Capgemini Consulting

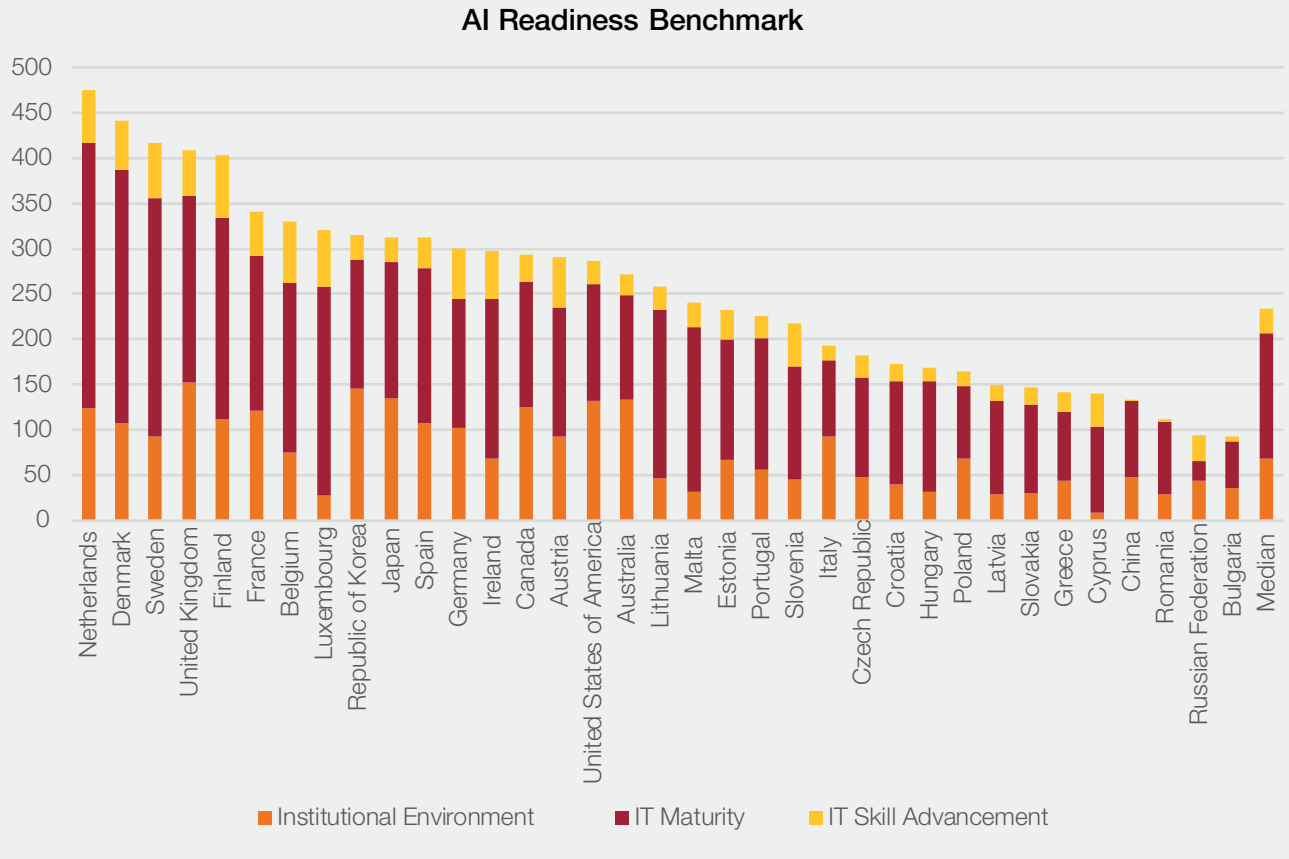
Artificial Intelligence Benchmark

Executive Summary

Artificial Intelligence (AI) will disrupt a large breath of markets and transform organizations, institutions and societies. AI is expected to bring profound positive impacts, as well as the risks and possible pitfalls. The European Union member states recently signed a Declaration of cooperation on AI to ensure the EU's competitiveness in this field and deal with possible challenges arising from it. The European Commission is also boosting funding in support of AI with the aim of increasing overall investment in it to at least 20 billion Euro's by 2020. For countries, it is of paramount importance to be ready to reap the benefits of AI. This benchmark shows the state of readiness of countries and enables them to compare themselves and see where they stand in this process of becoming "AI ready": Where being AI ready is defined as:

> ***Artificial Intelligence readiness is the extent to which a country and its institutions & businesses have the ability to reap the benefits of AI.***

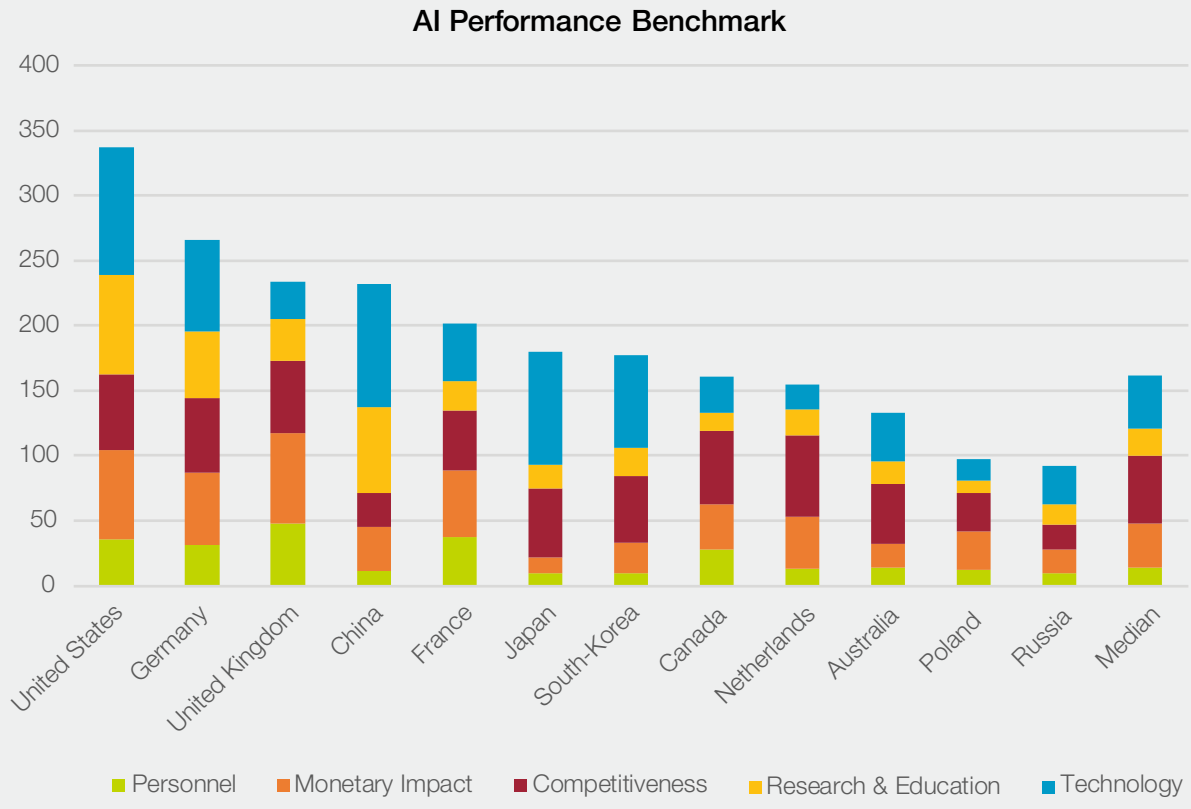
The benchmark contains indicators for three key components that are defined as the foundation of AI readiness, namely the (1) Institutional Environment, the (2) Technological Maturity and the (3) Skill Advancement. These are aggregated to form a total score on which a country rank is based. The final results are presented in Figure 1.



