government agencies and

[19] Brundage, M, et. al, 2018.
[20] OECD, 2017, pp.282–283

expertise in assuming responsibility for regulations and regulatory oversight over AI and data needs in innovation processes. An important part of this is for these government agencies and experts to collaborate directly in R&D and innovation processes where new AI applications are being developed.

The new General Data Protection Regulation (GDPR) within the EU for the protection of personal data is a very important regulatory development.

> *"One of the purposes of the General Data Protection Regulation … to protect the fundamental rights and freedoms of individuals, in particular their right to protection of personal data … basic provisions on the right to privacy and the protection of personal data form the basis for further legislation on the processing of personal data, both in the current Data Protection Directive 95/46/EU – implemented in Sweden by the Personal Data Act – and in the new General Data Protection Regulation…. The General Data Protection Regulation also aims to create a uniform and equivalent level for the protection of personal data within the EU so as not to hinder the free flow of data within the Union. This is achieved through the direct application of the Regulation in the different Member States and having the same rules apply throughout the Union. Other purposes with developing a new General Data Protection Regulation have been to modernise the Data Protection Directive's rules from 1995 and to adapt them to the new digital society."*[21]

How different actors are able to interpret and implement the GDPR in their various activities and in society as a whole will be a very important process for the value-creating potential of AI in Sweden and for managing potential risks with AI.

[21] Swedish Data Protection Authority, https://www.datainspektionen.se/dataskyddsreformen/dataskyddsforordningen/introduktion-till-dataskyddsforordningen/dataskyddsforordningens-syfte/, 08/04/2018

7 Sweden's ecosystem of companies for AI-related innovation

With the short time available for completing the present report, it has not been possible to provide a comprehensive picture of AI-based activities in Swedish business. In Chapter 4, a brief overview has been provided of the conditions for such activities in different parts of the business sector. This overview was based on surveys and interviews with different companies in Sweden, SWOT analyses from various company constellations, and comments from companies and other actors in connection with a workshop organised by Vinnova on 13 April 2018. This basis has been combined with the knowledge available at Vinnova from the AI-related projects funded by the agency.

In this chapter, an attempt is made to more closely account for different types of company involvement in AI-related development, as well as briefly discuss the links between different types of companies. In addition to the sources mentioned above, a special analysis has been made of Swedish involvement in AI-related patenting. The results of this analysis are presented in detail in Appendix 1 of this report and are summarised in this chapter. Furthermore, data from Arbetsförmedlingen's (Swedish Public Employment Service) database of job listings has been analysed for the period 2011–2017. This data has the advantage of having wide coverage. It has been supplemented with a compilation of AI companies in Sweden from the Nordic Tech List, information from individual companies' websites, as well as general news reports in the open media.

7.1 Swedish participation in patenting within the field of AI

In cooperation with Teqmine Analytics Oy, Swedish actors' patenting within AI has been studied. Teqmine has created a database of patent applications to the European Patent Office (EPO), the United States Patent and Trademark Office (USPTO) and the World Intellectual Property Organization (WIPO). The majority of Swedish participation for international markets is considered to be covered by applications to these patent offices. The same would apply to other countries in Europe and North America, while coverage can be expected to be worse for countries in Asia.

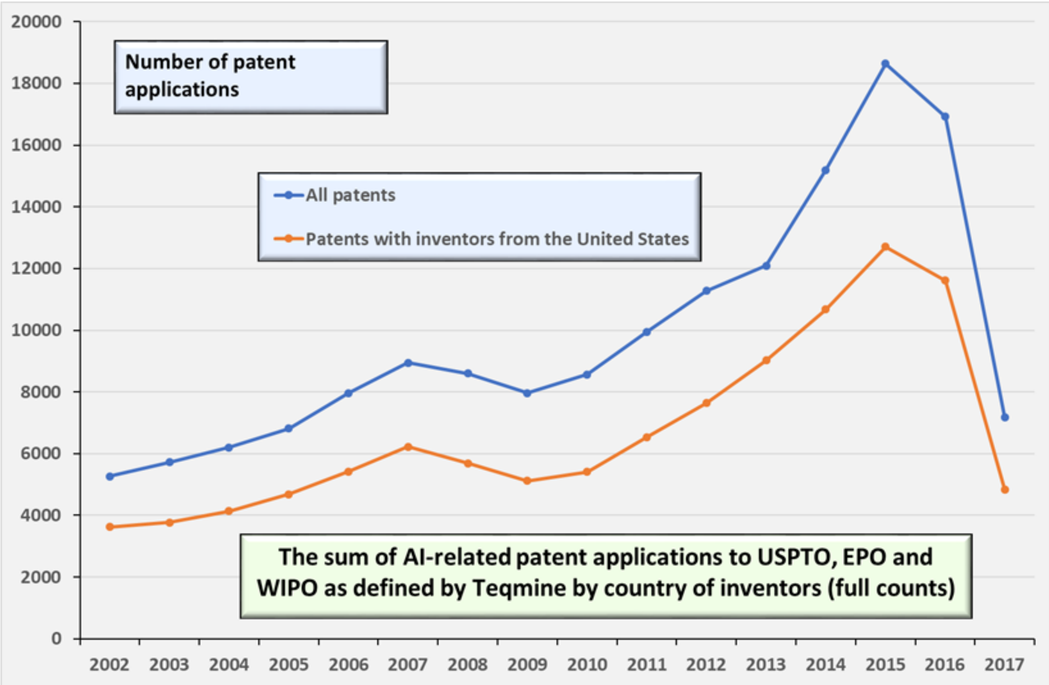
The selection of patent applications is based on a free text search with AI-related keywords in the full text of all patent applications to the three patent offices.[22] A Swedish patent has been defined as a patent where at least one inventor has given a Swedish address in the patent application. The applicant ("assignee") on a patent application is usually an organisation, but in some cases it may be an individual inventor.

[22] The following keywords have been used: artificial intelligence; learning algorithm; machine learning; unsupervised learning; neural network; self-organizing map; self-organizing feature map; kohonen map; bayes classification; support vector machine; clustering algorithm; markov model; random forest; hidden forest; bayesian statistics; classification engine.

Processing of patent applications often takes several years, which affects when and how completely different types of information become available. The time from submission of the application to publication of the application also varies between the different patent offices. The data analysed relates to patent applications published at the end of 2017, which means that most of the applications submitted in 2017 are missing, and the same applies to a not insignificant proportion of the applications from 2016. Some applications from previous years may also be missing. For patent applications published in the last couple of years, information about the assignee is still missing in a lot of cases.

AI-related patent applications have increased sharply since 2010 and growth has accelerated further from 2014, Figure 23. Incomplete data for 2016 and 2017 mean that growth for these years cannot yet be estimated.

Figure 23. Number of AI-related patent applications filed with USPTO, EPO and WIPO which have been published by the end of 2017, by year of submission of application.

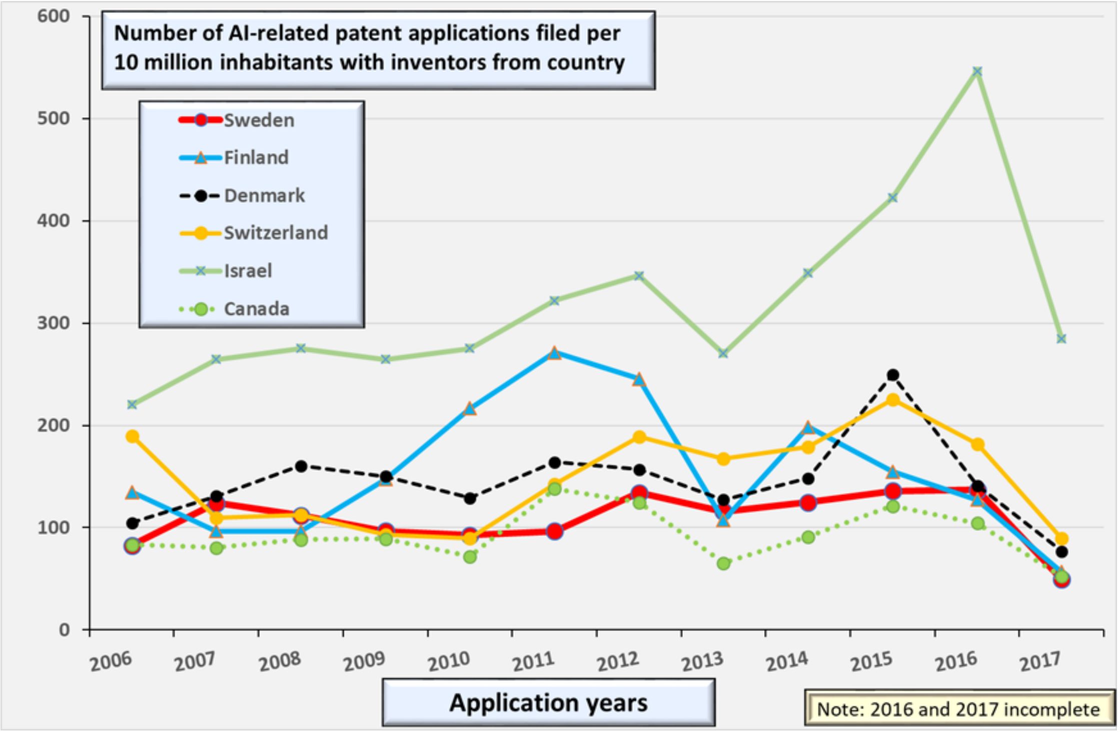


Source: Teqmine and Vinnova

The proportion of patent applications with at least one inventor from Sweden in 2006–2011 was about 1.1 per cent, but dropped to 0.8 per cent in 2012–2017. Given that a patent may include inventors from several countries, the Swedish proportion is relatively modest, and Sweden has obviously not fully kept pace with the rapid growth that has taken place in recent years. To further highlight Sweden's position, a comparison has been made with developments in Finland, Denmark, Switzerland, Israel, Singapore and Canada, Figure 24. The comparison provides further support for the image of Sweden being in a modest position, both in terms of level and development, at least up to and including 2015. Data for 2016 and 2017 is still too incomplete to allow any assured conclusions. Among the comparable countries, Israel's development is very impressive.

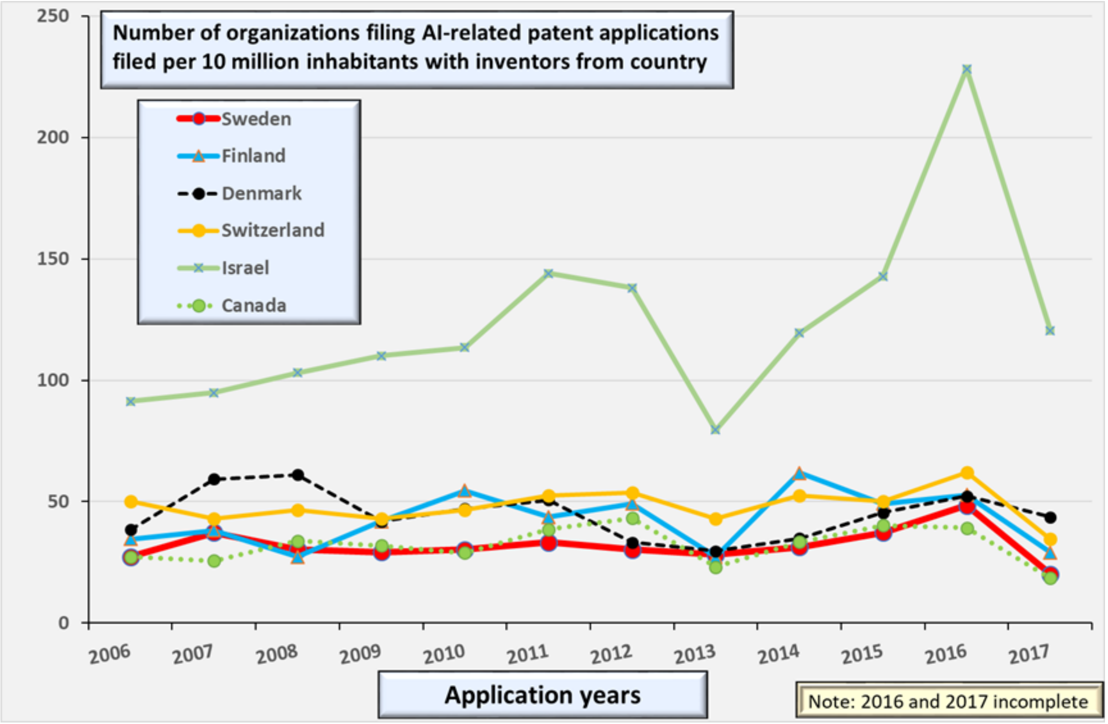
A significant spread of AI patenting to more organisations, most of which are companies, took place in 2015 and 2016, Figure 25. The increase in 2016 will most likely prove to be even greater than shown in Figure 25 when complete data on assignees is established.

Figure 24. AI-related patent applications 2006–2017 with inventors from Sweden and five other countries per 10 million for each country and year for a submitted application



Source: Teqmine and Vinnova

Figure 25. Number of organisations that have applied for an AI-related patent in 2006–2017 with at least one inventor from Sweden and five other countries per 10 million inhabitants for each country and year for a submitted application



Source: Teqmine and Vinnova

Teqmine has used machine learning to divide AI patents into 30 clusters. The clusters vary in size and growth rate. Table 3 shows the number of patents for each cluster for the periods 2006–2011 and 2012–2017. In addition, it presents the proportion of patent applications with inventors from Sweden as well as Sweden's position relative to Finland, Denmark, Switzerland, Israel and Canada calculated per capita. The table also lists individual companies that are assignees with at least 4 patent applications with an inventor from Sweden within their respective patent cluster. Table 4 contains a more complete list of companies with Swedish inventors.

Table 3. Sweden's relative position in AI-related patenting in a global comparison and compared to Finland, Denmark, Switzerland, Israel and Canada for 30 patent clusters

Topic Area	World Total		Sweden's share of World total (%)		Sweden's per capita rank among 6 countries		Assignee organizations with at least 4 patent applications with Swedish inventors 2006-2017
	2006-17 (number)	Increase from 2006-11 to 2012-2017 (%)	2006-11	2012-17	2006-11	2012-17	
Human-Computer Interaction	9632	322	2,3	0,9	4	3	Sony; Assa Abloy; FlatFrog; Ericsson; Huawei
Smart Traffic	5980	137	2,0	1,1	2	2	AB Volvo; Ericsson; Volvo Cars; Husqvarna
Data Science: Modelling-Training-Learning-Classification	6335	118	1,1	0,9	3	4	Ericsson
Electricity - Grids - Therapy - Misc (change name)	3340	115	1,5	0,5	4	5	
Computer Memory and Processing	12981	111	0,2	0,5	6	4	Ericsson; QlikTech; Microsoft; Assa Abloy
Mechanical Sensors	3201	88	1,3	0,5	5	6	
Computer Networks	3627	86	2,0	2,8	2	2	Ericsson
Payment and Transaction Processing	11185	82	0,3	0,2	6	5	
Health and Patient Systems	3374	73	0,7	0,4	5	6	Elekta
VR/AR and Wearable Sensors	3321	68	0,6	0,8	5	5	Tobii
Radiation Therapy - Light - Misc (change name)	3654	66	1,3	0,9	3	3	FlatFrog; Sensa Bues
Natural Language Processing	7976	53	0,4	0,1	5	6	
Signal Processing (Radio)	4508	46	1,4	1,6	5	2	FlatFrog; ABB
Information Search and Recommendations	9648	46	0,7	0,6	5	4	Ericsson; Sony, Spotify
Cameras and Image Processing	9201	46	1,0	0,7	4	5	Tobii; Autoliv; Ericsson; Exini Diagnostics
Industrial Process Control	2698	30	0,9	1,4	5	4	Ericsson
Nanotechnology for Semiconductors	1391	29	1,0	0,1	4	5	
Cellular Network Management (Radio)	2698	28	1,1	4,3	3	1	Ericsson; Assa Abloy
Combustion Engines - (Gas - Oil - Fuel) (cahnge name)	2494	25	1,9	0,3	4	6	AB Volvo
Gene Technology 2	1678	24	1,2	0,3	6	5	
Speech & Sound Recognition	3698	21	1,6	1,2	5	4	Ericsson, Dolby, Google; Sony
Health Diagnostic - Biomarkers (Personal Health?)	3304	12	1,9	1,4	5	4	GE Healthcare; Immunovia; Sensa Bues; AstraZeneca
Drug Modelling and AI for Pharmaceuticals	4053	-1	2,3	0,9	4	4	AstraZeneca; Immunovia; Apodemus
Clustering Algorithms	6200	-5	2,9	1,2	2	4	Ericsson; FlatFrog; Scania
Document Identification - Authentication - Translation	2123	-7	1,1	0,4	3	5	GE Healthcare
Genetic Cancer Testing	2090	-9	0,8	1,6	6	3	Immunovia
Gene Technology 1 (DNA Sequence Modelling)	3194	-25	0,4	0,4	5	6	Novozymes; Henkel AG & Co. KGaA
Horticulture and Agriculture	143	31	(too few patent applications in 6 countries)				
Digital Data Processing	3658	33	(too few patent applications in 6 countries)				
Virtual Reality Displays	683	44	(too few patent applications in 6 countries)				
All Topics	**138068**	**61**	**1,1**	**0,8**	**5**	**5**	

Source: Teqmine and Vinnova

The tables show that Ericsson strongly dominates Swedish AI patenting with computer networks and the operation of mobile communications networks as particular areas of strength, which means that these areas also appear as areas of strength for Sweden, a position that has also been strengthened. Smart transport and vehicles represent one of the fastest subareas for patenting within AI and is of particular importance for Sweden which has several major vehicle companies in the country. In this area, with regard to patenting, Sweden has not been able to keep pace with developments globally but rather has seen its share of patenting halved. About a quarter of all AI patents with one Swedish inventor have foreign organisations as assignee. Most of the current groups have no or very limited R&D in Sweden.

Table 4. Companies that, as an assignee, applied for at least 4 AI-related patents, each with at least one inventor from Sweden 2006–2017

Company/Business Group	Swedish Org		Foreign Org		Total
	2006-2011	2012-2017	2006-2011	2012-2017	
Ericsson	94	132			226
SONY (and earlier Sony Ericsson)	39	14		13	66
FlatFrog Laboratories AB	15	20			35
AB Volvo	29	5			34
Tobii AB	2	12		6	20
ABB	2		5	11	18
Immunovia AB	8	9			17
Assa Abloy AB		17			17
AstraZeneca	10		5	2	17
Scania	7	3			10
SPOTIFY AB		10			10
Volvo Car Corporation	1	9			10
GE Healthcare	1	4	5		10
Huawei Technologies Co., Ltd.		1	3	6	10
SensAbues AB	4	5			9
Vermillion, Inc	3		5		8
Google Inc.			2	6	8
Autoliv	4	3			7
QlikTech International AB		7			7
Fingerprint Cards AB		6			6
DOLBY Laboratories Licensing Corp			2	4	6
Zi Decuma AB	6				6
Elekta AB (Publ)		5		1	6
Skype Limited			6		6
NOVOZYMES A/S			4	1	5
Microsoft Corporation			5		5
HUSQVARNA AB		5			5
DeLaval Holding AB	2	3			5
GN ReSound A/S			4	1	5
HENKEL AG & CO. KGAA				5	5
Integrum AB	2	2			4
EXINI DIAGNOSTICS AB	4				4
Cellavision AB	3	1			4
MKS Instruments, Inc.			4		4
Apodemus AB	4				4
Axis AB	2	2			4
20 organizations with 3 patent applications	20	16	18	6	60
47 organizations with 2 patent applications	35	22	26	11	94
115 organizations with 1 patent application	24	40	28	23	115
name of organization missing		2	1	5	8
All organizations	**321**	**355**	**123**	**101**	**900**

Source: Teqmine and Vinnova

A closer look at companies that have applied for AI-related patents with an inventor from Sweden shows that these can be broadly divided into the following groups:

- LM Ericsson
- Large groups with headquarters in Sweden, which have chosen to almost exclusively apply for patents from a parent company or subsidiary registered in Sweden, for example: AB Volvo, Assa Abloy, Scania, Volvo Cars, Autoliv, Elekta, Husqvarna, DeLaval.[23]

[23] Volvo Cars and Scania are part of foreign-based groups and Autoliv's parent company is registered in the United States.

- Large foreign-based groups with headquarters outside Sweden but with extensive R&D in Sweden. These groups have to varying degrees applied for patents through subsidiaries in Sweden as well as parent companies or subsidiaries outside Sweden, for example: Sony Mobile (incl. former Sony Ericsson), ABB, Astra Zeneca, GE Healthcare.
- Large foreign-based groups with no or negligible R&D in Sweden. Almost all patenting has taken place through parent companies or subsidiaries outside Sweden, for example: Microsoft, Huawei, Novozymes, Dolby, Google, GN Resound, Henkel, MKS Instruments
- Young companies and start-ups within the IT area, of which several have been bought by foreign companies, for example: FlatFrog, Tobii, Spotify, Qlik Tech, Fingerprint Cards, ZiDecuma, Skype, Axis, Mapillary, Asplund Data, Context Vision, Cint.
- Young companies and start-ups within life science, of which a few have been bought by foreign companies, for example: Immunovia, Integrum, Exini, SensAbues, Cellavision, Apodemus.

In the group of young IT companies, there are several of the most successful young technology-based companies in Sweden.

7.2 A more complete picture of the ecosystem of companies in Sweden for AI-related innovation

Although patents can play an important role as intellectual property (IP) for competitiveness within AI-related activities, the relative importance of the patents varies depending on the business area. Access to large amounts of relevant and well-structured data is of crucial importance in many cases. Development of new business models and the ability to work in an integrated manner across a company's various functions and with partner companies also plays a major role.

The picture of the Swedish business community's commitments as indicated above based on patent data is therefore incomplete in many respects. By supplementing with other information as described in the introduction to this chapter, it is possible to identify more fully the categories of companies that together in the coming years will constitute the ecosystem of companies for AI-related innovation in Sweden. A rough attempt in this direction is shown in Figures 26 and 27.

Ericsson is a unique company in the Swedish innovation system with by far the largest R&D activity in Sweden. This, combined with the fact that AI is a key technology for the company, plays a very central role in the ecosystem for AI-related innovation. In the case of other parts of the business sector that are already highly committed to AI-based development, these are mainly found in the transport equipment industry as well as in a number of relatively young but already successful internet-based companies.

Figure 26. An overview of the ecosystem of companies for AI-related innovation in Sweden

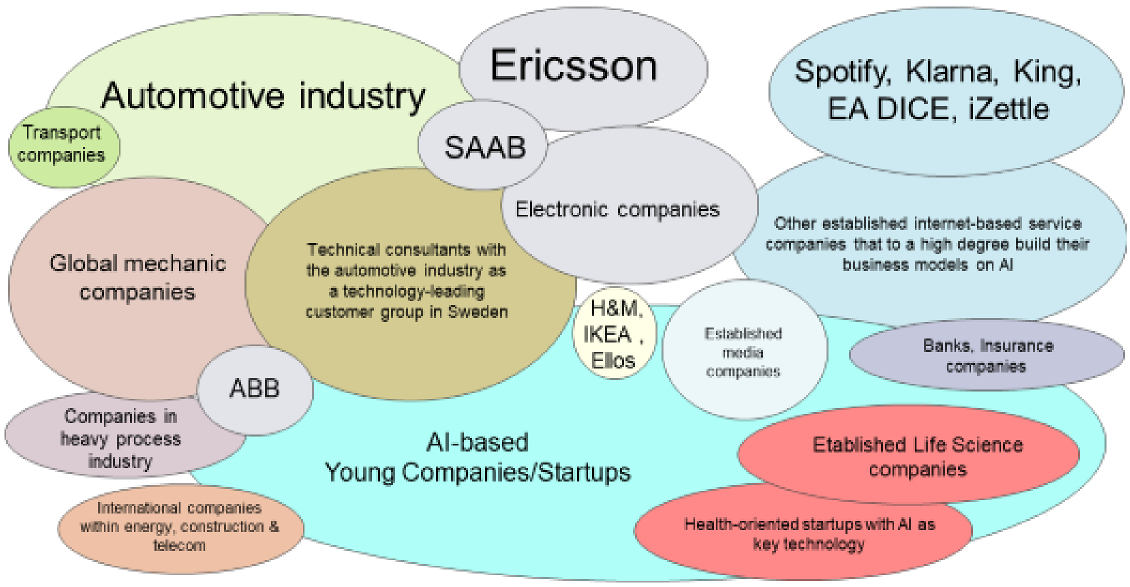
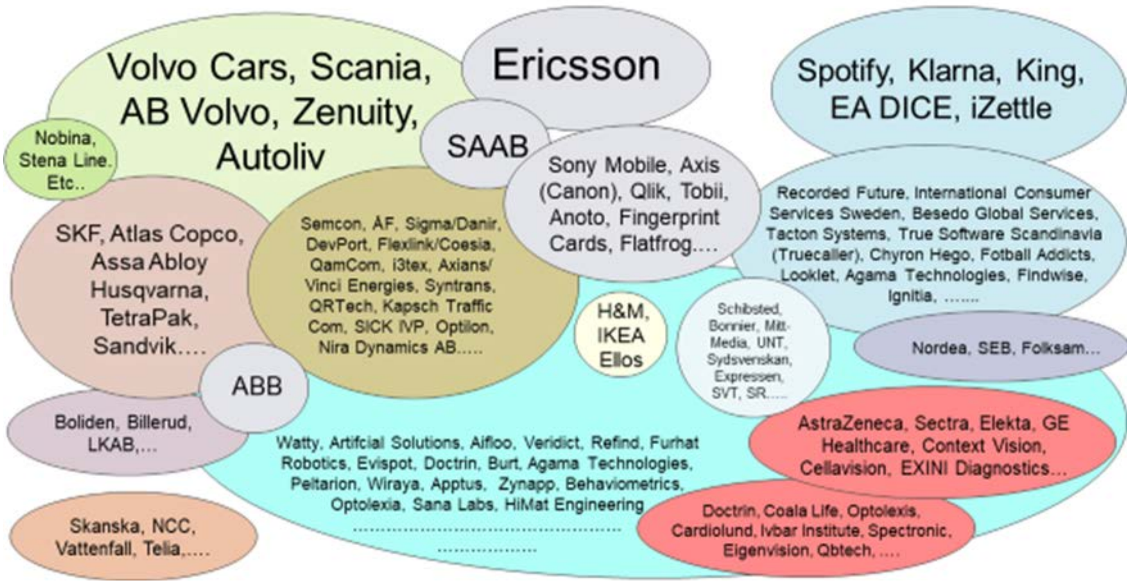


Figure 27. An overview of the ecosystem of companies for AI-related innovation in Sweden with an exemplification of companies in broad company categories in Figure 26



For its size, Sweden has a uniquely large and advanced transport industry with three globally active vehicle companies and the SAAB defence group with the development and manufacture of both combat aircraft and submarines. Autoliv, the world's leading vehicle safety company, also has an important part of its R&D in Sweden. In 2015, the transport equipment industry alone accounted for over one fifth of the Swedish business sector's R&D. Scania, AB Volvo, Volvo Cars, SAAB and Autoliv[24] all have extensive and multi-faceted AI-based development. In April

[24] Beginning in the third quarter of 2018, Autoliv will be divided into two companies; one for so-called passive security that will continue under the name Autoliv, and a new company, Veoneer, which will take over the development of products for driverless vehicles, advanced driver-assistance systems and electronic products for vehicle safety.

2017, Volvo Cars and Autoliv established a jointly owned company, Zenuity, to drive the development of autonomous vehicles. With offices in Göteborg, Linköping, Munich and Detroit, the company expects to have 600 employees within a couple of years. In addition to the use of AI for vehicle propulsion, Scania and AB Volvo use AI for the development and implementation of new services for, among other things, preventive maintenance and improved fuel economy.

The development of autonomous vehicles is particularly demanding with high complexity in the systems being developed, the need to integrate many different technologies, and the requirement to achieve very high reliability in real time with short response times. The use of AI in the transport sector is not limited to the transport equipment industry, but also largely affects transport service companies.

In contrast to the long-established automotive industry in Sweden, the internet-based companies that have been developed, especially in Stockholm, into successful international companies are relatively young. Skype was the pioneer company, but since it was acquired by Microsoft, there are virtually no employees left in Sweden. Spotify, which has revolutionised the music industry through its music streaming service, and the two fintech companies Klarna and iZettle are still Swedish-owned. The two gaming companies King and DICE are currently owned by Activision Blizzard and Electronic Arts respectively.

Overall, these five companies had, at the end of 2016, over 3,000 employees in Sweden in total and could be said to be the core of the internationally acclaimed ecosystem for developing internet-based services that have been built in Sweden with a strong concentration in Stockholm. This ecosystem is very well connected internationally. As the companies work completely digitally in relation to a global consumer market and thus have access to extensive consumer data, AI offers great opportunities for business development which the companies have built up competence in order to realise.

There are a further large number of companies originating in Sweden that offer internet-based services that are highly dependent on AI and which are still smaller and/or in the earlier stages of development than those just mentioned. It is notable that the majority, if not all, have their sights set on a global market.

One group of companies gathered under the somewhat misleading category "electronics company" has at least initially focused more on the development of products rather than services and is well represented among Swedish companies with many AI patents. Most of these have their head office in Lund-Malmö. Sony Mobile, formerly Sony Ericsson, has been the company in Sweden that has applied for most AI patents after Ericsson. Following gradual downsizing, operations are now significantly smaller than before. At the same time, the company has probably served as a nursery for other companies. The most successful of the companies in the group is Axis. It was acquired a few years ago by the big Japanese technology group Canon, which is building a new headquarters for Axis in Lund with room for 1,300 employees. Qlik and Tobii are two other companies that have grown rapidly to a substantial size and are generally considered successful even if they are still reporting a loss. Qlik has been acquired by the US equity company Thoma Bravo, which has moved its headquarters to the

United States. Tobii, which has its headquarters in Stockholm, has developed eyetracking technology in which AI is an important component.

Among companies with many AI patents, a group of life science companies can be found with AstraZeneca at the forefront. Elekta is the largest Sweden-based medical technology company, followed by Sectra. For several of these companies, the use of AI methods is focused on image analysis in one form or another, an area of research deemed strong in Sweden. Recently, a “national arena for research and innovation concerning artificial intelligence, AI, for medical image analysis (AIDA)” was established through a grant from the strategic innovation program Medtech4Health. AIDA’s physical core environment is the Center for Medical Image Science and Visualization (CMIV) at Linköping University. Sectra has the handling of medical images as one of its main areas. Cellavision, Exini Diagnostics, both based in Lund, and Context Vision, currently based in Stockholm, are all building their business today to a large extent on the use of AI for the analysis of medical images.

A large number of companies with primary or strong focus on AI have been formed in recent years. Nordic Tech List has identified more than 160 companies active within “AI & Machine learning”. Of these, just under two thirds were established in 2013 or later. Some of these develop internet-based services that they themselves market to end customers or intend to market. Some of these are services within health and social care. Other companies see their role rather as suppliers of AI expertise to other companies. Without doubt, there is a great need to gain access to such expertise in many companies, and in public organisations as well.

The latter companies can be seen as a subset of IT and technical consultants, a large and growing sector within Swedish business. There is a strong indication that the interaction between, on the one hand, IT and technical consulting companies and other knowledge-intensive service companies, and on the other hand, activities in global companies operating in Sweden today is the central axis around which innovation development is taking place with a view to a global market. The vast majority of graduate engineers and computer scientists and PhDs within mathematics, computer science, technology and science that enter the business sector are today employed in knowledge-intensive service companies of widely varying sizes. Utilisation of the competence found at these companies for value creation requires adding it to global value chains. The main channel for this is through large global companies with development and production in Sweden. An alternative channel, but nonetheless a significantly narrower channel value-wise, is the young internet-based service companies that are independently able to market their digital services internationally.

If this role of IT and technical consultancy companies in the Swedish innovation system is correct, it is very important that these companies quickly build up expertise within AI so that they can offer this to their global corporate customers in Sweden. A large part of this competence building needs to be done through the continuing professional development of existing staff. It is hard to judge how far IT and technical consultancy companies have come in this process, but there are strong indications that most things remain to be done.

There are a large number of global companies with a substantial part of their R&D base and production in Sweden, in addition to those already discussed. Although these companies are likely to be in great need of using external AI competence, it is imperative that they also build up internal AI competence internally. This occurs to a certain extent, but the rapidly changing requirements in the area of competence building are high. Sweden has an expansive mechanical industry and heavy process industry, so it is important that AI is highly utilised in these industries. The mechanical industry's potential to utilise AI to develop and implement services that create increased and in some respects brand new customer benefits is similar to that already mentioned for the heavy automotive industry.

Ikea and H&M are unique companies that, by virtue of their global consumer market, potentially have access to extensive customer data and thereby extremely good prospects for pursuing AI-based business development. Sweden also has large international companies in the construction industry, energy production and banks with sufficient resources to seriously engage in the use of AI in the development of their operations, therein contributing to the development of AI usage in Sweden in their sectors.

8 Sweden's AI research

The rapid development of applications of AI that has taken place in recent years has not primarily been based on new scientific evidence but rather has primarily been based on an explosion in the availability of data in electronic form and increased computing power. These practical advances have, of course, also had an effect on the research conducted in the world and have led to increased interest in further developing known AI methods and algorithms as well as attempting to develop completely new methods adapted to the new conditions in terms of data availability and computing power.

By analysing the publication of articles in scientific journals, it is essentially possible to get an overview of research activities within a particular area. The extent of the scientific publication can give a good idea of the extent of the underlying research, but there is hardly any unequivocal proportionality between the two. The relative value of the published scientific contributions varies.

What makes bibliometric analysis – i.e. the analysis of patterns in scientific publication – unique is that it can use the fact that the exchange of scientific information through publication in scientific journals largely constitutes an integrated global system and that there are databases that cover a very large proportion of journals generally considered important by participants in this system.[25] In bibliometric analysis, it is common to use the occurrence of citations of an article in other scientific articles as a measure of the "quality" of the article.

The driving forces to openly communicate the results of independent research vary between different types of organisations and depending on the goals and content of the research. There are also ways of communicating scientific knowledge other than publishing in scientific journals. Within the academic world in particular, there is a strong driving force to publish, as this greatly influences career opportunities. For these and other reasons, bibliometric analysis does not produce simple and absolute conclusions about the scope and character of the underlying research, but properly used it can provide valuable indications that then need to be scrutinised and further evaluated using other information and other methods.

For research in artificial intelligence, bibliometric analysis offers some particular challenges:

- A major and important part of the scientific communication within AI takes place at conferences. The documentation from AI conferences in databases that forms the basis for bibliometric analysis is incomplete and of inferior quality compared to that of regular articles in scientific journals.
- Research where AI is used within specific applications is not necessarily published in AI journals or at AI conferences, which makes it difficult to identify this type of research.

Below, different data sources and methods will be used to try to explain these challenges. One of these is data for articles in journals that in the Clarivate Analytics database Web of Science have been classified as belonging to the subarea "Artificial Intelligence" within the broader field

[25] All research areas are not equally as global in nature, which affects the usability potential of bibliometric analysis.

of "Computer Science". In addition to comparisons of publication volume, this data also provides the opportunity to compare citation rates for articles from different countries. This is especially important in assessing the importance of the huge expansion in the volume of published articles from China.

Most of the articles found in Web of Science in AI journals are so-called "proceeding papers" and originated as a contribution to conferences. Conferences are thus largely represented among the publications in AI journals. However, a review of which conferences are included in the Web of Science database shows that the coverage of the highest rated AI conferences is low. Based on data from another bibliometric database, Scopus, a special review has thus been performed of contributions to the 19 highest ranked AI conferences.

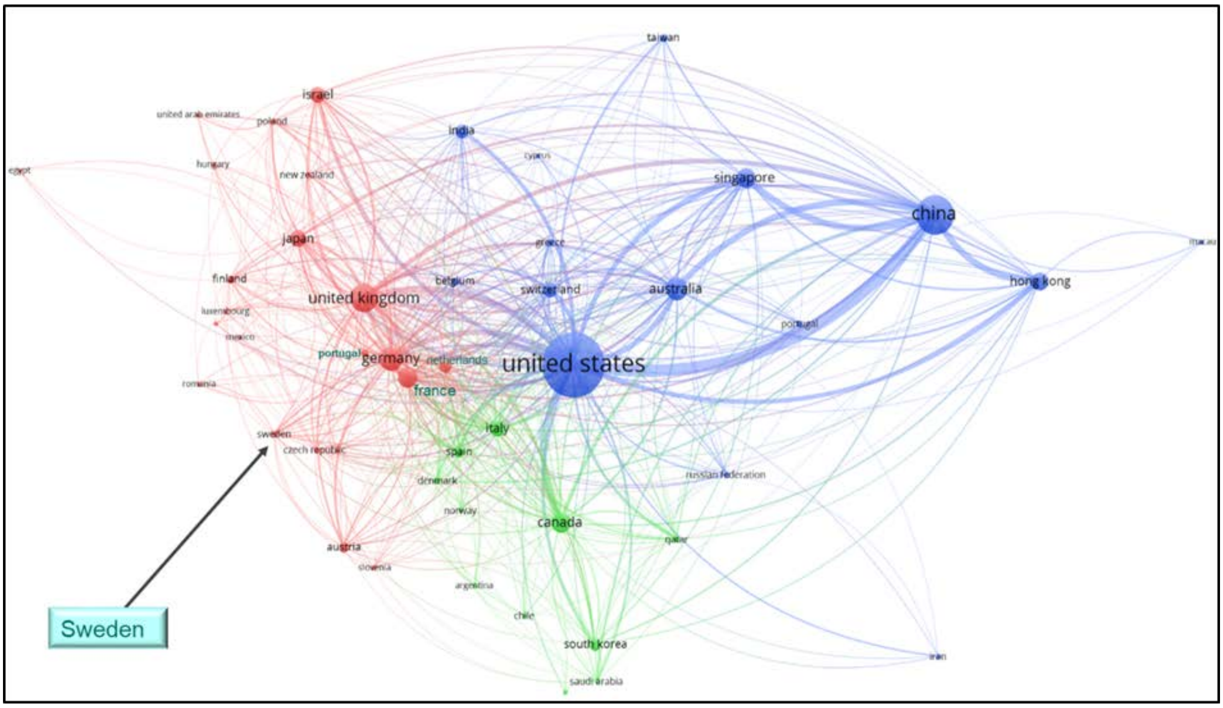
The significant global attention that has come to focus on artificial intelligence in recent years is primarily grounded in the increased use of machine learning in various applications. What is referred to as "deep learning" has yielded particularly striking results. In order to, at least to some extent, capture the dynamics of this development, the results of an article search based on keywords are presented, specifically "artificial neural net", a commonly used term that is closely linked to deep learning.

In conclusion, the three afore-mentioned types of data are used to give an idea of how AI research in Sweden is distributed among different organisations.

8.1 The USA dominates the research front but China is quickly gaining ground

It is a general perception that the development in the field of AI, both research-wise and commercially, is dominated by the United States with China as the main challenger, while Europe has tended to lose ground relatively speaking. Analysis of contributions to the 19 highest ranked AI conferences since 2010 strongly supports this view, Figure 28. American researchers participate in almost half of all conference contributions. Researchers from China have increased their attendance at the conferences. Their share is approaching one fifth. It is worth noting that there is a great exchange between researchers in the USA and China in the form of co-authorship.

