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Artificial Intelligence for innovation in Austria

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Abstract: Artificial Intelligence (AI) has been claimed to carry enormous potential for service and product innovation. Policy makers world-wide aim to foster environments conducive for AI-based innovation. This paper addresses the current lack of empirical data for evidence-based innovation policies and for specific AI-based innovation management. We present data from Austrian companies regarding degree of implementation and challenges of AI-based innovation. The results depict the image of an emerging technology applied in many sectors: while there are innovative solutions, the corresponding business models are still developing. Companies are facing various challenges from regulation to human resources and data collection. Managing AI innovation will be particularly difficult for smaller enterprises where these problems are often more pronounced than in larger industries. Specific AI innovation management challenges include attention to managing expectations and ensuring historic metadata expertise.

Keywords: Artificial intelligence; AI; innovation; Austria; SME, AI innovation management.

1 Introduction

Artificial Intelligence (AI) has been claimed to carry enormous potential for service and product innovation. As a result, policy makers world-wide aim to foster environments conducive for AI-based innovation. However, there is very little published empirical work on AI innovation management challenges to date. This contrasts with a large amount of studies – including those published by large multinational consulting firms – proclaiming an enormous potential of AI technologies. Although the visionary dimension of these studies is often inspiriting, real-world data is also necessary for evidence-based innovation policy making. Such factual evidence is even more important for specific approaches to AI-based innovation management. Consequently, the aim of this study is to present empirical data from Austrian companies on specific challenges of AI-based innovation.

The paper aims to provide empirical evidence for specific innovation management challenges of companies using AI which is a very broadly defined group of economic entities. This breadth was chosen with the purpose of supporting evidence-based policy making for AI-innovation. The long-term perspective of this study is to help design a national AI strategy and to design specific support measures for AI-based innovation.

Existing work and context

Smart technologies are considered major drivers of innovation (Lee & Trimi 18, Makridakis 17) and of knowledge for innovation (Fischer & Fröhlich 01). A broad range of policy papers (Agraval et al. 19, Dutton 18) and marketing studies from consulting companies argue for the innovation potential and economic benefits of AI (e.g. PAICE 18, Li et al. 17). However, little empirical data on specific practical challenges of AI-based innovation exists.

The study was part of a larger exercise to estimate the economic footprint of Austrian AI companies and of current international strategies to support an AI environment conducive for innovation. The study design therefore included a larger-scale estimation of AI technology application in various sectors of the Austrian economy. For this, data from various innovation and research project databases was analysed. The resulting information was put in the context of the economic statistical data for Austria to understand the size of the overall importance of AI technologies already deployed. Interviews with experts were a part of the exercise. Here, we report only on these interviews in the context of innovation policy and innovation management.

From a more general point of view, this study provides an example of technology-related innovation management challenges, cf. (Prem, 2015).

Defining Artificial Intelligence

The current lack of empirical data is aggravated by the lack of a commonly accepted definition of AI. Many including the European Commission [EC 2018] define AI based on its objective to create human-like behaviour in machines for perception, reasoning, and action.

Another option is to focus entirely on AI learning systems. Although this includes a vast amount of applications and sectors, it does exclude the more rule-based systems often used for user interfaces and in systems requiring predictable and understandable behaviour. A definition solely focused on learning would exclude traditional AI systems in natural language translation. Expert systems, or case-based reasoning systems and other types of rule-based reasoning systems would also be excluded.

An appropriate definition of AI can also be based on the various academic subfields of AI as a field in computer science and engineering, i.e. reasoning (e.g. logic), learning (e.g. neural networks), machine perception (e.g. understanding of speech, text, images or videos), and autonomous behaviour (e.g. autonomous driving, robotics). Note that this is a mix of technology-related aspects (e.g. learning) and more application-oriented ones, e.g. machine perception.

For the analysis in this paper, we use a corresponding characterization based on the various academic and engineering AI subfields. Such a definition is well aligned with the organization of AI research and with classification schemes of funding agencies. Industrial robotics was excluded for this reason as it is more a field of automation and production engineering, while autonomous robotics (such as autonomous vehicles, lawn mowers etc.) was included. In addition, focusing only on machine learning – as seems to be a current emerging trend – would exclude the field of rule-based AI that is comparatively strong in Austria.

2 Methodology

Focus and selection

The focus of our study is on Austrian companies using AI technologies for innovation. We report results from 11 interviews with experts from producers or users of AI technologies for innovative products and services. The selection of potential AI-innovators was based on a keyword list to identify AI technologies belonging to academic AI subfields. These keywords were listed in English and German.

