



Artificial intelligence in banking

A lever for profitability with limited implementation to date

June 4, 2019

Author
Orçun Kaya
+49 69 910-31732
orcun.kaya@db.com

Editor
Jan Schildbach

Deutsche Bank AG
Deutsche Bank Research
Frankfurt am Main
Germany
E-mail: marketing.dbr@db.com
Fax: +49 69 910-31877

www.dbresearch.com

DB Research Management
Stefan Schneider

Artificial intelligence (AI) is a significant step forward in the digitalisation and transformation of modern businesses. In short, it refers to computers' capability to acquire and apply knowledge without programmers' intervention.

Investors are lining up to be part of the imminent change. AI attracted USD 24 bn in investments globally in 2018, a twelvefold increase since 2013. US start-ups received the most attention, followed by Chinese, which already outpaced European AI start-ups.

Within Europe, Germany, France and the UK are the frontrunners in experimentation and in the implementation of AI. In light of intensified global competition, the European Commission proposed a EUR 9 bn budget to fund AI-related projects between 2021 and 2027.

Similar to earlier examples of information technology (IT) implementation in financial services, AI promises great efficiency gains and potential revenue increases. To date though, AI implementation in banking has been modest. AI is being tested for real-time identification and prevention of fraud in online banking as well as in know-your-customer (KYC) processes. Robo-advisors are also evolving over time to become true AI solutions. Looking forward, regulatory measures around data privacy and concerns regarding cybersecurity might create obstacles to AI use in banking. In addition, the highly regulated nature of banking may cancel out some efficiency gains of AI.

AI's potential contribution to bank profitability should not be underestimated. Empirically, AI has a significant positive impact on European banks' return on assets (ROA). By increasing labour productivity, AI technologies could structurally reduce costs in the banking sector. Rapid implementation of AI technologies is, therefore, central to fighting persistently weak profitability and to remaining competitive.



Introduction

Huge progress in computer hardware, software and internet technologies have irreversibly changed our societies. It is now difficult to imagine an economic agent without computers, internet or mobile devices. The pace at which IT is evolving offers great opportunities to expand the client base, introduce new products or improve existing ones and to increase efficiency in a relatively short period of time. On the other hand, if companies miss out on the current IT wave, they might be overtaken by events soon.

Among the various IT breakthroughs of recent years, the advancement in AI is particularly remarkable. In short, AI refers to computers having cognitive skills similar to humans, which could result in immense efficiency gains for firms and their clients alike. The financial sector has been one of the early experimenters with AI technologies, not least due to its likely contribution to stronger profitability. It is therefore essential to take a closer look at the potential role of AI in banks' digital transformation.

Artificial intelligence: A giant step beyond standard IT applications

To date, IT solutions in the business world have by and large focused on automating repetitive tasks that would otherwise require human involvement. The boundaries for these IT applications have been set by their developers, and by design these solutions have been limited in their capabilities. They have largely been static and unable to comprehend or act on their own. With technology evolving rapidly, however, this is increasingly changing.

Artificial intelligence refers to the ability of computer programs to acquire and apply knowledge without human intervention and involvement. By observing the world around them and analysing information autonomously, AI systems draw conclusions and take appropriate actions. They learn from their previous judgements and, depending on the level of accuracy, improve their performance over time.

AI as a term was first coined at the Dartmouth Conference in 1956¹ and is not new per se. In recent years, though, some breakthroughs in IT have allowed tremendous momentum in AI's capabilities:

- i) The expansion of internet usage has led to huge amounts of digital information being generated and stored. In about 10 years, the amount of data generated worldwide grew some 17 times. Forecasts point to another fivefold increase between now and 2025. This large volume of information, once cleaned and structured (i.e. big data), is at the core of data-driven decision-making.
- ii) There has been a colossal increase in the processing power of computers. A standard measure of that, the number of transistors, has increased 10 m times since the 1970s. The speed of central processing units, another element contributing to processing power, rose by a factor of 6,750 over the same period.² This enables algorithms to process information at much faster rates and contributes to the accuracy of their decision-making.
- iii) Other developments – such as the reduction in data storage costs, advancements in data mining processes or an increasing number of IT experts – have further fuelled the feasibility and capability of AI. While the