Figure 28. Conference contributions during the 19 highest ranked series of AI conferences 2010–2017

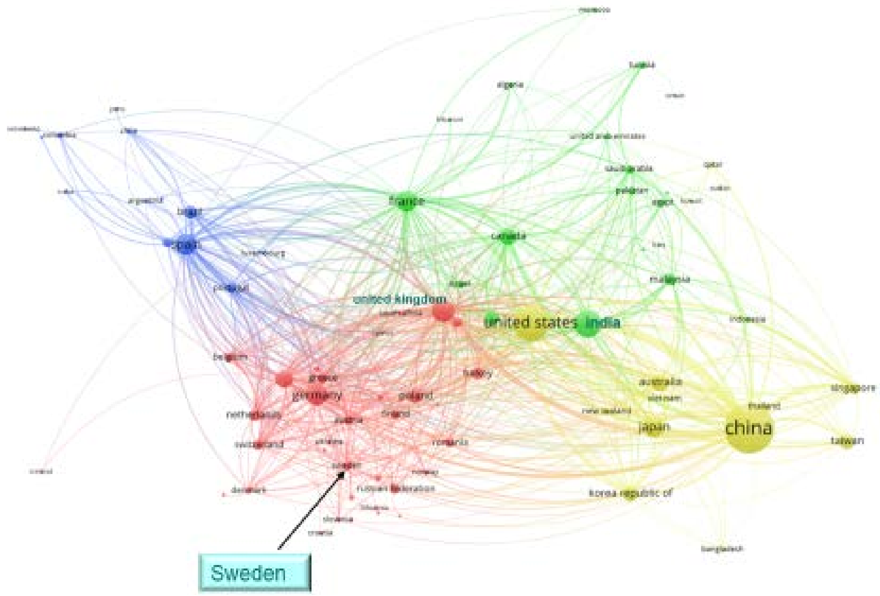


Source: KTH Bibliometric Group and Vinnova. Processing data from Scopus

If the comparisons are broadened to apply to all articles published in journals classified as belonging to AI as a subarea of computer science, the picture changes significantly – in particular, China's position is strengthened, Figure 29. In this respect, Chinese authors dominate in a quarter of all publications, compared to about one-seventh with authors from the USA.

The differences described can be seen as an expression of the differences in the average level of AI research conducted in the USA and China, where the highest ranked AI conferences represent the research front within AI research. The number of times that scientific articles or conference contributions are cited by other researchers is a commonly used indicator of "research quality". A few years ago, the average citation rate for articles published 2012–2015 within AI with authors from China was only a little over a third of that for articles with authors from the United States. Although the average was low for Chinese publications, among the 10 per cent highest-cited publications there were nearly as many with authors from China as from the USA.

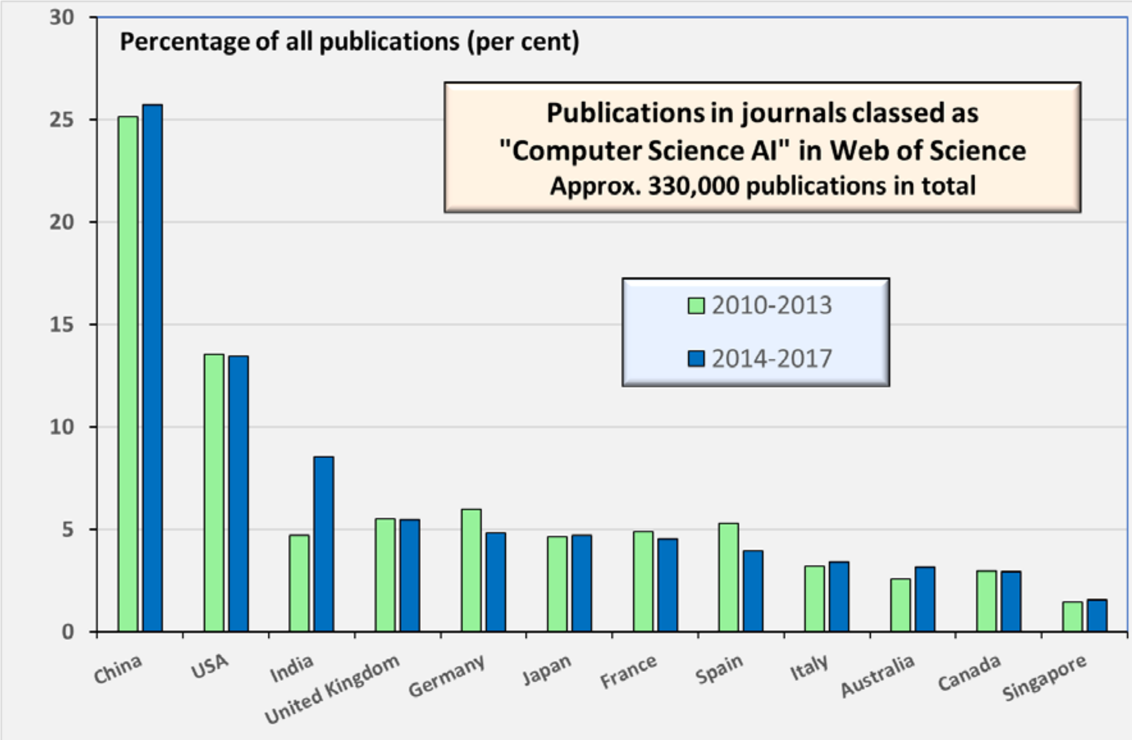
Figure 29. Publications in journals classified as "Computer Science - Artificial Intelligence" in Web-of-Science with a publication year as and from 2012 and registered in a database up until September 2017



Source: KTH Bibliometric Group. Processing data from Web of Science

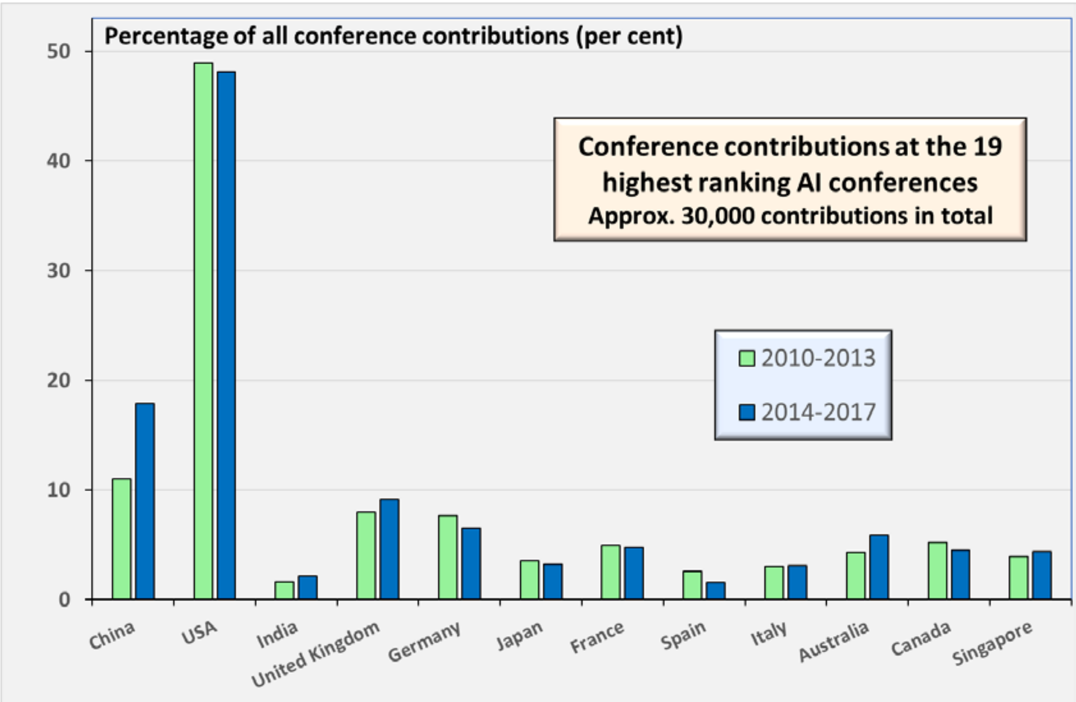
Figures 30 and 31 allow a direct comparison of the national distribution of conference contributions to the leading AI conferences and wider publication in AI journals. China's increased presence at the most prominent AI conferences is significant. India has increased its publication volume significantly but has low attendance at the leading AI conferences. Unsurprisingly, coming up behind the USA and China are bigger countries in Europe and Japan. What is more unexpected is the strong position held by Australia, Canada and Singapore. Canada is on the same level as France with a population of only half the size. Australia is not far behind Germany in conference contributions with a quarter of Germany's population. The fact that Singapore, with just under six million inhabitants, has almost as many conference contributions as France says a lot about how strong research has grown in Singapore. Considering that research within AI, as well as most other areas, is highly concentrated to only two universities, it is clear that Singapore has very strong research environments that also have strong links to both the USA and China.

Figure 30. Leading countries' share of the world production of publications in AI journals in Web-of-Science



Source: Vinnova. Processing data from Web of Science
Note: The data for 2017 is incomplete. Data retrieval was done on 4 April 2018.

Figure 31. Leading countries' share of conference contributions to the 19 highest ranked conference series within AI



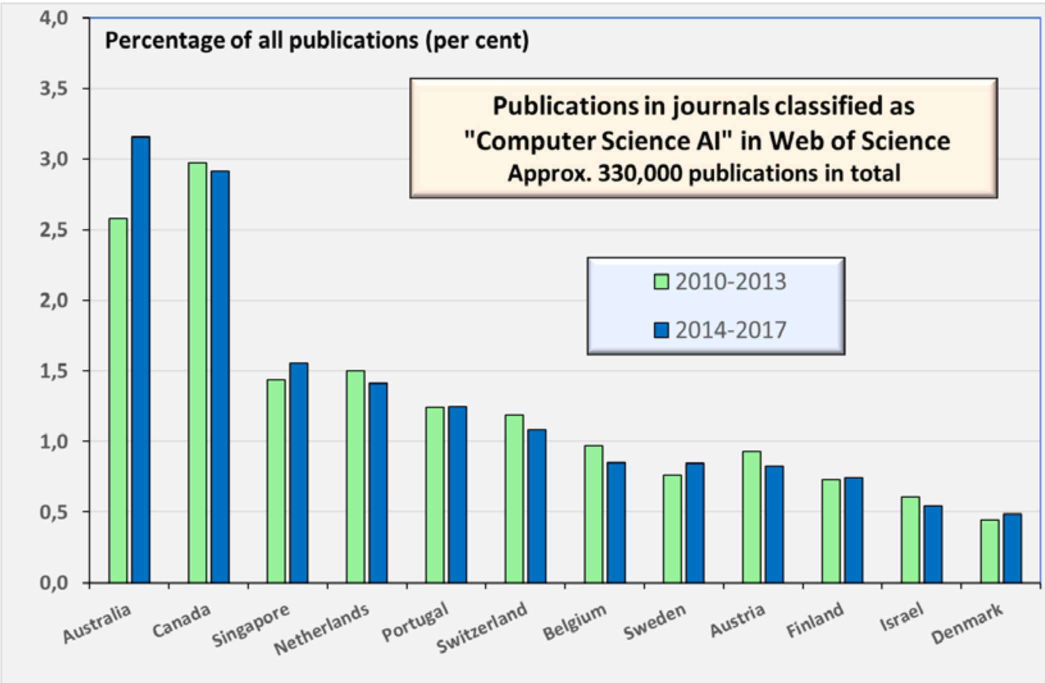
Source: KTH Bibliometric Group and Vinnova. Processing data from Scopus

8.2 Within AI research as a whole, Sweden is relatively weak

Figures 32 and 33 show data corresponding to that just discussed for Sweden and for countries that are reasonably comparable in regard to development level and population size. The populations of Canada, Australia and the Netherlands have about three times, twice and 1.6 times that of Sweden, while Portugal, Belgium and Austria basically have the same number of inhabitants. Switzerland and Israel have an approximately 15 per cent smaller population, and Singapore, Finland and Denmark have just over half.

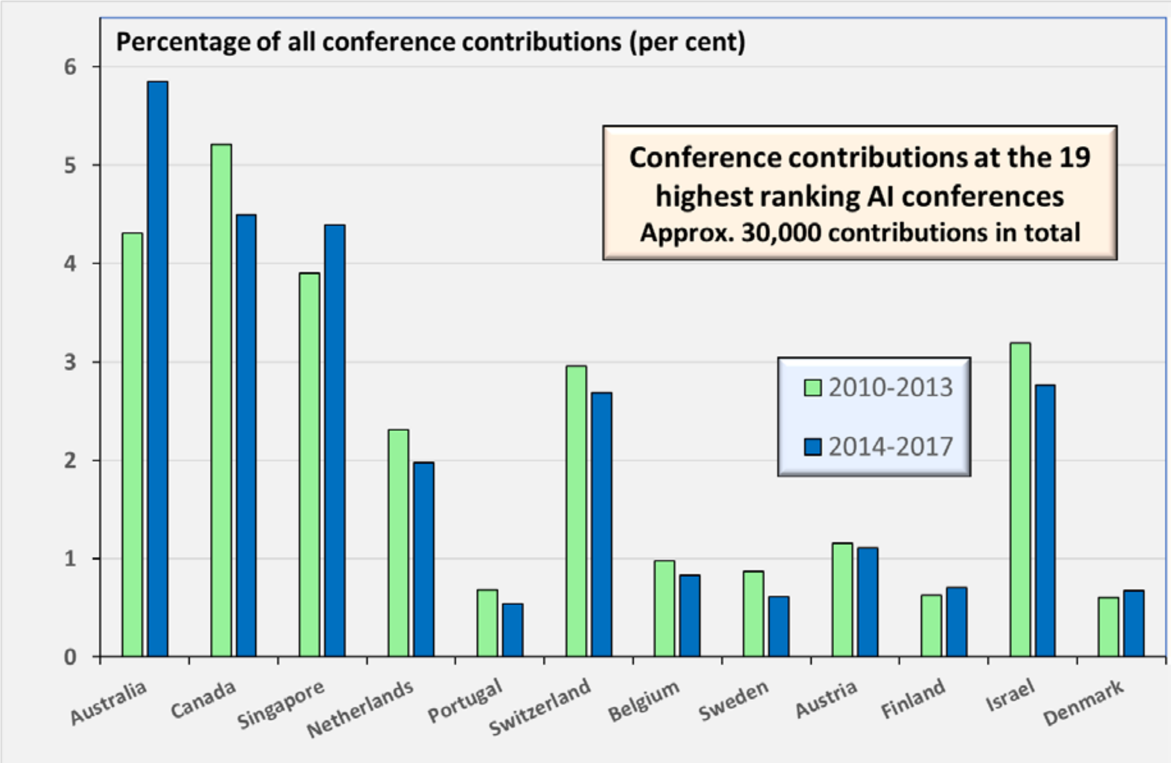
With these differences in population size in mind, Sweden's position within AI research must be considered weak. This applies in particular to attendance at the leading AI conferences where, on a per capita basis, only Portugal is at the same low level as Sweden among the listed countries. There is also no positive trend identified for Sweden. After Singapore, calculated per capita, Israel and Switzerland show the strongest conference presence with Australia shortly after.

Figure 32. Share of the world production of publications in AI journals in Web-of-Science for countries comparable to Sweden



Source: Vinnova. Processing data from Web of Science
Note: The data for 2017 is incomplete. Data retrieval was done on 4 April 2018.

Figure 33. Share of conference contributions to the 19 highest ranked conference series within AI for countries comparable to Sweden



Source: KTH Bibliometric Group and Vinnova. Processing data from Scopus

The selection of the 19 highest ranked AI conferences does not necessarily provide a true and fair view of the extent of AI research at the front line in Sweden. The conferences cover all subareas of AI. Among other things, there is no conference focused on robotics, a relatively strong area in Sweden, among the 19 conferences. Similar remarks can probably be made regarding other research areas that have large, and often growing, elements of AI but where the main conferences have a different focus than AI. This applies, in particular, to more application-oriented AI research within, for example, medicine and self-driving vehicles.

Even with these reservations, it seems undeniable that AI research in Sweden is too scarce and too limited in its contact with cutting-edge research in the area. This, of course, does not exclude the fact that individual research groups conduct high-quality research, but even the most established environments are relatively small in an international comparison.

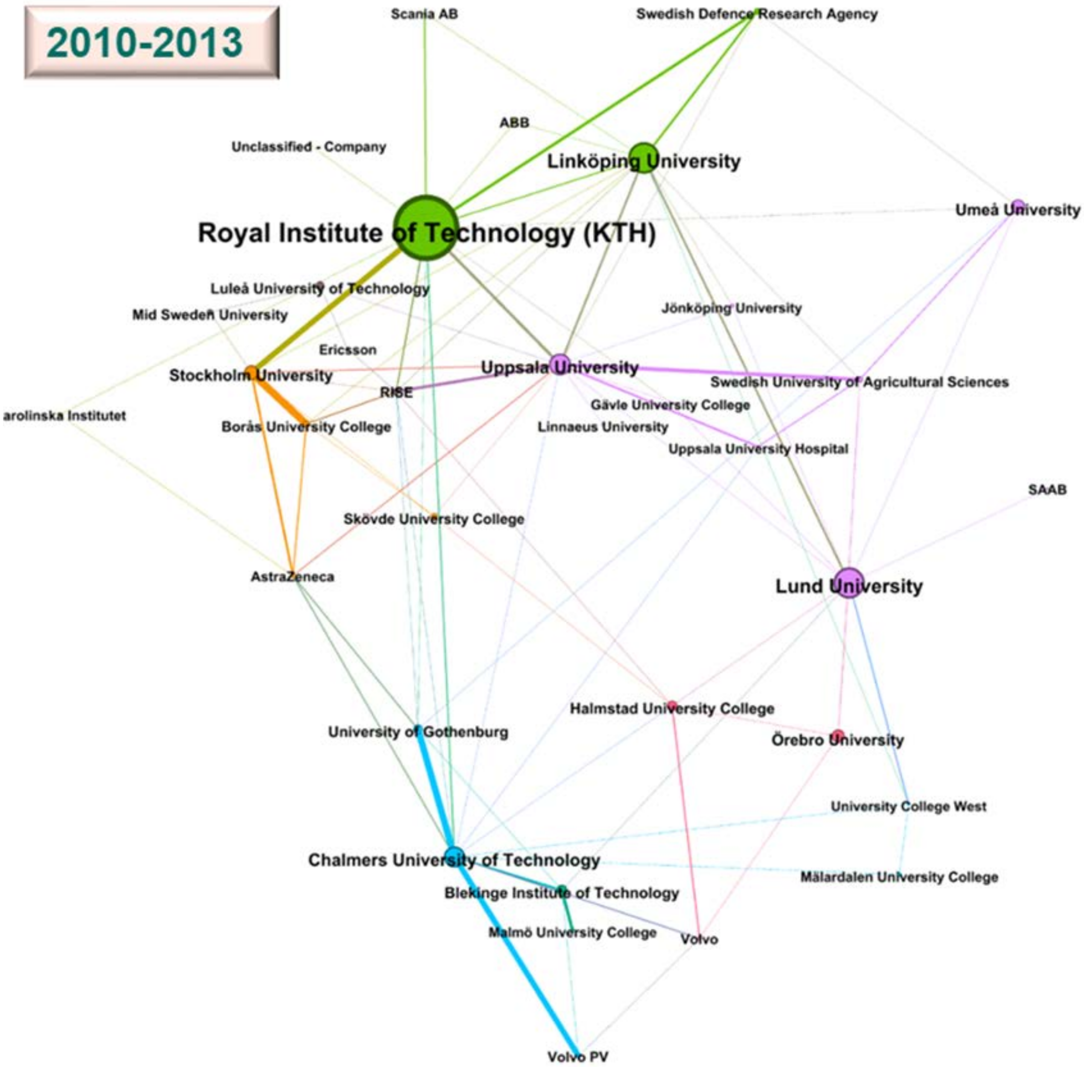
8.3 Research environments within AI in Sweden

To get a picture of the structure of the Swedish research system within the field of AI, data on publication in AI journals has also been analysed at the level of individual researchers, their research environments and their connection to each other through co-publishing. Figures 34–37 present the same type of data discussed so far at a national level for individual universities, institutes and other organisations in Sweden.

The most extensive AI research in Sweden is conducted at KTH, followed by Linköping University. These are followed by Chalmers, Lund University and Uppsala University with approximately the same volume of publication. AI research is also conducted at the young universities and KTH's dominance has diminished in pace with the research expanding considerably at several higher education institutions.

In terms of participation in leading AI conferences, this is roughly divided between the five above-mentioned universities and RISE Swedish Institute of Computer Science (SICS), while the contribution from other higher education institutions is marginal. As the focus of AI research can vary widely between different organisations and the area coverage is uneven, concrete conclusions should not be drawn from the involvement of individual organisations in the 19 selected conferences.

Figure 34. Organisations in Sweden with at least two publications between 2010–2013 within "Computer Science – AI" in the Web-of-Science database as well as links between organisations through co-authorship

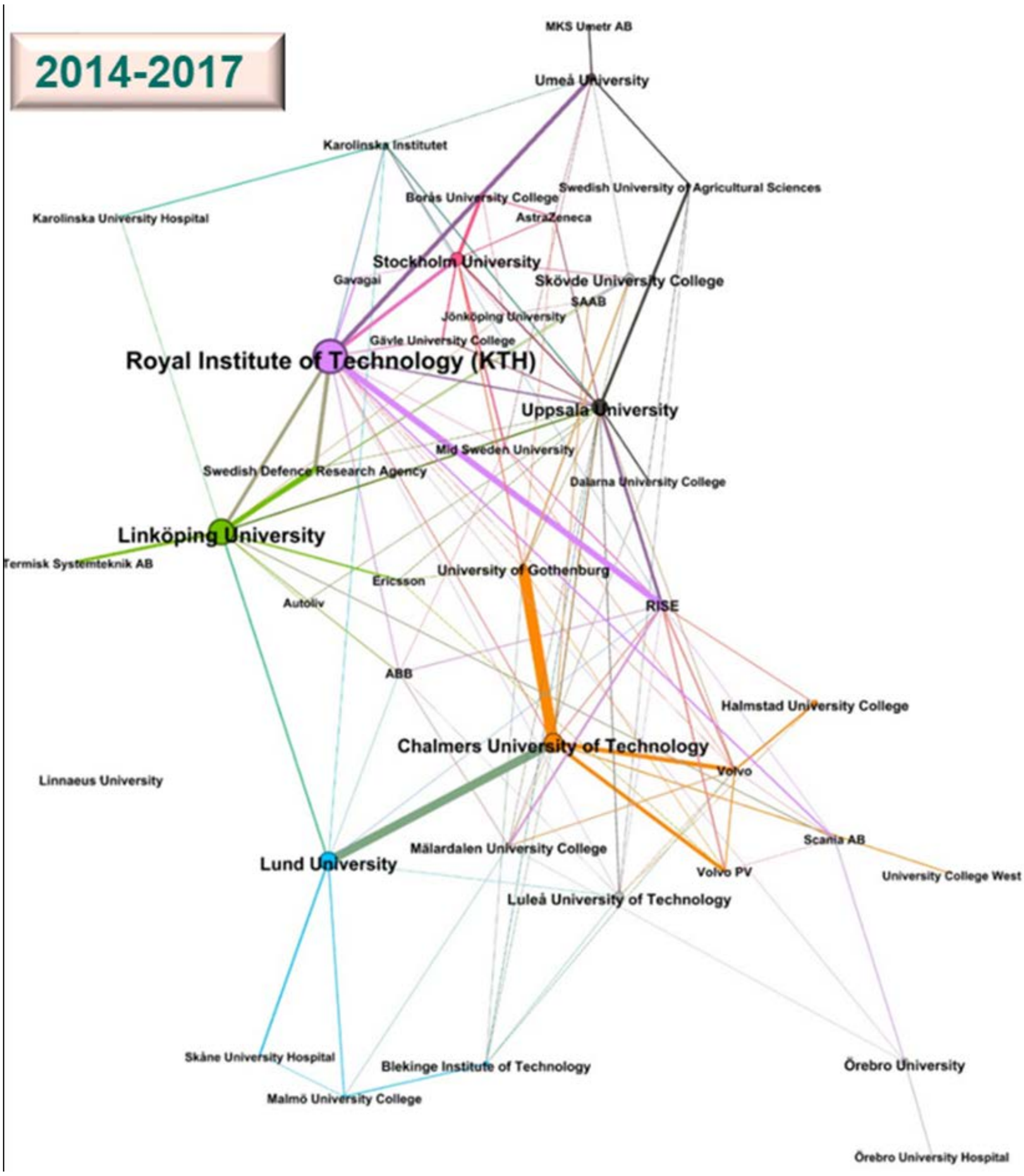


Source: Swedish Research Council. Processing data from Web of Science

The larger research environments emerging include, Figure 35:

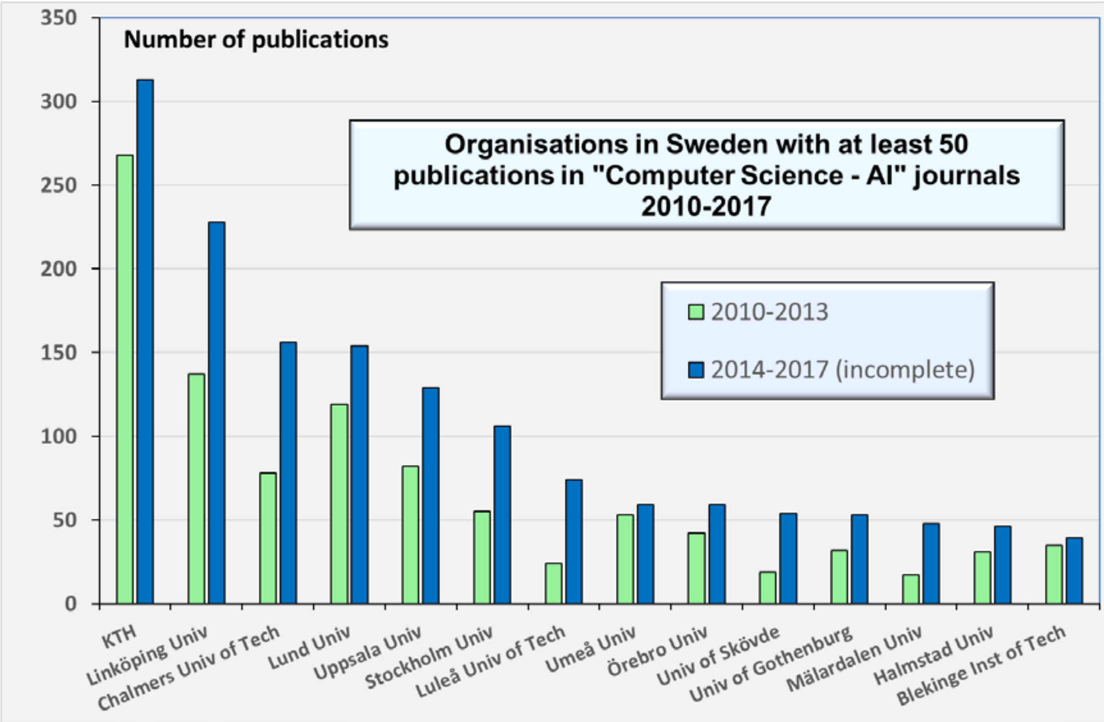
- Department of Robotics, Perception and Learning, KTH
- Department of Speech, Music and Hearing, KTH
- Mathematical Imaging Group, Lund University
- Computer Vision Laboratory, Linköping University
- Department of Information Technology, University of Borås/Department of Computer and Systems Sciences, Stockholm University
- Center for Applied Autonomous Sensor Systems, Örebro University

Figure 35. Organisations in Sweden with at least two publications between 2014–2017 within "Computer Science – AI" in the Web-of-Science database as well as links between organisations through co-authorship



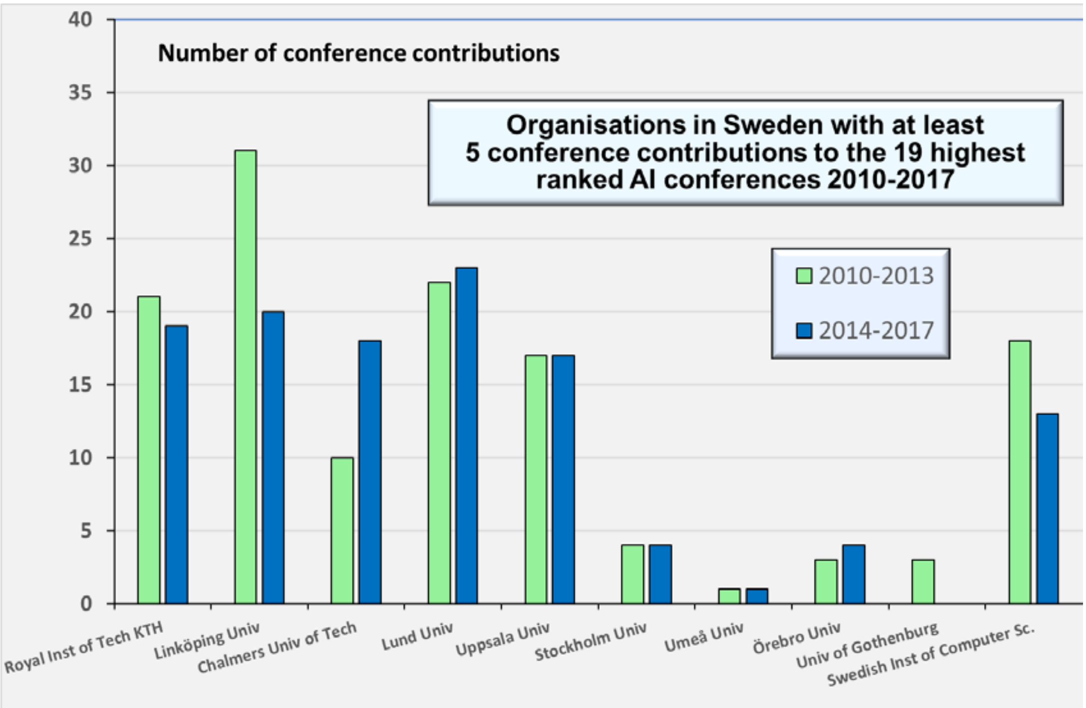
Source: Swedish Research Council. Processing data from Web of Science
Note: The data for 2017 is incomplete. Retrieval from database was in November 2017

Figure 36. Organisations in Sweden with at least 50 publications in AI journals in Web-of-Science 2010–2017



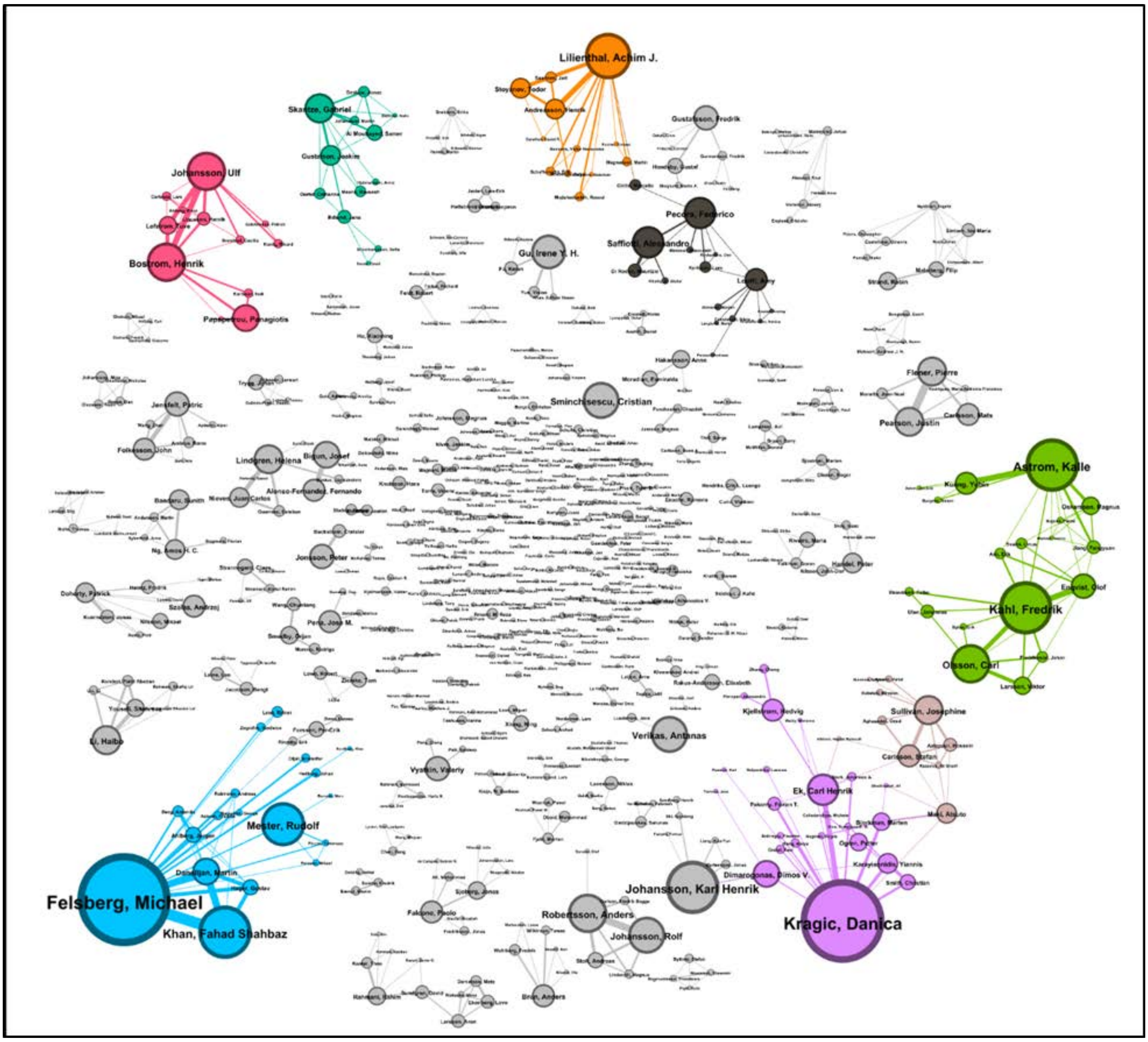
Source: Vinnova. Processing data from Web of Science
Note: The data for 2017 is incomplete. Data retrieval was done on 4 April 2018.

Figure 37. Organisations in Sweden with at least 5 conference contributions to the 19 highest ranked AI conferences 2010–2017



Source: KTH Bibliometric Group and Vinnova. Processing data from Scopus

Figure 38. Researchers in Sweden with at least two publications between 2012–2016 within "Computer Science – AI" in the Web-of-Science database as well as links through co-authorship



Source: Swedish Research Council. Processing data from Web of Science

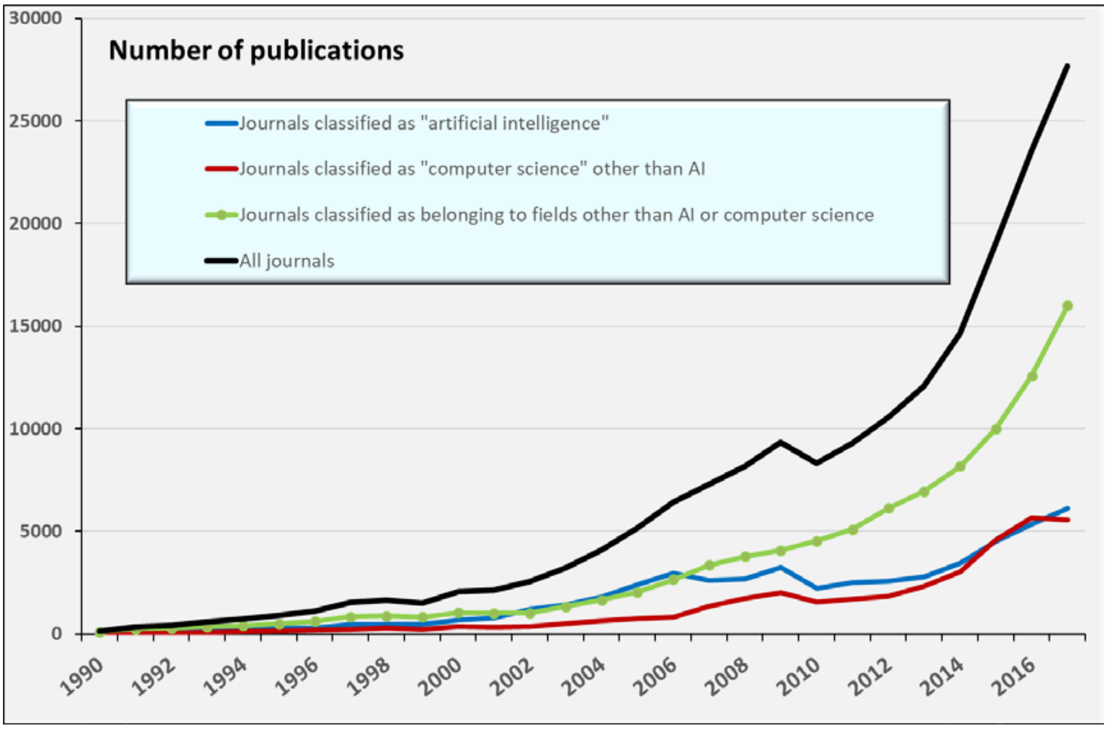
8.4 A large and growing part of the AI research relates to applications

The significant global attention that has come to focus on artificial intelligence in recent years is primarily grounded in the increased use of machine learning in various applications. So-called deep learning has yielded particularly striking results. The increased use of AI is only reflected to a small extent in conferences and journals with AI specialists as the primary target group. Analysis based on keywords ("artificial neural net") closely linked to deep learning gives the impression that Sweden – from a relatively favourable starting point at the turn of the century when technology was still in its infancy – failed to adequately invest in the growing experimentation with the technology that was taking place in some other countries and gradually lost ground. Pleasingly, there is evidence that a positive trend break occurred in 2017.

AI encompasses a number of methods with the possibility of use in almost all areas. This makes it difficult to identify research relating to the use of AI. In order to nonetheless – albeit incompletely – highlight Sweden's position regarding the use of AI, a keyword-based search has been performed in the Web-of-Science database. The keywords used are: "machine learning", "artificial neural networks", "support vector machine", "deep learning", "convolutional neural networks".[26] These cover only a portion of the AI methods available, but should provide a fairly representative picture of broad elements of AI.[27]

For the publications selected, it is clear that the majority are published in journals that are not primarily aimed at AI experts. Some are published in journals with a primary focus on elements of computer science other than AI. However, the overwhelming majority are found in journals that are neither classified in the narrow category of AI nor in other subareas of computer science. Particularly striking is that increased publication in AI journals in recent years has followed a continuous expansion outside of AI journals that only broke out for a couple of years around the latest financial crisis. This supports the perception that the expansion within AI in the past few years has been driven by applications of already known AI methods, an expansion which in turn has stimulated intensified research into the development of AI methods as such, Figure 39.

Figure 39. Publications in Web-of-Science identified by means of AI-related keywords, broken down by field classification of the journals where the publication took place.