The list includes topics in machine learning, knowledge representation and reasoning, autonomous robots (including autonomous driving), machine learning, pattern recognition, and natural language processing. For example, it includes "neural network", "deep learning", "connectionism" etc. to discover innovation and research projects in machine learning. This list is based on IT expert knowledge and existing classification schemes such as the ACM classification often used by innovation agencies. Potential companies were identified using innovation agency databases, industry data, and job search data related to artificial intelligence.

Table 1 Excerpt from the keyword list used for the identification of relevant entities (11 of 36).

English	*German*
Artificial Intelligence	Künstliche Intelligenz
Machine Learning	Maschinelles Lernen
(Artificial) neural network, neural net	(Künstliches) neurales Netz, neuronales Netz
Expert system	Expertensystem
Knowledge representation	Wissensrepräsentation
Natural language processing	Sprachverarbeitung, natürlichsprachige Systeme
Computer vision, Image understanding	Computervision, Bildverstehen
Autonomous robots, autonomous system	Autonome Roboter, autonome Systeme
Problem solving	Problemlösen
(Automatic) Reasoning	Automatisches Schlussfolgern
Knowledge engineering	Wissenstechnik, Wissensverarbeitung
…	…

Source: Author's own definition.

Interviews

We conducted interviews with 11 representatives from companies that are active in AI. This included private research institutes creating AI applications. In most cases, the persons interviewed were CEOs, CTOs or department heads of the companies. The set included both small-and-medium sized enterprises as well as large industry players. All companies in our set deploy or develop AI solutions with the aim of creating innovative services or products.

The interviews were performed following a structured interview guideline about company characteristics, activity sectors, core competencies, innovative AI applications, motivations for using AI, technologies used, the role of start-ups, business models, main customers, barriers and obstacles.

3 Results

The study resulted in a rather coherent picture of the state-of-deployment of current AI technologies. This means that there was broad agreement between the experts on aspects such as the general opportunities of AI for innovation, on the current state of its deployment, and on many of the challenges and problems which companies are facing today.

Sectors and application areas

The selected company experts covered a range of sectors with a certain focus on automotive and other machining industries. These sectors are traditionally strong areas of the Austrian economy with many innovative SMEs and also large industry.[1] The firms included dedicated AI companies that address broad economic sectors including the service sector. The experts were also asked about their core competencies to better distinguish consultants, AI application developers form other enterprises that internally develop their own AI-based solutions. The interviews listed the following areas:

- Analytics, Text Mining, Information Capture
- Enterprise Content Management
- Privacy protection
- Transport and mobility
- Automotive
- General AI
- Sign language
- Natural language understanding

Although only experts from 11 companies were interviewed in detail, the number of developed AI applications discussed in these interviews was more than 35. They include all sorts of application areas of AI from online sentiment analysis to trend and incident analysis in documents, autonomous driving, intelligent search to identify experts, predictive maintenance for industrial applications, rolling stock optimization in the transport domain, software defined network management, an intelligent travel agent, sign language translation, financial risk management, or AI assistants for human resource management. The applications can be roughly classified in the following categories and examples (cf. Table 2):

[1] As an example, the Austrian Business Agency lists machinery, electronics and mechatronics as Austria's leading sectors. https://investinaustria.at/en/downloads/brochures/machinery-electronics-mechatronics-austria-2014.pdf

Table 2 AI application areas and examples of AI-based innovations.

Area	*Example*
Language, speech and dialogue systems	Chatbots, travel agent, HR-assistant, semantic search, support systems, search
Text analysis, knowledge management and knowledge extraction	Trend and threat analysis in texts, information extraction, sentiment analysis
Industrial automation and plant operation	Industry 4.0, optimization, predictive maintenance, simulation, video-based error detection, automation of complex manual procedures, sensor fusion
Video and image classification	Processing of sound, image, video and text; security applications
Autonomous operations	Autonomous vehicles, autonomous operation of plants
Information technology applications	Software defined networks, software maintenance, security, anonymisation
Finance	Finance and risk management

Source: Expert interviews (right column) and author's classification (left).

The main motivations for using or developing AI for innovative products and services include automation, process optimization (e.g. adaptation, acceleration), improved efficiency (with respect to costs, personnel) or increased flexibility, complexity management, and knowledge management. AI technologies used include machine learning, data analysis and prediction techniques, natural language processing, image analysis, deductive systems, and knowledge graphs.