Machine learning

1

There are various approaches to programming computers so that they mimic human decision-making. Decision trees, ranking or prioritising are among the more established solutions. A relatively new approach is **machine learning** (ML). ML is a subset of AI and refers to computer programs that recognise patterns and make predictions based on them. Typical examples are internet platforms that recommend particular products or news stories to users who might like them based on previous preferences. By continuously analysing new data and scenarios, ML tools make adjustments to decision-making processes without being specifically programmed to do so. They are therefore able to learn from data. Subcategories of ML are deep learning, as well as supervised, unsupervised and reinforcement ML.

ML tools process vast quantities of data through **neural networks**. In short, these are processes which classify data on successive layers. In doing so, they rely on the probabilities of possible outcomes. They make decisions based on the most likely outcome, even though it might turn out not be the perfect choice in the end. However, neural networks involve a feedback loop. Depending on the accuracy of the outcome from previous trials, they update their approach to perform better the next time.

Source: Deutsche Bank Research

¹ See McCarthy, Minsky, Rochester, Shannon (1955).

² Moore's Law states that the processor speed of computers, or the number of transistors on an affordable central processing unit, doubles approximately every two years.



Artificial intelligence in banking

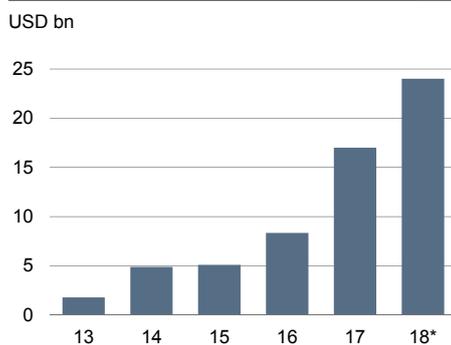
hard drive cost per gigabyte has come down from around USD 5,000 in 1990 to some USD 0.025 today, the number of IT specialists grew by 50% in the euro area between 2007 and 2017, for example.

Big data as input, data identification methods such as machine learning and the greater affordability of these tools have been the driving factors behind AI's recent rapid success in understanding languages, recognising objects and sounds, and observing and solving problems autonomously.

Artificial intelligence investments on the rise

Strong growth in VC investments in AI start-ups globally

2



*estimated

Sources: OECD, Deutsche Bank Research

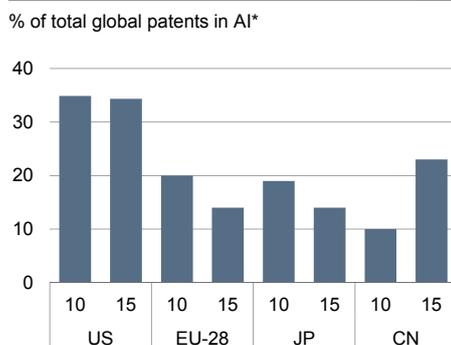
Thanks to its rapid evolution in recent years, AI is being experimented with and implemented in several areas. Due to measurement issues, however, quantifying its deployment is hardly a straightforward task. Indeed, firms might deploy AI to increase efficiency in their processes, which is not directly observable for analysis. Moreover, it is sometimes difficult to differentiate between more standard IT solutions and sole AI applications. To partly overcome these drawbacks, information on venture capital (VC) investments in AI start-up firms may be useful.³ In 2018, AI start-ups received a staggering USD 24 bn globally, up from less than USD 2 bn in 2013. Growth in VC investments over the past two to three years has been particularly strong. AI firms have also increasingly become acquisition targets. Over the last 20 years, a total of 434 companies in the AI sector have been acquired, 220 of them since 2016 alone.⁴