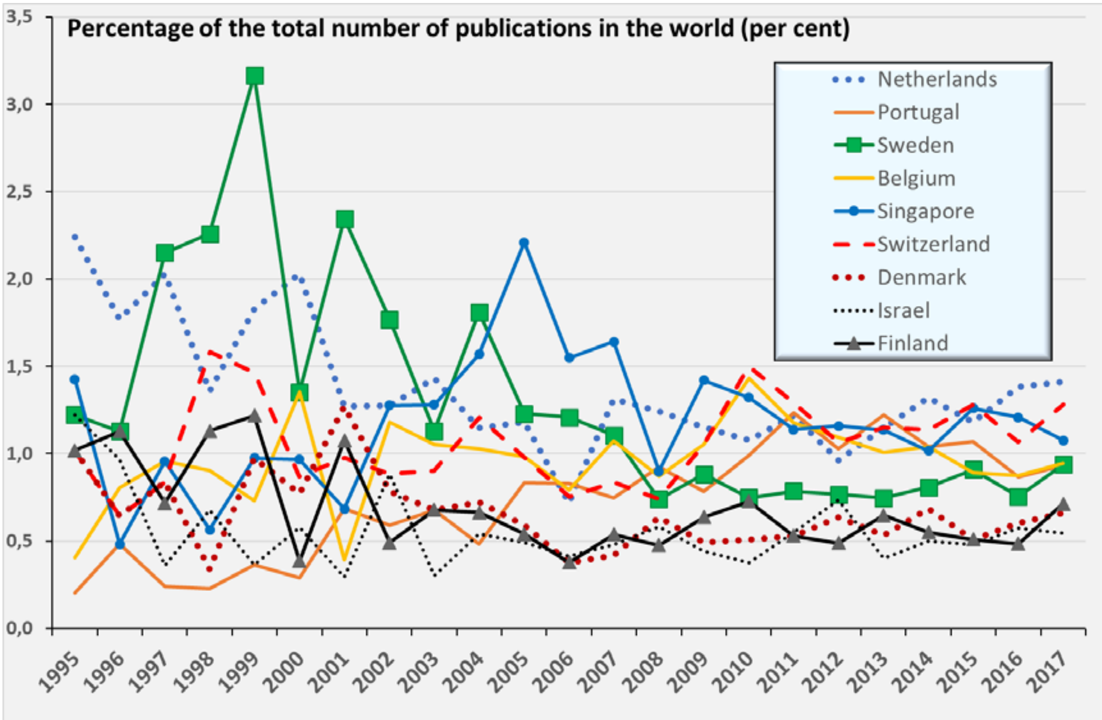


Source: Vinnova; processing data from Web of Science
Note: The data for 2017 is incomplete. Data retrieval was done on 27 April 2018.

[26] To be precise, the following search terms have been used: "machine learning" (61,578), "artificial neural net*" (69,089), "support vector machine" (63,099), "deep learning" except articles in journals classified as educational research (9,248), "convolutional neural net*" (8,514). The figures in brackets indicate the number of publications globally published in the period 1995–2018, based on data retrieved on 28 April 2018.
[27] An example of an area with a strong AI connection that is likely under-represented is computer vision.

In Figure 40, Sweden is compared with a number of other countries of comparable size as regards the publications selected by the keyword-based search as described above. The comparison is limited to journals that are neither AI journals nor journals classified within any other subarea of computer science. The comparison can roughly be considered to relate to publications that primarily describe the use of AI rather than the development of AI methods as such. During a ten-year period around the turn of the century, Sweden distinguished itself through more active use of AI than other countries in the comparison. Following this, Sweden's relative position has gradually been weakened and is today trailing most comparable countries per capita. Sweden's share of the global publishing volume certainly stabilised after 2010, but countries such as Switzerland and Singapore have simultaneously strengthened their positions.

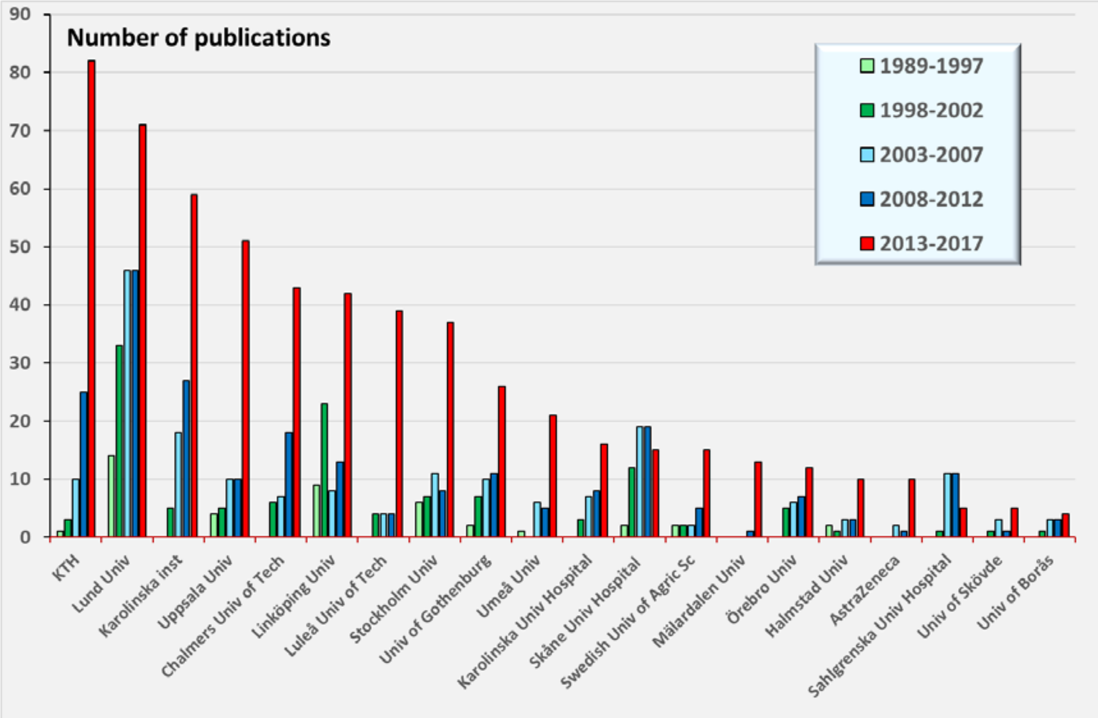
Figure 40. Publications in Web-of-Science identified using AI-related journals classified within areas other than "computer science" for selected countries



Source: Vinnova; processing data from Web of Science
Note: The data for 2017 is incomplete. Data retrieval was done on 27 April 2018.

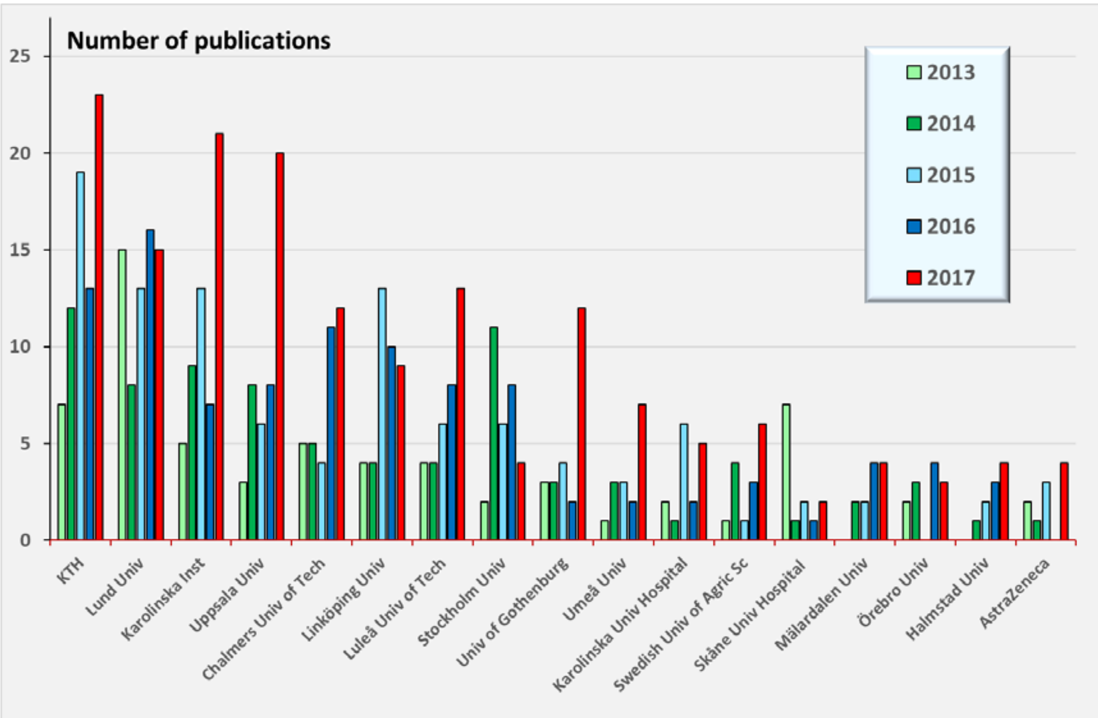
Development has progressed differently in different organisations in Sweden. For a long time, researchers at Lund University dominated the field. A large number of Lund University's publications concerned applications within medicine and included cooperation with Skåne University Hospital, Figure 41. Today, the distribution between the different universities is much more even. For many of the universities, there was a sharp increase observed in 2017, Figure 42.

Figure 41. Organisations in Sweden with at least 10 publications between 1989–2017, identified with AI-related keywords in journals classified within areas other than "computer science"



Source: Vinnova; processing data from Web of Science
Note: The data for 2017 is incomplete. Data retrieval was done on 28 April 2018.

Figure 42. Organisations in Sweden with at least 10 publications between 2013–2017, identified with AI-related keywords in journals classified within areas other than "computer science"



Source: Vinnova; processing data from Web of Science
Note: The data for 2017 is incomplete. Data retrieval was done on 28 April 2018.

8.5 Conclusions

Based on the bibliometric data presented in this chapter, Sweden's position within AI research must be considered relatively weak compared to the overall situation for Swedish research.

However, the fact that a large and important part of the scientific communication within AI takes place at conferences makes bibliometric analysis of AI research problematic. The results presented must therefore be considered preliminary. In particular, there is a need to broaden the scope in studying Swedish researchers' participation in international conferences. However, the Swedish presence at the highest ranked AI conferences seems to be surprisingly low. Additionally, this view needs to be supplemented with data from conferences with strong elements of AI but with another main focus, for example within robotics and autonomous vehicles.

Based on publication volume, the most extensive AI research in Sweden is conducted at KTH and Linköping University, where there are also some of the strongest research environments in Sweden. Other research environments that distinguish themselves from a Swedish perspective are found at Lund University, Chalmers University of Technology, Örebro University, and in collaboration between researchers at Stockholm University and the University of Borås. In comparison with leading research environments internationally, however, the leading Swedish research environments are nevertheless small.

A very preliminary analysis of research related to the use of AI shows that Sweden's position today is relatively weak here also. That being said, in line with the developments that have taken place internationally, a significant increase in activity has occurred in the past few years and more recently for several universities. Experience in research focusing on AI-usage is therefore significantly more widely represented at Swedish universities compared to just a few years ago.

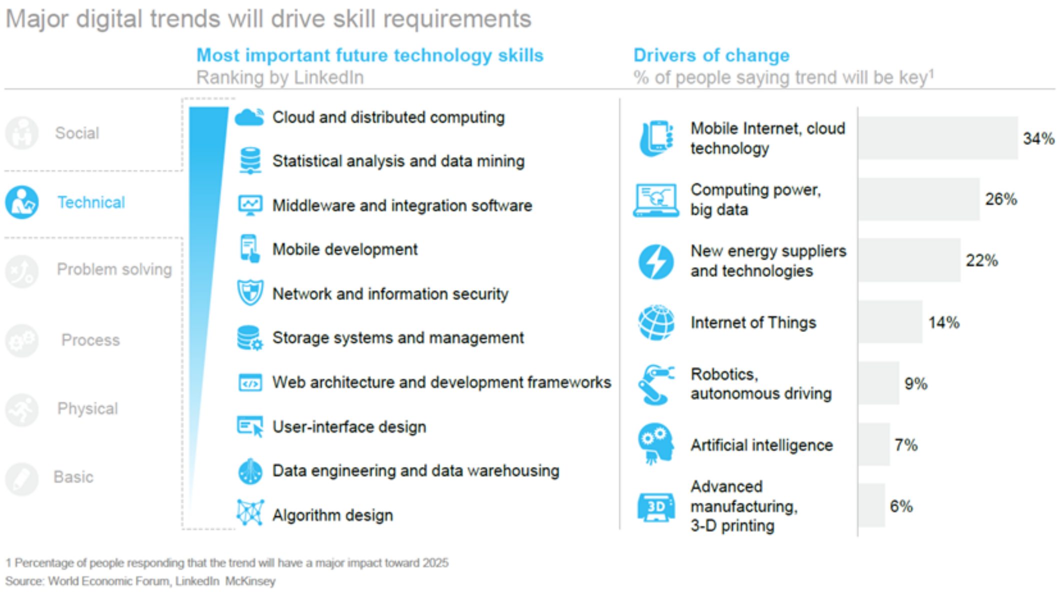
9 Sweden's AI-related competence

This chapter discusses scenarios for AI-related competence, Sweden's skills provision and competence base regarding ICT specialists.

9.1 Competence scenarios and the demand for competence

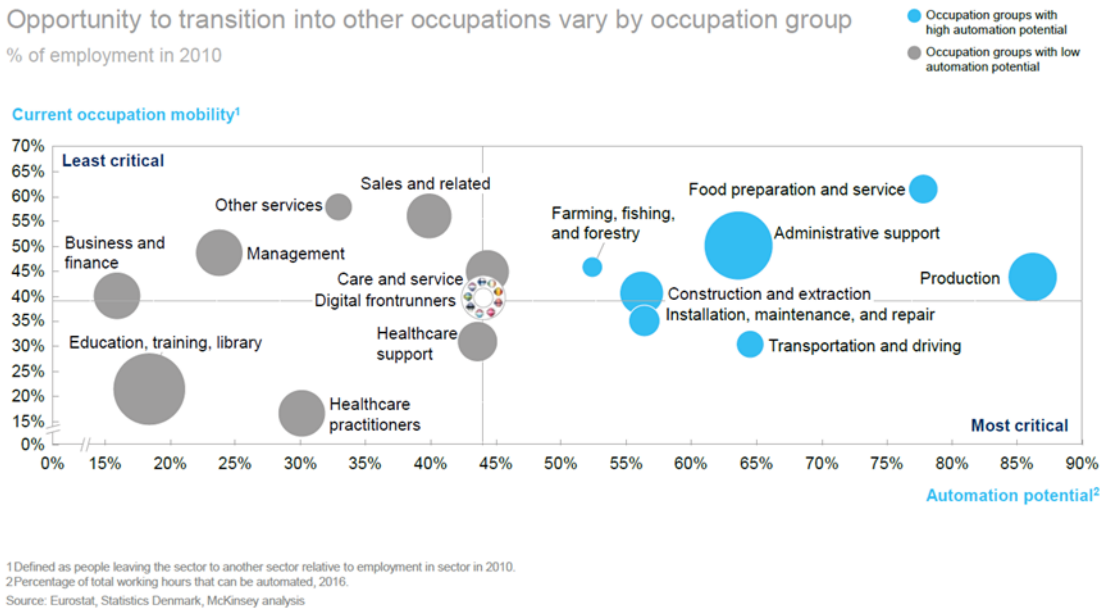
Digitalisation has already significantly impacted competence needs, recruitment patterns and the labour market to a significant extent. This development will continue, and there is much to suggest that competence needs and the labour market will change even faster in the wake of society's digitalisation. It is probable that increased use of AI applications in the business and public sector will significantly enhance the requirements for competence renewal for individuals and businesses, Figures 43 and 44.

Figure 43. Scenario of competence needs linked to digitalisation



Source: McKinsey&Company, Digitally-enabled automation and artificial intelligence: Shaping the future of work in Europe's digital front-runners, October 2017
Comment: The nine countries the scenarios concern are: Belgium, Estonia, Finland, Ireland, Luxembourg, the Netherlands, Norway and Sweden.

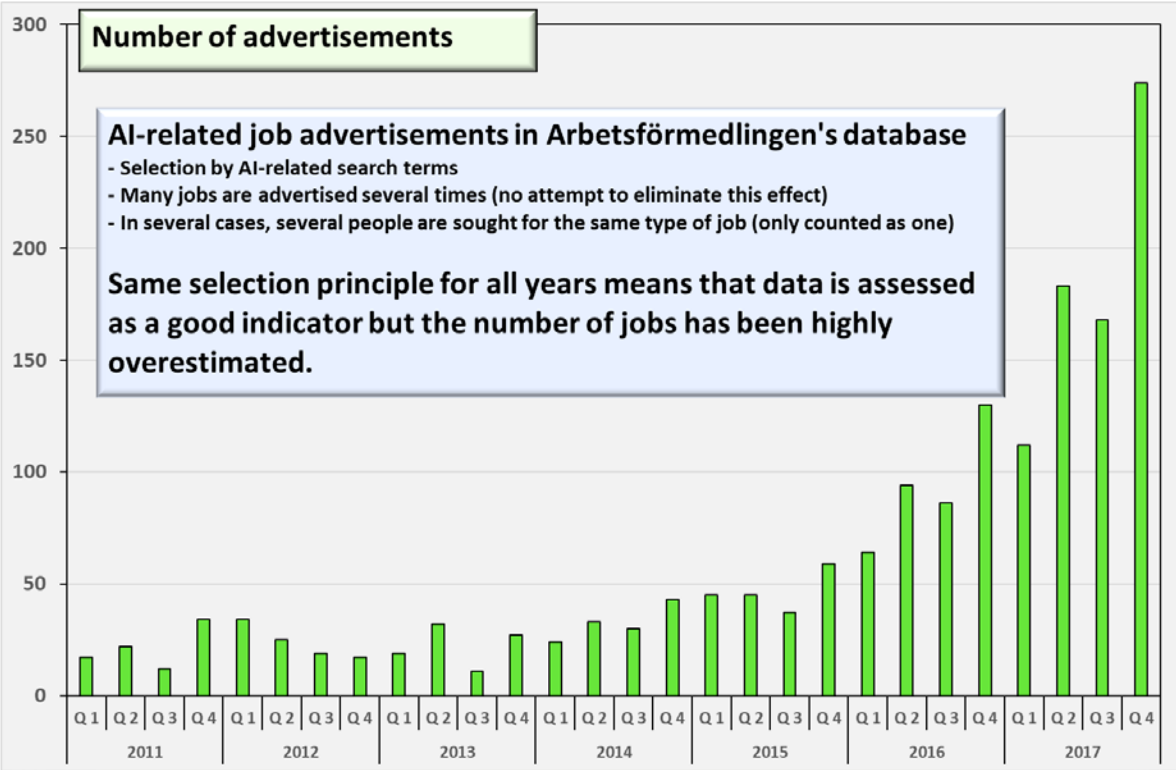
Figure 44. Scenario of needs for competence renewal linked to digitalisation



Source: McKinsey&Company, Digitally-enabled automation and artificial intelligence: Shaping the future of work in Europe's digital front-runners, October 2017
Comment: The nine countries the scenarios concern are: Belgium, Estonia, Finland, Ireland, Luxembourg, the Netherlands, Norway and Sweden.

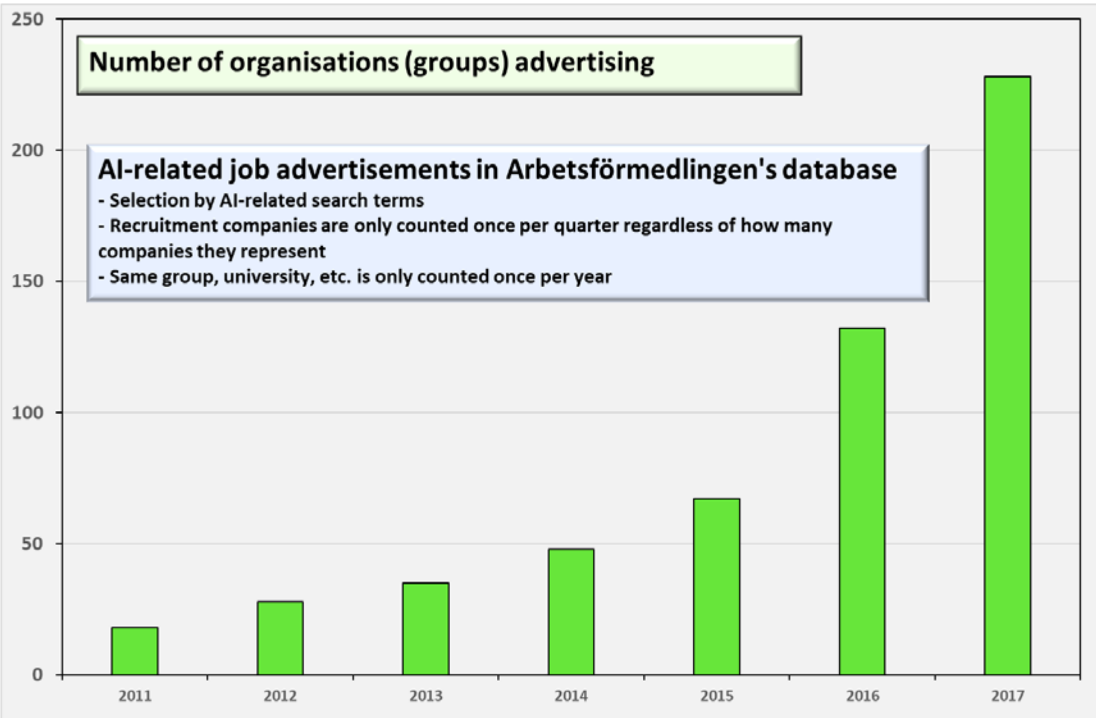
The demand for AI competence is increasing rapidly on a global scale and it is also increasing very rapidly in Sweden. It has not been possible to approximate total demand, but a processing of Arbetsförmedlingen's (Swedish Public Employment Service) data provides a clear picture of a very rapid increase in demand in recent years, Figure 45. Arbetsförmedlingen's data also shows a very rapid increase in the number of different organisations seeking AI competence, Figure 46.

Figure 45. AI-related job advertisements in Arbetsförmedlingen's database 2011–2017



Source: Vinnova processing data from Arbetsförmedlingen

Figure 46. AI-related job advertisements in Arbetsförmedlingen's database 2011–2017



Source: Vinnova processing data from Arbetsförmedlingen

9.2 International comparison of ICT specialists

International statistics only allow relatively rough comparisons between countries and there is no national or international data for AI specialists. It is therefore not possible to directly identify the availability of AI competence in the Swedish economy based on existing statistical nomenclature. However, it is possible to identify workers with an educational background that can be expected to have greater potential for competence development within the AI field compared with workers with another educational background. Examples of such educations include data, programming, mathematics and statistics. This does not mean that further education within AI is unimportant for people with other educational backgrounds. On the contrary, AI competence will likely require reinforcement in almost all areas, but the need and conditions ought to vary greatly.

From Eurostat, there are statistics on the number of employed ICT specialists[28], which should be an important competence base for AI competence. This data can also be related to total employment. It is important to note that these statistics do not say anything about AI competence. It is not possible, on the basis of this data, to say something about the extent of the need for education and further training within AI.

Gainfully employed ICT specialists

The number of employed ICT specialists in Sweden has increased from approximately 254,000 in 2007 to close to 311,000 in 2016. The proportion of total employment held by ICT specialists increased during the period from 5.6 to 6.3 per cent, see Figure 48. In an international comparison, Sweden has a high proportion of ICT specialists. In 2016, only Finland had a higher share. Over time, several countries (though not all) show a more positive development in terms of the proportion of employed ICT specialists compared to Sweden. This has meant that Sweden's head start in relation to these countries has decreased in the past ten-year period, Figure 47.

Data from Eurostat shows that a relatively small proportion of companies in Sweden (18 per cent in 2016) have ICT specialists employed. Corresponding figures for Denmark and Finland are 25 and 24 per cent respectively. However, there is a big difference between large companies where 71 per cent have ICT specialists employed, while only 16 per cent of Swedish SMEs have ICT specialists employed.

In terms of recruitment or attempts to recruit ICT specialists, Sweden is also placed relatively low. Eight per cent of Swedish companies claim to have recruited or attempted to recruit ICT specialists in 2016. This is comparable to Denmark (11 per cent) and Finland (9 per cent). Again, there is a significant difference between large companies where 43 per cent have recruited or tried to recruit. The corresponding figure for SMEs is 7 per cent.

Of the companies that have recruited/attempted to recruit ICT specialists, 50 per cent of companies in Sweden have difficulty filling the vacancies. A slightly greater proportion of large

[28] Eurostat defines ICT specialists as "*workers who have the ability to develop, operate and maintain ICT systems, and for whom ICT constitute the main part of their job*". The definition of ICT specialists is based on the occupational classification, and utilises the educational orientation as a complement. For more information, see http://ec.europa.eu/eurostat/cache/metadata/en/isoc_skslf_esms.htm#meta_update1474465177387

companies (55 per cent) compared with SMEs (50 per cent) experience difficulty recruiting ICT specialists, and 25 per cent of Swedish companies have given their staff additional training in 2016 with the aim of upgrading ICT skills. In Finland, the corresponding figure is 34 per cent, and in Denmark, 28 per cent. Here too, there is a big difference between large companies (74 per cent) and SMEs (23 per cent), Figure 48.

Figure 47. Number of employed ICT specialists in Sweden and its share of total employment 2007–2016

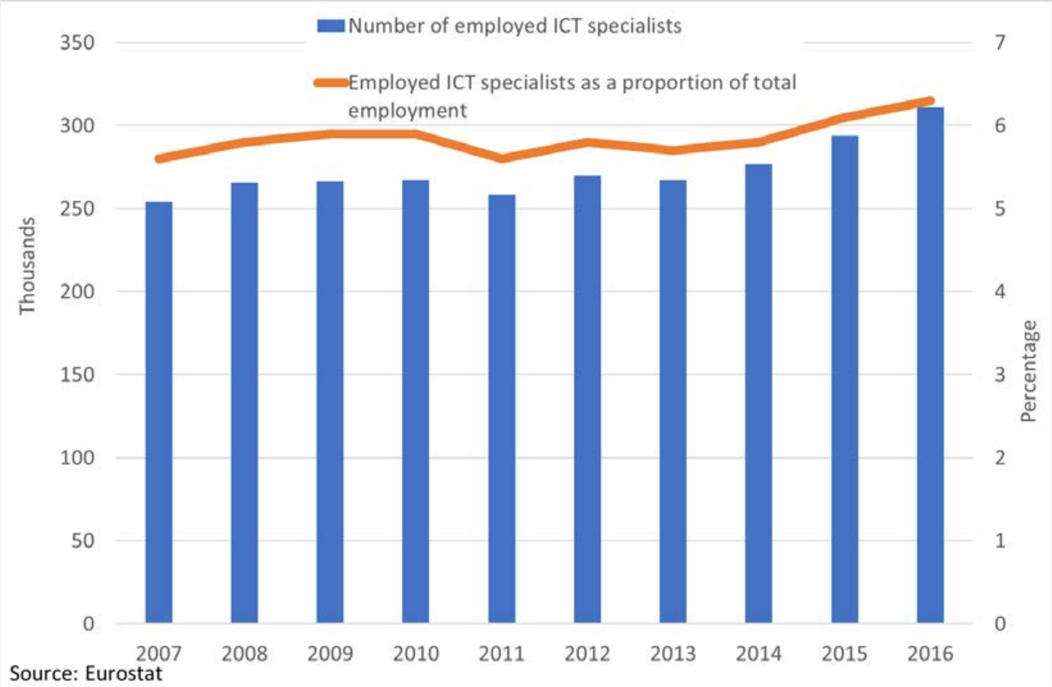
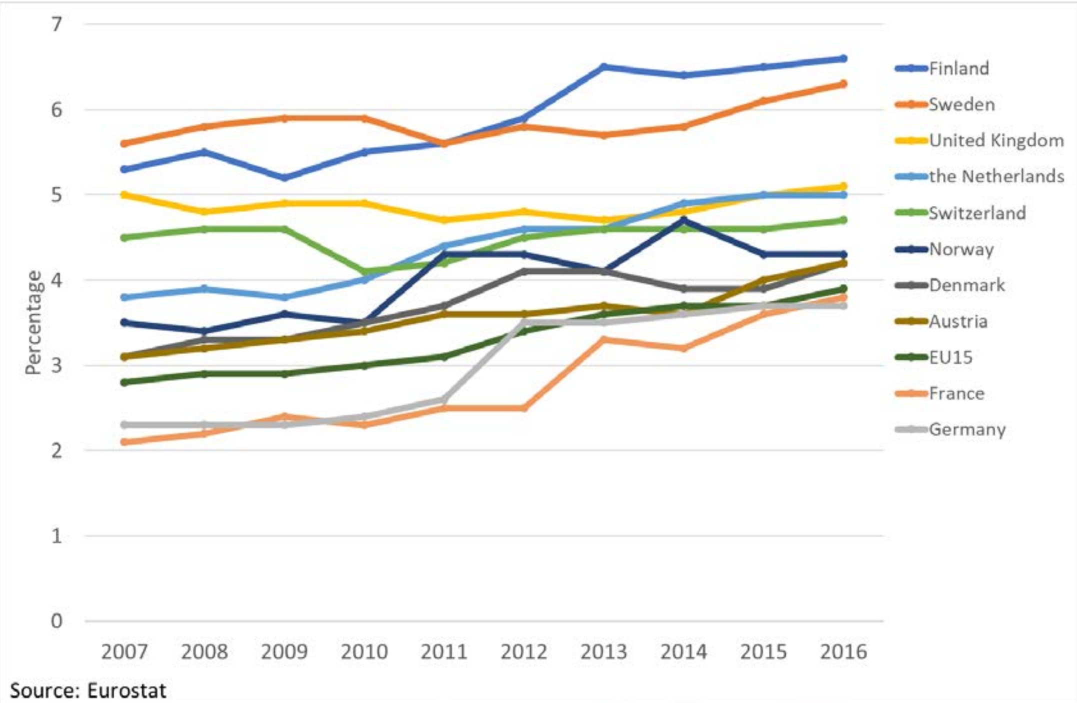


Figure 48. Percentage ICT specialists of total employment for a selection of countries 2007–2016



9.3 ICT competence in the Swedish labour force

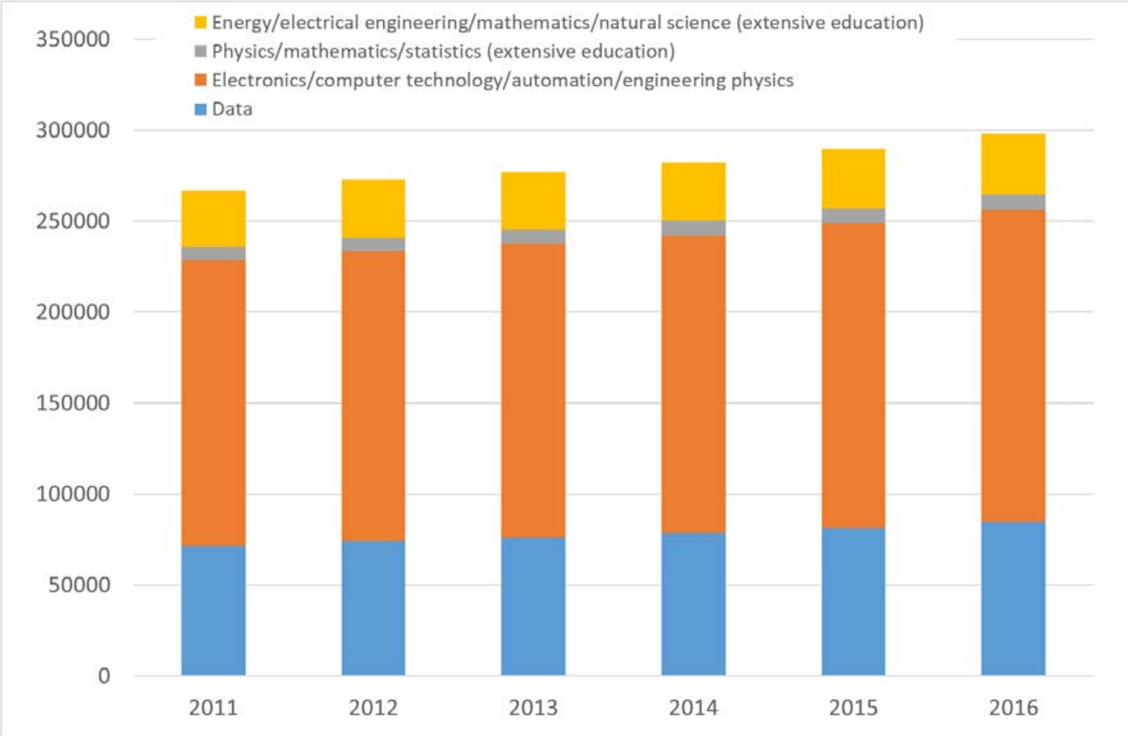
Based on Statistics Sweden's Swedish Educational Terminology (SUN), educational orientations have been identified where the conditions for competence development within AI are considered to be particularly good. The educational orientations that have been assumed to have particularly good conditions include:

- Data (educational orientation 48)
- Electronics (educational orientation 523)
- Computer Technology (educational orientation 523)
- Automation (educational orientation 523)
- Master of Science in Engineering Physics (educational orientation 520a)
- Post-secondary education (at least 3 years) within Physics/Mathematics/Statistics (educational orientation 441z, 461z and 462z)
- Post-secondary education (at least 3 years) in Energy Engineering, Electrical Engineering and Mathematics/Natural Science (educational orientation 522a, 522x and 469x)

Statistics from Statistics Sweden show that the total number of employed workers with one of these educational backgrounds (hereinafter referred to as ICT specialists[29]) has increased from almost 267,000 in 2011 to nearly 298,000 in 2016, see Figure 49. As a percentage of the total number of employed workers, their share has increased from 5.9 per cent in 2011 to 6.2 per cent in 2016, see Figure 50.

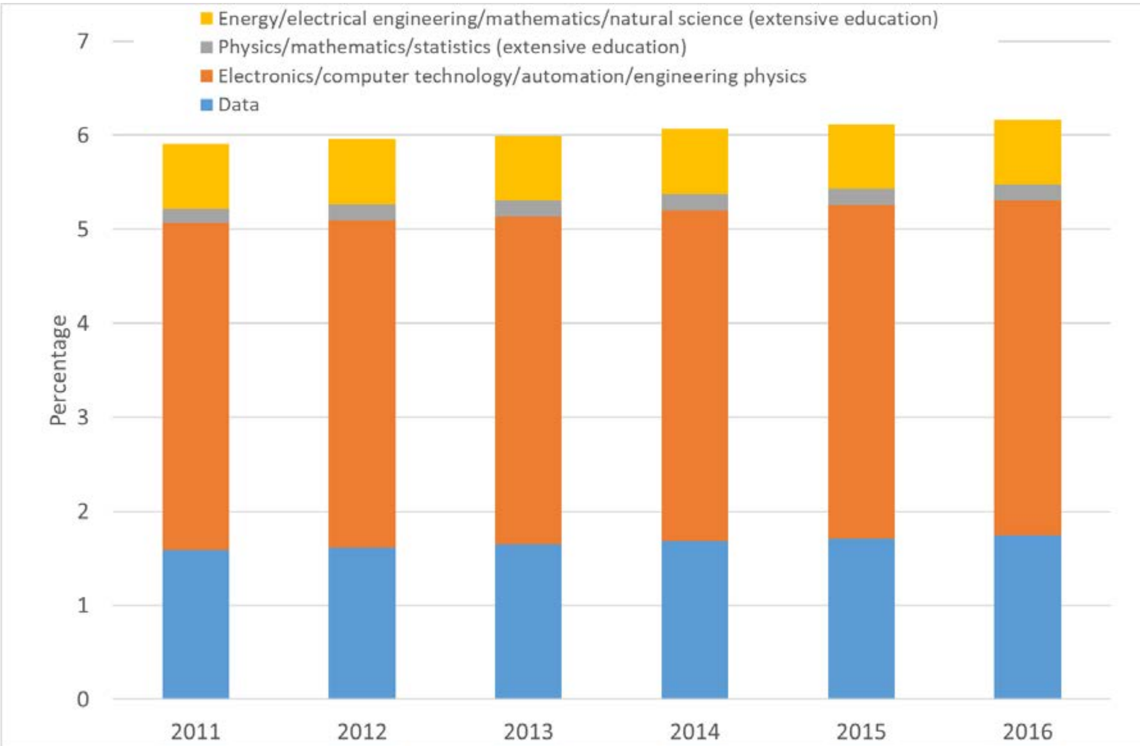
[29] Note that ICT specialists here differs slightly from Eurostat's definition (see previous footnote). Here the selection is based on educational orientations. However, most of the people included here (about 82 per cent) have an education that, according to Statistics Sweden, is defined as IT. We have therefore chosen to retain the term ICT specialists for this group as well.

Figure 49. Number of employed workers with an education within ICT/Mathematics in Sweden 2011–2016



Source: Statistics Sweden

Figure 50. Percentage of employed workers with an education within ICT/Mathematics in Sweden 2011–2016

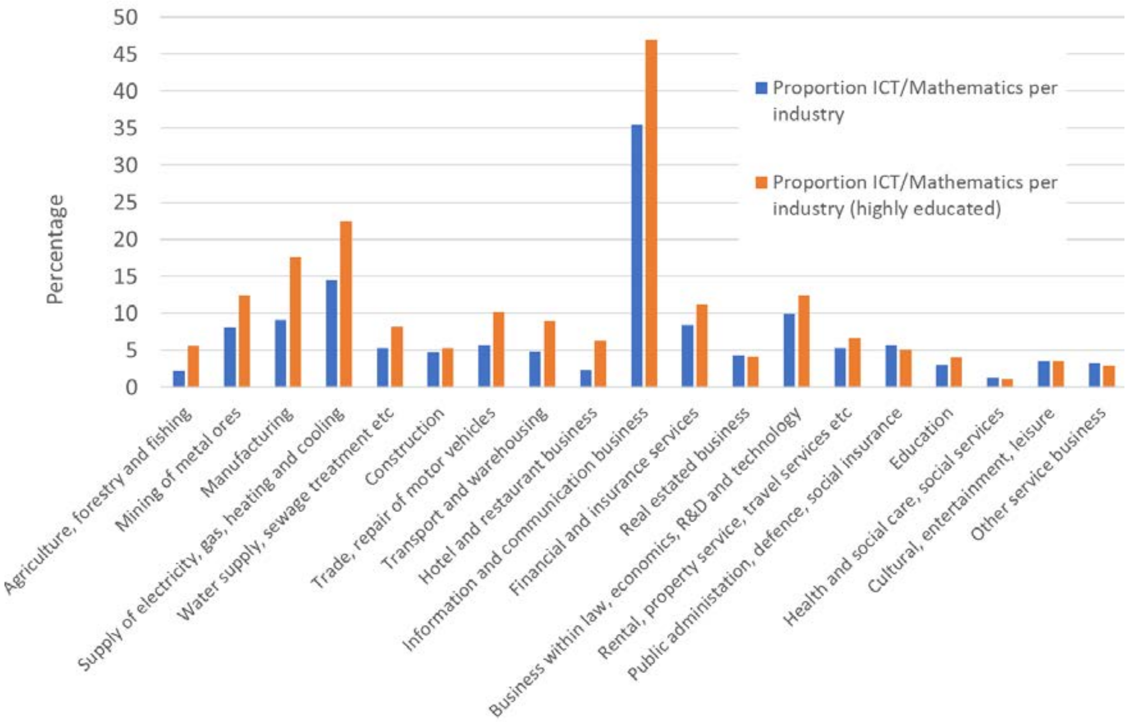


Source: Statistics Sweden

As instructed by Vinnova, Statistics Sweden has divided the employed workers by branch of industry in which they are employed. The picture that emerges is that the percentage of employed ICT specialists in terms of total employment varies widely between different industries. Figure 51 shows the percentage of gainfully employed ICT specialists (regardless of education level) in relation to total employment within each branch of industry, as well as the percentage of highly educated ICT specialists (at least 3 years post-secondary education and PhDs) in relation to all employees with extensive education in each branch of industry.