Technologies

The following table (Table 3) provides an overview of the concrete AI technologies that the experts mentioned in the interviews and the corresponding AI field.

Table 3 Technology field and concrete technologies mentioned by the experts.

Technology field	*Used technologies*
Machine learning	Neural networks, convolutional neural nets, deep learning evidence-based methods
Data analysis and prediction	Predictive analytics, prescriptive analytics
Natural language processing	Language generation, language understanding (text, speech), text mining, semantic search, content analysis
Image and video processing	Image recognition, pattern recognition, video analysis
Knowledge processing	Deductive systems, knowledge graphs, knowledge representation systems

Source: Expert interviews (right column) and author's classification (left).

The role of start-ups and new AI business models

There is a prevailing opinion among those interviewed that start-ups have a vital role to play in both the application and deployment of AI innovations. They are considered the main leaders and carriers of competence in the technology and praised for their flexibility compared to large industry actors. Specialized start-ups are also believed to invest more in the development of novel AI methods compared to large software industry. Also, the interviewees consider their solutions to be more straightforward to deploy compared to the more complex environments of providers of comprehensive frameworks. On the downside, AI start-ups can be difficult to identify.

Regarding AI solution business models, the respondents suggest that these are still being investigated and not fully clear as the focus is often on quality improvements rather than new business models. It is expected that price planning and dynamic pricing may become a more important aspect of AI applications. AI-as-a-service has already emerged as a specific case and there is a trend towards licensing per service, per application case or based on volume. In addition, there is a trend to shift the development of solutions to the customer given the appearance of more mature training tools for data-driven AI solutions.

AI-applications and AI-development are central to many consulting activities in the domain. Indeed, it is sometimes difficult to clearly delineate consulting companies from AI application developers. There are even indications that a new profession – the AI trainer – is emerging: experts in the application domain with competencies in data analytics, where the former is more important than the latter.

Many interviewed experts were convinced that sooner or later no company (at least in a technical domain) can be successful without a certain degree of automation and, hence, autonomy. This will make AI a general computer method with a strong focus on data-driven approaches to system creation, but also on automation.

Challenges and barriers

From an innovation management perspective, the lack of experts is the biggest challenge for the experts in our interviews. This concerns general IT-experts, but also IT-staff with dedicated AI expertise: AI generalists, AI specialists in neural networks, AI software engineers, data scientists. The interviewed experts also pointed out that currently even graduates from technical universities including computer science graduates may not necessarily have sufficient AI expertise

Another main barrier are the costs for creating the required know-how and for innovations: AI development times tend to be longer than expected as many AI techniques often require many trial-and-error cycles. Robotic technologies were also listed as often costly.

The respondents also identify a lack of knowledge about AI in the sense that there is insufficient general awareness and knowledge in the company including C-level executives. This often results in unrealistic expectations about AI. Managing AI-based innovation is a huge challenge for experts when there is not even an agreed definition of AI. Today’s lack of AI knowledge also reduces the credibility of AI solutions. There are many claims from marketing people that cannot be confirmed in practice resulting also in a lack of acceptance of failures in the innovation process. This comes on top of the recognized challenge that many solutions based on machine learning cannot easily give explanations of their behaviour. The lack of clear regulation and legislation is a related problem, e.g. for responsibility in the health sector and in control applications or other engineering fields.

SMEs trying to apply AI are often hesitant because of these uncertainties. In addition, they are challenged by the fact that they may be lacking data - in terms of volume or quality. Innovation managers are often having difficulties to estimate the realizability of AI-based innovation projects, in particular when using statistical techniques such as neural networks.

The following table (Table 4) provides an overview and classification of the barriers and challenges mentioned in the interviews.

Table 4 Barriers and challenges and some examples (interviews).

Barriers and challenges	*Examples*
Lack of qualified staff	IT-experts (general), IT-staff with AI expertise, data scientists, specialists and generalists, software developers, AI experts
Costs	Know-how creation, development costs, long development times (trial and error for innovative solutions), hardware costs for robotics
Lack of knowledge	Insufficient information about AI (general), unrealistic expectations, insufficient competence in AI (with not even the definition being clear)
Credibility of AI solutions	Unrealistic claims regarding AI and disappointment
Technical aspects	Lack of explainability for learning systems, lack of data – strong limitation for AI, especially for SMEs
Regulation	Current legal regulation, e.g. in the health sector; unclear responsibilities for overall system behaviour
Hesitation	Hesitation of executives, especially with SMEs, but also hesitation of customers
Hype	Risk that the current hype about AI hampers its development, because it blurs the view of real opportunities and creates wrong expectations

Source: Expert interviews (right column) and author's classification (left).