Of the total VC volume in 2018, almost USD 15 bn went to AI start-ups in the US, and another USD 6.5 bn went to Chinese firms. In 2017 and 2018, the number of VC deals flattened out. Yet the average volume of VC investments surged, an indication of VC flowing into more mature AI firms whose capital needs are larger than those of typical seed stage start-ups. In China, for example, SenseTime Group, a computer vision and deep learning technology developer, raised USD 1.6 bn in VC funding in 2018. With the new capital, the value of the company rose to over USD 6 bn, making it the world's most valuable AI unicorn. In the US meanwhile, it is primarily large tech firms which invest in AI start-ups.

To VC investors, AI appears to be a truly transformative technology with significant potential, like the internet and mobile revolutions in past decades. How do AI start-ups use the funds they receive? First observations indicate that they hire new AI talent (which proves to be costly and difficult to find) and expand their services. Investors might therefore need to wait a while before they see meaningful returns on their investments.

Patents in AI: China outpacing the EU

3



*AI-related patents are patents in cognition, meaning and understanding, large-capacity and high-speed data storage, high-speed computing, large-capacity information analysis.

Sources: OECD, Deutsche Bank Research

Artificial intelligence and intellectual property rights

A technological field usually is more useful and has a greater value for the economy in the years to come if there is a substantial increase in the number of patents filed in this particular field.⁵ There were some 20,000 patent applications in AI-related technologies in 2016, double the figure of 2010. Around 50% of that was accounted for by AI patents in computer vision. This technology is mostly used in self-driving cars and shows how intense competition in this area currently is. Of the total AI patent applications in 2015 (the latest available data

³ The OECD identifies AI start-ups as firms whose business model focuses on i) "artificial intelligence", "machine learning" and "machine intelligence"; ii) "neural networks", "deep learning", and "reinforcement learning"; and iii) "computer vision", "predictive analytics", "natural language processing", "autonomous vehicles", "intelligent systems" and "virtual assistant".

⁴ See WIPO (2019).

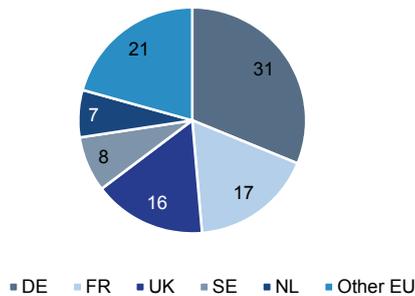
⁵ See Inaba and Squicciarini (2017) for a detailed explanation.



Artificial intelligence in banking

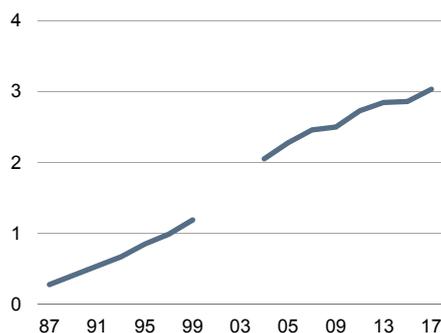
AI activity concentrated in a small set of EU countries 4

% of total AI patent applications in the EU between 2010 and 2015



Sources: OECD, Deutsche Bank Research

ATM to bank branch ratio in Europe* 5

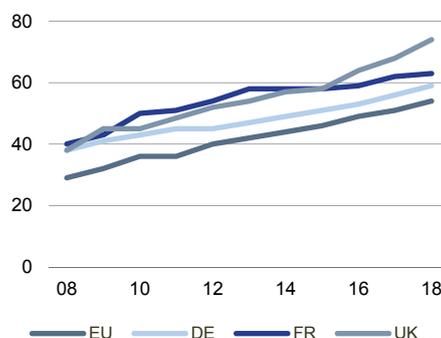


*data includes Finland, Norway, Denmark, Sweden, Belgium, Spain, the Netherlands, Switzerland, Italy, the UK, France, and Germany till 1999 and all EU countries later on.