For the economy as a whole, the percentage of ICT specialists is 6.2 per cent, and for the highly educated ICT specialists, the percentage is 9.1 per cent of all highly educated workers in the economy. The intensity of ICT specialists varies widely between different branches of industry. Information and communication activities (SNI 58–63) have the clearly highest concentration of ICT specialists. It is also high within, for example, Supply of electricity, gas, heating and cooling (SNI 35) and Manufacturing (SNI 10-33), Figure 51.

Figure 51. Percentage of employed workers per industry with an education within ICT/Mathematics in 2016. For all levels of education and for those with extensive education



Source: Statistics Sweden

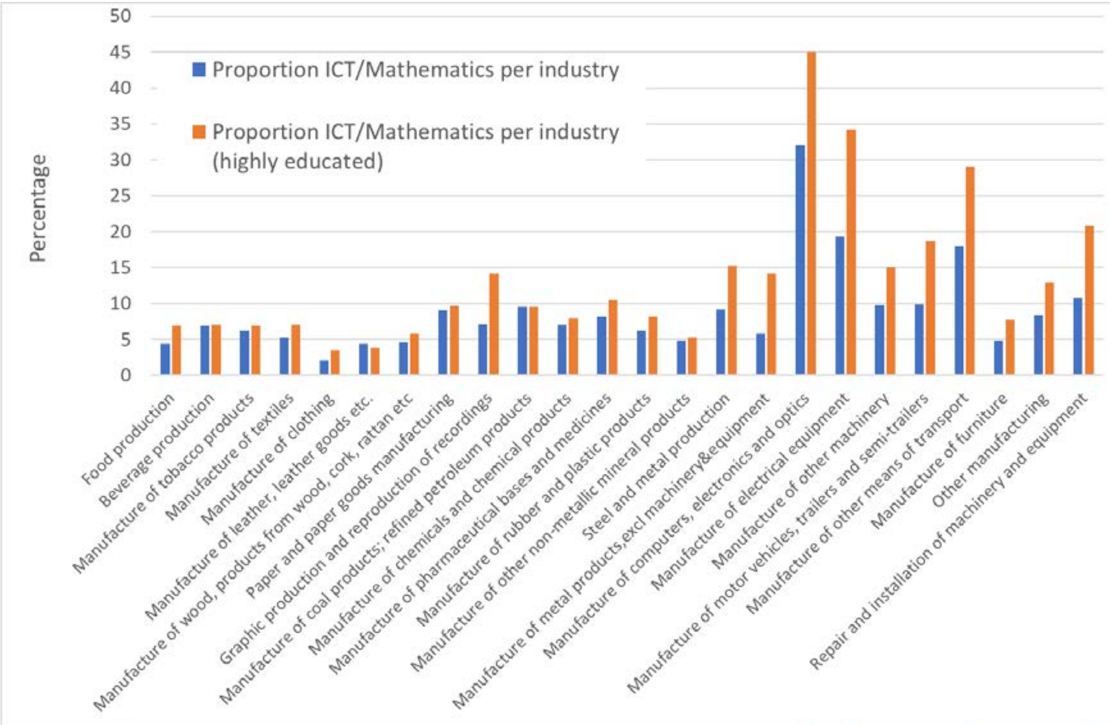
Gainfully employed ICT specialists in the manufacturing industry[30]

In 2016, nearly 540,000 people were employed in the manufacturing sector, which corresponds to approximately 11.2 per cent of Sweden's total employment. Of these, about 49,000 people had a background within educational orientations which we have here referred to as ICT specialists.

[30] The manufacturing sector consists of the SNI codes 10–33.

The number of highly educated workers (at least 3 years of post-secondary education or third-cycle studies) in the manufacturing sector with ICT training amounted to approximately 15,300 people, which corresponds to almost 18 per cent of the total highly educated workers in the manufacturing sector. There are some industries in the manufacturing sector where the intensity of highly educated workers within ICT is significantly higher. This applies, for example, to the Manufacture of computers, electronics and optics (45 per cent), the Manufacture of electrical equipment (34 per cent) and the Manufacture of other transport equipment (29 per cent), Figure 52. On the other hand, there are several industries where the intensity of highly educated workers within ICT is significantly lower than the average. Servicification and statistical reclassifications of all or part of activities make it difficult to draw any conclusions about possible changes over time.

Figure 52. Percentage of employed workers per industry in the manufacturing industry with an education within ICT/Mathematics in 2016. For all levels of education and for those with extensive education



Source: Statistics Sweden

Gainfully employed ICT specialists in the ICT sector

One way to partially check for reclassifications from the manufacturing sector to the service sector is to aggregate related industries from both the manufacturing sector and service sector.

The ICT sector is defined according to the OECD as:

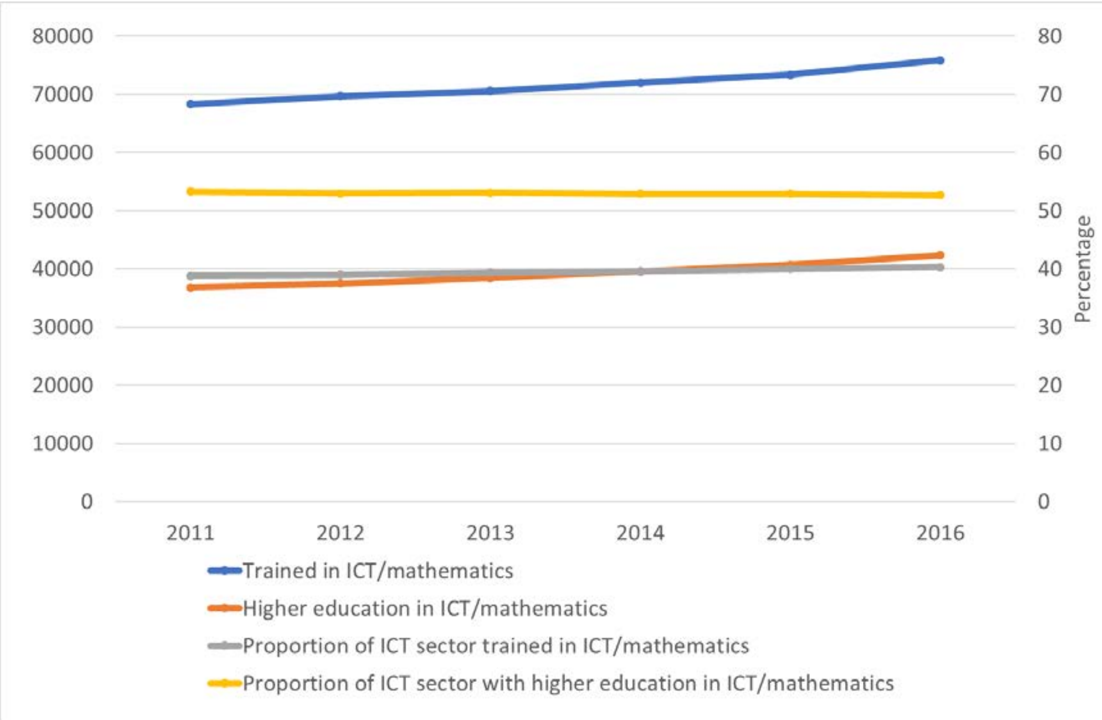
- SNI 261 Industry for electronic components and printed circuit boards
- SNI 262 Industry for computers and peripherals
- SNI 263 Industry for communications equipment
- SNI 264 Industry for consumer electronics
- SNI 268 Industry for magnetic and optical media

- SNI 465 Wholesale trade of information and communications equipment
- SNI 582 Software publishers
- SNI 61 Telecommunications
- SNI 62 Computer programming, computer consultancy, etc.
- SNI 631 Other information service companies
- SNI 951 Repair workshops for computers and communications equipment

The ICT sector employed around 176,000 in 2011 and 188,000 in 2016, which corresponds to almost 4 per cent of Sweden's total employment. In an international comparison, the percentage of workers in the ICT sector is relatively high in Sweden. In 2015, Sweden ranked seventh among the OECD countries[31] .

About 25 per cent of all those with an ICT education and approximately 36 per cent of all highly educated people with an ICT education were employed in the ICT sector in 2016. In 2011, the number of employees with an ICT education in the ICT sector was just over 68,300. In 2016, the number had increased to almost 75,900 people. The number of highly educated people (i.e. at least 3 years of post-secondary education or third-cycle studies) amounted to 36,800 in 2011 and 42,300 in 2016. The intensity, i.e. the percentage of total workers in the ICT sector with an ICT education, is slightly increasing and reached 40 per cent by 2016. The corresponding percentage for the highly educated is relatively constant around 53 per cent, Figure 53.

Figure 53. Number and percentage of employed workers with an education within ICT/Mathematics in the ICT sector 2011–2016



Source: Statistics Sweden

[31] OECD (2017), OECD Digital Economy Outlook 2017, OECD Publishing, Paris

Gainfully employed ICT specialists within two groupings of company groups

Vinnova has also commissioned Statistics Sweden to develop educational profiles for specially singled-out groups. Specifically, this applies to two groups of company groups; firstly, large company groupings engaged in R&D, and secondly, international groupings with their main activities outside the manufacturing sector. The first group includes Ericsson, AstraZeneca, Volvo Cars/Cevt, Saab (defence), AB Volvo, Scania, ABB, ÅF, Sandvik, Alten, Atlas Copco, Tieto, GKN Aerospace, GE Healthcare, Nevs, Bombardier, SonyMobile, TetraPak, Semcon, Autoliv, HIQ and Axis/Swedish Canon. The second group includes Postnord, PEAB, Nordstjernan, IKEA, H&M, Vattenfall, Securitas, SEB, Nordea, Swedbank, Handelsbanken, Stena metall/Stena AB, Telia and Skanska. The employed workers in the respective groupings of company groups and the employed workers outside the groupings of company groups have been categorised into 5 roughly defined industry classifications[32] which simplified can be described as:

- Manufacturing
- Private services
- Public services
- Other branches of industry
- Unclassified branch of industry

The total number of employed workers in the first group, R&D groups, amounted to approximately 148,700 in 2015. The total number of employed workers in the second group, International groups outside the manufacturing sector, amounted to approximately 170,200 in 2015. Most of the workforce in the R&D groups is employed in the manufacturing sector, 115,800, and private services 32,700. In the group of international groups, the majority is employed in private services, 126,300, and other industries, 37,300.

In the R&D groups, some 32,500 have an education within ICT, of which approximately 19,500 have extensive education (at least 3 years of post-secondary education or third-cycle studies). In the international groups outside the manufacturing sector, approximately 12,500 employed workers have an education within ICT, of which almost 4,500 have extensive education, Figure 54.

In relation to the total number of employed workers in the R&D groups, nearly 22 per cent have an education within ICT. Focusing solely on those with extensive education, the proportion of those with an ICT education is close to 35 per cent. Corresponding data for the employed workers in the international groups outside the manufacturing sector is 7.3 per cent and 12 per cent respectively. By comparison, it can be mentioned that the proportion with an ICT education among the workers in the manufacturing sector that are not included in the two groups is 7.6 per cent and 13.5 per cent if only those with extensive education are studied, Figure 55.

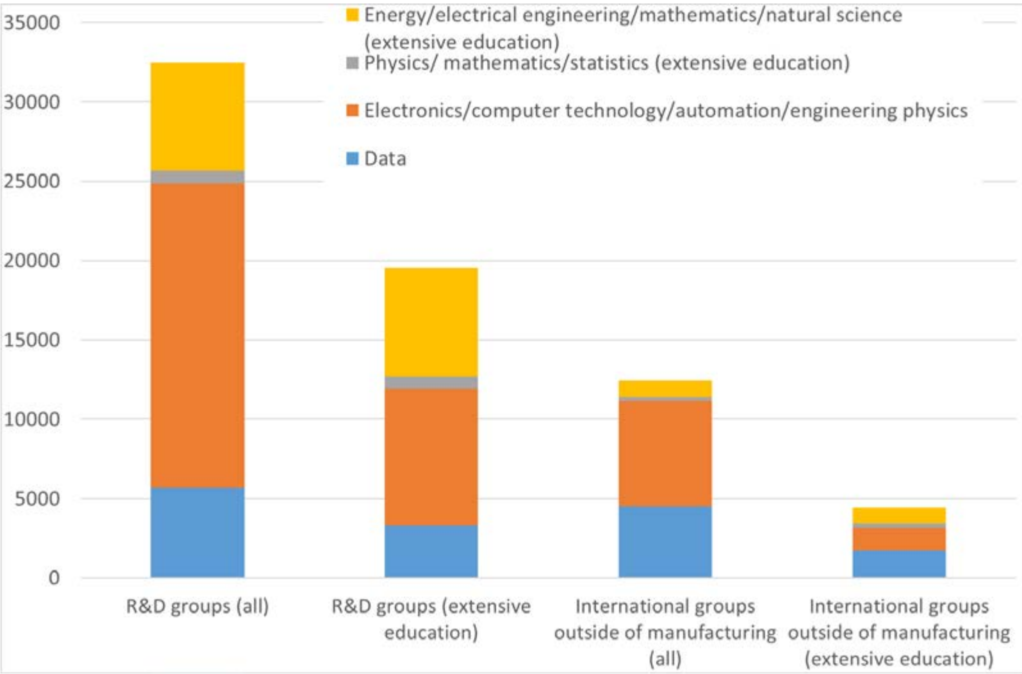
The majority (78 per cent) of the employed workers in the R&D groups are employed in the manufacturing sector. The intensity of employees with ICT education in these groups is significantly higher than for the remaining employees in the manufacturing sector. 22 per cent

[32] Manufacturing consists of Division C, Private services consists of Divisions G-N, R, S, T, Public services consists of O, P, Q, U, Other branches of industry consist of A, B, D, E, F and Unclassified branch of industry covers the employed workers where the branch of industry is unknown. For a more detailed summary of the branches of industries that are included in the respective industry category, see https://www.scb.se/contentassets/d43b798da37140999abf883e206d0545/struktur-sni2007.pdf

of the R&D groups employed workers work within private services. Even for this group, the percentage with an ICT education is significantly higher than that for the remaining employees in private services.

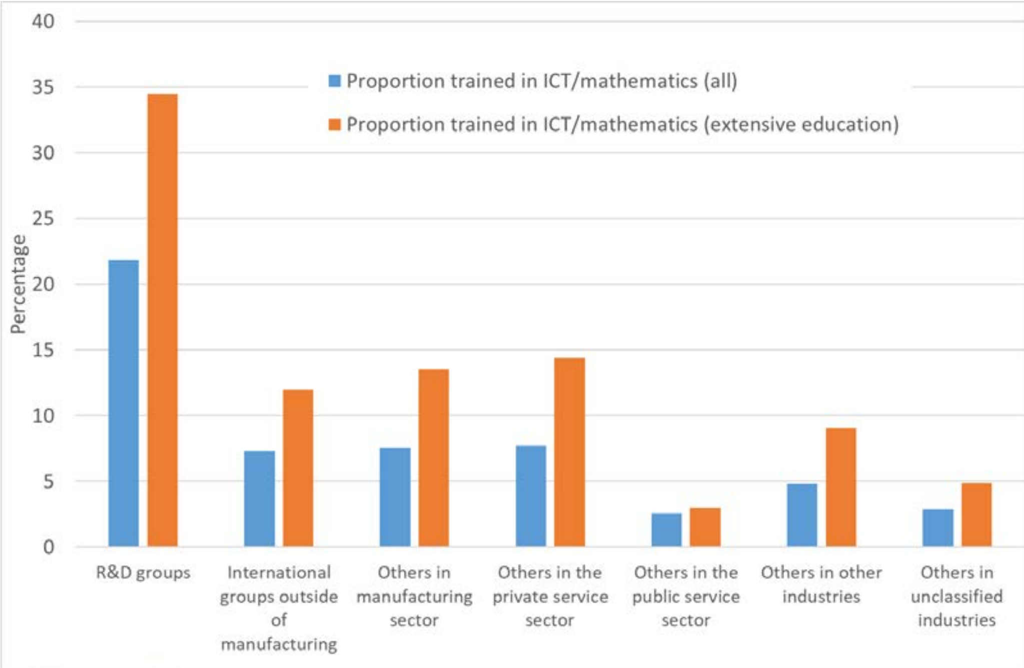
For the international groups outside the manufacturing sector, the majority are employed within private services (74 per cent) and within other industries (22 per cent). The intensity of employees educated within ICT in these groups is similar to the remaining employees within these business groups.

Figure 54. Number of employed workers within ICT/Mathematics in two groupings of company groups. Firstly for all employed workers and secondly for those with extensive education



Source: Statistics Sweden

Figure 55. Number of employed workers within ICT/Mathematics in two groupings of company groups and among other employed workers. Firstly for all employed workers and secondly for those with extensive education



Source: Statistics Sweden

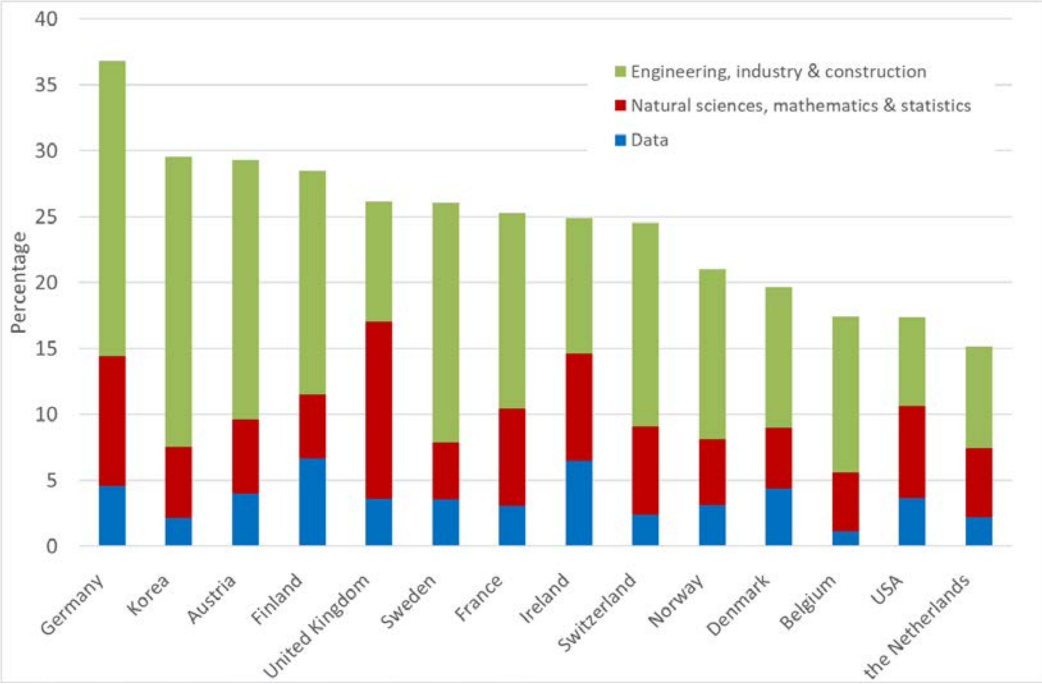
Examination of ICT specialists in an international comparison

A lack of internationally comparable data means that international comparisons must be based on more loosely defined education categories. In Education at a Glance[33], the OECD presents data on the proportion of graduates from post-secondary (tertiary) STEM education (Science, Technology, Engineering and Mathematics), which is broader than what we have defined as ICT specialists. The proportion of graduates within STEM educations in Sweden is 26 per cent, see Figure 56. In this respect, Sweden ranks after countries such as Germany, Finland and Austria, but before countries like Norway, Denmark, the USA and the Netherlands.

The OECD Online Education Database[34] presents data on the number of graduates from post-secondary education at a more defined level, but the key between Swedish SUN codes and the international nomenclature ISCED-F 2013 is not clear for all educational orientations. However, there is the opportunity to compile comparable statistics for the educational orientations Data, Electronics/Computer Technology/Automation, Mathematics/Statistics and Physics, see Figure 57. For Sweden, the percentage of graduates within these areas was approximately 7 per cent. In this respect, Sweden ranks lower than countries such as Germany, Finland and Austria, but higher than countries like Norway, Denmark and the Netherlands.

[33] OECD (2017), Education at a Glance 2017: OECD Indicators, OECD Publishing, Paris.
[34] OECD, OECD.stat

Figure 56. Percentage of graduates with a post-secondary education within the STEM field in 2016

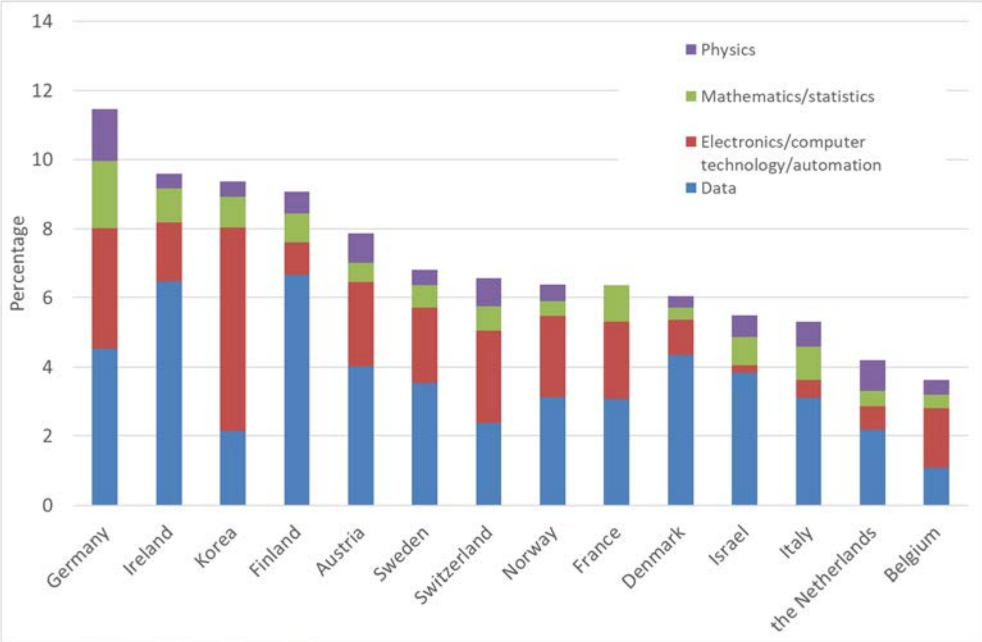


Source: OECD

The OECD Online Education Database[35] also includes the number of persons graduated from third-cycle studies (including licentiate degrees) within the educational orientations Data, Electronics/Computer Technology/Automation, Mathematics/Statistics and Physics. For Sweden's part, the proportion of PhDs in 2016 within these areas amounted to approximately 17.5 per cent, which means that Sweden places in the top of countries studied, Figure 58.

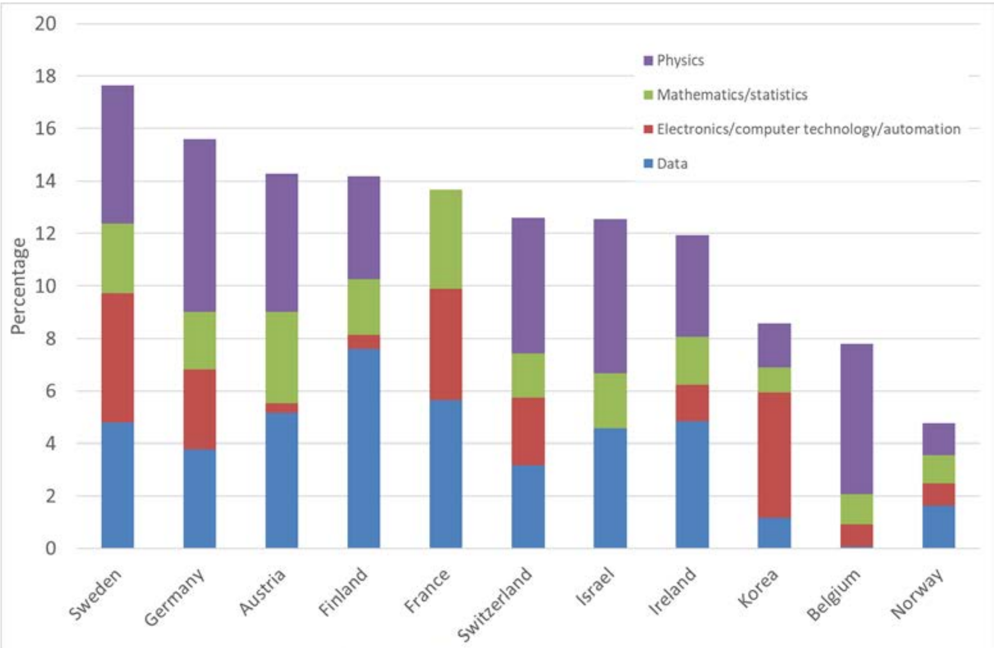
[35] OECD, OECD.stat

Figure 57. Percentage of graduates with a post-secondary (tertiary) education within ICT, Electronics/Computer Technology/Automation, Mathematics/Statistics and Physics in 2016



Source: OECD
Note: For France, there is no data available on graduates within Physics.

Figure 58. Percentage of graduates with a PhD within ICT, Electronics/Computer Technology/Automation, Mathematics/Statistics and Physics in 2016



Source: OECD
Note: For France, there is no data available for graduates within Physics, and for Israel, graduates from within Electronics/Computer Technology/Automation is missing.

10 Higher education institutions

Universities and university colleges will play a key role in Sweden's AI development, as AI competence will be crucial for Sweden's ability to realise the AI potential. Education, continuing professional development and research within AI will in this context be central, both in terms of generating basic AI competence and cutting-edge competence within AI.

This chapter discusses the conditions and driving forces at higher education institutions when it comes to addressing the challenges in terms of priorities and continuous renewal that will be required for Sweden's skills provision and international appeal within AI.

10.1 Globalised knowledge landscape

A global knowledge landscape is rapidly emerging. The previous relatively closed national systems are opening up the borders for knowledge, talent and resources. Both individuals and knowledge have become more mobile across boundaries.

The globalised knowledge landscape has also increased the opportunities for and the necessity of international collaborations, but has also given rise to increased competition for students and teachers[36] . Funding flows are also becoming increasingly international, for example, as a result of increasing funding through the EU, but also through companies developing global research networks to a greater extent[37] . Universities can be regarded as increasingly competitive and no longer natural or automated parts of the state or national society. This international competition will to a high degree characterise the AI area.

Sweden's AI development and the higher education institutions' (HEIs) attractiveness and roles for the provision of skills within AI will place high demands on higher education institutions. On the one hand, it will make great demands on their ability to continuously develop, adapt and dimension educational programmes and continuing professional development courses to society's needs for AI education for different areas, and for people with different basic competencies. On the other hand, there will be great demands on the ability to prioritise research in order to be at the international frontier of research within AI.

The number of students studying abroad has increased markedly in recent years and is expected to continue to increase over the next ten years. Between 2001 and 2012, the number of globally mobile students more than doubled, i.e. students who study outside their home country[38] . Between 2005 and 2015, the number of foreign students in the USA[39] increased by 85 per cent while the number of foreign students at top universities in the UK has almost doubled

[36] OECD (2015), Scoping paper for CSTP/TIP project on higher education institutions in the knowledge triangle. DSTI/STP(2015)6, OECD, Organisation for Economic Co-operation and Development.
[37] Jacob, M. (2015), Draft RIO Country Report 2014: Sweden. Nilsson, R. (2015), Statlig FoU-finansiering i Sverige 1981–2014 [Government R&D funding in Sweden 1981–2014], working document, VINNOVA
[38] OECD (2014), Education at a Glance 2014: OECD Indicators, OECD Publishing. http://dx.doi.org/10.1787/eag-2014-en
[39] Wall Street Journal (2015), International students stream into US colleges, M. Jordan, 24 March. http://www.wsj.com/articles/international-students-stream-into-u-s-colleges-1427248801

over the same period[40]. In Australia, the number of international university students has increased by 50 per cent between 2004 and 2014.[41] In Denmark, the Netherlands and Austria, the number of international students has more than doubled in ten years[42] .

With this increased mobility, it is important that Swedish universities strengthen their global profile and become attractive environments for knowledge development. This can firstly attract individuals and research resources, and secondly strengthen the regional environment[43]. An international perspective also strengthens the qualitative driving forces for individual teachers and researchers[44].

In Sweden, the number of foreign students decreased as a result of the introduction of tuition fees for students from outside the EU/EEA in 2011[45]. In 2013/2014, the number of students coming from countries other than the EU/EEA was 62 per cent lower than before the introduction of tuition fees[46]. It is mainly "free mover" students from Africa and Asia that have dropped off. Nowadays, the majority of foreign students are European exchange students who only stay one or two semesters[47].

Another change that creates new challenges and opportunities for the global university system is digital development. Although the consequences of this are difficult to predict, it is clear that education and research can now be conducted in forms that are no longer linked to a particular time or place. This further increases the fight for students, researchers and resources, which places additional pressure on the institutions to define their areas of strength and profiles, and find ways to link them to the offering and channels being developed through net-based knowledge. The emergence of Massive Open Online Courses (MOOCs) is a clear example of this. These offer opportunities for reaching new and larger audiences and innovative ways of measuring and following learning. They have the potential to become a radical innovation within the world of education, but the consequences are still difficult to overlook.

Another international development with important implications for higher education institutions in many parts of the world is increasing signs of a matching problem between the demand for skills and competencies in the labour market on the one hand, and high structural unemployment on the other. This trend is noted in a large number of countries and, in many cases, also includes groups of individuals with a tertiary education. The situation has led to a more fundamental discussion about the content and focus of higher education, such as whether more people with cutting-edge competence within different areas are needed, or

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[40] The Telegraph (2015), Number of foreign students at top universities doubled in less than a decade, research finds. J. Espinoza, 29 May http://www.telegraph.co.uk/education/educationnews/11639807/Number-of-foreign-students-at-top-universities-doubled-in- less-than-a-decade-research-finds.html

[41] https://internationaleducation.gov.au/research/International-Student-Data/Pages/InternationalStudentData2014.aspx

[42] UNESCO Institute for Statistics database

[43] Bienenstock et al., (2014), Utbildning, forskning, samverkan. Vad kan svenska universitet lära av Stanford och Berkeley? [Education, research, collaboration. What can Swedish universities learn from Stanford and Berkeley?] SNS förlag.; Jacob, 2015.

[44] Jacob, 2015 Bienenstock et al 2014

[45] Swedish Higher Education Authority, UKÄ (2015), Higher Education Institutions, ANNUAL REPORT 2015. Swedish Higher Education Authority, Sweden's official statistics.

[46] Swedish Higher Education Authority, UKÄ (2014), Higher Education Institutions, International Student Mobility in High Education 2013/2014, Swedish Higher Education Authority, Sweden's official statistics, Statistical messages UF SM 1402.

[47] Ibid.

whether young people should be provided with a comprehensive and broad skill set that allow them to quickly adapt to varying tasks and careers[48].

Globalisation, digitisation and matching challenges have put questions about the future of the knowledge system high on the political agenda worldwide.

10.2 Development of higher education institutions in Sweden

In line with international development, Swedish higher education institutions (HEIs) have gone from being elite universities for the few to become mass universities. This is a consequence of several factors, but primarily the ambition to raise the general education level of society.

> *The higher education institutions have great freedom to independently decide on the design of their education offering and the content of the courses and programmes. However, according to their appropriation directions, the education in offer at higher education institutions is to respond to students' demand and the needs of the labour market. Student demand is of great importance to the design of education as the state funding for education at the first and second-cycle level is based on the number of registered students and their grade production.*[49]

At the same time, there is a growing expectation on higher education institutions to contribute actively and purposefully to societal development in broad terms[50]. These institutions have therefore moved towards becoming key players in different types of innovation processes. It assigns them a more complex mission where many different roles and expectations interact – curiosity-driven and application-oriented research, collaboration and education[51]. This complex mission requires a pronounced idea or vision of how different roles and assignments relate to each other.

Today's higher education institutions in Sweden, as well as in many other countries, have a historically unique degree of self-determination over resource allocation, organisation and working methods. Their duties and mandates have been significantly expanded. This requires a change in the organisation and management of the university in order to – independently and in cooperation with other stakeholders and financiers – identify sustainable working methods, goals and ambitions[52].

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48 Institute for the Future (2011), Future Work Skills 2020. http://www.iftf.org/uploads/media/SR-1382A_UPRI_future_work_skills_sm.pdf

49 Swedish Higher Education Authority, UKÄ, Samverkan om dimensionering av utbildning – En kartläggning – rapportering av ett regeringsuppdrag [Collaboration on the design of education – A survey – reporting a government commission], Report 2018:4, p.6.

50 Berggren, H. (2012), Den akademiska frågan – en ESO-rapport om frihet i den högre skolan [The academic issue - an ESO report on freedom in higher education], Report to the Expert Group on Public Economics 2012:3, Ministry of Finance.; Ejermo, O. (2012), Universitet som drivkraft för tillväxt och utveckling [University as the driving force for growth and development]. Reprocentralen Örebro University, Research Network Debate, Swedish Entrepreneurship Forum; Carlsson et al., (2014), Research Quality and the Role of the University Leadership; Eriksson, L. and Heyman, U. (2014), Resurser för utbildning och forskning [Resources for education and research]. Ref. 14/014 SUHF April 2014; Perez Vico et al. (2015), Universitets och högskolors samverkansmönster och dess effekter [Collaboration patterns of higher education institutions and their effects].
VINNOVA analysis.

51 Berggren, 2012

52 See e.g. Dijstelbloem et al., (2013), Why Science Does Not Work as It Should And What To Do about It. Science in Transition POSITION PAPER, October 17, 2013; OECD (2013), Science, Technology and Industry Scoreboard 2013, chapter 5; European Commission (2014), Background document – Public Consultation, 'SCIENCE 2.0': Science in transition,

There are major differences in how different higher education institutions have handled their different roles and expectations. The differences are not only explained by strategic choices but also relate to circumstances and basic conditions. A certain variation in how the universities work is therefore inevitable, but several studies indicate that there is a need for a more active approach to mission coordination[53] .

A major change challenging academic leadership is the expansion of the higher education sector. Today, the higher education sector is one of the largest employers, with HEI staff accounting for 30 per cent of state employees in Sweden[54]. During the 2000s, the number of employees at HEIs increased by 31.4 per cent. The number of students went from 12,000 in 1950 to 40,000 in the academic year 2008/2009[55].

Not only the volume has increased, but also the area of responsibility. HEIs have developed into mass institutions with broad tasks and mixed mandates[56]. Within Swedish HEIs, basic research, applied research and teaching are gathered under the one roof[57]. These various activities have many different types of goals and stakeholders, and are often carried out on quite different conditions[58]. Sweden's investments in HEIs are considerable in an international context, and have increased significantly in recent decades – especially since 2005[59]. Societal expectations have continued to rise in parallel with an increase in government resources for HEIs.

The major investments, the development towards mass universities, and an increasing importance in research within the field of societal development in general have overall increased the State's interest and need to govern HEIs[60]. Through the autonomy reform, the State has shifted from direct control to goal setting through the monitoring of quantitative and qualitative results. This goal setting is sometimes perceived as disruptive to the organisations[61], while others claim that greater autonomy needs to be balanced with monitoring[62]. Internationally, autonomy has almost always been followed by more robust quality management[63].

The increasingly central role assigned to HEIs is reflected in the large number of goals to which the organisation must relate. These include regional growth and competitiveness, labour market needs, knowledge development and academic quality, as well as various social and

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DIRECTORATES-GENERAL FOR RESEARCH AND INNOVATION (RTD) AND COMMUNICATIONS NETWORKS, CONTENT AND TECHNOLOGY (CONNECT).

[53] Berggren, 2012; Öquist G. and Benner, M. (2012), Fostering breakthrough research: a comparative study. Royal Swedish Academy of Sciences. Halmstad: Print One; OECD, 2015.

[54] Jacob, 2015

[55] Bienenstock et al., 2014

[56] Berggren, 2012; Bienenstock et al, 2014

[57] Öquist and Benner, 2012; Carlsson, 2014

[58] Öquist and Benner, 2012

[59] UKÄ, 2015

[60] Berggren 2012; Lidhard and Petrusson, 2012

[61] Berggren, 2012

[62] Lidhard and Petrusson, 2012

[63] OECD, 2015

economic societal challenges[64]. Research funding is linked to the multifaceted goals and has thereby become increasingly complex and heterogeneous[65].

This diversity of goals – together with the relatively weak and reactive leadership within Swedish HEIs – has created uncertainty about the direction of Swedish research policy and its effects on the long-term conditions for HEIs[66]. There is also no overall political consensus regarding the view on organisation and leadership, resource allocation models and the relationship between different types of HEIs[67]. In addition, there is no comprehensive research policy approach and the knowledge base concerning the position of the Swedish research system is fragile[68].

The complexity of operations, the increased autonomy, complex funding flows and increased pressures from the outside world together impose higher demands on conscious, active and responsible leadership[69]. It is therefore of the utmost importance for the future of the Swedish HEI system to develop such leadership[70].

Although the need for strategic leadership has been clear, HEI executive bodies in Sweden have mainly carried out administrative governance[71]. Therefore, the academic legitimacy of HEI executives bodies has generally been limited[72]. Academic credibility is important for academic leaders, but it must be combined with clear visions, ambitions and integrity if leadership is to be strong and effective[73].

The management is also hampered by the funding system which has been targeted at specific groups and individuals, while the universities' own scope for governance has been weakened[74]. The resources and thus the power lie mainly with research groups and faculties that operate relatively independent of the HEI executive bodies. The consequence is that the space for a HEI as an organisation to act forcefully is remarkably small. HEI executive bodies have small ambitions when it comes to organising and steering the operations, other than at a very overarching level. Changes are made primarily through specific programmes and recipient groups, which yields an outcome at a group or subject level but not in the wider context of HEI activities. Changes in the organisation's actions are thus made through individual researchers and groups acting on the impetus of their surroundings[75].

[64] Berggren, 2012; Ejermo, 2012; Carlsson et al., 2014; Eriksson and Heyman, 2014; Perez Vico, 2015
[65] Öqvist and Benner, 2012; Eriksson and Heyman, 2014; Jacob, 2015
[66] Öquist and Benner, 2012
[67] Jacob, 2015, UKÄ, 2015
[68] Eriksson and Heyman, 2014
[69] Berggren, 2012; Carlsson et al., 2014; Öquist and Benner, 2014; Heckscher S. et al. (2014), Ökad handlingsfrihet för statliga lärosäten, rapport till Stockholm [Increased freedom of action for state HEIs], Report to Stockholm – Uppsala University Network, April 2015.
[70] Bienenstock et al., 2014
[71] Carlsson et al., 2014; Öquist and Benner, 2012, Jacob, 2015, Bienenstock, 2014
[72] Öquist and Benner, 2012
[73] Carlsson et al., 2014
[74] Jacob, 2015
[75] Benner, M. (2013), Nordiska universitet i jakt på världsklass – en jämförelse mellan två universitet i Danmark och Sverige [Nordic Universities in the hunt for prominence – a comparison between two universities in Denmark and Sweden], Growth Analysis, Working paper/Memo 2013:20.