In addition to assessing AI readiness, we also conducted an assessment of the level of current performance in AI for a limited number of countries. AI performance is defined as:

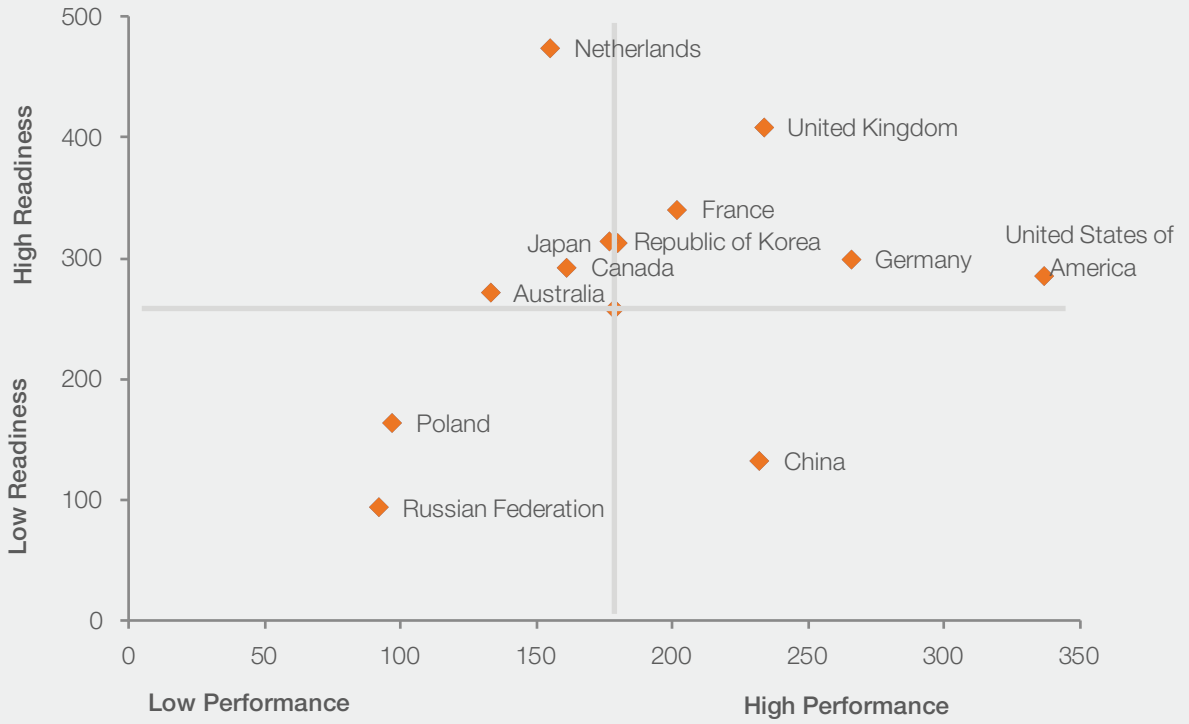
> ***AI performance is the extent to which a country and its institutions & businesses have committed to the pursuit of a leading position in Artificial Intelligence.***

The AI Performance Benchmark uses performance indicators to indicate a global leadership rank by creating five categories: (1) Personnel, (2) Monetary Impact, (3) Competitiveness, (4) Research & Education and (5) Technology. This benchmark steps away from the aggregated relative perspective and instead focuses on absolute numbers. The findings are presented in Figure 2.



By combining both benchmarks and splitting the graph into four quadrants based on the median, the following categories of countries can be established:

- High readiness, high performance
- High readiness, low performance
- Low readiness, high performance
- Low readiness, low performance



Needless to point out, is that countries falling under the low-low category should put most effort in a transformation, if they wish to be able to compete and benefit from Artificial Intelligence. Countries that fall in the high-high category should continue in a similar fashion. The biggest gains can be realized by countries in the low-high category, as they perform well but are unable to reap the full benefits of AI. The reverse holds for countries in the high-low category, as they can take advantage of AI, but they don't have the best performance in the field. They have a big incentive to increase their performance as they are already able to reap all the associated benefits of AI.