Sources: World Bank, Humphrey et al (2003), Deutsche Bank Research

Internet banking shows persistent growth 6

Users in % of adult population



Source: Eurostat

with respect to countries), the US accounted for about one-third, a more or less stable share since 2010. Within the US, it was the tech giants who filed the largest number of AI patents. China made up 25% of the applications in 2015, up from 10% in 2010. Japan and the EU-28 each had a share of 14%, both down from around 20%. China increasingly seems to be replacing the EU and Japan in AI research and development with potentially significant implications in the future.

Within the EU, half of all AI patent applications originated in Germany and France. Together with the UK (16%) and Sweden (8%), four countries account for the lion's share. Given that patents create a legal monopoly, they introduce important first-mover advantages. Considering potentially large economies of scale, countries unable to implement AI now might be at risk of remaining behind for a long period of time.

In light of intensified global competition in IT in general and AI in particular, the European Commission proposed a budget to fund research and innovation projects in Europe in March 2019. *Horizon Europe* is the successor of *Horizon 2020*, which has a volume of EUR 77 bn to be spent between 2014 and 2020. *Horizon Europe* aims to allocate EUR 100 bn between 2021 and 2027. One of the main sub-categories of *Horizon Europe* is the *Digital Europe Programme*, which aims to invest EUR 9 bn specifically in high-performance computing and data, AI, cybersecurity and advanced digital skills projects. Even though *Horizon Europe* represents an important step forward in enhancing AI technology in Europe, its ability to drive successful AI projects remains to be seen. Indeed, its predecessor received 115,000 innovation and research proposals between 2014 and 2016, yet only 14,000 proposals were selected for funding, a very low success rate. The high rate of over-subscription is evidence of strong demand for funding. But the large number of rejected applications points to some underlying problems. Alternative solutions, such as enhancing IT literacy at early ages or improving IT infrastructure, might be necessary to increase the number of high-quality AI and innovation projects.

Earlier examples of IT implementation in banking

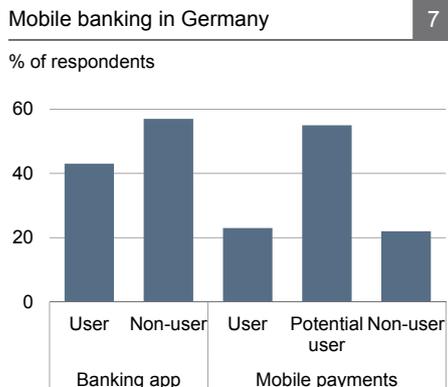
Banks are usually early adopters of IT opportunities. This is true not just for the back office, where modern technologies have been used for a long time (e.g. to process payments), but also for the front-end. An example are automated teller machines (ATMs), one of the earliest IT applications in banking. These devices replaced the repetitive tasks of bank employees in cash withdrawal and account balance checks. They made it easier for clients to access standard banking services while also making banks more efficient. Since the first ATM was installed in London in 1967, they have become standard devices in branches. In Europe, their numbers have grown to three ATMs per bank branch in 2017, up from one ATM per four bank branches in 1987. With bank employees relieved of routine cash-handling tasks, they were able to take on other services such as relationship banking (i.e. catering to clients' individual needs) and offering other bank services like credit cards, loans and investment products.⁶

Online banking is another example of banks adopting client-facing new IT. Starting from the late 1990s, the use of internet as a medium for banking services has increased immensely. Direct or internet banks with very few or no physical branches emerged. Virtually all banks started providing online banking services. In 2018, more than half of the adult population in the EU used internet banking to check their account balances or transfer funds. In some countries, such as Denmark, internet banking penetration rates are particularly high (90%). In Germany, 59% of individuals used internet banking in 2018, up from only

⁶ See Autor (2015).