4 Discussion

Austrian companies are recognizing AI as an important technical enabler of innovation. Although there has been research in AI technology for more than 50 years, there is a sense of novelty that seems to be driving experimentation. Many aspects of this technology are still emerging, and companies are trying to understand what the possibilities of the technology are, what their own capabilities are, and where the benefits really lie for innovation.

Innovation characteristics of AI

AI is not yet a fully mature technology and it is not even fully clear which methods and approaches or techniques are included in its definition. The AI concept often rather describes features of the (desired) application. The term is often defined as *making computers do what so far only humans can do.* This is also how the term originated around the 1960s in the US. It should be obvious that this characterization of the AI concept is really an oxymoron as it implies that it is a moving target: it emphasizes technological abilities not yet doable by computers. This also means that whenever a technology that originated in AI research matured, it became part of the standard repertoire of computer science and was no longer considered proper AI. This is one of the reasons for the difficulties in clearly defining the term.

The general aim of AI is to make computers smarter in both human perception, decision-making, and action. In these cases, AI systems do not necessarily always have to outperform humans. In many new application areas, AI systems are developed with the aim to achieve automated perception, decision-making or action with less-than-human degrees of precision. In these cases, the AI system can add round-the-clock performance or simply a way to deal with very large amounts of data. Examples are image recognition and classification applications that may not be always 100% correct but help to pre-sort cases for human inspection. Other applications of AI may actually target improved quality, e.g. in AI-based medical image classification or high-precision robotics applications.

The motivations listed in the interviews why to use AI are broad and often overlapping. Automation and process improvements are a big driver, another area is management of complexity including knowledge management. Other motivations obviously are increased efficiency regarding technical parameters or personnel resources and costs. Besides of these qualitative innovation targets, AI promises to deliver technical solutions in areas that could not be previously solved by computer applications. For example, learning AI systems trained on large amounts of data can be used for automated video classification. This enables previously unavailable solutions in security applications helping to improve quality and reduce costs.

In summary, there is a broad range of innovation promises for AI – from mere improvements to enabling completely novel product and service offerings. And indeed, the innovation examples in the interviews clearly range from incremental innovation (e.g. quality improvements in production using AI for error detection) to 'new to the world' innovation (automation of sign language translation). The emphasis in the interview examples is on incremental improvements, with some examples of automation of processes that could not be automated without the application of AI.

AI in engineering

There are good reasons why many companies in Austria innovating with AI operate in the engineering domain: learning AI systems in many cases require large amounts of training data. Such data is usually difficult to create, unless already provided by technical systems such as digital production systems, plant control systems, or other technical systems that continuously monitor and often control operation. Engineering environments (in electronics or automotive production or in machining) therefore appear to be prime candidates for rolling out novel AI services simply due to the availability of sufficient amounts of data. It became clear in our interviews that indeed the very existence of data is a major driver of experimentation with AI-based innovations. This "data-push" is combined with a "technology-push" of current AI development tools that are now available often at rather low costs – or even for free.

In addition, engineering companies may be more likely to have the required skill set as regards computer engineers and data scientists compared to the service sector, for example. They are used experimenting with novel technologies and typically have a mindset adjusted to technological competitiveness.

Experimentation, resources and capabilities

The focus on experimentation in the interviews has both a technological and a company dimension. The relative novelty of AI for most companies means that companies are exploring their AI innovation resources and capabilities (Tidd & Bessant 14). This includes in particular functional capabilities such as experienced personnel, but also resources including data. Other potentially limiting technical aspects include computational requirements for AI training or AI application.

There is a second dimension inherent in the technological characteristics of AI, at least for learning systems or data-driven systems. At the current state-of-the-art, developing AI systems is a process of trial-and-error. While there are of course often situations in which novel technical solutions require an iterative approach, the situation is exacerbated in the case of AI because of the inherently statistical nature of many AI solutions. For such statistical (learning) systems it is often not fully clear if a solution is possible at all.

In addition, the tuning of learning systems requires several stages of training and test cycles. This lack of technical predictability becomes an important challenge for innovation management if there are inflated expectations about the possibilities of AI technology. Many company experts warned about the danger of disappointment that may arise from very high expectations and only mediocre performance of an AI solution. The resulting disillusionment could eventually mean that companies refrain from exploring potentially promising solutions for too long.