In practice this means that China and the United States both have the most to gain, scoring subpar in AI readiness while currently performing well. Germany, France, Japan, Republic of Korea and to a lesser extent Australia, Canada and the Netherlands especially when size is considered, perform well in both readiness as well as performance. They are all scoring well on digitization measures, infrastructure components and population measures, and should focus on further developing their IT Skill Advancement to create more and better specialists in the field of AI to enhance their performance. Poland and Russia should focus both on increasing all their performance indicators, for example by improving their basic IT infrastructure, their institutional readiness and by educating the population.

To avoid missing out on the potential of AI and to safeguard us from any potential risks, companies and countries need to make fundamental changes to become ready for integrating AI holistically into their strategies, business operations and lives. The following policy recommendations could be considered to aid in this process:

- AI awareness should be increased by intensively experimenting with AI

- Existing legal frameworks need to be revised to create a favourable AI-enabled environment

- SMEs and bigger companies should work collaboratively and prioritize the low complexity and high benefit projects to create quick wins

- Data sharing and accessibility should be stimulated

- The skills gap between the general workforce and the one that can work with AI needs to be decreased

Foreword

The are many studies and academic papers on the topic of AI that vigorously try to forecast the possible effects that the AI revolution may bring. Although there is some contradiction between these papers, there is one thing they all agree on: AI is not just a trend or a timely phenomenon. On the contrary, the benefits of AI are already prevalent and will change life as we have come to know it. Capgemini found that amongst nearly 1000 organizations who were implementing AI, 63% said that AI has not eliminated any jobs in their organization, 83% of these organizations even reported that AI instead has created more. It is undisputed that AI will create a plethora of opportunities. It is however unknown if countries are ready to benefit from these opportunities.

This paper addresses this highly relevant question through two benchmarks:

- A benchmark to see how ready countries are to reap the benefits of AI

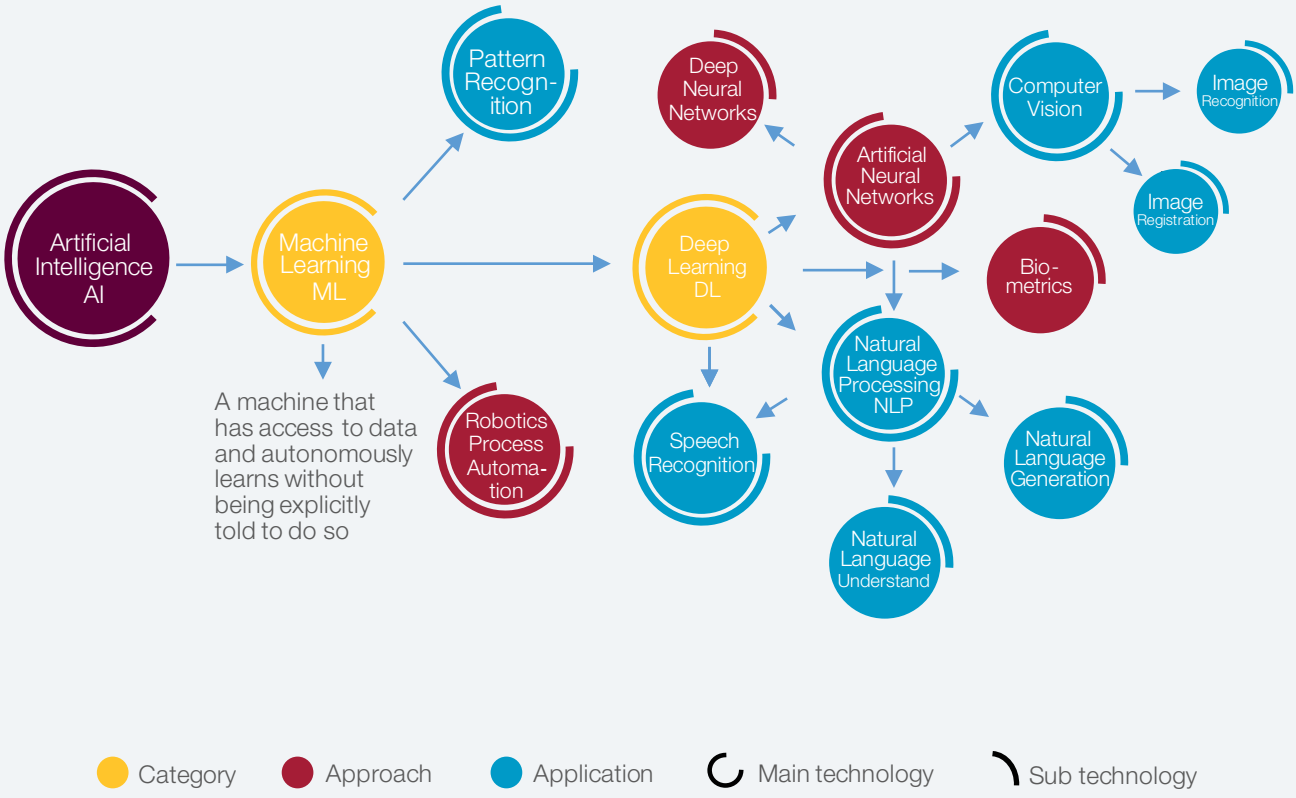
- A benchmark to assess the performance of the AI quality and capabilities of specific countries