A lack of strategic leadership can partly be related to HEIs being complex and difficult-to-manage organisations[76]. The difficulties can be explained by the complicated mix of cultures found within HEIs, encompassing elements that are bureaucratic, academic, economic and relating to civil society[77]. In addition, the activities of researchers and teachers are highly individualistic – commitment to their own assignment is strong while loyalty to the common structures is weak[78]. One explanation for the relatively weak management of HEI operations thus entails rigidities in organisational forms[79]. If HEIs are to take on a broader societal role, their administrative framework needs to be softened[80].

10.3 Challenges for research

Sweden is one of the countries that invests most public funds in research and development when viewed as a percentage of GDP, with only Austria and South Korea reporting a higher share. When comparing total research revenue at universities and university colleges as a percentage of GDP among OECD countries, only Denmark is ranked higher than Sweden. This means that, relatively speaking, Swedish HEIs as a whole receive a lot of funding and considerable public funds for research.

Despite significant increases in resources, there is evidence that Swedish research has lost its leading international role, especially with regard to highly cited research. However, Swedish research still holds a high international position, and both citations and publications are on the increase, but Sweden is no longer a leading and driving presence within key areas. Countries such as Denmark, Switzerland, the Netherlands and Singapore have a significantly better international position compared with Sweden in terms of highly cited publications, and countries such as Germany and Austria seem to be well on track to move past Sweden shortly[81].

Sweden's research has thus not necessarily deteriorated, but the quality of research in other countries is improving at a faster pace, despite massive increases in funding in Sweden. This is evident, for example, in the outcome of the recent Leiden Ranking (2015). External and competitive research funding has risen faster than direct government funding. However, the proportion of needs-motivated collaborative research represented by funding from, for example, Vinnova, the Swedish Energy Agency and the Swedish National Space Agency has declined over time, while the proportion relating to council funding (in particular, the Swedish Research Council, but also Forte and Formas) has increased[82] .

The development requires an overall picture of and strategy for how Swedish research is conducted, organised and relates to new knowledge horizons. An important part in the creation of scientific advancements lies in the connection to societal problems: participating at an early stage of the development of knowledge within fast-growing problem areas and in how research is related to education and cooperation. In particular, there are clear obstacles in the research system to developing new transdisciplinary and interdisciplinary research tracks and to

[76] Öquist and Benner, 2012, Berggren, 2012; Lidhard Petrusson, 2012
[77] Berggren, 2012
[78] Ibid
[79] Heckscher et al., 2014; Jacob, 2015
[80] Heckscher et al., 2014
[81] Öquist and Benner, 2012
[82] Nilsson, 2015

establishing strategic priorities and accumulating a power base on one's own initiative. Such renewal of the research tracks and the ability to initiate strategic power accumulation will be of great importance to Sweden's AI development.

10.4 Challenges for education

Swedish higher education is generally considered to be of a high and good quality, but there are signs of declining quality and a lack of ties to societal problems. The current system of education planning means that new working methods and new forms of working are blocked. In addition, education has faced major challenges due to greater focus on research, especially with regard to financial resources, and due to misguided incentives in state governance.

A major challenge for universities lies in the linking of research to education, where students inject knowledge and experience into society and create networks and relationships pertaining to this knowledge[83]. Education in Sweden has been strongly characterised by the sector's strong expansion. Between 1990 and 2004, the number of full-year students in Sweden more than doubled[84], which is a significantly faster increase compared to other countries[85], and likely at the expense of quality deterioration[86] and a heavy workload[87].

However, the increased volume of students has not been matched by allocated resources. For several years there have been more students than what the funding is intended to finance[88]. The significant increase in resources for research has not been matched within education[89]. Since 2007, R&D revenue has risen significantly more than education revenue, with the consequence that the share of HEI revenue going to R&D has increased from 53 to 58 per cent between 1997 and 2014[90]. Swedish HEIs currently incur higher costs for research than for education, which is unique to Sweden and Switzerland[91]. The increased volume and inadequate funding of education have also contributed to increasing the gap between education and research[92].

However, the renewal, quality and content of education has disappeared from the political focus. The clear focus on research has created a major distortion in the resource allocation between education and research in the last decade[93]. An important reason for this is that research is given higher status than education. Academic competence is often equated with research competence, which indicates an underestimation of the key role of education for

[83] Bengtsson, L. (2013), Utbildningssamverkan för jobb, innovation och företagande [Education collaboration for jobs, innovation and entrepreneurship], Almega, https://www.almega.se/MediaBinaryLoader.axd?MediaArchive_FileID=e67be621-8331- 4fea-afae-8d0b27776b34&FileName=Utbildningssamverkan_f%c3%b6r_jobb_A.pdf, access 06-06-14.
[84] Eriksson and Heyman, 2014
[85] Ejermo, 2012
[86] Björnsson et al., (2015), UNIVERSITETSREFORM! Så kan vi rädda och lyfta den högre utbildningen [UNIVERSITY REFORM!How to save and promote higher education], Samhällsförlaget.
[87] Björnsson et al., 2015; Ehn Knobblock, I. (2014), Disputerad och sen då? En intervjustudie om forskarutbildades arbetslivserfarenheter utanför högskolan [Got a PhD so now what? An interview study of PhDs' work experience outside of university], Fackförbundet ST.
[88] UKÄ, 2015
[89] Jacob, 2015
[90] UKÄ, 2015
[91] UKÄ, 2015
[92] Berggren, 2012; Öquist and Benner, 2012
[93] UKÄ, 2015

societal development and skills provision[94]. Research successes are often highlighted, but it is harder to achieve the same recognition with excellent teaching[95].

Research quality is examined and evaluated significantly more carefully than quality in education, which gives research higher priority among individuals[96]. Thus, research successes are rewarded by the system, but not education to the same extent[97]. This is evident in the extensive research evaluations carried out by HEIs (e.g. Uppsala, Lund, KTH, Gothenburg), which have rarely included the link between research and education. Another example is a lack of support for teachers in developing their educational skills or developing teaching material[98].

This also has an impact on an individual level. For the individual teacher and researcher, education is often seen as a burden, something you have to do if you do not get funding, and something that inspires indifference or a negative response[99]. Career paths within academia are primarily focused on research successes[100].

Universities have been given great responsibility for designing and organising their own education, and finding ways to renew and develop content and focus within education. The State enters the process at a late stage, following up on the quality of implementation and outcomes and only determining a rough allocation of resources ("ceiling amount"). It should have stimulated innovation and renewal, but there are many indications that the education format in Sweden is quite traditional, with few examples of genuine change and adaptation.

In conjunction with the university reform in 1993, the course became the basic unit in education. The Higher Education Ordinance states that:

> *all first and second-cycle education shall be conducted in the form of courses with the addition that courses may be combined into education programmes.*

The Swedish education system is characterised by fairly homogeneous education programmes, with clear divisions between areas: technology, economics, humanities, medicine, etc.[101] The programmes are also quite similar across HEIs[102]. In addition, it has proved difficult to introduce new subjects into the programmes, and Swedish education programmes are characterised by an early specialisation. There is therefore a need to introduce new knowledge that focuses on strengthening critical and interdisciplinary thinking and educating the student as a whole[103].

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[94] Bienenstock et al., 2014
[95] Dijstelbloem et al., 2013
[96] Geschwind, L., and Broström A. (2014), Managing the teaching–research nexus: ideals and practice in research-oriented universities, Higher Education Research & Development, DOI: 10.1080/07294360.2014.934332; VINNOVA (2011), The Knowledge Triangle. Report on Government Commission, Ref. 2010-02061.
[97] Carlsson et al., 2014; OECD, 2015
[98] Bienenstock et al., 2014
[99] Bienenstock et al., 2014; Jacob, 2014
[100] Bienenstock et al., 2014; Ehn Knobblock, 2014
[101] Berggren, 2012; Bienestock et al., 2014
[102] Eriksson and Heyman, 2014; Official Government Inquiries (2015), Högre utbildning under tjugo år [Higher education over twenty years], SOU 2015:70.
[103] Berggren, 2012; Bienenstock et al., 2014

The quality, focus and relevance of education programmes need to be adapted to changes in the labour market and in the rest of the world, but also moved closer to research, just as research needs to be linked more closely to education. New knowledge, new expectations and new social and technological conditions are, however, not reflected in today's largely traditional educational landscape, and completely new forms of linking research, societal needs and educational forms are needed.

The 2015 inquiry concerning the education offering found that the connection to the current and future needs of the labour market was weak and that remarkably little genuine change work had been initiated – the major reorganisation of education policy notwithstanding[104]. In addition, course evaluations have little impact on the development of course content[105]. The sharp distortion in resource allocation between education and research over the last decade[106] has further enhanced the traditional nature of the education where the close link between research/researchers and education is broken. UKÄ notes:

> *"In recent years, higher education institutions have prioritised education programmes at the expense of freestanding courses, inter alia, as a response to the education policy implemented by the then government during the 2006–2014 term of office. Education has thus increasingly taken on the character of initial training for working life. In recent years, the Government that took office in 2014 has emphasised the importance of the education offering enabling continuing professional development, but the ongoing expansions mainly cover programme-structured education. In terms of higher education institutions assuming responsibility for continuing professional development, state governance has therefore not provided any clear support. …. UKÄ notes that it is not an uncomplicated matter for the higher education institutions to increase the offering of continuing professional development courses for the gainfully employed, and that it is not obvious to what extent this is their responsibility."* [107]

Higher education is thus primarily organised into qualification-oriented programmes and the cycles for these programmes are long, sometimes up to ten years.

The resource allocation system for higher education in Sweden rewards the volume of course places and achievements, i.e. throughput. Opportunities to allocate funds for the development of programmes is therefore severely limited.

> *"In order for the courses to be economically viable, the institution has a vested interest in the sufficient number of students participating. This means that the education programmes should not be too narrow or niche, which may contradict an interest in the education meeting a specific need"*[108]

The Swedish education system is thus largely based on the students' choice and demand, and with the admission and selection rules established today, HEIs have difficulty controlling who applies for and who is accepted to courses. Freestanding courses developed in collaboration with the business sector can also be taken by students for other reasons.

[104] SOU, 2015
[105] Bienenstock et al., 2014
[106] UKÄ, 2015
[107] UKÄ, 2018, pp.82–83
[108] UKÄ, 2018, p.82

"At the same time, today there are more opportunities to set requirements and criteria for admission and selection regarding courses and programmes, such as work experience, than we might currently utilise. For example, a Postgraduate Diploma in Specialist Nursing requires both a degree and work experience."[109]

Continuing professional development courses will be increasingly important in the future, in line with the increased need for lifelong learning for an ever-changing labour market.

"[However], there is no… complete picture of the demand for continuing professional development for the gainfully employed, even though employer organisations carry out surveys among their members concerning the need for skills development. For the higher education institutions there are also a number of restrictions that make it difficult to offer such education. In order for the courses to be economically viable, the institutions have a vested interest in the sufficient number of students participating. This means that the education programmes should not be too narrow or niche, which may contradict an interest in the education meeting a specific need. Moreover, the throughput is lower on freestanding courses than on programmes, which means that the financial compensation is lower. If the low throughput is due to the fact that it is too difficult to link studies to gainful employment, it is not sufficient for representatives of the labour market to request freestanding courses. Employers may also need to facilitate employees' participation in continuing professional development." [110]

Basically, the course-based system provides advantages over a programme-based education system in terms of responding to educational needs in the form of continuing professional development. At the same time, the deregulated labour market provides opportunities for the flexible design of continuing professional development courses.[111]

"The number of continuing professional development courses, within the total range of freestanding courses, has increased over a twenty-year period (1993–2014) from 18 per cent to 27 per cent.

- *Continuing professional development courses consist mostly of short courses (<30 credits)*
- *The proportion of continuing professional development courses at the second-cycle level is small but stable*
- *There are an equal amount of continuing professional development courses on campus as are provided through distance education*
- *Most continuing professional development courses are found within the humanities, teacher training and healthcare programmes – but numbers have dropped across these subjects in recent years."*[112]

However, freestanding courses often have a lower throughput. Even online courses, MOOCs and distance courses often have a low throughput. Basically, the institutions therefore have weak incentives to develop freestanding courses and distance education. Contract education, where companies or public sector actors pay for courses linked to their skills development needs, is

[109] A leading university representative for one of Sweden's largest universities.
[110] UKÄ, 2018, p.81.
[111] Official Government Inquiries (2016), Digitaliseringens effekter på individ och samhälle – fyra temarapporter [Digitalisation effects on individuals and society – four thematic reports], SOU 2016:85. Haikola, L., Högskola och livslångt lärande – vilken roll bör högskolan spela för att svara mot kunskapssamhällets behov av kompetensutveckling? [University and lifelong learning – what role should university play in responding to the knowledge society's need for skills development?]
[112] SOU 2016:85, p.287

another opportunity to establish the driving forces to develop and implement continuing professional development in the form of freestanding courses. However, it is important to review the incentive systems of HEIs and to design a resource allocation system that encourages institutions to develop and provide continuing professional development courses for the increasingly diverse and rapidly changing needs of the labour market.

11 R&D investments in AI in Sweden

R&D investments that stimulate research, development and innovative applications of AI will be of great importance to Sweden's AI development. Almost half of the State's R&D funding, totalling SEK 37 billion, went directly to universities and university colleges in 2017. Almost one third went to research-funding agencies and one fifth went to other civil authorities.

Thus, the majority of the AI research conducted in Sweden should be financed through basic funding for universities and university colleges. However, how this funding is allocated to AI research through basic funding has not been studied in any detail in this analysis. This chapter provides a more general discussion on more wide-scale R&D investments in AI by government agencies and by public and private research foundations.

11.1 Swedish Research Council

The Swedish Research Council (VR) is a government agency under the Ministry of Education and Research and has a leading role in developing Swedish research of the highest scientific quality and thus contributing to the development of society. In 2017, VR paid out a total of SEK 6.4 billion in support primarily to basic research within all areas of science and to research infrastructure. In addition to funding research, the authority is advisor to the government in research-related issues.

VR has investigated how much research funding has gone into AI-related research in recent years, and more precisely the appropriations granted in the period 2013–2017. They find that there is no simple definition and delimitation of AI research.

> *"Research within the area is in a stage of great expansion. New methods and ideas are still being developed and it is not uncommon for opinions to differ between researchers as to what exactly should be defined as Artificial Intelligence."*

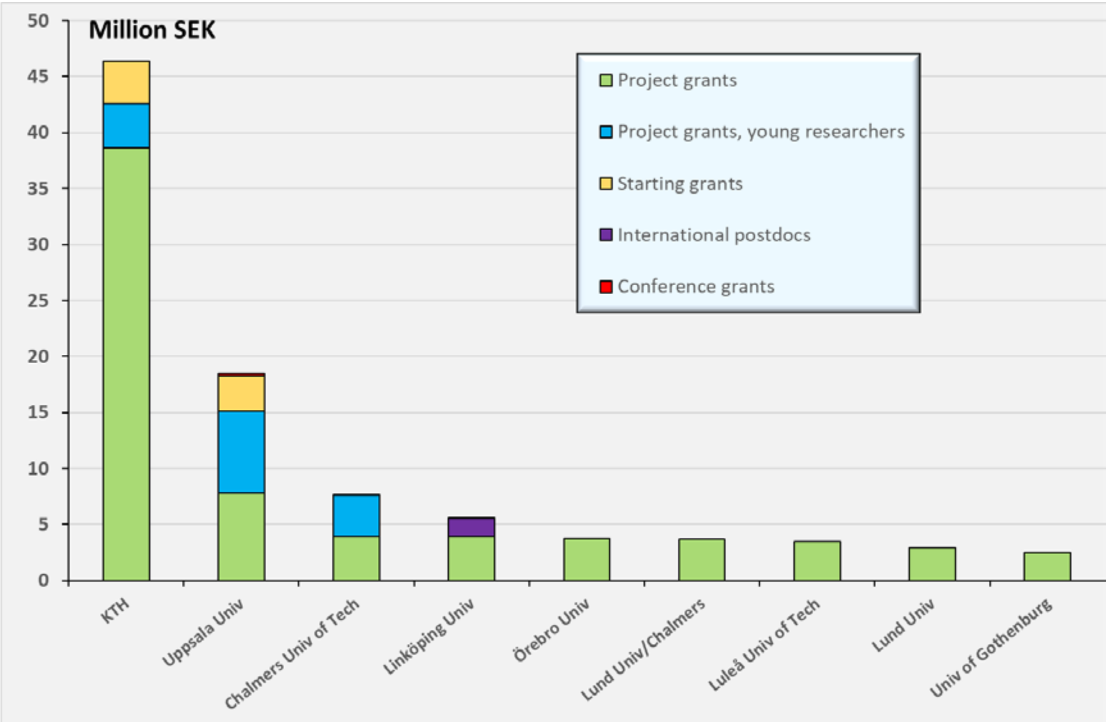
VR therefore chose to use a generous definition of AI-related research as a point of departure. The following approaches were used:

> *"To identify relevant projects, searches were conducted in the Swedish Research Council's database with a large number of relevant keywords. (Keywords used: AI, artificial intelligence, neural networks, type theory, brain simulation, neuromorphic computing, computational neuroscience, approximate reasoning, representational learning, symbolic relations, machine learning, probabilistic programming, computational statistics, functional programming, Monte-Carlo, Bayesian, uncertainty model, human-robot interaction, computer vision, object recognition, feature detection, image analysis).*
>
> *In order to ensure that relevant research was not excluded due to missing keywords, a manual review was also performed on all abstracts for the approved applications received from preparation groups NT-2 (computer science) and NT-14 (signals and systems) during the period.*
>
> *All research aimed at developing new or existing understanding in the field has been included. However, projects that apply already existing methods to achieve results within their own area*

have been excluded. (For example, research that uses machine learning to develop better disease diagnosis or tissue sample analysis)."

Based on data produced by VR according to the approach described above, Vinnova has compiled a summary as shown in Figures 59–61 below. In total, VR has identified 33 AI-related projects with a total grant volume of approximately SEK 95 million, decided on at some point during the period 2013–2017. Of these, 20 are "regular" project grants, four are project grants to young researchers, two are starting grants, one is a grant for postdoctoral employment abroad and six are smaller contributions for participation in conferences. The average size of the three former types of grants is approximately SEK 3.5 million. The funding is the result of open calls that are not specifically intended for AI but has involved competition with applications in other areas.

Figure 59. Grants for AI-related projects from VR decided on during the period 2013–2017 (excl. "environmental grants") and broken down by HEI and type of grant[113]



Source: Swedish Research Council. Data processed by Vinnova.

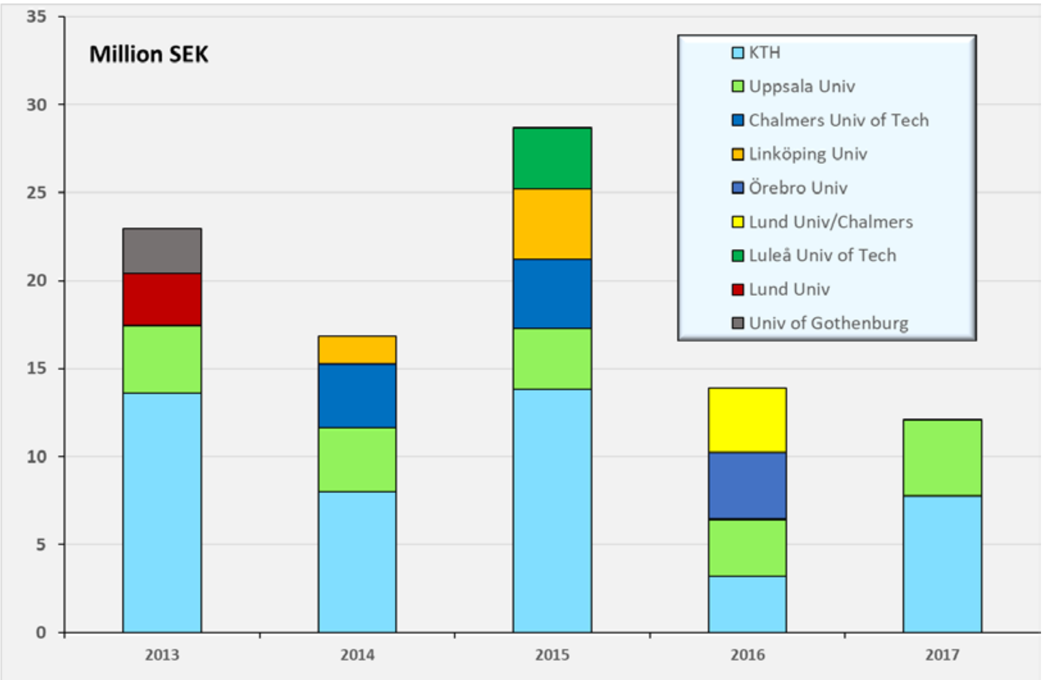
Researchers at KTH dominate as grant recipients and account for about half of the allocated funds, Figure 59. Almost a fifth of the funds have gone to researchers at Uppsala University.[114] In most cases, it involves single grants for each research environment. A research environment that stands out is the Department of Robotics, Perception and Learning at KTH with no less than four of the project grants (conference contributions excluded). Research environments with two project grants include: Department of Speech, Music and Hearing, KTH; Department of Information Technology (Automatic Control), Uppsala University; Mathematical Imaging Group, Lund University.

[113] Researchers at the University of Skövde and Stockholm University have also received conference contributions. These are so small that it could not be registered in the figure and therefore they have not been included.
[114] One researcher has had ties to both Lund University and Chalmers.

VR has also distributed a further two large grants, so-called "environmental grants", where a significant AI element has been identified. One of them, "NewLEADS – New approaches for model-based learning of dynamic systems", is a collaboration between researchers at KTH and Uppsala University.[115] The second environmental grant, "Spin current-based microwave oscillators, sensors, and neural networks", relates to a collaboration between the University of Gothenburg and KTH.[116] The appropriations amount to SEK 24 million and SEK 23 million respectively for the period 2017–2022. These two grants are not included in the figures.

Given the greatly increased interest in AI by society, the business sector and the research world, it is somewhat surprising that there is no upward trend in the funding of AI projects in VR's project portfolio. The trend has gradually been declining after a clear peak in 2015, Figure 60. As the total number of grants is so small – between three and eight grants per year if conference contributions are excluded – perhaps far-reaching conclusions should be avoided in terms of a two-year declining trend. However, if the low level of recent years persists, there is cause for concern.

Figure 60. Grants for AI-related projects from VR decided on during the period 2013–2017 (excl. "environmental grants") and broken down by HEI and year of decision

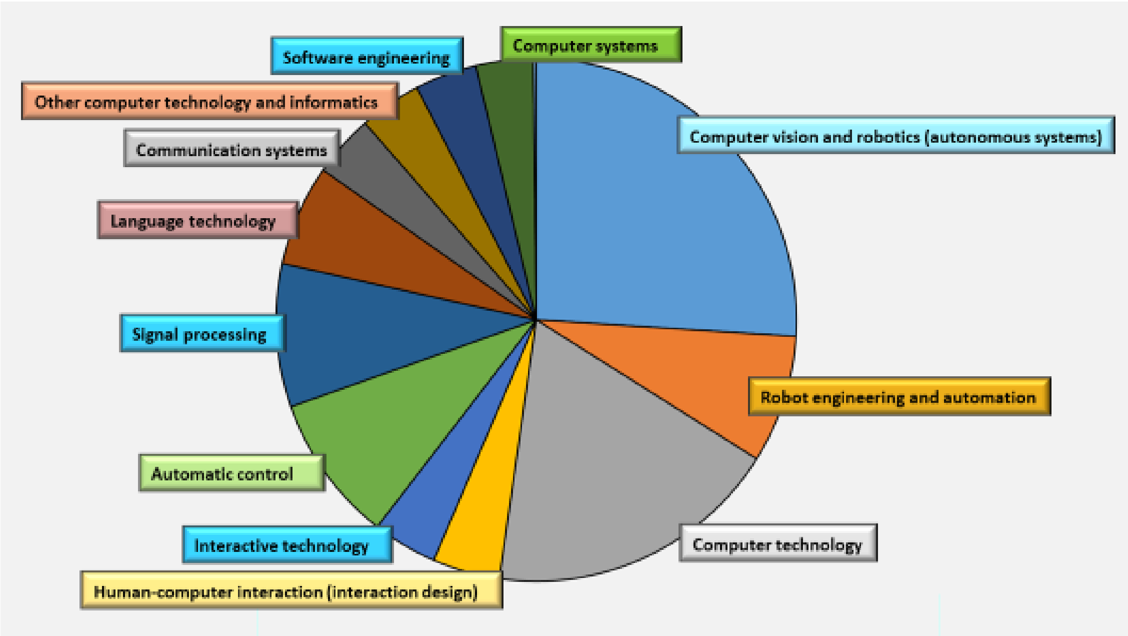


Source: Swedish Research Council. Data processed by Vinnova.

Figure 61 shows how the amount for the 33 VR-funded AI-related projects is broken down between Statistics Sweden's research subjects. A strong connection to computer vision and robotics is evident.

[115] http://www.uu.se/nyheter-press/nyheter/artikel/?id=9990&typ=artikel
[116] https://science.gu.se/aktuellt/nyheter/Nyheter+Detalj/stort-anslag-till-forskning-i-fysik.cid1428539

Figure 61. Grants for AI-related projects from VR decided on during the period 2013–2017: Breakdown of grant amount between Statistics Sweden's research subjects



Source: Swedish Research Council. Data processed by Vinnova.

As described initially, VR's mapping of AI-related projects is "aimed at developing new or existing understanding in the [AI] field. However, projects that apply already existing methods to achieve results within their own area have been excluded." This means that additional research projects that primarily apply, rather than develop, AI methods may well have received funding from VR.

11.2 Vinnova

Vinnova is Sweden's governmental innovation agency. Its mission is to contribute to sustainable growth by creating better conditions for innovation. This is primarily achieved through the financing of innovation projects and research to develop new solutions. In total, Vinnova invests approximately SEK 3 billion to promote innovation. Vinnova stimulates collaboration between companies, universities, university colleges, public sector actors, civil society and other actors nationally and internationally. An important aspect is contributing to strengthening research and innovation environments in the long term.

Vinnova continuously performs portfolio analyses of its activities within the framework of the strategic work. To this end, Vinnova has developed an analysis tool linked to its data warehouse. The data warehouse is also used for budget forecasts, daily project follow-ups and operational monitoring. The data warehouse currently has up-to-date information on all ongoing and completed projects at Vinnova since 2011. Data can be analysed based on predefined categories and taxonomies, such as actors, sectors, size, research area, etc., but also through text analysis based on keywords in project descriptions or other project information.

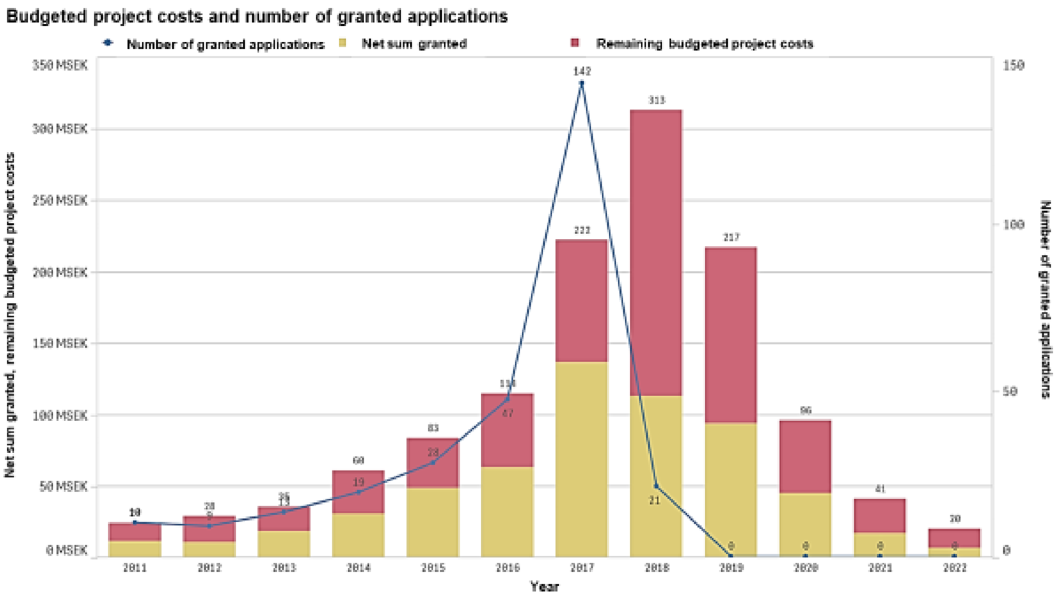
For this report, a text analysis has been performed for keywords associated with AI.[117] The AI projects have been identified with keywords in the following fields; project description, project title, project objectives and project reference. We therefore work on the premise that the projects are self-described as AI-related. We have focused on terms closely related to central concepts within AI and machine learning, but have excluded terminology that belongs to closely related but significantly broader applications, such as self-driving cars and smart expert systems. This has resulted in about 40 keywords.

Vinnova has performed quality checks on the results, but there are many grey zones linked to AI. The assessment is that the rule-based method used is restrictive. An in-depth analysis of links to key application areas and connections to other technology areas is important to do, but has not been possible within the framework of this study.

As of 28 March 2018, Vinnova had approved a total of 288 AI projects since 2011. The analysis of AI projects in Vinnova's project portfolio shows that AI projects have increased dramatically in the project portfolio in 2017 and 2018, Figure 62.

The total funding volume from Vinnova to these 288 projects is SEK 578 million. Since almost all of these projects require collaboration and all projects require stakeholder financing, the total turnover of these 285 projects amounts to over SEK 1.2 billion. The average number of project partners is 2.6. The gender balance is skewed. In only 16 per cent of the projects, the project manager is a woman.

Figure 62. AI projects in Vinnova's project portfolio 2011–2018



Source: Vinnova

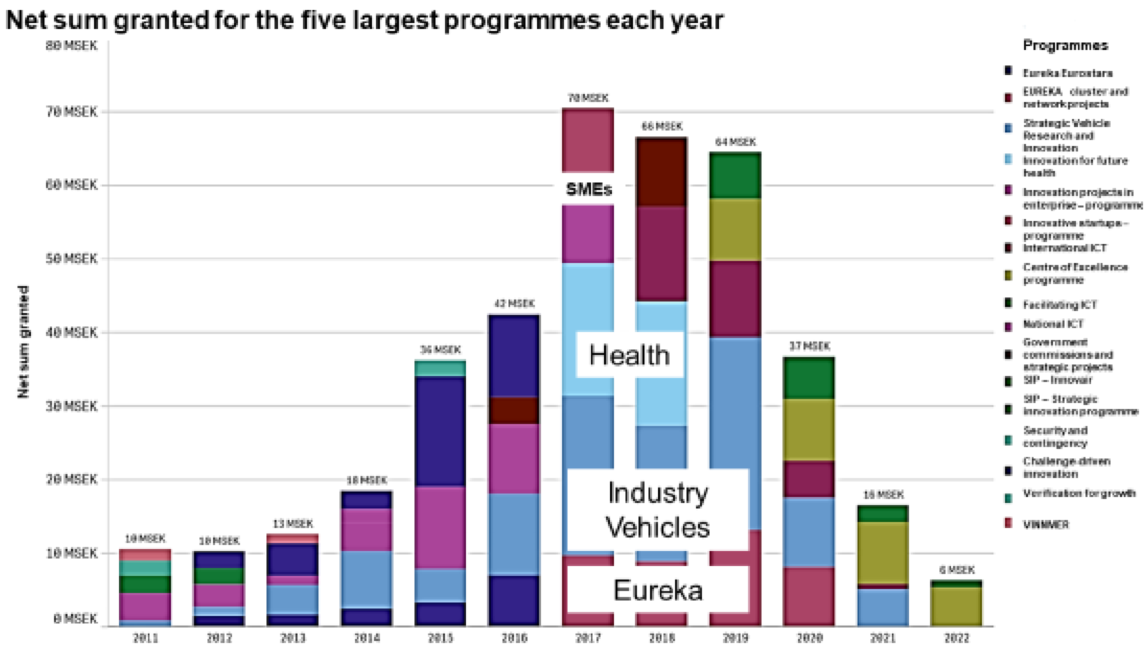
[117] The keywords used are: AI, (AI), AI-, artificiell intelligens, artificial intelligence, neuralt nätverk, neural network, neurala nätverk, bayes, markov model, djupinlär, djup inlär, djupt lärande, deep learning, deep-learning, maskininlär, machine learning, självlärande, självinlär, unsupervised learning, learning algorithm, automatiserade algoritmer, klusteralgoritm, clustering algorithm, classification engine, random forest, self-organizing map, self-organizing feature map, stödvektormaskin, support vektor ma, support vector ma, bildigenkänning, digital patologi, beslutstödssystem, (SOM), (SOFM).

Most of the AI projects in Vinnova's project portfolio have emerged within the framework of calls for proposals without a particular focus on AI. Exceptions are two calls in 2017, one regarding AI within health, medical care and social services and one call regarding "Machine learning – FFI" in 2017 within the Strategic Vehicle Research and Innovation programme.

The 285 AI projects are divided among several of Vinnova's various programmes, Figure 63. A large number of the projects are found within:

- Programme for Strategic Vehicle Research and Innovation (FFI)
- Programme calls for "Decision support system for health and medical care and social services using artificial intelligence" and "Artificial intelligence for better health"
- Various Strategic Innovation Programs (SIP)
- International programmes (Eureka Eurostars, two Eureka clusters, Ecsel Joint Undertaking, and Active and Assisted Living Programme (AAL)
- General programmes that support SMEs
- Pilot and spearhead project concerning digitalisation within the framework of government commissions to Vinnova.

Figure 63. AI projects in Vinnova's project portfolio 2011–2018 in the five programmes with the largest volume of AI projects



Source: Vinnova

There is variation in how strongly AI features in the projects. Not least in the largest projects where AI is one of several elements in complex projects where the processing of big data with AI methodology is an important but not dominant feature. The single largest project is the Digital Cellulose Center (DCC) competence centre. The element of AI is described as follows:

> *"The research within DCC will focus on the fundamental challenges related to creating new durable, electroactive composite materials and structures, but also on developing software (such*

as 'Deep learning') that can exploit the large amount of new data that will be generated by Digital Cellulose to create valuable new services and lessons."[118]

In total, more than 200 individual companies participate in the AI projects. Of these, the majority participate in only one project. Small and medium-sized enterprises' (SMEs) participation is more or less evenly distributed between the specific SME programmes (excl. Eureka Eurostars which is presented under the heading "International Cooperation") and other programmes.

Companies aside from SMEs are found primarily within the Strategic Vehicle Research and Innovation programme, International Cooperation and Strategic Innovation Programs. A handful of groups with extensive R&D in Sweden (AB Volvo, Volvo Cars, Scania, SAAB and Ericsson) together account for nearly 60 per cent of the total involvement of companies other than SMEs. Relatively extensive involvement by other companies is found in international projects (Telia, SE Bank, Sigma and Bombardier), in part by the member companies in the Digital Cellulose Center, most of which are forest industry companies.

Among research organisations, Linköping University, RISE ICT, Luleå University of Technology, KTH, Chalmers, Mälardalen University, Innventia, Frauenhofer-Chalmers Research Centre for Industrial Mathematics and Karolinska Institutet show the greatest participation in the order mentioned. However, the total funding for each organisation is strongly impacted by participation in the Digital Cellulose Center (with funding over six years) and a few major international projects. Within the Strategic Vehicle Research and Innovation programme and the Strategic Innovation Programs, Linköping University and Chalmers dominate among the research organisations.

Public sector involvement is concentrated to county councils/university hospitals. Stockholm County Council/Karolinska University Hospital participate in several projects, the largest of which, a so-called reality lab, aims at

"Accelerating the use of 'AI' (artificial intelligence) within healthcare, by driving the development and implementation of imaging diagnostic AI solutions based on patient and operational needs."

Jönköping County Council cooperates with Telia, Linnaeus University and three companies in Sweden in a major Eureka CelticPlus project "From empowering to Viable Living". The project, which is led by Telia and has a total budget of EUR 9.6 million, aims at using advanced ICT solutions to make it easier for the elderly to stay living at home:

"This supports the analysis and interpretation of data of individuals and also on a big scale. The use of state-of-the-art machine learning and big data analysis methodologies, together with a profound IoT based data acquisition, will allow the development of sophisticated predictive

[118] A similar example is the Productive4.0 project within the framework of the "Ecsel Joint Undertaking" programme. In this very large project, which aims to develop integrated and "seamless" automation and networking solutions and engages more than 100 partner organisations, six Swedish organisations (reported as separate subprojects of the data presented) participate with total funding of approximately SEK 68 million. The link to AI is described as follows: "In the process, reference implementations such as 3D printer farms, customised production or self-learning robotic systems will benefit from specific technical and conceptual approaches in areas such as service-oriented architecture (SOA), IOT components and infrastructures as well as process virtualisation and standardisation."

health related services. FRONT-VL will ensure highest standards of privacy and data ownership of the individual."

Together, Karolinska University Hospital and Jönköping County Council account for 60 per cent of public sector involvement in the AI-related projects.

11.3 Swedish Foundation for Strategic Research

The Swedish Foundation for Strategic Research (SFF) finances research within science, technology and medicine in the amount of approximately SEK 600 million a year. The foundation promotes the development of strong research environments of the highest international class which are important for the development of Sweden's future competitiveness. The foundation has two main criteria for its funding:

- Relevance and expected impact in society
- Scientific quality.

Within the framework of the thematic initiative *Information-Intensive Systems*, SSF financed AI research with approximately SEK 100 million during the period 2012–2017. In 2015, another SEK 300 million was allocated to 10 projects for AI research for the years 2016–2021 within the framework of a thematic initiative *Smart Systems*. This was followed in 2016 by additional investments in which a total of SEK 200 million was allocated to seven AI research projects for the years 2017–2022. For the period 2018–2023, another SEK 300 million has been allocated to ten AI research projects. Furthermore, over the past few years, almost SEK 150 million has been allocated for projects that feature machine learning.

Overall, SSF has allocated approximately SEK 1 billion to AI projects since 2012. The majority of these funds will be disbursed in the next 3–5 years.

11.4 The Knowledge Foundation

The mission of the Knowledge Foundation is to strengthen Sweden's competitiveness by financing research and skills development at Sweden's university colleges and new universities in collaboration with the business sector. The Knowledge Foundation does not call for proposals within specific research areas but rather these are chosen by the HEIs and researchers together with the private sector stakeholders. The Knowledge Foundation's funding is matched in size by the private sector stakeholders.

As an estimate, the Knowledge Foundation has financed AI-related research and skills development with funds of around SEK 1 billion over the past 10 years. However, the total volume is uncertain and depends on what is considered to be AI-related. A number of the Knowledge Foundation's more important AI-related investments are presented below. Some research profiles financed by the Knowledge Foundation are related to the field of AI, including:

- Semantic Robots, Örebro University, SEK 36 million (total volume: SEK 83 million), 2014–2020.
- Big Data – Scalable resource-efficient systems for big data analytics, Blekinge Institute of Technology, SEK 36 million (total volume: SEK 87 million), 2014–2022.

- CAISR – Center for Applied Intelligent Systems Research, Halmstad University, SEK 36 million (total volume: SEK 133 million), 2012–2020.
- Infofusion – Information fusion from databases, sensors and simulations (completed), University of Skövde, SEK 30 million (total volume: SEK 60 million), 2005–2011.