Artificial intelligence in banking



Sources: Postbank Digital Study (2018), Deutsche Bank Research

35% in 2007. For clients who have little time to visit a branch, online banking has become the main tool for standard services.

The way that bank clients access the internet has changed as well. Germans, for example, are increasingly using their mobile devices for internet banking, and some 40% of them have a banking app on their mobile phones. Moreover, one-fifth of them also use their apps for mobile payment services. This is particularly popular among younger, more educated and internet-savvy individuals. With banks and their clients meeting on virtual platforms and ever more people using online services, banking is becoming less and less branch-dependent.

Artificial intelligence in banking

For banks, data is essential to almost all business lines, from traditional deposit taking and lending to investment banking and asset management. Autonomous data management without human involvement therefore offers great opportunities for banks to improve speed, accuracy and efficiency. Potential AI applications in banking can be classified into four broad categories: 1) customer-focused front office applications, 2) operations-focused back office applications, 3) trading and portfolio management, 4) regulatory compliance.⁷ At least for now, banks by and large are still experimenting with AI technologies rather than fully implementing them in their processes. Customer- and operations-focused AI solutions seem to be undergoing more intensive exploration than others:

- i) AI is being tested for real-time identification and prevention of fraud in online banking. Indeed, credit card fraud has become one of the most prevalent forms of cybercrime in recent years, which is exacerbated by the strong growth in online and mobile payments.⁸ To identify fraudulent activity, AI algorithms check the plausibility of clients' credit card transactions in real time and compare new transactions with previous amounts and locations. AI blocks transactions if it sees risks.
- ii) AI is also being tested in KYC processes to verify the identity of clients. AI algorithms scan client documents and evaluate the reliability of the information provided by comparing it with information from the internet. If AI algorithms identify inconsistencies, they raise a red flag and a more detailed KYC check by bank employees is performed.
- iii) Another area where banks are experimenting with AI technologies is chatbots. Chatbots are digital assistants that interact with clients by text or voice and aim to address their requests without the involvement of a bank employee.
- iv) Banks are also exploring AI to visualise information from legal documents or annual reports, for example, and to extract important clauses. AI tools create models autonomously after observing the data and back testing to learn from their previous mistakes to improve accuracy.
- v) Some existing financial technology tools evolve as true AI solutions over time, too. Good examples include robo-advisors that enable full automation in certain asset management services and online financial planning tools that help customers make more informed consumption and saving decisions. As these financial technology solutions mature, they increasingly use techniques that search data and find patterns in them autonomously.

AI implementation in banking 8

| | |
|----------------------------------|---|
| Customer-focused | -Credit scoring -Insurance policies -Client-facing chatbots -Know your customer |
| Operations-focused | -Capital optimisation -Model risk management -Stress testing -Fraud detection |
| Trading and portfolio management | -Trade execution -Portfolio management |
| Regulatory compliance | -Regulatory technology -Macroprudential surveillance -Data quality assurance -Supervisory technology |

Sources: FSB (2017), Deutsche Bank Research

⁷ For a detailed overview on how AI is being implemented in the individual categories of table 8, please see FSB (2017).

⁸ See Mai (2018).



In their quest to become more efficient, banks mostly seem to be exploring AI applications to replace activities which are costly, laborious and repetitive. The focus is on operational risk management gains like fraud detection or improved KYC and on opportunities for cost reduction like chatbots or robo-advisors.

A real-life application of AI: Deutsche Bank's Alpha-Dig platform

9

Using AI and machine learning tools, it is possible to quantify geopolitical risk and predict its effect on financial markets. For example, Deutsche Bank's Alpha-Dig platform (Alpha-Dig) infers context from news media, social media, and other natural language articles, and then builds a picture of a country's political risk profile.