The aim of this paper is to highlight the importance of being 'AI-ready' and to provide countries with a means to assess how well they are currently performing in the field of AI and measure how capable they are to take advantage of it.

Contents

Artificial Intelligence

Artificial Intelligence (AI) is the capability of a machine to replicate intelligent human behaviour and human decision-making capabilities. AI is a computer system that can become smarter by experience, similar to humans. Machine Learning is a form of Deep Learning and is the most common type of AI, but various other categories, approaches and applications exist. There is a legion of different definitions of AI but this paper focuses on the broad applications and as such chooses the following definition: “The capability of a machine (non-human) to replicate intelligent human behaviour and human decision-making capabilities. AI should have the ability to perform as well as or better than a human when performing a task



Artificial Intelligence benchmark

AI will disrupt businesses, industries, and governments with the potential to profoundly transform how people live, interact and work. A Capgemini study of nearly 1,000 organizations implementing Artificial Intelligence highlights the growth opportunity of AI and counters fears that AI will cause massive job losses in the short term. We also identified the major benefits AI can bring to the public sector. To reap these benefits, the right ecosystem and capabilities are needed. Countries must prepare now and start to consider how ready they are for AI adoption. This means they need to assess the extent to which they as a country, could not only adopt AI, but also fully leverage its potential. Furthermore, to fortify the importance of readiness, we assessed the level of performance in AI. This also highlights potential misalignments with deemed importance and the real benefits that are to be gained. We have created the following definitions of AI readiness and AI performance:

> ***"AI readiness is the extent to which a country and its institutions & businesses have the ability to reap the benefits of AI.***