In addition to investments in research profiles, the Knowledge Foundation finances a number of other major projects within AI, including:

- AIR – Interaction with autonomous systems, SEK 27 million, 2015–2019, Cooperation between: University of Skövde, Halmstad University, Örebro University.
- BISON – Big Data Fusion, University of Skövde, SEK 14.8 million (total volume: SEK 27 million), 2015–2019.
- KDDS – Knowledge-based decision support through optimisation, University of Skövde, SEK 14.8 million (total volume: SEK 27 million), 2015–2019.
- Smarter (step 1) – Short courses at second-cycle level for professionals. Smart Industry with Autonomous and Intelligent Systems. Örebro University, SEK 3.7 million, 2017–2019 (continued in step 2, 4 years).
- MAISTR (step 1) – Short courses at second-cycle level for professionals. Data analysis and digital service innovation based on AI technology. Halmstad University in cooperation with the University of Skövde and RISE (SICS), SEK 3.7 million, 2018–2020 (with possible continuation in step 2, 4 years).

Further initiatives from the Knowledge Foundation linked to AI are ongoing and will be initiated in 2018.

11.5 Knut and Alice Wallenberg Foundation

Knut and Alice Wallenberg Foundation (KAW) announced on 14 November 2017 that the foundation will invest SEK 1 billion over 10 years, i.e. SEK 100 million per year, in research and third-cycle education in order to "build competence within different aspects of AI; Machine learning, deep learning, and mathematics". The initiative is being implemented as an enhancement of the foundation's previous investment in the Wallenberg Autonomous Systems and Software Program (WASP), launched in 2015 with Linköping University as host university. There are already elements of AI in some of the projects run within the framework of the initial funding to WASP. As of 2017, WASP stands for Wallenberg AI, Autonomous Systems and Software Program.

> *"WASP is a major national initiative for basic research, education and faculty recruitment. The total budget for the program is more than SEK 3.5 billion, and major goals are more than 50 new professors and more than 300 new PhDs within AI, Autonomous Systems and Software. The ambition is to advance Sweden into an internationally recognised and leading position in these areas, and WASP is now taking a step by launching a first broad investment in Artificial Intelligence. The offering includes several different positions to build and strengthen AI in Sweden."* [119]

The participating universities, Linköping University, Chalmers, KTH, Umeå University and Lund University, together with Swedish companies, are expected to contribute to the initiative with additional resources, with the latter facilitating industry-employed doctoral students

[119] http://wasp-sweden.org/

among other things. Professor Danica Kragic, KTH, will lead the research on machine learning and deep learning, and Professor Johan Håstad, KTH, will lead the mathematical research relevant to AI.

WASP's strategic instruments are:

- "An international recruitment program, providing the brain-gain to establish new research areas, and to reinforce existing strengths in Sweden. The recruitment program aim for both outstanding younger researchers as well as established experts. This is achieved by offering recruitment packages that are attractive by international standards."
- "A national graduate school with close interaction with Swedish industry with the aim to raise the knowledge level in Sweden. The graduate school is dimensioned to produce at least 300 new PhDs, with at least 80 of those being industrial PhD students."
- "Platforms for research and demonstration in collaboration with other parties. The participating universities have substantial existing infrastructures that can be leveraged for this purpose. Further reinforcement will be achieved by including industrial demonstrators, or even by aiming for new larger highly visible initiatives on an international scale."

The entire WASP initiative is relevant to and will strengthen AI development in Sweden, although about a third of the focus is specifically on AI.

12 AI investments in other countries

There is intense discussion on AI's potential and impact on societal development in all OECD countries, China, within the EU and in many countries outside the OECD. National strategies for AI development have been formulated in a number of countries with the aim of laying the foundations for policy development and accumulating a power base to utilise AI for innovation, competitiveness and welfare. This chapter summarises policy discussions and policy initiatives from some countries that are considered to be relevant to the formulation of future strategies and measures in Sweden.[120]

12.1 USA

At the same time as the American election campaign culminated in October 2016, the Obama administration, as one of the first governments, published a study as a basis for national policy on AI. This consisted of two cross-sectoral policy documents setting out the main focus for civil federal efforts in addressing developments within AI.

Three problems were in focus:

1. How can the government support the development of AI and its positive effects?
2. What significance will AI have at workplaces and how can the American population receive education and training for future jobs?
3. How can the government support people during this change while at the same time creating economic growth that will benefit everyone during this revolution?

One of the reports, "Preparing for the Future of Artificial Intelligence"[121] , contains a broad overview of the current development status and potential use for AI as well as recommendations on the initiatives that should be implemented at the federal level. The second report, "The National Artificial Intelligence R&D Strategic Plan"[122] , specifies areas for research and development efforts that should be made at the federal level. The approach in both documents is very broad and great emphasis is placed on ethical and societal aspects of increased use of AI and the knowledge needs that result.

The R&D plan is part of the comprehensive coordination of the federal government's overall R&D investments under the auspices of the National Science and Technology Council and its various committees and subcommittees. The process of developing the R&D plan was based,

[120] In addition to the countries discussed in this chapter, the AI strategies in Japan and the Netherlands should also be of great interest to Sweden: Japan (March 2017): Artificial Intelligence Technology Strategy. http://www.nedo.go.jp/content/100865202.pdf); Report on Artificial Intelligence and Human Society (http://www8.cao.go.jp/cstp/tyousakai/ai/summary/aisociety_en.pdf. The Netherlands (November 2017): Digital Society Research Agenda. http://www.vsnu.nl/files/documenten/Domeinen/Onderzoek/DigitaleSamenleving/VSNU%20Digital%20Society%20Research%20Agenda.pdf

[121] https://obamawhitehouse.archives.gov/sites/default/files/whitehouse_files/microsites/ostp/NSTC/preparing_for_the_future_of_ai.pdf ; In December 2016, a follow-up report was published entitled "Artificial Intelligence, Automation, and the Economy": https://www.congress.gov/bill/115th-congress/house-bill/4625/text/?format=xml

[122] https://www.nitrd.gov/PUBS/national_ai_rd_strategic_plan.pdf

inter alia, on several open meetings where some of the leading American analysts, researchers and companies were represented. The body primarily responsible for the process was the Networking and Information Technology Research and Development Subcommittee (NITRID).

The R&D plan is hardly a plan in the true sense of the word but is primarily a framework for specific initiatives and actions by various federal authorities where the concrete planning is handed over to the latter. For Sweden's part, the documents are of greatest value firstly in the in-depth discussion of AI's possible contribution to development in a number of social sectors, and secondly in identifying areas where public initiatives are needed.

In general terms, the R&D plan states that the federal government's investments should primarily concern areas that fall outside of consumer markets[123]. Seven priority areas are identified and developed in the report:

1. Make long-term investments in AI research.124
2. Develop effective methods for human-AI collaboration.125
3. Understand and address the ethical, legal, and societal implications of AI.
4. Ensure the safety and security of AI systems.
5. Develop shared public datasets and environments for AI training and testing.
6. Measure and evaluate AI technologies through standards and benchmarks.
7. Better understand the national AI R&D workforce need.

It is worth noting that the interaction between human and AI-based systems is considered to be so central that it is presented as a separate priority area. It is also interesting to note that the supply of data is deemed crucial, and it is considered desirable that data for the training of algorithms can be made open and publicly available.

The report points out that the implementation of measures under priority areas 1 to 6 above may require new ways of working and collaborating for the R&D-funding authorities. There is emphasis on the need for close collaboration with other federal R&D-coordinating bodies (including within cyber-security, privacy, robotics, software design, cyber physical systems, high-performance computing). In relation to priority area 7, it is recommended that a systematic mapping be performed in relation to the competence needs for AI development and the conditions for meeting these.

The process resulted in the following recommendations:

- Authorities should explore the opportunities to benefit from AI.
- Authorities that do not have internal competence within advanced data analysis or AI are advised to collaborate with companies and researchers with such expertise. The management at authorities should also have sufficient AI competence.

[123] "The Federal government should therefore emphasize AI investments in areas of strong societal importance that are not aimed at consumer markets—areas such as AI for public health, urban systems and smart communities, social welfare, criminal justice, environmental sustainability, and national security, as well as long-term research that accelerates the production of AI knowledge and technologies."
[124] The following subareas are described in the plan: Data analysis; Perception; Theoretical limitations for AI; General AI; Scalable AI; Human-like AI; Robotics; AI Hardware
[125] Sub-areas: Human-AI communication; Strengthening of human ability; Natural language processing; Interface and visualisation.

- Open data to be used for AI-related purposes should be prioritised.
- The Government itself should specifically support key authorities in engaging in high potential AI projects even though these entail high risk.
- Authorities should work together within the area of competence building and to develop AI standards and identify the best methods.
- Sufficient technical AI competence must be represented in discussions on AI regulation.
- Authorities should have access to staff representing a variety of technical backgrounds. This can, for example, be achieved through exchange programs with states.
- The government should closely follow the development of AI, not only in the United States but also in other countries.
- The government should ensure the availability of AI specialists in the United States in various ways. Both specialists and users need to increase in number, competence and diversity.
- The Government should closely follow AI's impact on the labour market.
- Authorities using AI as decision support where individuals are affected should be extra careful to ensure that these decisions are effective and legally certain using evidence-based methods.
- Schools and universities that teach AI should include various related aspects of ethics, security and privacy in the education.
- The government should develop a strategy for international AI involvement. The government should also deepen its collaborations concerning AI with key international stakeholders such as other governments, international organisations, industry and academia.

In total, it is estimated that federal authorities have financed non-classified R&D within the area of AI in the amount of approximately USD 1.1 billion in 2015. The United States also has many major AI initiatives within defence and the defence industry. In addition to civil federal R&D investments there is thus a likely comprehensive federal funding of classified AI-related R&D.

Even after the new administration took over in January 2017, activities in several of these areas are ongoing, for example, through cross-party cooperation in the Senate and the House of Representatives. At the same time, many researchers and entrepreneurs in the United States see a risk of, inter alia, new migration policy (harder to hire foreign expertise) and tax policy leading to a reduction in the US's leading role in the AI. During the second half of 2017, three new federal law were introduced that address the use of AI. Two of these regulate the use of self-driving cars to increase safety and the third was the establishment of a cross-party advisory committee to handle AI issues.

One of the many active discussions concerning AI taking place among federal authorities is what each authority should do independently and what should be the focus of cooperation. An area that has proven suitable for cooperation is the opportunity for citizens and companies to interact with authorities through voice-controlled products such as Alexa, Cortana, Google Home and Siri. The central General Service Administration has an ongoing programme in which some thirty government agencies participate in creating this general interface for the authorities. Similar activities exist at the state level and in several cities.

However, it is still unclear how and to what extent the proposals and recommendations presented in the R&D plan have been implemented during the Trump administration.[126] An indication that there is political commitment in Congress is the cross-party proposal presented in Congress on 12 December 2017 to establish a Federal Advisory Committee on the Development and Implementation of Artificial Intelligence ("FUTURE of Artificial Intelligence Act of 2017")[127] and the hearings which have been held in this case.

In addition to the policy discussion taking place at the federal level, there are similar activities in many states. Furthermore, there is an extensive exchange of competence, data and research across different geographic clusters in the United States. These are the major AI-based companies such as Google, Facebook, Microsoft, Amazon, IBM and Apple, which collaborate with startups and universities, in particular in Silicon Valley, Seattle and the Boston area.

12.2 China

The Chinese government has far-reaching plans for the use of AI. China's current AI plan for 2018–2020 has been interpreted as a vision for the whole of China's economy. Some of the areas in which China invests heavily include hardware for AI, robots for people with disabilities, AI in healthcare, manufacturing and AI for energy efficiency. China aims to become the world's leading AI nation by 2030. This goal is broken down into different five-year plans. Within the Ministry of Science and Technology there is a special office for the promotion of AI.

Aside from the governmental commitment in the form of investments like a new research park costing the equivalent of SEK 18 billion in Beijing, many companies like Baidu, Alibaba, Tencent and Xiaomi invest heavily in AI. Many of the leading American AI companies have established themselves in China, while several Chinese AI companies are part of the major AI clusters in the United States.

One of the most important resources for being able to develop good AI applications is the availability of large amounts of data to train the systems. China, through its large population, often has good access to this resource.

In addition to the fact that the central government in China is making major investments in AI, investments are also taking place in several major cities. More than 300 cities are investing in the use of AI in their smart city programmes. In July 2017, China launched a special AI strategy entitled "A Next Generation Artificial Intelligence Development Plan".[128]

According to Andrew Ng, a leading researcher and entrepreneur within AI in both China and the United States, China is very well informed on AI activities taking place in North America

[126] One initiative in line with the recommendations from the two reports is "The NIST Machine Learning & AI Initiative" (https://www.youtube.com/watch?v=UAKkickQ8gM) which aims to build a test bed for machine learning, including a database with so-called training data.
[127] https://www.congress.gov/bill/115th-congress/house-bill/4625/text/?format=xml
[128] https://chinacopyrightandmedia.wordpress.com/2017/07/20/a-next-generation-artificial-intelligence-development-plan/

and Europe, but the corresponding knowledge on China is low. One reason is probably the lack of language skills.

12.3 United Kingdom

In October 2017, the British government published a report on AI, “Growing the artificial intelligence industry in the UK”[129] , with recommendations regarding skills provision, data access, research and increased use of AI. The report, jointly commissioned by the Business Secretary and Culture Secretary[130], was written by a university professor (Wendy Hall, University of Southampton) and an entrepreneur (Jérôme Pesenti, CEO, BenevelentTech), and had the main purpose of identifying measures to promote the growth of the AI industry in Great Britain.

The industry strategy presented[131] by the British government in the form of a white paper on 27 November 2017 contained most of the initiatives recommended in the AI report from October. “AI & Data Economy” is listed as one of four grand challenges:

- **Growing the AI & Data-Driven Economy**: putting the UK at the forefront of the artificial intelligence and data revolution
- **Clean Growth**: maximising the advantages for UK industry from the global shift to clean growth
- **The Future of Mobility**: being a world leader in shaping the future of mobility
- **Ageing Society**: harnessing the power of innovation to help meet the needs of an ageing society

The basic idea behind the challenges has a great deal in common with the Swedish Government’s strategic cooperation programme.[132] For each of the challenges, initiatives are presented that are already planned with an opening for additional future efforts. Although the first challenge is formulated more broadly than simply AI, the measures presented in the strategy paper are mainly derived from the AI report. In the state budget presented in November 2017, GBP 75 million was earmarked for initiatives within the AI area, but it is unclear for what period.

One of the proposals in the AI report contained in the industry strategy is to appoint the Alan Turing Institute the status of a national institute for AI (in addition to its original mission). The institute has an interesting design and working methods, which should be of great interest to Sweden as a subject of study. Following (in principle) open competition, the institute was founded as an independent charity in 2015 by five universities[133] and the research council EPSRC, with the aim of serving as a national institute for data science with headquarters at the

[129] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/652097/Growing_the_artificial_intelligence_industry_in_the_UK.pdf
[130] Secretary of State for Business, Energy and Industrial Strategy och Secretary of State for Digital, Culture, Media and Sport.
[131] “Industrial Strategy White Paper – Building a Britain fit for the future” (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf
[132] The challenges are said to address “developments in technology that are set to transform industries and societies around the world, and in which the UK – if we muster our forces across sectors – has the opportunity to play a leading global role” and represent “an invitation to business, academia and civil society to work together to innovate and develop new technologies and industries in areas of strategic importance to our country”.
[133] Cambridge, Edinburgh, Oxford, UCL and Warwick

British Library. In November 2017, another four universities were accepted as partners in the institute.[134]

The institute is still under construction and major efforts have been devoted to defining the institute's operational focus more specifically. To this end, a very broad but thorough review of potential research areas was carried out through about 100 workshops and other consultations involving about 1,000 people.[135] Based on this work, a strategy for the institute[136] was presented in June 2016 which structures its activities, firstly in a number of basic research domains[137] and secondly in a number of broad areas of application.[138]

As core funding, EPSRC has allocated GBP 42 million and the five founding universities together have allocated GBP 25 million for the first six and five years respectively. Within some of the areas of application, a large portion of the activities are carried out together with strategic partners that contribute with resources.[139] A significant portion of the activities are conducted by researchers from partner universities that are linked to the institute part-time.

Skills provision is an important part of the planned efforts to develop AI and one third of the 18 recommendations in the AI report fall within this category and are also included in the industry strategy:

- Industry-funded Master's programmes with initial intake of 300 students.
- One-year supplementary education in AI at the Master's level for people who have already completed programmes within areas other than data science. In order to dimension these programmes, further studies of potential demand are needed.
- 200 new positions for doctoral students, including recruitment from abroad.[140]
- Online courses for continuing professional development that can be credited for a Master's degree.
- Measures for increased diversity among those working with AI.
- Research scholarships to retain and attract prominent researchers to conduct full or part-time (e.g. combined employment at universities and companies) research and teaching within AI in the UK.

On 25 April 2018 a major national collaborative initiative was announced that focuses on AI in the UK:

> *"The United Kingdom is planning a big investment in artificial intelligence technologies in a deal worth nearly £1 billion, or about $1.3 billion. The U.K. government said Thursday that part of its multi-year AI investment–about £300 million, or more than $400 million–would come from*

[134] Leeds, Manchester, Newcastle and Queen Mary University of London

[135] The results are summarised in a report: The Alan Turing Institute Scoping Programme (https://aticdn.s3-eu-west-1.amazonaws.com/2015/06/The-Alan-Turing-Institute-Scoping-Programme.pdf)

[136] https://aticdn.s3-eu-west-1.amazonaws.com/2016/06/Shaping-our-Strategy-The-Alan-Turing-Institute-1.pdf

[137] a) Mathematical Representations of data and models, providing foundations for analysis; b) Inference & Learning methodologies for data analytics, enabling scalable algorithms; c) Systems & Platforms to scale up and to scale out algorithmic and analytical tools; d) Social sciences methods and expertise for Understanding Human Behaviour from data.

[138] Engineering; Technology; Defence & Security; Smart Cities; Financial Services; Health & Wellbeing

[139] Strategic partners are currently the Department of Defence, Intel, HSBC and Lloyd's Register Foundation.

[140] This is based on an estimate from EPSRC that the demand for doctoral positions in machine learning and technical AI disciplines amounts to more than 500 in total in the country, and that approximately 40 per cent of applicants are deemed to have sufficient competence to be accepted.

U.K.-based corporations and investment firms and those located outside the country. Some of the U.S.-based companies involved with the U.K.'s AI deal include Microsoft, Hewlett Packard Enterprise, IBM, McKinsey, and Pfizer, ... As part of the deal, the Japanese venture capital firm Global Brain plans to invest about $48 million in U.K. tech startups and will open a European headquarters in the United Kingdom. The University of Cambridge will also give U.K. businesses access to a new $13 million supercomputer to help with AI-related projects." [141]

12.4 France

In March 2018, the results were published by a task force led by Cédric Villani, mathematician and parliamentary member, "For a meaningful Artificial Intelligence"[142]. The commission, given in September 2017, was to produce supporting material for an AI strategy for France and Europe.

The main focus of the strategy is:

- An Economic Policy Based on Data
  - × Reinforcing the European Data Ecosystem
  - × Consolidating and Raising the Profile of the French AI Ecosystem
  - × Leveraging Public Procurement
  - × A Clear Choice: Focusing on Four Strategic Sectors
  - × Initiating European Industrial Momentum with Regard to AI
  - × Transformation of the State: Leading by Example
- Towards Agile and Enabling Research
  - × Building a Network of Interdisciplinary Institutions for Artificial Intelligence
  - × Computing Means for Research
  - × Enhancing the Appeal of Careers in Public Research
  - × Stepping Up Interaction Between Academia and Industry
- Anticipating and Controlling the Impacts on Jobs and Employment
  - × Anticipating the Impacts on Employment and Testing Out
  - × Developing Complementarity Within Organizations and Regulating Working Conditions
  - × Setting in a Motion an Overhaul of Initial Training and Continuing Professional Skills
  - × Testing Out New Methods for Funding Vocational Training to Factor in Value Transfers
  - × Training AI Talent at All Levels
- Using Artificial Intelligence to Help Create a More Ecological Economy
  - × Making this Issue Part of the International Agenda
  - × Promoting the Convergence of the Ecological Transition and Developments in AI
  - × Designing AI that Uses Less Energy
  - × Releasing Ecological Data
- What are the Ethics of AI?

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[141] http://fortune.com/2018/04/25/uk-ai-artificial-intelligence-deal/
[142] Villani, C., For a meaningful Artificial Intelligence. Towards a French and European strategy.
A parliamentary mission assigned by the Prime Minister Édouard Philippe in September 2017, published 8 March 2018.
https://www.aiforhumanity.fr/pdfs/MissionVillani_Report_ENG-VF.pdf

- × Opening the 'Black Box'
- × Considering Ethics from the Design Stage
- × Considering Collective Rights to Data
- × How Do We Stay in Control?
- × Specific Governance of Ethics in Artificial Intelligence
- For Inclusive and Diverse Artificial Intelligence
  - × Gender Balance and Diversity: Striving for Equality
  - × Developing Digital Mediation and Social Innovation so that AI Benefits Everyone

On 29 March 2018, President Macron presented his vision and strategy to secure France's position as a leader within AI[143], based on the strategy material developed within Villani's task force.

The main points of the strategy are:

- Developing an aggressive data policy:
  1. Encourage companies to pool and share their data
  2. Create data that is in the public interest
  3. Support the right to data portability
- Focus on four sectors:
  - × Health field – Predictive and personalized medicine will make it possible to monitor patients in real time, and improve the detection of anomalies in electrocardiograms.
  - × Transport field – In the transport field, the development of the driverless car is a key industrial priority.
  - × Defence and security field – AI could be used to detect and even respond to cyberattacks that cannot be detected by humans, and facilitate the analysis of multimedia data.
  - × Environmental field – the development of monitoring tools for farmers will pave the way for smart agriculture benefiting the entire agrifood chain.
- To better connect geographical regions and AI research areas:
  - × Create interdisciplinary AI institutes (3IA) in selected public higher education and research establishments. These institutes must be spread throughout France and cover a specific application or field of research.
  - × Allocate appropriate resources to research, including a supercomputer designed especially for AI applications in partnership with manufacturers. In addition, researchers must be given facilitated access to a European cloud service.
  - × Make careers in public research more attractive by boosting France's appeal to expatriate or foreign talents: increasing the number of masters and doctoral students studying AI, increasing the salaries of researchers and enhancing exchanges between academics and industry.
- New training models must be planned and tested to prepare for these professional transitions:
  - × Create a public laboratory on the transformation of work. The creation of a public laboratory on the transformation of work will encourage reflection on the ways in which automation is changing

[143] AI for Humanity. French Strategy for Artificial Intelligence. The President of the French Republic presented his vision and strategy to make France a leader in artificial intelligence (AI) at the Collège de France on 29 March 2018. https://www.aiforhumanity.fr/en/

occupations. It will also make it possible to test tools supporting professional transitions, especially for those likely to be most affected by automation.

- × Develop complementarity between humans and machines. To improve future working conditions, reflections must focus on developing a "complementarity index" for businesses, and including all aspects of the digital transition in social dialogue. This could result in a legislative project on working conditions in the automated era.
- × Test new methods for vocational training. This testing would make it possible to address AI-related changes to value chains. Currently, businesses fund the vocational training of their own employees. However, for their digital transformation, they often call on other actors who capture value and play a key role in automating tasks but do not help fund vocational training for employees. New funding methods must therefore be tested through social dialogue.

- Making AI more environmentally friendly:
  - × Firstly, by creating a research centre focusing on AI and the ecological transition. This centre could contribute to projects such as Tara Oceans, which is at the crossroads of life sciences and ecology.
  - × Secondly, by implementing a platform to measure the environmental impact of smart digital tools.
  - × As part of this approach, it must help AI become less energy-intensive by supporting the ecological transition of the European cloud industry.
  - × Lastly, ecological transition must go hand in hand with the liberation of "ecological data". AI can help reduce our energy consumption and restore and protect nature – for instance, by using drones to carry out reforestation, or by mapping living species through image recognition technology.
- Opening up the black boxes of AI. Artificial intelligence technologies must be socially acceptable:
  - × Develop algorithm transparency and audits by developing the capacities necessary to observe, understand and audit their operation. To do so, a group of experts must be created to analyse algorithms and databases, and research on explainability must be supported to encourage civil society to carry out its own evaluations.
  - × This means focusing on three areas of research: producing more explainable models, producing more interpretable user interfaces, and understanding the mechanisms at work in order to produce satisfactory explanations.
  - × Consider the responsibility of AI actors for the ethical issues at stake:
    - By including ethics in training for AI engineers and researchers.
    - By carrying out a discrimination impact assessment, along the lines of France's privacy impact assessment (PIA), to encourage AI designers to consider the social implications of the algorithms they produce.
  - × Create a consultative ethics committee for digital technologies and AI, which would organize public debate in this field. This committee would have a high level of expertise and independence. Indeed, 94 per cent of those interviewed considered that the development of AI in our society should be regularly addressed in public debates.
  - × Guarantee the principle of human responsibility, particularly when AI tools are used in public services. This includes setting boundaries for the use of predictive algorithms in the law enforcement context. It also means extensively discussing any development of lethal autonomous weapons systems (LAWS) at the international level, and creating an observatory for the non-proliferation of these weapons.

The day following the launch of France's AI strategy, there was an announcement of the establishment of *the PRAIRIE Institute*, "a center of excellence dedicated to artificial intelligence in Paris" in collaboration between CNRS, Inria and PSL University, together with Amazon, Criteo, Facebook, Faurecia, Google, Microsoft, NAVER LABS, Nokia Bell Labs, PSA Group, SUEZ and Valeo.[144]

The overarching goal is "to become an international reference in the field of artificial intelligence" through collaboration between industry and academia. Three operations for a 5-year collaboration are:

- to make a significant contribution to driving progress in fundamental knowledge in artificial intelligence (AI) freely distributed among the international scientific community;
- to take part in solving concrete problems with a major application-related impact;
- to contribute to training in the field of artificial intelligence.

12.5 Canada

Canada has a prominent place in research and has attracted several of the leading American IT companies to establish AI labs in Canada. In April 2015, an analysis was conducted of the possibilities and conditions with AI in Canada: Artificial Intelligence in Canada. Where do we stand?[145]

In March 2017, the Canadian government announced that it was investing CAD 125 million in a "Pan-Canadian Artificial Intelligence Strategy". This aims at strengthening the collaboration between strong research environments in Toronto-Waterloo, Montréal and Edmonton (where major state research efforts have been made previously), with the goal of Canada continuing to attract companies to invest in AI operations in the country. An in-depth interview with one of the key people in the development of AI research in Montréal provides a good picture of how such a strong research and innovation environment was able to be built up in this city.[146]

12.6 Finland

Finland does not have the same long, broad and deep tradition of AI as the United States, China and Japan. Nor do they have the resources to compete in the future with the research centres in these big countries. They are rather dependent on niche vertical areas and on collaborations to become a prominent nation in the use of AI. However, even if this limits the choices, it has often been a successful strategy to place oneself high up in the value chain.

The Finnish Government, with the prime minister at the forefront, has expressed a clear goal of Finland being a leading AI nation, with this implying no least the intention of becoming a leading player in the use of AI. Prime Minister Juha Sipilä wants to create a common vision for how society uses AI to increase prosperity. He believes that this requires new skills, new thinking to solve problems, forward-looking decision making and a dynamic labour market. Finance Minister Mika Lintilä has also emphasised the importance of Finland maintaining a high pace in the introduction of AI in society.

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[144] https://www.inria.fr/en/news/news-from-inria/launch-of-the-prairie-institute
[145] https://www.ictc-ctic.ca/wp-content/uploads/2015/06/AI-White-paper-final-English1.pdf
[146] "Why Montreal Has Emerged As An Artificial Intelligence Powerhouse" https://www.forbes.com/sites/peterhigh/2017/11/06/why-montreal-has-emerged-as-an-artificial-intelligence-powerhouse/#1a987b4323bd

In 2017, the "Artificial Intelligence Working Group" was established in the Ministry of Economic Affairs and Employment. The working group has analysed Finland's strengths and weaknesses in a world that is quickly beginning to use AI. The working group's analyses indicate that if the development of Finland as an AI nation is not driven by political means, the average GDP growth for the period 2017–2030 will be 0.8 per cent while employment is expected to decline by 0.5 per cent. If, on the other hand, AI development is actively pursued, the analysis indicates an average GDP growth of 3.0 per cent and an employment increase of 5.0 per cent during the period.

The conclusion from the working group is that for Finland to continue to be a successful welfare state, it is necessary to quickly learn new technology and start using it. This applies to individuals, companies and the public sector. In the public sector, one can see the possibilities for anticipating needs and acting faster and more correctly to respond to these, while at the same time providing a more personalised service.

The working group has made recommendations that focus on the following areas:

1 How the Finnish industry's competitiveness can be strengthened using AI.
2 How data can be used in all areas of society.
3 How to simplify and speed up the use of AI.
4 How managers get adequate AI skills and how to ensure AI competence.
5 How the government can make crucial decisions regarding, among other things, investments in the AI area.
6 How AI helps Finland build the world's best public sector.
7 How to secure the partnerships that Finland needs.
8 How Finland becomes a leader within AI.

The working group also emphasises the importance of Finland having good access to qualitative data in order to train and build AI applications. It is believed that this is already one of Finland's leading assets in international competition.

Finland has created a strong centre for research at the University of Helsinki. Many initiatives are currently taking place in the field of healthcare. In Espoo, a project is ongoing to combine data within the social services in order to analyse and identify new ways of providing services to citizens and counteracting social exclusion. Even in industries that are central to Finland, such as the forestry industry, AI development is ongoing.

An important element to ensure Finland's success is for the big organisations' management to rapidly acquire strategic and commercial competence within AI. When Nokia's chairman, Risto Siilasmaa, discovered a couple of years ago that he had difficulty discussing the possibilities of AI, he began to study the subject in detail. Not only did he acquire strategic competence within AI but also continued with the mechanisms on which AI is based. In addition to using this within the companies he works at, he gives talks and has also been able to support Finnish politicians.

References

AI for Humanity. French Strategy for Artificial Intelligence. The President of the French Republic presented his vision and strategy to make France a leader in artificial intelligence (AI) at the Collège de France on 29 March 2018. https://www.aiforhumanity.fr/en/ Retrieved on 27 April 2018.

Alan Turing Institute (2016), The Alan Turing Institute Scoping Programme

Alan Turing Institute (2016), The UK's New National Institute for Data Science. Shaping our Strategy.

Atomico (2017), The state of European Tech

Bengtsson, L. (2013), Utbildningssamverkan för jobb, innovation och företagande [Education collaboration for jobs, innovation and entrepreneurship], Almega, https://www.almega.se/MediaBinaryLoader.axd?MediaArchive_FileID=e67be621-8331- 4fea-afae-8d0b27776b34&FileName=Utbildningssamverkan_f%c3%b6r_jobb_A.pdf, access 06-06-14.

Benner, M. (2013), Nordiska universitet i jakt på världsklass – en jämförelse mellan två universitet i Danmark och Sverige [Nordic Universities in the hunt for prominence – a comparison between two universities in Denmark and Sweden], Growth Analysis, Working paper/Memo 2013:20.

Berggren, H. (2012), Den akademiska frågan – en ESO-rapport om frihet i den högre skolan [The academic issue – an ESO report on freedom in higher education], Report to the Expert Group on Public Economics 2012:3, Ministry of Finance.

Bienenstock et al., (2014), Utbildning, forskning, samverkan. Vad kan svenska universitet lära av Stanford och Berkeley? [Education, research, collaboration. What can Swedish universities learn from Stanford and Berkeley?] SNS förlag.

Björnsson et al., (2015), UNIVERSITETSREFORM! Så kan vi rädda och lyfta den högre utbildningen [UNIVERSITY REFORM! How to save and promote higher education], Samhällsförlaget.

Brundage, M, et. al. (2018), The Malicious Use of Artificial Intelligence: Forecasting, Prevention and Mitigation: Forecasting, Prevention and Mitigation.

Brynjolfsson, E & McAfee, A., Machine Platform Crowd

Brynjolfsson, E & McAfee, A., The Second Machine Age

Canadian Institute for Advanced Research CIFAR (2017), Pan-Canadian Artificial Intelligence Strategy Overview.

CapGemini, Turning AI into Concrete Value

Carlsson et al., (2014), Research Quality and the Role of the University Leadership

CCP Central Committee and the State Council China (2017), A Next Generation Artificial Intelligence Development Plan

Dijstelbloem et al., (2013), Why Science Does Not Work as It Should And What To Do about It. Science in Transition POSITION PAPER, October 17, 2013.

Domingos, P,. The Master Algorithm

Ehn Knobblock, I. (2014), Disputerad och sen då? En intervjustudie om forskarutbildades arbetslivserfarenheter utanför högskolan [Got a PhD – now what? An interview study of PhDs' work experience outside of university], Fackförbundet ST.

Ejermo, O. (2012), Universitet som drivkraft för tillväxt och utveckling [University as the driving force for growth and development]. Reprocentralen Örebro University, Research Network Debate, Swedish Entrepreneurship Forum.

Ekholm, A,. Människan och maskinen [Human and machine]

Eriksson, L. and Heyman, U. (2014), Resurser för utbildning och forskning [Resources for education and research]. Ref. 14/014 SUHF April 2014.

European Commission (2014), Background document – Public Consultation, 'SCIENCE 2.0': Science in transition, DIRECTORATES-GENERAL FOR RESEARCH AND INNOVATION (RTD) AND COMMUNICATIONS NETWORKS, CONTENT AND TECHNOLOGY (CONNECT).

Evans, H., Hu, M., Kuchembuck, R., Gervet, E. (2017), Will you embrace AI fast enough? AT Kearney.

Forbes (2017), Why Montreal Has Emerged As An Artificial Intelligence Powerhouse. Retrieved on 27 April 2018.

Fortune (2018), United Kingdom Plans $ 1.3 Billion Artificial Intelligence Push. http://fortune.com/2018/04/25/uk-ai-artificial-intelligence-deal/ Retrieved on 25 April 2018.

Gagné, J-F. (2018), The Global AI Talent Pool

Geschwind, L., and Broström A. (2014), Managing the teaching–research nexus: ideals and practice in research-oriented universities, Higher Education Research & Development, DOI: 10.1080/07294360.2014.934332

Government of Japan (2017), Report on Artificial Intelligence and Human Society. Unofficial translation. Advisory Board on Artificial Intelligence and Human Society, Cabinet Office.

Governo (2018), Artificiell intelligens i offentlig sektor. Hur realiserar vi potentialen? [Artificial intelligence in the public sector. How do we realise the potential?].

Hall, W and Pesenti, P (2017), Growing the Artificial Intelligence Industry in the UK.

Heckscher S. et al. (2014), Ökad handlingsfrihet för statliga lärosäten, rapport till Stockholm [Increased freedom of action for state HEIs], Report to Stockholm – Uppsala University Network, April 2015.

High, P. (2017), Why Montreal Has Emerged As An Artificial Intelligence Powerhouse, Forbes, published on 06/11/2017

Hitoshi Koshiba (2016), Research Status of ICT/AI International comparison featuring Korea, China and Japan, NISTEP.

HM Government UK (2017), Industrial Strategy. White Paper. Building a Britain fit for the future.

Information and Communication Technology Council Canada (2015), Artificial Intelligence in Canada. Where do we stand?

Inera AB, AI och automatisering för första linjens vård [AI and automation for the first line of care]

Infosys, Leadership in the Age of AI

Inria (2018), Inria takes part in PRAIRIE Institute launch. https://www.inria.fr/en/news/news-from-inria/launch-of-the-prairie-institute. Retrieved on 27 April 2018.

Institute for the Future (2011), Future Work Skills 2020. http://www.iftf.org/uploads/media/SR-1382A_UPRI_future_work_skills_sm.pdf

Jacob, M. (2015), Draft RIO Country Report 2014: Sweden.

Kelly, K., The Inevitable

Lindsjö, Göran (2017), En AI-redo statsförvaltning [An AI-ready public administration].

Manyika, J., Chui, M., Miremadi, M., Bughin, J., George, K., Willmott, P. and Dewhurst, M., (2017), Harnessing automation for a future that works. [online] McKinsey & Company. Available at: <https://www.mckinsey. Com/global-themes/digital-disruption/harnessing-automation-for-a-future-that-works> Retrieved on 6 April 2018.

McCarthy (1956), the Dartmouth Summer Research Project

McKinsey & Company (2017), Digitally-enabled automation and artificial intelligence: Shaping the future of work in Europe's digital front-runners.

Ministry of Economic Affairs and Employment of Finland (2017), Finland's Age of Artificial Intelligence. Turning Finland into a leading country in the application of artificial intelligence. Objective and recommendations for measures. 47/2017

National Institute of Standards and Technology. U.S. Department of Commerce (2017), The National Science & Technology Council Machine Learning/AI Initiative (YouTube), https://www.youtube.com/watch?v=UAKkickQ8gM, published on 11 September 2017.

New Energy and Industrial Technology Development Organization NEDO Japan (2017), Artificial Intelligence Technology Strategy. Report of Strategic Council for AI Technology.

Nilsson, R. (2015), Statlig FoU-finansiering i Sverige 1981–2014 [Government R&D funding in Sweden 1981-2014], working document, VINNOVA.

OECD (2013), Science, Technology and Industry Scoreboard 2013, chapter 5.

OECD (2014), Education at a Glance 2014: OECD Indicators, OECD Publishing. http://dx.doi.org/10.1787/eag-2014-en

OECD (2015), Scoping paper for CSTP/TIP project on higher education institutions in the knowledge triangle. DSTI/STP(2015)6, OECD, Organisation for Economic Co-operation and Development.

OECD (2017), OECD Digital Economy Outlook 2017, OECD Publishing, Paris.

OECD (2017), Education at a Glance 2017: OECD Indicators, OECD Publishing, Paris.

OECD (2017), OECD The Next Production Revolution: Implications for Governments and Business, OECD Publishing, Paris.

Perez Vico et al. (2015), Universitets och högskolors samverkansmönster och dess effekter [Collaboration patterns of higher education institutions and their effects]. VINNOVA analysis.

Purdy, M. and Daugherty, P. (2016), Why Artificial Intelligence is the Future of Growth, Accenture.

Purdy, M. and Daugherty, P. (2017), How AI Boosts Industry Profits and Innovation, Accenture.

Official Government Inquiries (2015), Högre utbildning under tjugo år [Higher education over twenty years], SOU 2015:70 .

Official Government Inquiries (2016), Digitaliseringens effekter på individ och samhälle – fyra temarapporter [Digitalisation effects on individuals and society – four thematic reports], SOU 2016:85. Haikola, L., Högskola och livslångt lärande – vilken roll bör högskolan spela för att svara mot kunskapssamhällets behov av kompetensutveckling? [University and lifelong learning – what role should university play in responding to the knowledge society's need for skills development?]

Stirling, R and Truswell, E., Oxford Insights

Stockholm City, Department of Digital Development. Artificiell Intelligens, robotisering och VR/AR [Artificial Intelligence, robotisation and VR/AR

Swedish Data Protection Authority (2018), https://www.datainspektionen.se/dataskyddsreformen/dataskyddsforordningen/introduktion-till-dataskyddsforordningen/dataskyddsforordningens-syfte/ Retrieved on 8 April 2018.

Swedish Higher Education Authority, UKÄ (2014), Higher Education Institutions, International Student Mobility in High Education 2013/2014, Swedish Higher Education Authority, Sweden's official statistics, Statistical messages UF SM 1402.

Swedish Higher Education Authority, UKÄ (2015), Higher Education Institutions, ANNUAL REPORT 2015. Swedish Higher Education Authority, Sweden's official statistics.