For AI innovation management it is particularly interesting that companies may not fully understand their data resources to the extent necessary for AI solutions. Small companies may be lacking the kind of long and consistent data sets typically required for deep learning solutions. More critically, the interviews suggested that this is a specific problem for smaller companies and that it is very hard for most of them to know precisely what information is in their data, for what time periods data is reliable, etc. This kind of metadata expertise can be essential in assessing the technical viability of an AI solution and in designing an AI system and an efficient development process.

From the perspective of innovation management, data is an interesting case as it represents both a *technical* and a *historic* dimension. The usability and value of any given data set will depend on technical characteristics of the precise AI technology, e.g. deep learning, case-based reasoning or symbolic expert system. In addition, data carries an element of history that is typically not well described in explicit metadata information. Rather, this history requires competent interpretation of human domain experts in order to understand any potential limitations but also opportunities. In the interviews this aspect of domain knowledge in combination with a proper appreciation and understanding of the available data was mentioned as a current shortcoming. Here, some experts suggested the potential future job profile of an ‘AI training’ expert – perhaps not fully aware of the required in-depth understanding of the historic data dimension.

In summary, there are at least three specific aspects of AI innovations that require consideration for innovation management: technologies, resources and capabilities.

- Resources: data sets and knowledge in combination with data expertise
- Resources: AI tools in combination with AI tool / AI training expertise
- Capabilities: domain experts providing the required domain knowledge

This suggests that successful development of AI-based innovations at an early (pre-market) stage may already require three different types of experts: AI experts, domain experts, and metadata experts.

Value creation

On the demand side, customers consider obvious criteria such as costs and value proposition of an innovative solution. Less obvious specific AI-related aspects are trust and understandability or the ability to explain and predict system behaviour. These aspects are closely linked. In engineering domains, it is particularly important that solutions (e.g. for control, but also maintenance, automation etc.) are reliable. In many cases where AI solutions promise improvements over traditional approaches this comes at the price of reduced clarity and predictability. This is not necessarily only true for statistical learning systems. Even large-scale rule-based systems may easily become practically untraceable and extremely difficult to predict.

The related challenges for AI-based innovation have become an important subject in research policy but also in AI research. Interestingly, the focus in the public discussion is often on explainability, which is a rather different concept. In any case, the typical iterative development and the necessity to assess quality through testing is a challenge for AI-based innovation in engineering as many potential customers express concerns about the reliability of innovative AI solutions even where they may outperform existing systems.

For the case of Austria this is a further key aspect to consider. As mentioned before, the strong machining, electronics and automotive industries can build applications on historic data. However, they may also have very tight requirements or expectations regarding predictability, reliability and explainability of systems. For the AI innovation manager this may imply a preference for solutions that exhibit these characteristics. And in areas that are less regulated or where there is no hard requirement for full predictability and explainability it means a particular focus on testing, evaluation and demonstration to gain the necessary trust.

Following our interviews, the question of AI-specific business models remains an interesting open issue. Many of the respondents did not see such a model emerging just yet. The mentioned change of business model such as shifting from products to services is more in line with typical business model innovation following digitization (Prem 2015b).

The more interesting case is AI-as-a-service where it may be necessary to distinguish online creation of AI systems (e.g. training neural network models) from online use of already trained AI systems. Issues such as data ownership, dynamic service pricing or intellectual property rights of AI models could become AI-specific innovation challenges and methods.

4 Conclusions and further work

The data collected from the interviews with experts aiming for AI-based innovations identifies key challenges for innovation management. Some of these challenges are specific to AI-based solutions.

In the context of recently published AI strategies, the interviews suggest that significant emphasis needs to be put on human factors including training on and communication of AI techniques. Successful AI innovation management also needs to address the availability of high volumes of good-quality data, especially in small-and-medium-sized enterprises. Of particular importance is human expertise in AI and the application domain, but also on historic and semantic aspects for the case of statistical techniques that rely on past data.

The study informed the development of an Austrian national AI strategy. The data is also useful for innovation managers seeking to understand both the opportunities and challenges of companies aiming to deploy innovative AI solutions. For researchers, the data suggests potential new focus topics of further research, e.g. AI-related business model development, proper management of expectations in AI-related innovation processes, and further insights into the constraints emerging from the historic aspects of data and the required metadata expertise.

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