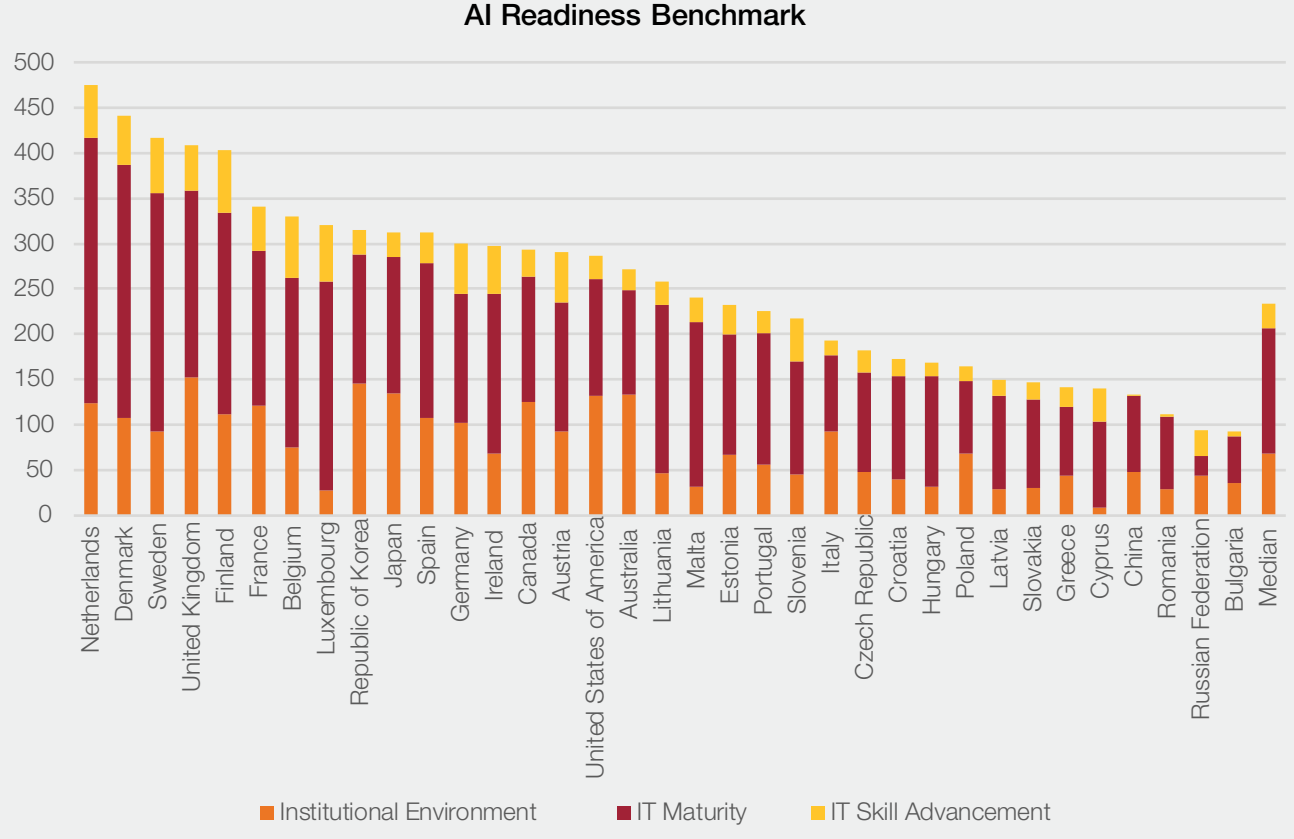
> ***"AI performance is the extent to which a country and its institutions & businesses have committed to the pursuit of a leading position in Artificial Intelligence."***

This benchmark allows countries to compare themselves and see where they stand in the journey of becoming AI ready and what their relative performance level is. The aim is to highlight the importance of being AI-ready, showing that the level of readiness does not necessarily correspond to the level of performance, and through this the possible benefits do not align with the level of performance in AI.

Readiness Benchmark

From Figure 4 above it is immediately evident that IT Maturity is the largest contributor to the scores of countries and even though there are some outliers, the general level is well developed. What the best countries have in common is that besides an above average developed IT Maturity and thereby infrastructure, is that their IT Skill Advancement is also much better than the median. Even within the top 10 countries, there are large fluctuations in the Institutional Environment and these only increase when the entire benchmark is considered. The leading countries put themselves at the top by having a comparatively well-developed Skill Advancement. However, one can see that even for the top five countries, IT Skill Advancement makes up a relatively small part of their overall score. Stepping away from the relative view this is a clear indicator that all countries should improve their Skill Advancement. Becoming a leader, therefore requires a well-developed technological infrastructure in the entire country combined with an effective e-Government and a strong focus on the development of the necessary skills. From this it follows that skill development is important only when it can be utilized, hence infrastructure should be the first focus of improvement, combined with the Institutional Environment.