Alpha-Dig first uses algorithms to mine global financial news as a proxy for how much media attention there is towards certain countries' risks. The process uses Natural Language Processing and machine learning techniques to infer context in a news article and ensure that positive and negative indicators are gleaned from it. As a second step Alpha-Dig overlays learnings from Wikipedia whose articles are largely accurate and easily readable for machines. To adjust for potential biases, the platform uses readership data to see what topics are trending. Once data from the mainstream financial news is enhanced with learnings from Wikipedia, Alpha-Dig can create a picture that shows how political issues have become more or less important over time. Among other statistical methods, Z-scores can be calculated, which look at the average amount of daily geopolitical news for a topic in the recent past and see what proportion of all geopolitical news is consumed by that topic. If a particular political event is receiving attention that is greater than two standard deviations more than normal, it is labelled an 'outlier' event. Obviously, no system can accurately forecast geopolitical implications all the time. But via tools like Alpha-Dig, an objective measure that can assist investors in what are notoriously difficult times can be created, thanks to advancement in AI.

Source: Deutsche Bank Research. Konzept. January 2019, p. 34-39.

Impediments to the use of artificial intelligence in banking

Despite its immense potential, some external factors might slow down AI implementation in banking. To begin with, the EU's General Data Protection Regulation (GDPR), which came into force in 2018, contains preventive clauses on automated decision-making. This affects not only the financial industry but all sectors in general. Article 22 of the GDPR states: "The data subject shall have the right not to be subject to a decision based solely on automated processing, including profiling..." This is particularly problematic for AI tools whose decision-making by definition is solely automated. To overcome the restrictions under Article 22, human involvement at some stage might be a solution. I.e. at the end of the AI chain, the final decision could be given to humans. In addition, Article 13 of the GDPR involves disclosure provisions. For example, if an AI tool rejects a bank account or loan application, the client has the right to know the logic involved in this decision. Article 13 does not necessarily require the source code of the AI algorithm to be revealed in detail. Yet some information on the input parameters of the AI tool has to be disclosed. In any case, the intervention of human programmers might be required in order to fully comply with these and many other data privacy rules, a setback for the expected efficiency gains of AI.

Another likely impediment to AI use in banking is the potentially malicious manipulation of big data. For example, hackers might try to flood systems with fictitious data (fake social media accounts, websites, news) to influence AI decision-making. As a result, AI tools might come up with biased decisions and discriminate against certain individuals, or hackers could even take control of AI systems. With AI systems being connected to each other, malevolent issues might intensify. Even though AI itself has a relatively high level of accuracy in detecting cyber-attacks and malware, the continuous surveillance and monitoring of programmers might be necessary to address cybersecurity issues. The introduction of regulatory sandboxes, where the safety of new AI tools is tested in a real-world environment, might be beneficial in this context.

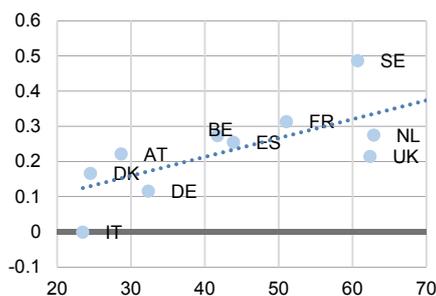


Artificial intelligence in banking

In the eyes of some observers, AI – and especially neural networks – have opaque reasoning and function as black boxes.⁹ These concerns arise from the sometimes complex AI algorithms and the inability of humans to visualise and understand these patterns. What aggravates the complexity problem is the fact that AI algorithms update themselves over time and become more connected. It is important to remember that AI predictions and decisions might be very close to those of humans in the end. Unlike humans though, AI by its nature is unable to communicate its reasoning. This complicates the use of AI, considering that processes in banking have to be fully traceable backwards even if the decisions made are reasonable and justified. If there is a problem with a decision, it needs to be clearly detectable at which step the error has occurred. The entire decision-making process has to be compliant with regulatory and supervisory rules and fully transparent. While it may also cancel out some efficiency gains, the involvement of human programmers and overseers might be a solution to reduce issues around the opaqueness of some AI algorithms. Despite these potential impediments, banks are dedicated to experimenting with AI, which could have significant profitability implications.