Swedish Higher Education Authority, UKÄ, (2018) Samverkan om dimensionering av utbildning - En kartläggning – rapportering av ett regeringsuppdrag [Collaboration on the design of education - A mapping – reporting a government commission], Report 2018:4

Swedish IT and Telecom Industries, Almega (2017), IT-kompetensbristen. [Lack of IT competence. A report on the Swedish digital sector's need for cutting-edge competence].

Swedish National Financial Management Authority, Digitaliseringen av det offentliga Sverige [Digitalisation of the public sector]

Swedsoft (2017), Vikten av livslångt lärande i en föränderlig, digitaliserad och globaliserad värld [The importance of lifelong learning in a changing, digitised and globalised world].

The Telegraph (2015), Number of foreign students at top universities doubled in less than a decade, research finds. J. Espinoza, 29 May http://www.telegraph.co.uk/education/educationnews/11639807/Number-of-foreign-students-at-top-universities-doubled-in- less-than-a-decade-research-finds.html

Teradata, State of Artificial Intelligence for Enterprise

UNESCO, Institute for Statistics database

U.S. Government (2016), Executive Office of the President. National Science and Technology Council. Committee on Technology. Preparing for the future of Artificial Intelligence.

U.S. Government (2016), The National Science and Technology Council. Networking and Information Technology Research and Development Subcommittee. The National Artificial Intelligence Research and Development Strategic Plan.

U.S. Government (2017), U.S. federal legislative information. H.R.4625 - FUTURE of Artificial Intelligence Act of 2017

Van der Zande, J., Teigland, K., Siri, S. and Teigland R. (2018), Substitution of Labor, From technological feasibility to other factors influencing job automation, Innovative Internet: Report 5, Stockholm School of Economics, Jan. 2018

Villani, C. (2018), For a meaningful Artificial Intelligence. Towards a French and European Strategy.

Vinnova (2011), Kunskapstriangeln [The Knowledge Triangle]. Report on Government Commission, Ref. 2010-02061.

VSNU Association of Universities the Netherlands (2017), Digital Society Research Agenda. Leading the way though cooperation in a Digital Society.

Wall Street Journal (2015), International students stream into US colleges, M. Jordan, 24 March. http://www.wsj.com/articles/international-students-stream-into-u-s-colleges-1427248801

World Economic Forum, The 10 skills you need to thrive in the Fourth Industrial Revolution

World Economic Forum, Insead and Samuel Curtis Johnson Graduate School of Management at Cornell University (2015), Global Information Technology Report

Öquist G. and Benner, M. (2012), Fostering breakthrough research: a comparative study. Royal Swedish Academy of Sciences. Halmstad: Print One

Appendix 1. Patent Analysis[147]

Artificial intelligence (AI) is a large and rapidly growing area for patenting world-wide. The growth in AI-related patent applications appears to have accelerated since around 2010 and AI is today one of the largest areas for patenting. Due to the delay between the time when a patent application is submitted and the time when a patent office publishes the application it is not yet possible to fully assess the developments after 2015. In all likelihood the strong attention given to developments in AI all over the world has caused a further rapid growth in AI-related patent applications.

AI-related patenting is still dominated by core information technology companies such as Samsung, Microsoft, IBM and Google, which have already built very large patent portfolios. AI-related patents are, however, increasingly being used in diverse business areas and attracting attention from a growing number of firms of all kinds and sizes, not least young and start-up firms which are attempting to leverage AI-technology to disrupt existing industries and develop new services.

United States, Japan and South Korea are generally considered leading the world in AI-related patenting, South Korea showing fastest growth. The precise order of the different countries depends on which patent offices are included in the analysis and thus for which markets the patent protection is sought. Following the top three countries are United Kingdom and Israel ahead of Canada, China and Germany, Israel's performance in recent years is impressive. In recent years, around 0,8 percent of the all AI-related patents included inventors from Sweden, making Sweden the 13th largest country.

While patents may be important as knowledge-based capital for AI-intensive business development, the relative importance of patents will differ depending on type of business. The great importance of access to data is widely recognized. Development of new business models as well ability to integrate a company's organization across business functions and with partner organizations also play a decisive role.

The diverse use of AI and its frequent combination with other technologies makes it impossible to use standard patent classifications for quantitative analysis of AI-related patenting. This report largely builds on a database for AI-related patenting developed by the Finnish patent analysis company Teqmine. The patents included in the database are judged to be broader than AI in a narrow sense and might probably better be characterized as encompassing "advanced data analytics". Using machine learning the patent applications have been classified into 30 "topics" according to similarities in technologies and applications. This allows the comparison between countries and individual organizations by topic.

In a global perspective, Sweden is, as might be expected, a small player in terms of AI-related patenting. Along with most European countries its share of world total patenting has decreased

[147] This appendix has been written by Lennart Stenberg, Vinnova, and Hannes Toivanen, Teqmine OY.

over time due to the rapid growth in Asia. Similar to many other rankings measuring innovative activities, on a per-capita basis Sweden is doing reasonably well, but behind Israel, Switzerland, Denmark and Finland among countries of comparable size. Sweden is slightly ahead of Canada in per-capita terms and recently increased its lead somewhat. Israel has increasingly outdistanced the other countries. In recent years, Sweden has grown at almost the same pace as Switzerland and Denmark and reduced the gap to Finland which has suffered a decline in its AI-related patenting in line with a general decline of the Finnish economy. The relative strong performance of the just mentioned five countries motivates a closer comparison between theirs and Sweden's development in terms of the topics of patent applications and the distribution among different types of organizations.

Sweden, Finland and Denmark each have one company with an outsized number of patent applications: LM Ericsson, Nokia and Novozymes respectively. While Ericsson's share of patent applications was about the same 2006-2011 as 2012-2017, in Denmark Novozyme's share increased significantly and Finland Nokia's decreased greatly. Excluding these three firms, Sweden closed its gap to Denmark while the gap to Finland remain large and unchanged. In Israel, Switzerland and Canada there were no companies with a similarly dominating position although big US IT-firms as a group led by IBM, Google and Microsoft, have a much larger presence there than in the three Nordic countries.

In all six countries, the number of companies actively patenting has increased in recent years. Exactly by how much cannot be ascertained as the assignee organization for more recent patent applications has not yet been published. Already named assignee organizations applying for patents with inventors from Sweden were 48 in 2016 compared to an average of 30 per year 2010-2014. When complete data are available the recent growth in patenting organizations is likely to be shown to have been even stronger. Adjusted for population size, the number of organizations applying for AI-related patents with inventors from Israel are at least three times as many as the corresponding number for any of the other three countries. On the same measure has improved its position relative to the other four countries and is today not far behind Switzerland and at the same level as Denmark and Finland. Worth noting is that when only domestically registered organizations are compared Sweden's relative position is weaker even if it has improved somewhat in recent years. More detailed analysis is required to assess whether this points to a weakness in the Swedish ecosystem for AI-related innovation.

Comparing the content of AI-related patenting between the five countries and as part of world total patenting, Sweden's strongest areas are, as might be expected, closely connected with Ericsson's core businesses in communication and computer networks. Sweden's world share in the area "computer networks" and "cellular network management" was 4,3 and 2,8 per cent respectively during 2012-2017 placing Sweden 1st and 2nd respectively among the six countries and in both cases showing a significant increase in the share from 2006-2011. As the only among the six countries with a large vehicle industry, Sweden placed 2nd in the area "smart traffic" behind Israel. Globally this has been the second fastest growing area after "human-computer interaction". In both areas Sweden's world share has been roughly halved from around two to one percent between 2006-2011 and 2012-2017. By comparison, Israel increased its world share of "smart traffic" from 1,8 to 2,8 percent between the same periods. The growing

Israeli strength in area of autonomous driving and driver assistance is further illustrated by the US $ 15 billion acquisition of Mobileye by Intel in 2017. In "signal processing" and "industrial process control", two areas which globally have shown moderate growth, Sweden's world share has increased and at around 1,5 percent 2012-17 it was well above Sweden's average for all areas put together. Sweden's world share was about the same in "health diagnostics - biomarkers" and "genetic cancer testing" while other health and life science areas left more to be desired.

Looking at the companies which have filed AI-related patent applications with inventors from Sweden, they may be broadly divided into the following main categories (some of the listed companies filed three patents 2006-2017 are thus not included in the Table 1 above):

- LM Ericsson
- Large companies with headquarters in Sweden (although some, such as Volvo Cars and Scania, being part of larger foreign-owned business groups)
- Swedish subsidiaries of large foreign-based groups with major R&D and manufacturing in Sweden but strong dependence on decision-making at foreign headquarters
- Large foreign-owned companies with limited activities in Sweden
- Young/start-up IT-companies (several of which have been acquired by foreign firms)
- Young/start-up life science companies (some of which have been acquired by foreign firms)

This structure reflects broadly how the innovation resources today are distributed between different types in the Swedish business sector in general with a mix of large global companies with big R&D-operations in Sweden and a large and growing group of knowledge-intensive entrepreneurial firms. *Largely missing are companies are many large firms in more traditional manufacturing and services industries as well as large IT- and technical consultants.* Some of them are found among firms with only few patent applications but their presence is indeed limited. The list of the most actively AI-patenting young/start-up IT-companies corresponds well with the most successful such companies coming out of Sweden during the last 20 years.

Many of the Swedish AI-patenting start-up companies have been acquired by foreign-based firms. On the positive side this can be viewed as a sign that the level of AI-related innovation in Sweden has been judged as attractive by foreign firms. A critical question is whether after the acquisitions the business activities are permitted to continue and grow in Sweden or are scaled down or even totally discontinued. The evidence so far appears to be somewhat mixed. The question, which is not unique to AI-related innovation, deserves to be studied in more depth than has been possible for this report. Among the AI-patenting Swedish start-up companies a large number of truly innovative solutions aimed at an international market can be identified and examples are described in the report. It should be emphasized that the recent increase in the establishment of AI-companies in Sweden is not yet reflected in the data.

Patent data as an indicator of AI-related activities

In the field of AI as in most other fields, patents are at best a partial indicator of innovative activities. Obtaining a patent is a means a company, other organization or an individual to acquire a temporary monopoly for exploiting an invention in return for making the content of the invention public. Whether patenting is an effective or attractive way for protecting one's innovation varies greatly between fields and situations. In some applications of AI the availability of large volumes of data is the most important factor for competitive strength. Furthermore, many applications of AI can be based on generally available methods and algorithms and thus not be restricted by patents. It is beyond the scope of this report to assess in any conclusive way the relative importance of patents for the development and applications of AI in different fields and contexts.

Whatever the role of patents in AI-related business activities, it seems clear that companies do submit a large number of AI-related patents and that the leading patenting companies are also those generally associated with a strong position in the AI-field. It therefore seems reasonable to assume that patenting will provide some insights into AI-related innovation activities in industry and allow comparisons across countries in this regard. While not being a conclusive indicator, used with care and combined with other indicators, patenting has been judged to be useful for the present report.

International comparisons of AI-related patenting

There are at least four major issues which need to be addressed when comparing AI-related patenting across countries:

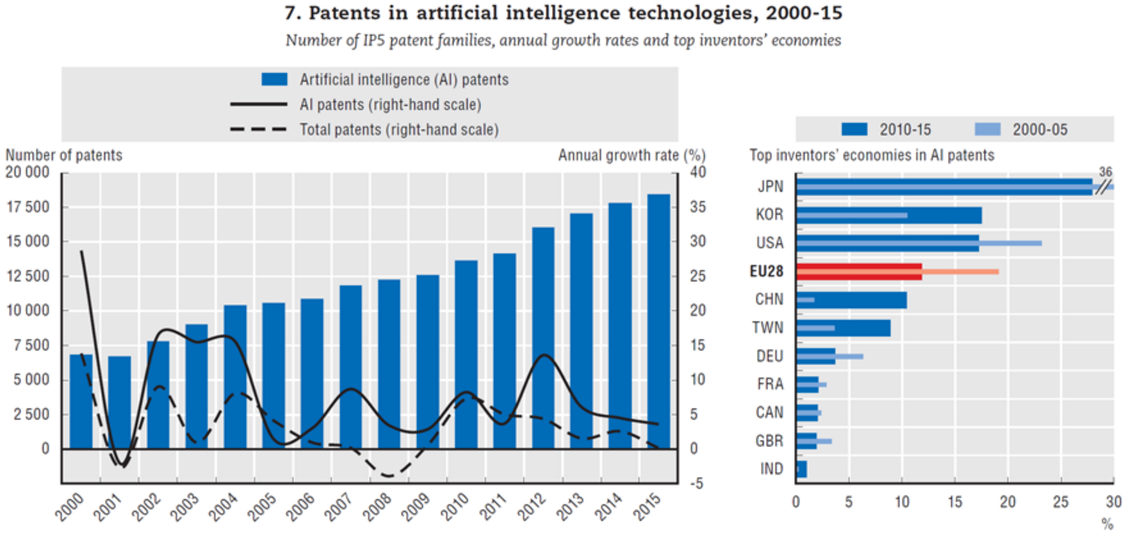
- How to define and find what are AI-related patents
- What routes and geographical scopes of patent applications to include; a patent application may be addressed to different patent agencies (e.g. USPTO, EPO, JPO, CPO, WIPO or national patent agencies in Europe)[148] with different jurisdictions
- Whether to look at the location of the inventors of a patent or the location of the assignee(s) (the organization(s) submitting the patent application)
- Whether to look at the patent applications or the granted patents

Publicly available data differ greatly in the above dimensions and are therefore not easily comparable. In the present report we have primarily used data from the Finnish company Teqmine. Before introducing this data, we will briefly show data from two other sources, one by the OECD based on data from five patent agencies and one from the USPTO showing patenting in the United States. Each of the two uses different delineations of Artificial Intelligence. The OECD data concerns applications while the USPTO data concerns granted patents.

In the report "OECD Science, Technology and Industry Scoreboard 2017" published in November 2017; OECD presents data on patents in what is labelled Artificial Intelligence as shown below.

[148] USPTO: United States Patent and Trademark Office; EPO: European Patent Office; WIPO: World Intellectual Property Organization.

Figure A1. 1 AI-patents according to OECD STI Scoreboard 2017



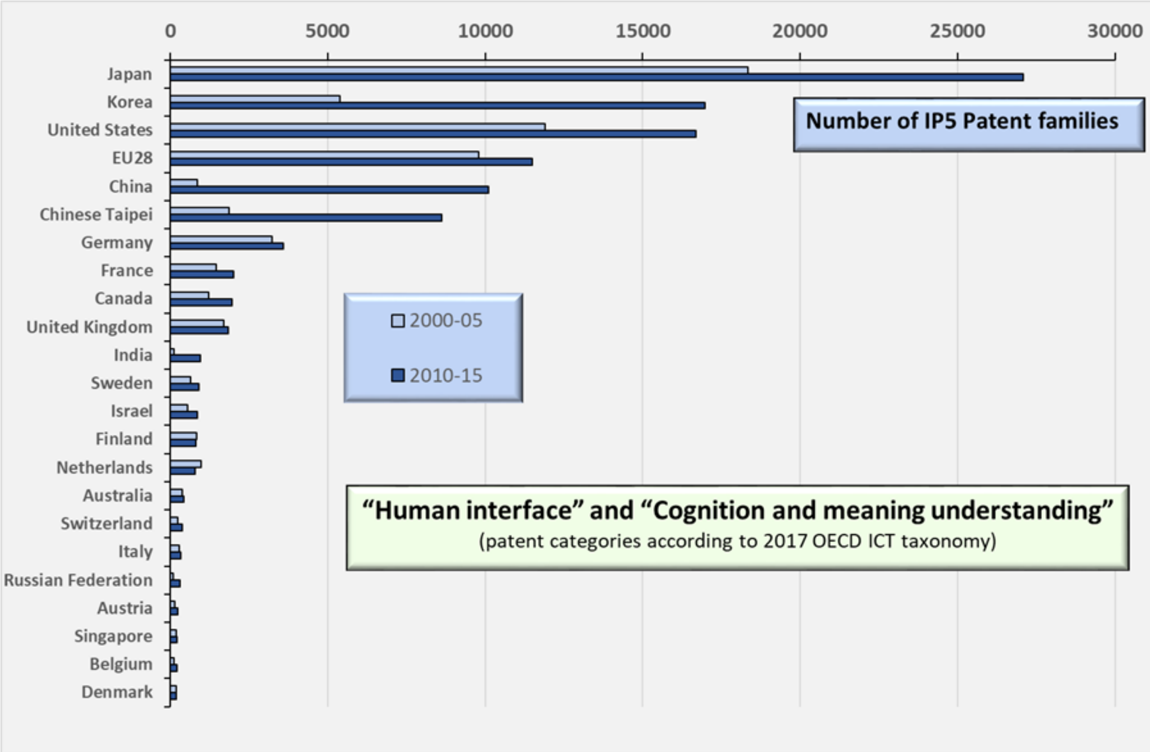
The data combines patent applications made to the five IP5 patent offices: USPTO, EPO, JPO, SIPO and KIPO.[149] Included are patents belonging so called IP5 patent families, i.e. patents which have been filed with more than one of the five patent bureaus, thus eliminating patents which are only aimed at the domestic market. To identify AI-patents, two categories have been selected in a new classification of ICT-patents, which in total includes 13 categories. The two categories are: "Cognition and meaning understanding" and "Human-interface".[150]

The published data only includes 10 individual countries. The underlying data is, however, available on the OECD website and includes altogether 33 countries.[151] Below are shown the data for the top 22 countries (plus the sum for EU28).

According to the OECD-data, Asian countries appear to be in a strong position with Japan in the lead and the United States as the only non-Asian country among the top five. For most countries the number of patent applications has grown significantly and in relative terms but most strikingly in China, South Korea and Taiwan. The data is based on the addresses of the inventors.[152] Compared with other European countries on a per-capita basis only Finland is doing better that Sweden. Sweden's share of the world total declined, however, from 1.2 per cent 2000-05 to 0.9 percent 2010-15.

[149] SIPO: the State Intellectual Property Office of the People's Republic of China; KIPO: the Korean Intellectual Property Office.
[150] For details about the classification see Inaba, T. and M. Squicciarini (2017), "ICT: A new taxonomy based on the international patent classification", *OECD Science, Technology and Industry Working Papers*, 2017/01, OECD Publishing, Paris. http://dx.doi.org/10.1787/ab16c396-en.
[151] http://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard-2017_9789264268821-en Graph: Patents for top technologies that embed artificial intelligence, 2000-05 and 2010-15
[152] So called fractional counts are used, meaning that if a patent has inventors from more than one country, the patent count of one will be divided between the countries from where the inventors come in proportion to the number of inventors from the respective country.

Figure A1. 2 AI-patents for top 22 countries according to data in OECD STI Scoreboard 2017



Source: See Figure 1

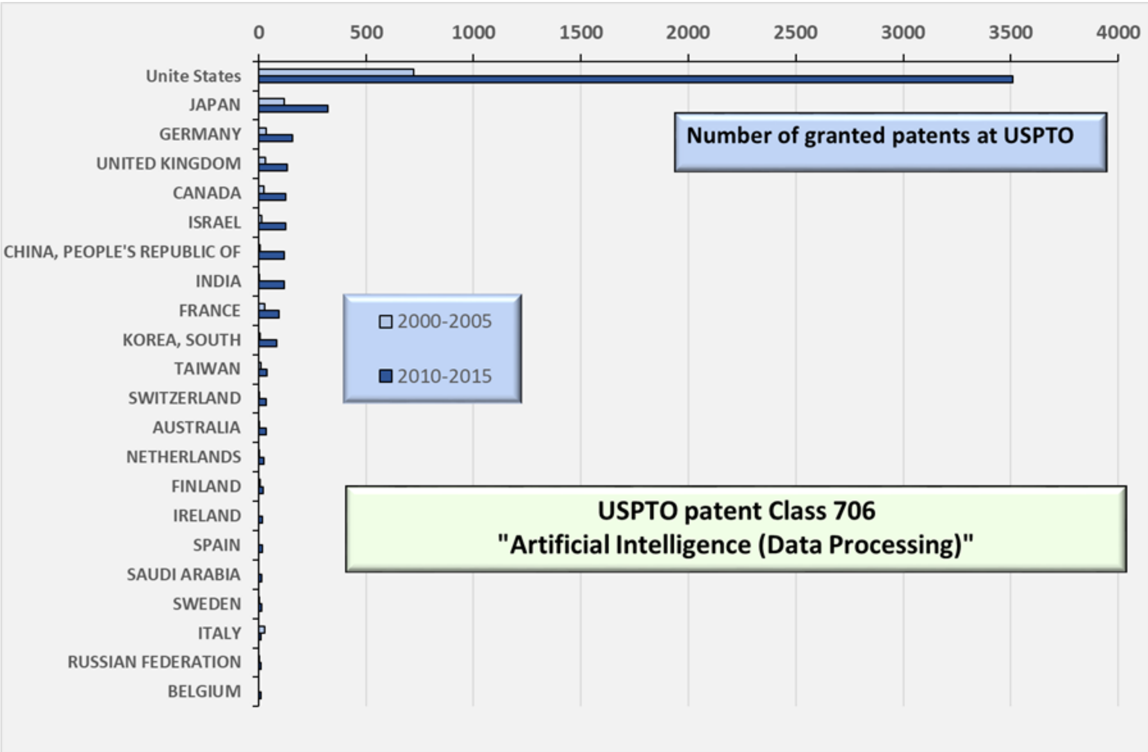
The weaker than expected relative position of the United States raises questions about how well the OECD-data measures AI-related patenting. The two patent categories on which the OECD AI-data is based were not developed specifically to cover Artificial Intelligence and looking at the individual patent classes included in the two categories it appears that especially the "Human Interface" category is only very loosely connected with AI. The important role of human interface technologies in consumer electronic products in which Asian countries tend to have a dominant position might therefore at least partly explain their strong position in the OECD data.

The large American market has made it natural for inventors all over the world to put a high priority on securing a patent in the United States. Patenting in the United States can therefore be seen as relatively neutral measure for comparing high value patents among inventing countries with the exception, of course, of inventors from the United States (and maybe also from neighboring Canada) which have an extra reason to patent in their domestic market. Figure 3 shows patents granted in the United States in a patent class explicitly labelled "Artificial Intelligence". The periods are the same as for the OECD data but in that case patent applications were counted while the US data are for granted patents.

As expected the United States dominates. Among other countries, Japan is also in this case leading. The top ten countries are almost the same except that Israel has jumped into sixth place while Taiwan fell to eleventh place. The relative strength of the countries has changed drastically moving the Asian countries, except Japan, down the ranking and Germany, United Kingdom and Canada moving up. While the number of AI-patent applications as defined by the

OECD approximately doubled between 2001-05 and 2010-15, the number of granted patents in USPTO AI patent class grew by a factor of five during the same time.

Figure A1. 3 Granted patents in the United States in patent class 706 by country of first inventor 2000-2005 and 2010-2015



Source: Data downloaded from USPTO website and analyzed by Vinnova

The USPTO classification of AI-patents is obviously much narrower than that used by the OECD. The OECD selection of patents is around 20 times larger than that of the USPTO for the period 2010-15. This said while taking into account the narrower geographical scope of the USPTO patents and the fact that the USPTO data concerns granted patents while the OECD data counts patent applications.

The total number with first named inventors from Sweden in the USPTO is only 5 and 13 respectively for the two periods making difficult to draw any clear conclusions about the Swedish position.

Hopefully the above two examples have shown that one has to be very careful when analyzing the relative position of countries in terms AI patents. There are many variables that need to be specified and it is by no means clear which set of specifications provide the most meaningful comparisons.

Teqmine’s database of AI-related patents

As already discussed, there is no indisputable way of defining an AI-related patent. This stems both from the fact that there are varying definitions of AI and the desirability of including not only inventions which develop new core AI technology but also inventions the novelty of which lies in new uses of more or less well-established AI technology. In addition to these definitional issues there are practical considerations of how to extract AI-related patents from very large databases.

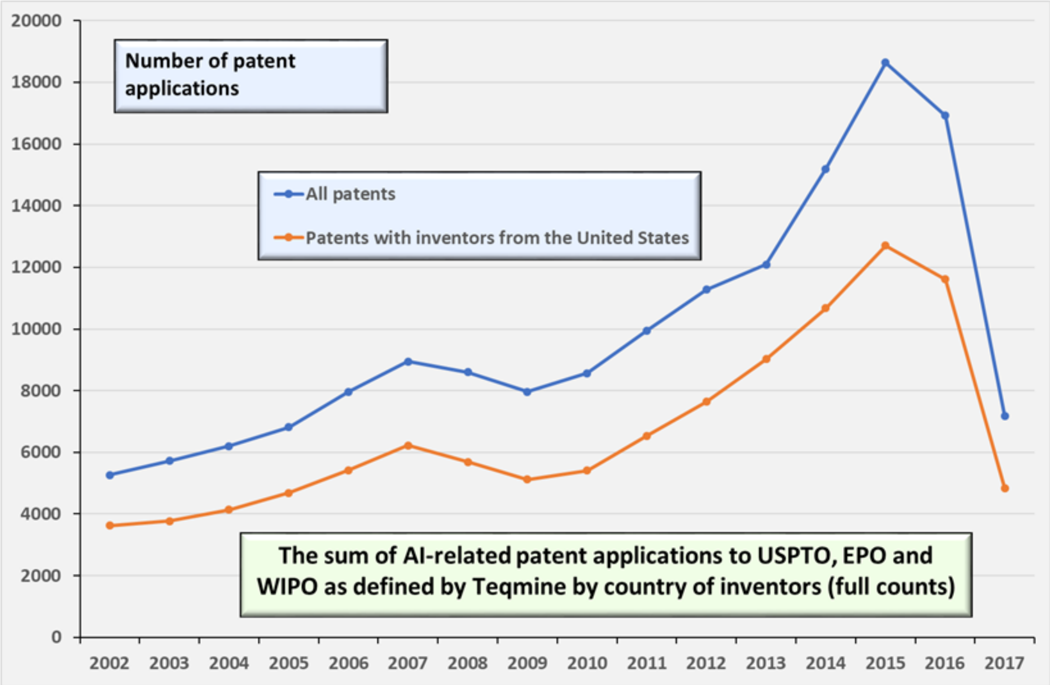
The method used in most of the remainder this report relies on a database for AI-related patents developed by the Teqmine company. It is based on the selection of a set of technical terms associated with certain AI-technologies which is used for searching through the full texts of patent applications in all fields and selecting those patent applications in which the terms appear. This procedure will result in a generous definition of AI-related patents and include also patents with fairly weak links to AI.[153] The database includes patents filed with EPO, USPTO and so called PCT patents filed with WIPO. In the following the sum total of patent applications to the three agencies will be used as an indicator. This may entail some double counting of patents when the same patent application has been published by more than one of the three agencies.

Figure 4 shows the number of AI-related patent applications that had been filed with the USPTO, EPO or WIPO 1990-2017 and published by the end of 2017. The time from the submission of a patent application until the patent office makes it public by publishing may be up to 18 months. This explains the decline in patent applications during 2016 and 2017 in Figure 4. Only part of the applications made during these years had yet been published at the end of 2017. Considering that the value for 2016 is still almost as high as that for 2015 suggests that the growth continued in 2016 and may even have accelerated.

had at least one inventor from the United States. Looking at countries other than the United States, Japan was long the leading country but was recently overtaken by South Korea. United Kingdom, Germany, Canada, China and Israel have in recent years accounted for roughly similar number of patent applications followed by France, India and Netherlands. Sweden comes in at 12th place at the same level as Switzerland and both countries have gradually strengthened their relative position. On a per capita basis Sweden and Switzerland and even more so Denmark, Finland, Ireland and Singapore are scoring well compared with larger countries except the United States. Among countries with small populations Israel is, however, in a category of its own. Canada is also doing well considering the size of its population. The fact that Teqmine's database does not include any data from the three large Asian patent agencies, the weight of patenting by inventors in China, Japan and South Korea should be expected to have been underestimated. For comparison of Sweden's patenting with other European countries, the database is judged to provide a fair picture. The database also allows an analysis of the content of Swedish patenting and identification of individual patenting organizations as will be discussed in the next section.

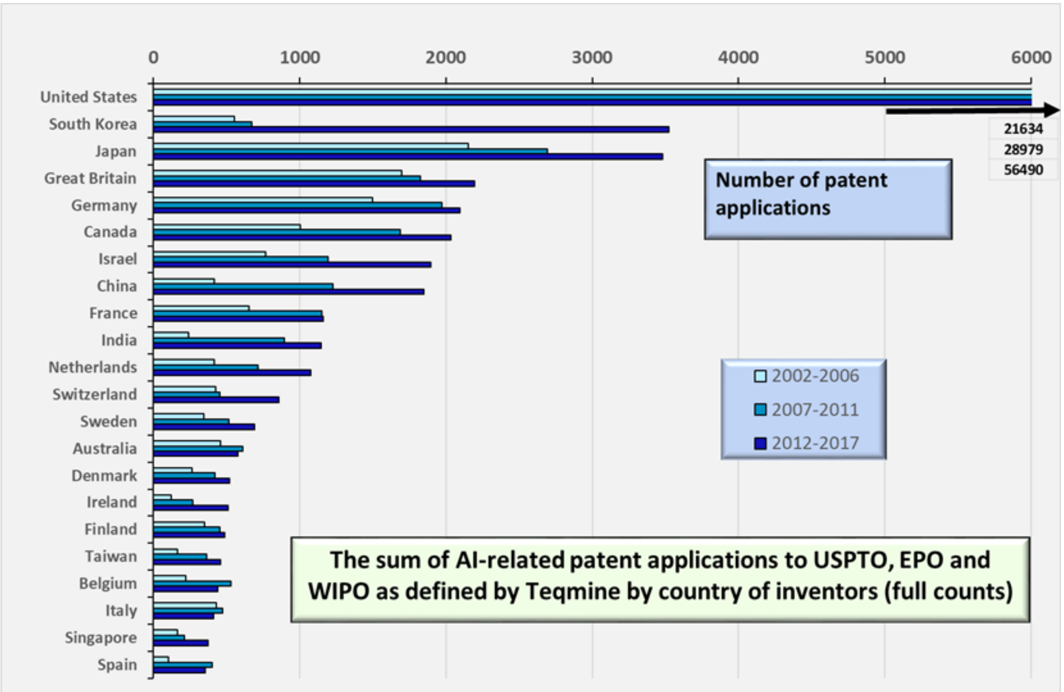
[153] A more detailed description of the methodology used in creating the database is found in Appendix.

Figure A1. 4 Number of AI-related patent applications (as defined by Teqmine) filed with the USPTO, EPO and WIPO 1990-2017 published by end of 2017



Source: Teqmine and Vinnova

Figure A1. 5 Number of AI-related patent applications (as defined by Teqmine) filed with the filed with the USPTO, EPO and WIPO 2002-2017 and published by end of 2017 by country of inventors



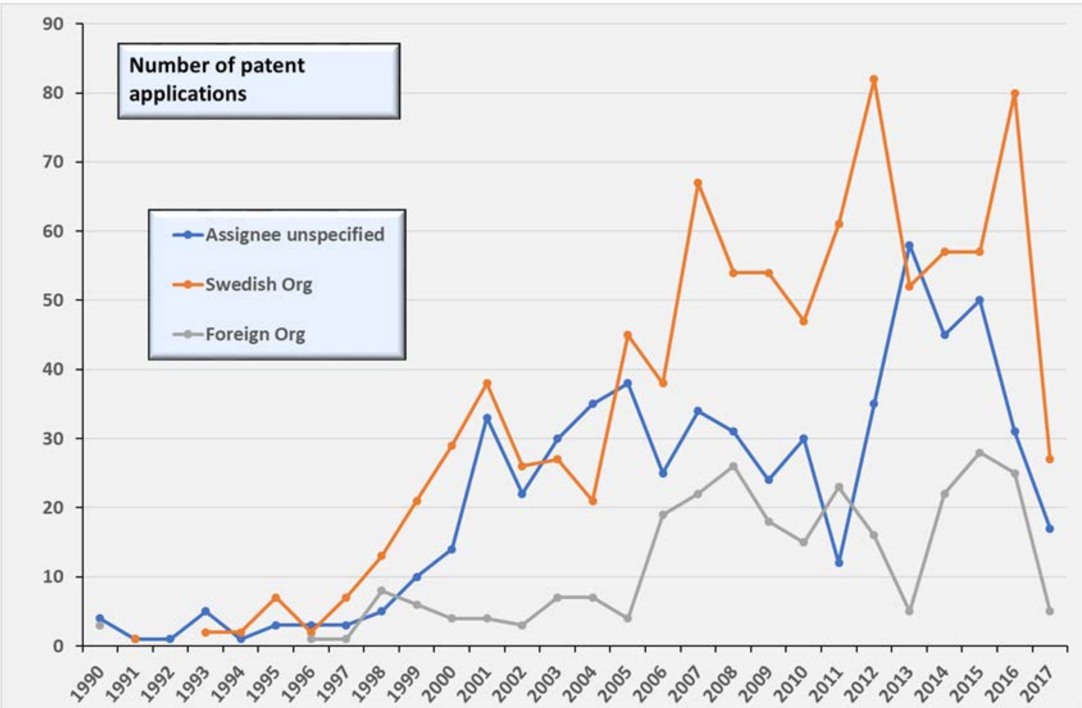
Source: Teqmine and Vinnova

The United States has been the dominant source of the AI-related inventions included in the Teqmine database. During the period 2002-2017, on average 67 percent of all AI-related patents Swedish organizations applying for AI-related patents

The data in Figure 5 above counts patents per country in terms the address of the inventors behind the respective patent. Some patents may have inventors from more than one country in which case it is counted once for each of the respective countries. In Figure 6, patents with at least one inventor from Sweden have been divided according to the assignee in the patent application. This may be an organization in Sweden or in some other country. In a few cases in which the application is made jointly between an organization in Sweden and an organization elsewhere, the application has been classified as being made by a Swedish organization.

In a fairly large number of cases there is no assignee organization registered on the patent application. This can either mean that an individual (rather than an organization) has applied for the patent or that, especially in more recent patent applications, an assignee organization has not yet been registered for the patent. The sharp increase in "assignee unspecified" from 2012 is most likely primarily due to the assignee organization not yet being specified rather than a big increase in the number of individual persons as applicants.[154] This means that the number of patent applications for identified organizations during the period 2012-2017 will in many cases be significantly underestimated for many organizations.

Figure A1. 6 AI-related patent applications (as defined by Teqmine) with at least one inventor from Sweden divided according to who has submitted the application (=the assignee)



Source: Teqmine and Vinnova

[154] The "assignee unspecified" applications are mainly from the USPTO due to the particularities of its processes of patent evaluations and documentation.

During the period 2002-2017, on average half of all patent applications with inventor from Sweden had a Swedish organization as assignee, another third had no assignee organization specified and around 15 percent foreign organizations. It should be noted that the so-called teachers' exemption for researchers at Swedish universities means that university researchers will often apply for patents as individuals (although in some cases they may apply through companies which they have established).

Table A1. 1 Organizations filing at least four AI-related patent applications with inventors from Sweden

Company/Business Group	Swedish Org		Foreign Org		Total
	2006-2011	2012-2017	2006-2011	2012-2017	
Ericsson	94	132			226
SONY (and earlier Sony Ericsson)	39	14		13	66
FlatFrog Laboratories AB	15	20			35
AB Volvo	29	5			34
Tobii AB	2	12		6	20
ABB	2		5	11	18
Immunovia AB	8	9			17
Assa Abloy AB		17			17
AstraZeneca	10		5	2	17
Scania	7	3			10
SPOTIFY AB		10			10
Volvo Car Corporation	1	9			10
GE Healthcare	1	4	5		10
Huawei Technologies Co., Ltd.		1	3	6	10
SensAbues AB	4	5			9
Vermillion, Inc	3		5		8
Google Inc.			2	6	8
Autoliv	4	3			7
QlikTech International AB		7			7
Fingerprint Cards AB		6			6
DOLBY Laboratories Licensing Corp			2	4	6
Zi Decuma AB	6				6
Elekta AB (Publ)		5		1	6
Skype Limited			6		6
NOVOZYMES A/S			4	1	5
Microsoft Corporation			5		5
HUSQVARNA AB		5			5
DeLaval Holding AB	2	3			5
GN ReSound A/S			4	1	5
HENKEL AG & CO. KGAA				5	5
Integrum AB	2	2			4
EXINI DIAGNOSTICS AB	4				4
Cellavision AB	3	1			4
MKS Instruments, Inc.			4		4
Apodemus AB	4				4
Axis AB	2	2			4
20 organizations with 3 patent applications	20	16	18	6	60
47 organizations with 2 patent applications	35	22	26	11	94
115 organizations with 1 patent application	24	40	28	23	115
name of organization missing		2	1	5	8
All organizations	**321**	**355**	**123**	**101**	**900**

Source: Teqmine and Vinnova

Table 1 shows how patent assignee organizations with four or more patent applications 2006-2017 with inventors from Sweden. The patent counts are divided according to whether assignee is in Sweden or abroad and between the two periods 2006-2011 and 2012-2017.

The Ericsson company alone made up 29 percent of all the patent applications from Swedish organizations during the first period and this share increased further to 37 percent during the second period. After Ericsson, Sony Ericsson and AB Volvo were the most actively patenting Swedish organizations. After Sony Corporation took full control of what became Sony Mobile, inventors in Sweden continued to contribute to AI-related patents but half of those patents were registered with Sony in Japan. AB Volvo's AI-related was very limited during the second period. Also the other Swedish vehicle companies – Scania, Volvo Cars and Autoliv – have filed a significant number of AI-related patents although far fewer than AB Volvo.

Among foreign-owned companies with large R&D and manufacturing in Sweden (other than Volvo Cars and Scania), ABB has tended to register patents with inventors from Sweden in Switzerland while AstraZeneca and GE Healthcare have shared the registration between Sweden and abroad. Among the large R&D-intensive companies in Sweden, SAAB filed only three AI-related patents and therefore did not make the list.

Among the other established Swedish based companies, Assa Abloy, a world leading company in locks and door opening solutions, stands out as a very active in AI-related patenting. (The company has less than 5 per cent of its employees in Sweden, so there may be additional patents with inventors from other countries registered abroad, something which may also hold for some of the other Sweden-based global business groups). Husqvarna and DeLaval are two other large Swedish business groups with a long history. Elekta is the second largest Swedish-based medical equipment company after Getinge.

A handful of the listed companies are foreign-based with fairly limited, and in a couple of cases no, activities in Sweden: Huawei, Vermillion, Google, Dolby, Novozymes, Microsoft, GN ReSound, Henckel and MKS Instruments. All except Vermillion, a medium-sized diagnostics company in California, are global firms. With very exceptions these firms have, not surprisingly, all chosen to register their patent applications through corporate units abroad.

The remaining 13 companies on the list in Table 1 all are technology-based companies and have their roots in Sweden, although a few have been acquired and today belong to business groups based abroad, notably Skype acquired by Microsoft, Axis acquired by Canon and Decuma first acquired by Zi Corporation, which in turn was acquired by Nuance, which still maintains a subsidiary in Lund.

Flatfrog Laboratories with an impressive number of AI-related patents has its mother company registered abroad but its headquarter in Lund. The company has developed optical technology based on opto-mechanics and signal processing for touch-screens and recently concluded a major collaboration and licensing agreement with Samsung. Tobii, Spotify, Qlik, Fingerprint Cards, Skype and Axis are all successful IT-firms originated in Sweden (several countries may justly claim to have fostered Skype). Immunova, SensAbuses, Integrum, Exini Diagnostics, Cellavision and Apodemus are all working in health-related businesses and to varying degrees depending on integrated advanced analytics in their product or services or in their R&D, with Exini and Cellavison explicitly employing AI. Adding to the companies on the list are an additional slightly over 100 Swedish-based and around 75 foreign organizations each with 1-3 patent applications.