Western European- and Scandinavian countries take the lead in AI readiness. The figure illustrates that even though they have a large variance in the quality of the Institutional Environment, they all score very well on IT Maturity and IT Skill Advancement. The key takeaway for these countries is to continue to develop their key IT infrastructure and skills platform along the same path. However, there is room for improvement regarding their Institutional Environment, where lessons can be learned from countries such as Japan



and the Republic of Korea. Taking a closer look at Japan and the Republic of Korea, it is evident that they are institutionally very well developed. Furthermore, they have a strongly-developed infrastructure, but lack the momentum in skill development, whereas the Western European countries such as Germany are outperforming them in terms of the specialist IT skills and the percentage of firms that provide IT training. Countries from the Anglosphere have in common that whereas theirs Institutional Environment is well developed, their IT Maturity and Skill Advancement are lagging behind. For these countries, the biggest gains lie in the improvement of the IT infrastructure in terms of network speed, increased IT birth-rates and the use of data collecting software such as ERP's and CRM's. The Southern European countries score average in all three categories and therefore should heed the general advice and focus on improving the more advanced indicators such as IT birth-rates and the percentage of enterprises that provide portable devices. Notable exceptions to this are Spain and Greece, with Spain having a better Institutional Environment and Greece lagging behind in every single component. The Central- and Eastern European countries could gain the most by improving their infrastructure first since they are lacking a high score on every AI readiness indicator. China and Russia show room for improvement in every single category and should therefore focus on providing a better IT infrastructure in their entire country and improving their e-Government capabilities to be able to let their entire countries benefit from AI. An overview of these results can be found in Appendix A.

AI Performance Assessment

In addition to assessing AI readiness, we developed another benchmark to gauge the level of performance of a country in the field of Artificial Intelligence. Five components have been defined as the foundation of AI performance: namely the (1) Personnel, (2) Monetary Impact, (3) Competitiveness, (4) Research & Education and (5) Technology.

The components, their definitions and some of the components of the indicators are as follows:

Personnel:

The extent to which the population has the necessary skill-set to work with AI is a key measure of performance. The larger the skill base and the better the quality of people with the required skills, the better the performance of a country's population. Since AI does not diminish jobs, but creates more than it destroys, a larger base of skilled people is an indication of a better performance in AI. This cluster focuses on indicators such as the number of AI specialists, number of vacancies and average years of experience in AI.

Monetary Impact:

The extent to which the economy is impacted by AI is a clear indicator of performance, as performance directly affects a country's economy. This component makes use of indicators such as the expected size of the data market in 2020, as well as the

percentage share of IT of total GDP to estimate the Monetary Impact.

Competitiveness:

This cluster focuses on two types of competitiveness: absolute measures of the productivity and competitiveness indexes. Indicators such as cloud computing ranking are used to assess the Competitiveness.

Research & Education:

Academic proficiency and public as well as private expenditure on AI research and development are elements of the category Research & Education. For academia the number of papers published on Artificial Intelligence as well as the number of universities seen as the best in this field are used as indicators. For research and development there is one good measurement which is the amount of investment in AI R&D.

Technology: The final category is that of technological performance. The higher the technological implementation of Artificial Intelligence, the better the performance will be. The Technology category uses indicators such as the robot density in a country and the operation stock of robots.