AI and bank profitability: An almost linear relation 10

2010-15 averages, ROA in % on y axis, number of AI patents normalised* on x axis

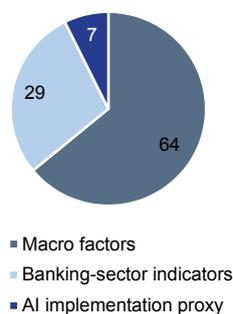


*Per 1,000 patent applications

Sources: ECB, OECD, Deutsche Bank Research

What explains banks' ROA in Europe? 11

% of variation in ROA explained by...



Results of panel regression. The dependent variable is the biannual ROA of the banking sector. Explanatory variables are GDP growth, inflation, cost-income ratio, non-performing loans, equity-to-assets ratio, total assets of banks, share of AI patents and time-fixed effects. The time dimension of the analysis is from 2010 to 2015. The countries included are Austria, Belgium, Denmark, Germany, France, Italy, Spain, Sweden, the Netherlands and the UK.

Source: Deutsche Bank Research

Artificial intelligence and bank profitability

AI might contribute to bank profitability in two ways: First, by taking over repetitive tasks from bank employees, autonomous AI software could reduce the demand for less-skilled labour and improve the efficiency of remaining bank staff. This is crucial, as employee compensation usually represents a large share of banks' cost base. Second, AI implementation could also contribute to revenue generation. For example, it might help banks to develop new products and offer tailor-made products better suited to client preferences. Nevertheless, quantifying the link between the use of AI and bank profitability is hard, not least due to issues around identification and a lack of micro data. From an aggregate angle, though, AI patent applications¹⁰ and ROA in the banking sector in European countries show an almost linear relation, with a correlation of 80%. Banks seem to be more profitable in countries where the level of AI patent activity is higher. At the same time, it is somewhat difficult at this early stage of AI diffusion in banking to assess the potential operational risks and associated costs for banks which might stem from the increased use of AI.

There are various factors that determine bank profitability which need to be accounted for in an empirical setting. In our panel regression, we control for macro and banking sector-specific indicators, as well as time-fixed effects, in addition to AI. In our sample, we covered data from ten EU countries and a time span from 2010 to 2015. The dependent variable of our analysis is the ROA of the banking sector in individual countries. Our results reveal that macro factors such as GDP growth and inflation are the most important contributors to bank profitability. These explain two-thirds of the variation in bank profitability. Banking sector indicators such as cost-income ratio, equity-to-assets ratio and non-performing loans explain some 30% of the variation in ROA. AI patents positively impact ROA at statistically significant levels and explain 7% of the variation in bank profitability. It is important to remember that there are large overlaps between standard IT solutions and sole AI applications and patents. For example, large-capacity and high-speed data storage, as well as high-speed computing patents, have a broader impact far beyond AI. In this vein, it may be fair to argue that bank profitability is positively related to stronger use of AI in specific and stronger use of IT in general. Obviously, the causality could also work the other way around, with more profitable banks investing more in AI.

⁹ See Bathaee (2018) for a detailed explanation.

¹⁰ We normalise the number of AI-related patents (i.e. divide them by the total number of patents in a given country) to eliminate potential outlier effects, such as an overall increase in patent activity.



However, in banking, IT implementation may be largely driven by (customer) demand and not necessarily by supply. Moreover, strong competition makes modern technology a priority even for those banks that are not profitable. The fact that AI impacts bank profitability means it might help European banks to address one of their core problems of recent years: persistently weak profitability.¹¹ By increasing labour productivity, AI technologies could structurally reduce costs in the banking sector.