Looking overall at the companies which have filed AI-related patent applications with inventors from Sweden, they may be broadly divided into the following main categories (some of the listed companies filed three patents 2006-2017 are thus not included in the Table 1 above):

- LM Ericsson
- Large companies with headquarters in Sweden, which have registered almost all their patents through Swedish companies: e.g. AB Volvo, Assa Abloy, Scania, Volvo Cars, Autoliv, Elekta, Husqvarna, DeLaval[155]
- Large foreign-owned companies with headquarters outside Sweden but major operations in Sweden; registration of patents has partly been through their Swedish subsidiaries and partly through their companies outside Sweden: e.g. Sony Mobile, ABB, Astra Zeneca, GE Healthcare
- Large foreign-owned companies with limited activities in Sweden; registration of patents has almost totally been through their companies outside Sweden: e.g. Microsoft, Huawei, Novozymes, Dolby, Google, GN Resound, Henkel, MKS Instruments
- Young/start-up IT-companies, several of which have been acquired by foreign firms: e.g. FlatFrog, Tobii, Spotify, Qlik Tech, Fingerprint Cards, ZiDecuma, Skype, Axis, Mapillary, Asplund Data, Context Vision, Cint
- Young/start-up life science companies, some of which have been acquired by foreign firms: e.g. Immunovia, Integrum, Exini, SensAbues, Cellavision, Apodemus

This structure reflects broadly how the innovation resources today are distributed between different types in the Swedish business sector in general with a mix of large global companies with big R&D-operations in Sweden and a large and growing group of knowledge-intensive entrepreneurial firms. Largely missing from the listed companies are many large firms in more traditional manufacturing and services industries as well as large IT- and technical consultants. Some of them are found among firms with only few patent applications but their presence is indeed limited. QamCom Technologies which describes itself as a "product development and specialist service provider in the areas of signal processing, communication systems, radar systems, automotive systems and functional safety" lists AI as one of its "domains" and specifies AI further as consisting of: Deep/Machine Learning; Convolutional Neural Networks; Object Detection and Classification.

Few of the listed firms would be characterized as AI-firms in the narrow sense. Most are rather users of AI or related advanced analytics technologies. CellaVision, founded already in 1994 by serial entrepreneur Per Fåhraeus, has developed products which "automate and rationalize the work that is traditionally done by laboratory personnel using conventional microscopes [..] "by introducing innovative automation, digital imaging and artificial neural network technology [..]. The company in December 2016 had 79 employees. Highly advanced mathematical algorithms were also the basis for C Technologies/Anoto and Precision Biometrics, both listed

[155] Volvo Cars and Scania are part of foreign-based business groups and Autoliv is legally a foreign-owned company.

among the AI-patenting companies and co-founded by Per Fåhraeus, with 156 and 20 employees respectively.

Three of the listed AI-patenting companies – Decuma, Cognimatics and Polar Rose AB (first called Ground Truth Vision) – were spun off from the Mathematical Imaging Group at Lund University around the turn of the century. Polar Rose was sold to Apple in 2010 and Decuma to Zi Corporation which in turn was sold to Nuance. Since 2016 Cognimatics is a subsidiary of the successful Swedish video-network company Axis, which in turn had been acquired by Canon in 2016. It thus appears that the intellectual property developed in Sweden was attractive. (It is unclear what if anything remains in Sweden of Decuma and Polar Rose today).

There are several other examples of AI-patenting Swedish start-ups being acquired by foreign firms:

Exini Diagnostics was sold to Progenics Pharmaceuticals in 2015. Exini's "technology was developed using unique image analysis derived from expert knowledge in medicine, image analysis, handling of large databases, and artificial neural networks".

The Swedish company Tracab, which applied target-seeking technology from Saab to track soccer players, was acquired by ChyronHego Corporation.

NIRA Dynamics is developing sensor fusion based systems for different vehicle applications and is today a subsidiary of AUDI AG.

In 2016 eBay acquired Expertmaker, a Swedish company founded in 2006 and that specializes in analysis of big data with a machine-learning twist. One of the previous owners of Expertmaker, Martin Rugfelt, recently established Sentian.ai together with three former colleagues from Expertmaker with the goal of developing AI-solutions for industry and the manufacturing and telecom industries, e.g. to help reduce stoppages.

In 2014, the US Food and Drug Administration (FDA) cleared the neuropsychological test – QbTest – developed by the Swedish company Qbtech to aid in the evaluation of treatment interventions in patients with ADHD. "QbTest is a computer-based test providing clinicians with objective and unbiased decision-making support when diagnosing and treating ADHD in children, adolescents and adults." QbTest was the first test in the world cleared by the FDA for this usage. The QbTest is based on a combination of "proprietary algorithms, precise motion tracking and unique tests of attention allied to an outcome-focused database".

Luleå-based Behaviometrics, founded in 2006, has developed security solutions based on what it calls "behavioral biometrics", which "uses continuous machine learning to authenticate users based, not on what they do, but on how they do it." It identifies a person through how the person handles the keyboard, the mouse, mobile phones or apps". In January 2018 the company, which in December 2016 had 22 employees, reported that it had raised 138 million SEK from a group of investors which included Cisco.

During the last two or three years there has been a steep increase in the establishment of AI-firms in Sweden. Of the 165 AI-companies listed on the Nordic Tech List's website 65 percent were established since 2013. Few of these firms should yet be expected to appear on published patent applications. Of all the Swedish AI-patenting companies identified in the Teqmine database only 8 were established since 2013: Mapillary, AIMO (earlier Lifesymb), Happy L-Lord, Ytterbia Innovation, UniqueSec, Genit Innovation, Glana Sensors and Racefox (earlier Wememove).

> *"Mapillary AB provides an online platform for crowdsourcing map photos. The company's platform enables users to collect photos that are combined into a collective street level photo view through tools, such as smartphones or action cameras "*

AIMO (earlier Lifesymb) is active in eHealth and InsurTech. The company has successfully developed its scanning technology, which in real time analyzes and evaluates human motion. The technology is based on 3D-camera sensors and artificial intelligence which provides individualized health analysis and recommendations directly to the consumer.

> *"UniqueSec AB is an innovative company, based in Gothenburg, Sweden. We develop advanced signal processing algorithms for small-scale commercial radars and design test and verification solutions for radars in different applications particularly in automotive."*

Racefox uses results from AI-research at KTH and SICS Swedish ICT to provide personalized training suggestions and feedback in real time for skiers by analyzing their movements when skiing. A sensor belt measures three-dimensional acceleration of the torso through built in movement sensors.

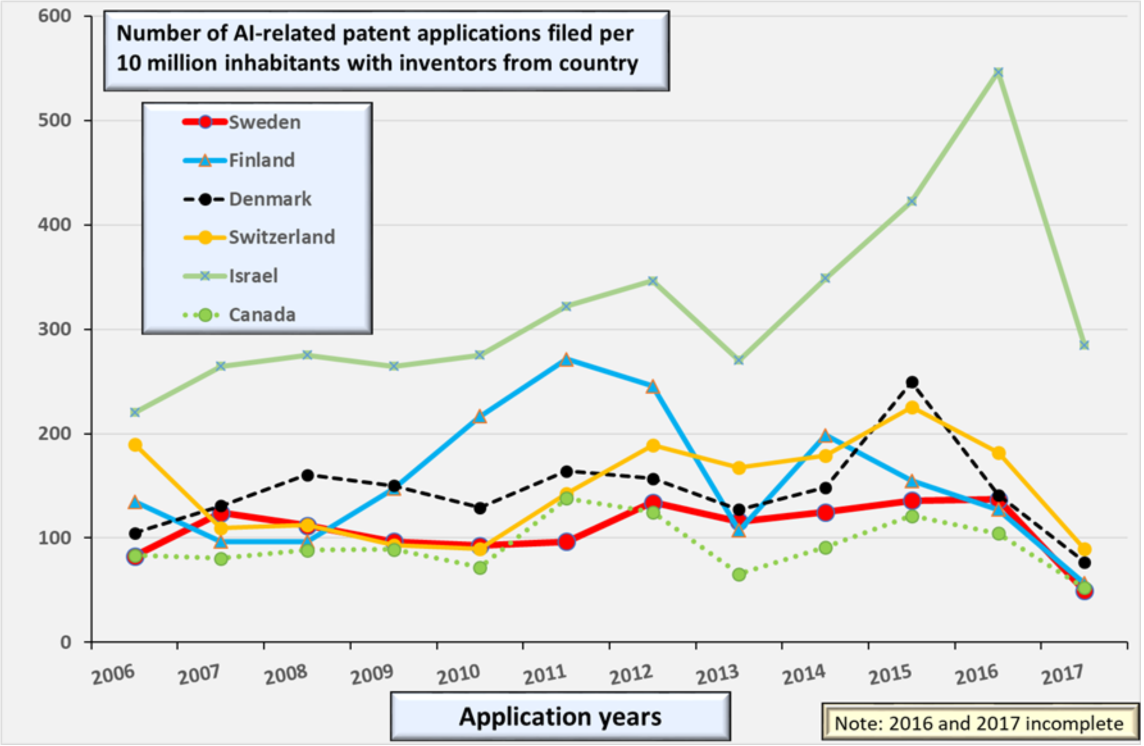
As history has shown, there is genuine uncertainty surrounding the development of start-up companies with a strong AI-component. A major challenge is how to increase the likelihood that these companies continue to develop and grow in Sweden, including in those cases when they are acquired by foreign companies.

As already indicated, another challenge is how to increase the involvement of large firms in more traditional manufacturing as well as services industries in AI-based innovations.

Comparing Sweden with countries of similar size

As previously shown, in a global perspective Sweden is, as might be expected, a small player in terms of AI-related patenting. Along with most European countries its share of world total patenting has decreased over time due to the rapid growth in Asia. Similar to many other rankings measuring innovative activities, on a per-capita basis Sweden is doing reasonably well, but behind Israel, Switzerland, Denmark and Finland among countries of comparable size. Sweden is slightly ahead of Canada in per-capita terms and recently increased its lead somewhat (Figure 7). Israel has increasingly outdistanced the other countries. In recent years, Sweden has grown at almost the same pace as Switzerland and Denmark and reduced the gap to Finland which has suffered a decline in its AI-related patenting in line with a general decline of the Finnish economy. The relative strong performance of the just mentioned five countries motivates a closer comparison between their and Sweden's development in terms of the distribution among different types of organizations and the topics of patent applications. The latter will be discussed in the next section.

Figure A1. 7 AI-related patent applications 2006-2017 with inventors from Sweden and five other countries per 10 million inhabitants of the respective country and year

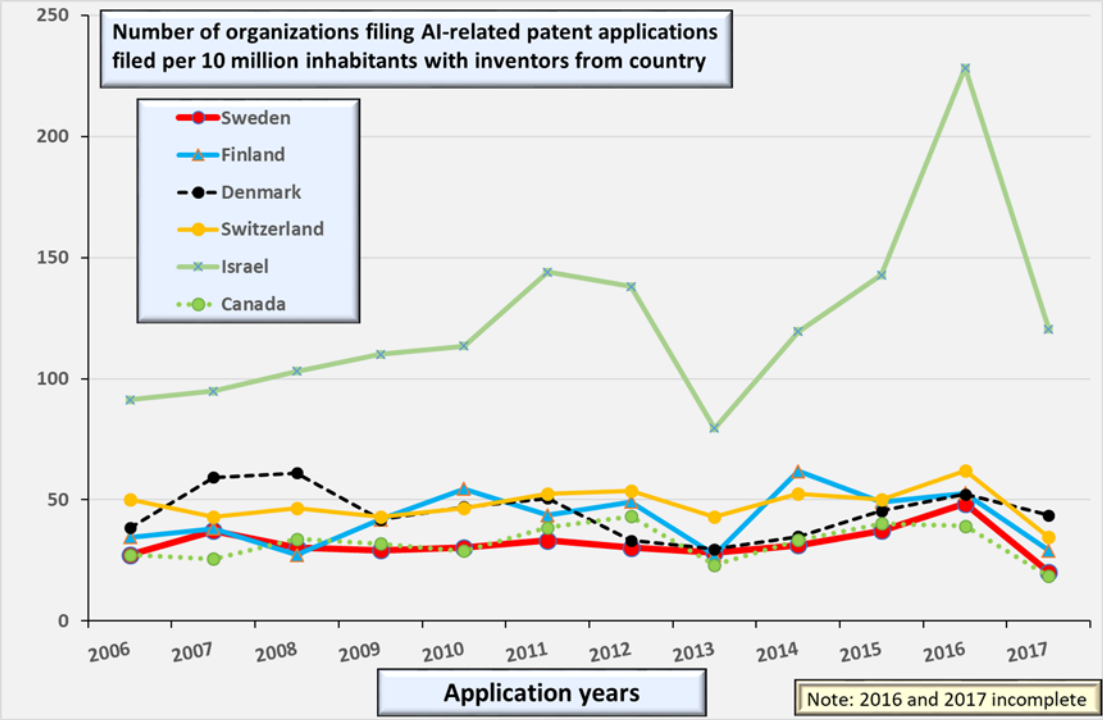


Source: Teqmine and Vinnova

Sweden, Finland and Denmark each have one company with an outsized number of patent applications: LM Ericsson, Nokia and Novozymes respectively. While Ericsson's share of patent applications was about the same 2006-2011 as 2012-2017, in Denmark Novozyme's share increased significantly and Finland Nokia's decreased greatly. Excluding these three firms, Sweden closed its gap to Denmark while the gap to Finland remain large and unchanged. In Israel, Switzerland and Canada there were no companies with a similarly dominating position although big US IT-firms as a group led by IBM, Google and Microsoft, have a much larger presence there than in the three Nordic countries.

In all six countries, the number of companies actively patenting has increased in recent years (Figure 8). Exactly by how much cannot be ascertained as the assignee organization for more recent patent applications has not yet been published. Already named assignee organizations applying for patents with inventors from Sweden were 48 in 2016 compared to an average of 30 per year 2010-2014. When complete data are available the recent growth in patenting organizations is likely to be shown to have been even stronger. Adjusted for population size, the number of organizations applying for AI-related patents with inventors from Israel are at least three times as many as the corresponding number for any of the other three countries. On the same measure has improved its position relative to the other four countries and is today not far behind Switzerland and at the same level as Denmark and Finland.

Figure A1. 8 Number of organizations filing AI-related patent applications 2006-2017 with inventors from Sweden and five other countries per 10 million inhabitants of the respective country and year



Source: Teqmine and Vinnova

Worth noting is that when only domestically registered organizations are compared Sweden's relative position is weaker even if it has improved somewhat in recent years. More detailed analysis is required in order to determine whether this is an indication that established firms and entrepreneurs in Sweden combined have insufficient capacity to absorb the outcomes of AI-related inventive activity in Sweden compared to the innovation ecosystems in the other five countries. In any case the numbers and differences are too small to allow any far-reaching conclusions. Differences in the degree and form of internationalization of industry and differences in the ownership of inventions by university researchers may play some role as to how patents are registered. In Israel, technology transfer organizations at the Technion, Weissman Institute, Tel Aviv University and Ben Gurion University together filed almost 200 AI-related patents 2006-2017.

Table 2 lists the organizations which have filed the largest number of AI-related patent applications with inventors from any the six specially studied countries. Ericsson's, Nokia's and Novozyme's dominance of AI-patenting in the respective three Nordic countries and in relation to any other organization in the six countries is conspicuous. Ericsson has increased its AI-related patenting while the opposite is the case for Nokia. The comparison is, however, limited to the six countries. After a series of mergers, today's Nokia is made up of the communication network businesses of former Nokia, Siemens, Alcatel and Lucent which means that patenting in Germany, France and the USA needs to be looked at in order to make a proper comparison of the two companies.

Table A1. 2 Organizations filing at least 20 patent applications 2006-2017 with inventors from six countries by country of inventors and country the assignee organization

Assignee organization	Country of inventor(s) (if at least 3 patents)	Registration country of Assígnee organization in relation to country of inventor(s)				Sum Total
		Domestic organizations		Foreign organizations		
		2006-2011	2012-2017	2006-2011	2012-2017	
Nokia	Finland	173	103			276
	Denmark			10	1	11
	Switzerland			5	4	9
L M Ericsson	Sweden	94	132			226
	Canada		1	12	14	27
	Finland			1	7	8
Novozymes A/S	Denmark	59	188			247
	Sweden			4	1	5
Z124 (and Imerj)	Canada			121	33	154
	Finland			57	10	67
IBM	Israel			49	27	76
	Canada		1	21	7	29
	Switzerland		2	15	7	24
Google	Switzerland			34	35	69
	Canada			18	12	30
	Israel			7	13	20
	Sweden			2	6	8
BlackBerry	Canada	58	39			97
Microsoft Corporation	Canada			45	3	48
	Israel			26	4	30
	Denmark			11		11
	Sweden			5		5
	Switzerland			2	1	3
TECHNION	Israel	57	19			76
ABB	Switzerland	18	23		1	42
	Sweden	2		5	11	18
	Finland	3			7	10
SONY CORPORATION (incl. former Sony Ericsson)	Sweden	39	14		13	66
Weizmann Institute of Science	Israel	31	21			52
Intel	Israel	2	6		31	39
	Finland		1	4	1	6
	Canada			1	2	3
	Sweden				3	3
Hewlett-Packard	Israel			11	32	43
	Canada			3	2	5
Deutsche Telekom AG	Israel			30	19	49
Ecole Polytechnique Federale de Lausanne (EPFL)	Switzerland	18	27			45
Siemens	Denmark			11	3	14
	Canada		1	12		13
	Switzerland		6	7		13
	Israel	3	1	1	1	6
Rockwell Automation Technologies	Canada			41	2	43
	Switzerland	1		2	1	4
AstraZeneca (incl. Medimmune)	Canada			22	4	26
	Sweden	10		5	2	17
DSM IP ASSETS B.V.	Switzerland			42		42
Nice Systems Ltd (acquired by Elbit Systems in 2015)	Israel	24	15			39
Tel Aviv University	Israel	22	16			38
Nestec S.A. (Nestlé group)	Switzerland	1	35			36
FlatFrog Laboratories AB	Sweden	15	20			35
Mobileye (acquired by Intel in 2017)	Israel		26	5	3	34
Compugen Ltd	Israel	33		1		34
AB Volvo	Sweden	29	5			34
F. Hoffmann-La Roche AG	Switzerland	14	8	1	1	24
	Canada	8	1			9
Oticon A/S	Denmark	9	21			30
Panaya Ltd. (acquired by Infosys in 2015)	Israel	1	29			30
The University of British Columbia	Canada	14	11			25
Novartis AG	Switzerland	11	15			26
NOVA Chemicals (International) S.A.	Canada			2	11	13
	Switzerland		13			13
GestureTek, Inc.	Canada	1	1	24		26
Cisco	Switzerland				23	23
Vestas Wind Systems A/S	Denmark	16	9			25
Thomson Reuters	Switzerland	1	18			19
	Israel		2	2	1	5
Ben-Gurion University of the Negev	Israel	9	15		1	25
University of Zurich	Switzerland	9	13			22
McGill University	Canada	19	4			23
Primal Fusion Inc.	Canada	10	12			22
GN ReSound A/S	Denmark	5	11			16
	Sweden			4	1	5
EMC Corporation	Israel			4	17	21
Verint Systems Ltd.	Israel	3	14	1	2	20
Tobii AB	Sweden	2	12		6	20
Sum of above-listed Assignee organizations (regardless of number of patents by organization with inventors in country)	Israel	**185**	**164**	**137**	**151**	**637**
	Canada	**110**	**71**	**322**	**90**	**593**
	Switzerland	**75**	**172**	**108**	**79**	**434**
	Sweden	**189**	**171**	**25**	**37**	**422**
	Finland	**176**	**104**	**62**	**25**	**367**
	Denmark	**89**	**229**	**32**	**4**	**354**

Source: Teqmine and Vinnova

Finland through Nokia, Sweden through Sony Ericsson (today Sony Mobile) and Canada through Blackberry all had large mobile phone companies which suffered from the iPhone and other new competitors. All three companies have filed a large number of AI-related patents. An interesting question is if and to what extent the drastic downsizing of the mobile phone operations of these companies in the three countries has played any role for AI-related developments in start-up companies. The company Z124 (also named Imerj) has been very active in AI-related patenting with inventors in both Finland and Canada.

As mentioned earlier and made clear in Table 2 leading global IT-firms, most of which headquartered in the USA, have are among the most active in filing patents by inventors especially in Israel but significantly also in Switzerland and Canada. In these cases, it can be assumed that most of the inventors have been employed at local subsidiaries. Among local entrepreneurial firms Mobileye in Israel is worth special mention. The company, which is a leading supplier of advanced systems for driver assistance and anti-collision systems, was acquired by Intel in 2017 for US$ 15 billion in the biggest acquisition of an Israeli tech company by value to date. The combination of Intel and Mobileye is today one of the key players in the development of technology for self-driving vehicles.

Content of Swedish AI-patents in international comparison

The Teqmine database of AI-related patent applications offers the possibility to broadly classify patents according to their content. Using machine learning technology, the patent applications have been classified into 30 "topics" according to similarities in technologies and applications. This allows the comparison between countries and individual organizations by "topic" (below referred to as "areas"). Based on this analysis it looks like the technological and business focus of Swedish AI efforts is broadening from its historical focus on ICT.

Comparing the content of AI-related patenting between the five countries and as part of world total patenting, Sweden's strongest areas are, as might be expected, closely connected with Ericsson's core businesses in communication and computer networks (Table 3). Sweden's world share in the area "computer networks" and "cellular network management" was 4,3 and 2,8 per cent respectively during 2012-2017 placing Sweden 1st and 2nd respectively among the six countries and in both cases showing a significant increase in the share from 2006-201. As the only among the six countries with a large vehicle industry, Sweden placed 2nd in the area "smart traffic" behind Israel. Globally this has been the second fastest growing area after "human-computer interaction". In both areas Sweden's world share has been roughly halved from around two to one percent between 2006-2011 and 2012-2017. By comparison, Israel increased its world share of "smart traffic" from 1,8 to 2,8 percent between the same periods. In "Signal processing" and "industrial process control", two areas which globally have shown moderate growth, Sweden's world share has increased and at around 1,5 percent 2012-17 it was well above Sweden's average for all areas put together. Sweden's world share was about the same in "health diagnostics - biomarkers" and "genetic cancer testing" while other health and life science areas left more to be desired.

Table A1. 3 Sweden's relative position in AI-related patenting in relation to the world as a whole and compared with Finland, Denmark, Switzerland, Israel and Canada

Topic Area (content broadly indicated by keywords)	World Total		Sweden's share of World total (%)		Sweden's per capita rank among 6 countries		Assignee organizations with at least 4 patent applications with Swedish inventors 2006-2017
	2006-17 (number)	Increase from 2006-11 to 2012-2017 (%)	2006-11	2012-17	2006-11	2012-17	
Human-Computer Interaction	9632	322	2,3	0,9	4	3	Sony; Assa Abloy; FlatFrog; Ericsson; Huawei
Smart Traffic	5980	137	2,0	1,1	2	2	AB Volvo; Ericsson; Volvo Cars; Husqvarna
Data Science: Modelling-Training-Learning-Classification	6335	118	1,1	0,9	3	4	Ericsson
Electricity - Grids - Therapy - Misc	3340	115	1,5	0,5	4	5	
Computer Memory and Processing	12981	111	0,2	0,5	6	4	Ericsson; QlikTech; Microsoft; Assa Abloy
Mechanical Sensors	3201	88	1,3	0,5	5	6	
Computer Networks	3627	86	2,0	2,8	2	2	Ericsson
Payment and Transaction Processing	11185	82	0,3	0,2	6	5	
Health and Patient Systems	3374	73	0,7	0,4	5	6	Elekta
VR/AR and Wearable Sensors	3321	68	0,6	0,8	5	5	Tobii
Radiation Therapy - Light - Misc	3654	66	1,3	0,9	3	3	FlatFrog; Sensa Bues
Natural Language Processing	7976	53	0,4	0,1	5	6	
Signal Processing (Radio)	4508	46	1,4	1,6	5	2	FlatFrog; ABB
Information Search and Recommendations	9648	46	0,7	0,6	5	4	Ericsson; Sony, Spotify
Cameras and Image Processing	9201	46	1,0	0,7	4	5	Tobii; Autoliv; Ericsson; Exini Diagnostics
Industrial Process Control	2698	30	0,9	1,4	5	4	Ericsson
Nanotechnology for Semiconductors	1391	29	1,0	0,1	4	5	
Cellular Network Management (Radio)	2698	28	1,1	4,3	3	1	Ericsson; Assa Abloy
Combustion Engines - (Gas - Oil - Fuel)	2494	25	1,9	0,3	4	6	AB Volvo
Gene Technology 2	1678	24	1,2	0,3	6	5	
Speech & Sound Recognition	3698	21	1,6	1,2	5	4	Ericsson, Dolby, Google; Sony
Health Diagnostic - Biomarkers (Personal Health?)	3304	12	1,9	1,4	5	4	GE Healthcare; Immunovia; Sensa Bues; AstraZeneca
Drug Modelling and AI for Pharmaceuticals	4053	-1	2,3	0,9	4	4	AstraZeneca; Immunovia; Apodemus
Clustering Algorithms	6200	-5	2,9	1,2	2	4	Ericsson; FlatFrog; Scania
Document Identification - Authentication - Translation	2123	-7	1,1	0,4	3	5	GE Healthcare
Genetic Cancer Testing	2090	-9	0,8	1,6	6	3	Immunovia
Gene Technology 1 (DNA Sequence Modelling)	3194	-25	0,4	0,4	5	6	Novozymes; Henkel AG & Co. KGaA
Horticulture and Agriculture	143	31	(too few patent applications in 6 countries)				
Digital Data Processing	3658	33	(too few patent applications in 6 countries)				
Virtual Reality Displays	683	44	(too few patent applications in 6 countries)				
All Topics	**138068**	**61**	**1,1**	**0,8**	**5**	**5**	

Source: Teqmine and Vinnova

Conclusions

In a global perspective, Sweden is, as might be expected, a small player in terms of AI-related patenting. Along with most European countries, its share of world total patenting has decreased over time due to the rapid growth in Asia. Similar to many other rankings measuring innovative activities, on a per-capita basis Sweden is doing reasonably well, but behind Israel, Switzerland, Denmark and Finland among countries of comparable size.

In the most recent years Sweden's AI-related patenting efforts have significantly grown as has the number of companies actively patenting. Already named assignee organizations applying for patents with inventors from Sweden were 48 in 2016 compared to an average of 30 per year 2010-2014. When complete data are available the recent growth in patenting organizations is likely to be shown to have been even stronger.

The telecom equipment company Ericsson has been and is still dominating Sweden's AI-related patenting. Sweden's strongest areas are, as might therefore be expected, closely connected with Ericsson's core businesses in communication and computer networks. Sweden's world share in the area "computer networks" and "cellular network management" was 4,3 and 2,8 per cent respectively during 2012-2017 and in both cases showing a significant increase in the share from 2006-2011.

Among small countries, Sweden is unique in having a large vehicle industry. "Smart traffic" is therefore a key area for Sweden. Globally this has been one of the fastest growing AI-related areas. Although Swedish patenting in the area has grown it has not kept pace with the rapid global development and as a result Sweden's world share has been roughly halved from around two to one percent between 2006-2011 and 2012-2017.

In "signal processing" and "industrial process control", two areas which globally have shown moderate growth, Sweden's world share has increased and at around 1,5 percent 2012-17 it was well above Sweden's average for all areas put together. In health-related areas Sweden's performance has been mixed with apparent relative strength in "health diagnostics - biomarkers" and "genetic cancer testing".

Due to the delay between the time when a patent application is submitted and the time when a patent office publishes the application it is not yet possible to fully assess the developments after 2015. The extent to which the sharply growing interest in AI in the last couple of years in Sweden as well as globally has translated into an increase in AI-related patenting remains cannot yet be determined from the available data.

While patents may be important as knowledge-based capital for AI-intensive business development, the relative importance of patents will differ depending on type of business. The great importance of access to data is widely recognized. Development of new business models as well ability to integrate a company's organization across business functions and with partner organizations also play a decisive role.

With these caveats, patenting nevertheless provides useful information on the structure and dynamics of AI-related innovative activities by allowing analysis internationally at the level of individual companies and with the possibility of differentiating by broad thematic areas.

Appendix: Data and Method used in the analysis

DATA

Patent data was obtained from the patent database maintained by Teqmine Analytics Ltd, which is based on USPTO, EPO and WIPO issued original XML publications of patent records.

The patent database covers all 1st time publications of new patent applications or grants without prior publications from USPTO, EPO and WIPO, totalling over 12 million patents on all technological fields. The data is detailed below:

Patent Data Details:

- United States Patents and Trademark Office patent data.
  - × Granted patents for the period 1990-2001
  - × First time applications / grants (Kind codes A1, B1, P1, since 2001–2017
- European Patent Office data.
  - × All first time publications / grants since 1978. EN-full-text patents. 1978–2017
- World Intellectual Property Organization data.
  - × All first time publications / grants since 1978. EN-full-text patents. 1978 – 2017

Patents were not grouped into patent families, thus allowing for individual members of a patent family to be counted multiple times, if filed in all offices.

METHODS

Preparation of the Artificial Intelligence technology map follows a proprietary routine and application of natural language processing and machine learning techniques developed by Teqmine.

Its main steps are:

1. **Stage 1. Selection.** Broad text mining of all patent description sections for any mention of key artificial algorithms or techniques.
   Terms used for text mining are: *Artificial intelligence, learning algorithm, machine learning, unsupervised learning, neural network, self-organizing map, self-organizing feature map, kohonen map, bayes classification, support vector machine, clustering algorithm, markov model, random forest, hidden forest, bayesian statistics, classification engine*
   This stage identified total of 183,658 records.
2. **Stage 2. AI Classification.** The patent set was classified by machine-learning techniques (Topic modelling) into 30 technology areas, or "Topics". This is realized by applying unsupervised learning methods to analyze the full-text context of the identified 183,658 patents.
3. **Stage 3. Validation and analysis.** The resulting machine learning generated classification scheme is validated by human experts, and, once accepted, analysis of the data is done.

Clear definition of what is "Artificial Intelligence" so that it could be applied directly to patent analysis does not exist. There are no exhaustive or comprehensive technology classifications or terms that would allow one to capture effectively everything that involves different aspects of machine learning. Thus, one needs to accept certain caveats when preparing a technology and patent map of Artificial Intelligence.

Teqmine has developed AI technology and patent since 2016, and its production has undergone several rounds of iteration. We have chosen to choose any patents that mention some of key machine learning terms, and include those in our selection.

This method inevitably captures patents that have different level of machine learning content: Some deal exclusively with machine learning, whereas others make only a passing mention. However, we believe that it is important to capture AI patents irrelevant to what degree they hold AI content, because the utilization of AI in new and remote areas (from core data science) is of great economic, social and political interest. For example, too rigid application of AI content would easily exclude patent publications that discuss application of machine learning in health context, for example.

Thus caution and skill are required to interpret our AI map correctly. Teqmine's classification engine does not classify every area of AI equally precisely and correctly, and interpretation of results should be done carefully. Secondly, the AI map in itself is a very large patent map, consisting of almost 200,000 patents, thus undermining human's capacity to comprehend its diversity well.

It is important to understand that Teqmine's AI map is intended to provide a broad overview, a bird's eye perspective, of a dynamic and fast evolving technology area. If one would need to look at minute details, other approaches and elimination of redundant data would be necessary.

Appendix 2. ICT-educated individuals in Sweden

Table A2. Percentage of ICT-educated individuals per industry, and percentage of ICT-educated individuals per industry of total number of employed persons. For all levels of education and for those with extensive education.

SNI	SNI TEXT	ICT-EDUCATED IN INDUSTRY (PER CENT)	ICT-EDUCATED IN INDUSTRY (PER CENT) EXTENSIVE ED.	ICT-EDUCATED IN INDUSTRY OF TOTAL NUMBER OF EMPLOYED (PER CENT)	ICT-EDUCATED IN INDUSTRY OF TOTAL NUMBER OF EMPLOYED (PER CENT), EXTENSIVE ED.
0	Main group missing	2.85	4.78	0.48	0.39
1	Agriculture and hunting and related service	1.95	5.87	0.36	0.21
2	Forestry	2.58	5.28	0.34	0.22
3	Fishing and aquaculture	2.94	11.28	0.02	0.01
7	Mining of metal ores	9.86	13.66	0.21	0.11
8	Other mineral mining	3.21	3.96	0.02	0.00
9	Service for mining	7.34	8.81	0.00	0.01
10	Food production	4.41	6.92	0.72	0.28
11	Beverage production	6.89	7.01	0.10	0.04
12	Manufacture of tobacco products	6.20	6.92	0.03	0.02
13	Manufacture of textiles	5.25	7.01	0.09	0.03
14	Manufacture of clothing	2.02	3.47	0.01	0.01
15	Manufacture of leather, leather goods etc.	4.38	3.76	0.01	0.00
16	Manufacture of wood and products from wood, cork, rattan etc. except furniture	4.58	5.82	0.50	0.11
17	Paper and paper goods manufacturing	9.03	9.70	0.85	0.32
18	Graphic production and reproduction of recordings	7.10	14.12	0.28	0.12
19	Manufacture of coal products and refined petroleum products	9.54	9.60	0.08	0.06
20	Manufacture of chemicals and chemical products	7.07	7.98	0.42	0.31
21	Manufacture of pharmaceutical bases and medicines	8.11	10.48	0.33	0.48
22	Manufacture of rubber and plastic products	6.25	8.09	0.40	0.12
23	Manufacture of other non-metallic mineral products	4.83	5.17	0.29	0.07
24	Steel and metal production	9.12	15.23	0.87	0.50
25	Manufacture of metal products, except machinery and equipment	5.85	14.07	1.37	0.64
26	Manufacture of computers, electronics and optics	32.01	45.01	2.00	2.45
27	Manufacture of electrical equipment	19.24	34.22	1.41	1.58
28	Manufacture of other machinery	9.76	15.04	2.17	1.67
29	Manufacture of motor vehicles, trailers and semi-trailers	9.85	18.64	2.30	2.40
30	Manufacture of other means of transport	18.01	29.01	0.88	1.20
31	Manufacture of furniture	4.77	7.75	0.23	0.07
32	Other manufacturing	8.31	12.93	0.32	0.31
33	Repair and installation of machinery and equipment	10.81	20.85	0.75	0.27

SNI	SNI TEXT	ICT-EDUCATED IN INDUSTRY (PER CENT)	ICT-EDUCATED IN INDUSTRY (PER CENT) EXTENSIVE ED.	ICT-EDUCATED IN INDUSTRY OF TOTAL NUMBER OF EMPLOYED (PER CENT)	ICT-EDUCATED IN INDUSTRY OF TOTAL NUMBER OF EMPLOYED (PER CENT), EXTENSIVE ED.
35	Supply of electricity, gas, heating and cooling	14.51	22.51	1.35	1.57
36	Water supply	7.48	7.13	0.08	0.05
37	Sewage treatment	6.06	8.17	0.07	0.04
38	Waste disposal; recycling	4.82	8.91	0.24	0.12
39	Sanitation, soil and water treatment and other pollution control business	2.20	4.88	0.00	0.00
41	Construction of houses	1.90	2.84	0.56	0.21
42	Construction work	6.25	4.93	0.66	0.16
43	Specialised construction business	5.62	8.35	4.22	0.53
45	Trade and repair of motor vehicles and motorcycles	3.75	8.71	0.97	0.29
46	Wholesale trade and commission trade except with motor vehicles	8.97	12.73	6.35	4.26
47	Retail trade except with motor vehicles and motorcycles	3.84	6.97	3.79	1.77
49	Land transport; transport in pipelines	4.38	10.36	2.01	0.81
50	Maritime transport	3.30	2.95	0.11	0.07
51	Air transport	3.38	5.38	0.06	0.04
52	Warehousing and support services for transportation	5.49	7.25	0.88	0.37
53	Postal and courier business	6.70	15.22	0.72	0.39
55	Hotel and lodging business	2.18	4.48	0.32	0.17
56	Restaurant, catering and bar business	2.33	7.27	0.97	0.49
58	Publishing	21.20	30.82	2.12	3.38
59	Film, video and television programme production, sound recordings and phonograms	6.63	8.01	0.30	0.24
60	Planning and transmission of programmes	8.35	6.54	0.19	0.14
61	Telecommunications	27.50	34.98	2.04	1.64
62	Computer programming, data consultancy, etc.	46.28	56.73	17.96	27.85
63	Information services	26.15	34.99	0.86	1.22
64	Financial services other than insurance and pension fund operations	8.45	10.36	1.57	2.14
65	Insurance, reinsurance and pension fund operations except for compulsory social insurance	8.41	13.75	0.61	0.81
66	Support services for financial services and insurance	8.10	11.59	0.45	0.68
68	Real estate business	4.34	4.10	1.15	0.58
69	Legal and financial consulting	2.82	2.59	0.46	0.57
70	Operations run by headquarters; consulting services to companies	10.95	13.65	2.34	3.67
71	Architectural and engineering consultancy; technical testing and analysis	12.64	14.82	4.29	5.93
72	Scientific research and development	20.97	24.35	1.29	2.78
73	Advertising and market research	7.71	12.16	0.66	0.74
74	Other business within law, economics, science and technology	6.71	9.95	0.69	0.94
75	Veterinary business	1.04	0.94	0.02	0.02
77	Rental and leasing	6.10	10.06	0.27	0.11
78	Employment services, staffing and other personnel related services	6.80	5.66	2.32	1.30

SNI	SNI TEXT	ICT-EDUCATED IN INDUSTRY (PER CENT)	ICT-EDUCATED IN INDUSTRY (PER CENT) EXTENSIVE ED.	ICT-EDUCATED IN INDUSTRY OF TOTAL NUMBER OF EMPLOYED (PER CENT)	ICT-EDUCATED IN INDUSTRY OF TOTAL NUMBER OF EMPLOYED (PER CENT), EXTENSIVE ED.
79	Travel agency and tour operator business and other travel services and related services	4.73	9.16	0.16	0.18
80	Security and surveillance business	8.97	13.65	0.65	0.21
81	Property service as well as upkeep and maintenance of green areas	2.91	5.46	0.81	0.31
82	Office services and other business services	4.75	9.00	0.72	0.32
84	Public administration and defence; compulsory social insurance	5.66	5.13	5.39	5.87
85	Education	3.04	3.97	5.32	9.09
86	Health and medical care	1.15	0.73	1.23	1.12
87	Health and social care with housing	1.27	2.06	1.05	0.59
88	Open social initiatives	1.71	1.99	1.42	0.83
90	Artistic and cultural activities and entertainment business	3.14	2.50	0.27	0.22
91	Library, archive and museum operations, etc.	3.05	2.30	0.17	0.18
92	Betting business	11.69	25.28	0.15	0.17
93	Sports, leisure and entertainment business	3.18	4.28	0.51	0.21
94	Lobbying; religious operations	2.90	2.31	0.58	0.42
95	Repair of computers, household goods and personal items	20.84	17.98	0.46	0.07
96	Other consumer services	1.61	4.18	0.28	0.15
97	Paid work in households	0.00	0.00	0.00	0.00
99	Operations of international organisations, foreign embassies, etc.	2.34	2.11	0.00	0.01

Vinnova is helping to strengthen Sweden´s innovation capacity

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