Concluding remarks

AI has the potential to revolutionise several aspects of our everyday life. Especially in the US and China, AI has attracted large investments in recent years and is increasingly being implemented. In Europe, the picture is somewhat mixed, with a couple of countries having an active AI landscape while others lag behind. Being aware of its potential, European policymakers have introduced measures to increase AI activity in Europe. AI also has the potential to fundamentally change aspects of financial services. To date, though, implementation in banking has been modest. Looking forward, regulatory measures around data privacy and the highly regulated nature of banking might create obstacles to AI implementation. Still, AI's potential contribution to bank profitability should not be underestimated. In an environment where competition in banking is growing ever more intense – thanks to data-driven financial services providers such as financial technology (FinTech) start-ups and large technology firms that are challenging traditional banking business models – rapid implementation of AI technologies might be pivotal for banks to remain competitive.

Orçun Kaya (+49 69 910-31732, orcun.kaya@db.com)

¹¹ See e.g. Schildbach (2017).



Literature

Autor, David H. (2015). Why Are There Still So Many Jobs? The History and Future of Workplace Automation. *Journal of Economic Perspectives*, 29 (3), 3-30.

Bathae, Yavar (2018). The Artificial Intelligence Black Box and the Failure of Intent and Causation. *Harvard Journal of Law & Technology*, 31 (2), 889-938.

FSB (2017). Artificial intelligence and machine learning in financial services: Market developments and financial stability implications.

Humphrey, David B., Magnus Willeson, Göran Bergendahl and Ted Lindblom (2003). Cost Savings from Electronic Payments and ATMs in Europe. FRB of Philadelphia Working Paper No. 03-16.

Inaba, Takashi and Mariagrazia Squicciarini (2017). ICT: A new taxonomy based on the international patent classification. *OECD Science, Technology and Industry Working Papers*, 2017/01. OECD Publishing, Paris.

Mai, Heike (2018). Card fraud in Germany: Few incidents, but high costs. Deutsche Bank Research. Talking Point.

McCarthy, John, Marvin L. Minsky, Nathaniel Rochester and Claude E. Shannon (1955). A proposal for the Dartmouth summer research project on artificial intelligence.

Postbank Digital Study (2018). Der digitale Deutsche und das Geld.

Schildbach, Jan (2017). Where do European banks stand? 10 years after the start of the financial crisis. Deutsche Bank Research. EU Monitor.

WIPO (2019). Artificial Intelligence. *WIPO Technology Trends*.

© Copyright 2019. Deutsche Bank AG, Deutsche Bank Research, 60262 Frankfurt am Main, Germany. All rights reserved. When quoting please cite "Deutsche Bank Research".

The above information does not constitute the provision of investment, legal or tax advice. Any views expressed reflect the current views of the author, which do not necessarily correspond to the opinions of Deutsche Bank AG or its affiliates. Opinions expressed may change without notice. Opinions expressed may differ from views set out in other documents, including research, published by Deutsche Bank. The above information is provided for informational purposes only and without any obligation, whether contractual or otherwise. No warranty or representation is made as to the correctness, completeness and accuracy of the information given or the assessments made.

In Germany this information is approved and/or communicated by Deutsche Bank AG Frankfurt, licensed to carry on banking business and to provide financial services under the supervision of the European Central Bank (ECB) and the German Federal Financial Supervisory Authority (BaFin). In the United Kingdom this information is approved and/or communicated by Deutsche Bank AG, London Branch, a member of the London Stock Exchange, authorized by UK's Prudential Regulation Authority (PRA) and subject to limited regulation by the UK's Financial Conduct Authority (FCA) (under number 150018) and by the PRA. This information is distributed in Hong Kong by Deutsche Bank AG, Hong Kong Branch, in Korea by Deutsche Securities Korea Co. and in Singapore by Deutsche Bank AG, Singapore Branch. In Japan this information is approved and/or distributed by Deutsche Securities Inc. In Australia, retail clients should obtain a copy of a Product Disclosure Statement (PDS) relating to any financial product referred to in this report and consider the PDS before making any decision about whether to acquire the product.