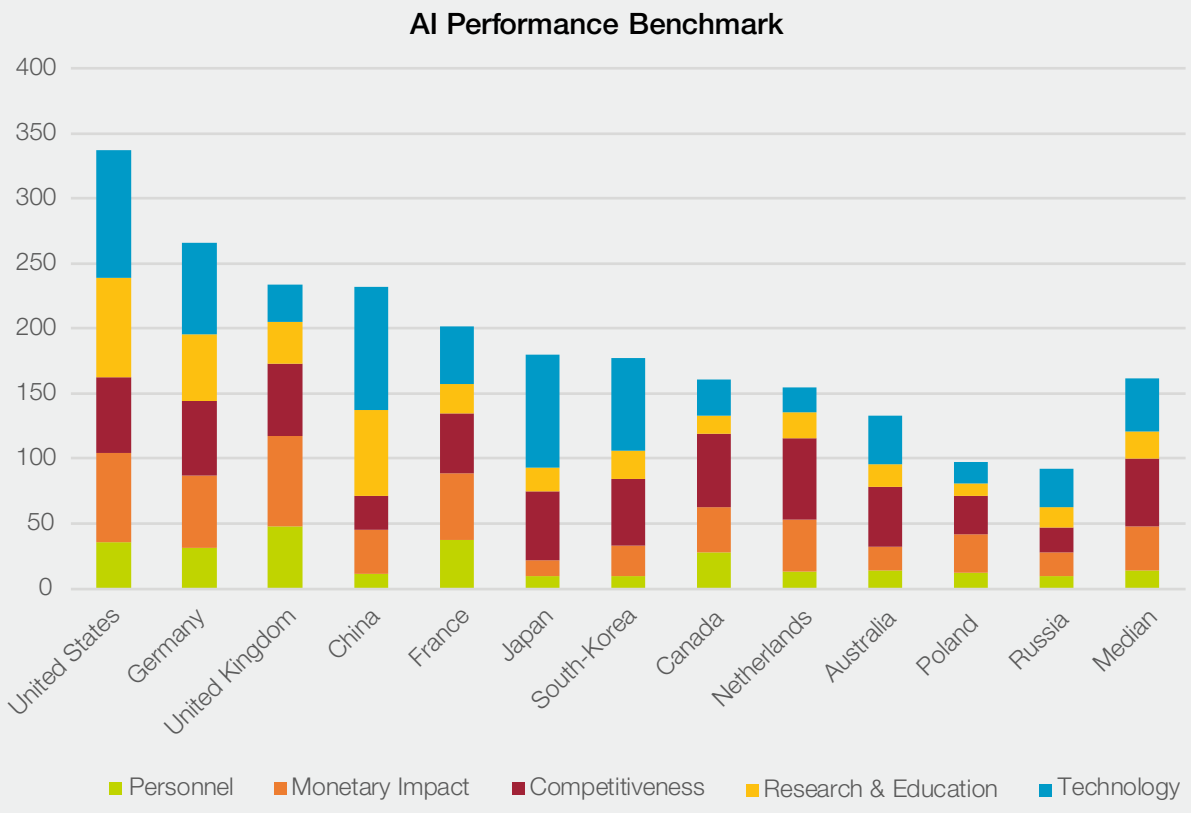
Performance Benchmark

For this benchmark, the country set has been limited to only 12. The chosen countries are based not on their expected performance in this benchmark, but out of sheer necessity as they were the only ones with enough available data. This lack of data can be explained since the measurements used are very specific or new. The absence of this data can for some countries also be an indication of limited performance.

What is clear from this benchmark is that of the five largest economies; The United States, China, Japan, Germany and France (in order of economic magnitude), four are positioned amongst the top five AI performers. Notably, only Japan misses out and scores marginally lower than what would be expected based on the size of their economy. The United Kingdom outperforms what would be expected when looking at GDP and achieves a 3rd place. Furthermore, what is noticeable is that only China scores below the median for Personnel and Competitiveness. For personnel, this can be explained by a lack of data. Assessing this it would be expected that China is more likely to be in the 3rd or even 2nd position, which would be in line with the expectancy created by their GDP. Canada, France, Germany and especially the UK do very well when it comes to Personnel. The Netherlands and Australia would need to increase their number of specialists to be able to keep up. There is little available data on Japan, the Republic of Korea, Poland and Russia. Monetary Impact is very dependent on absolute measures and as such Canada, and the Netherlands perform well given their size. China performs subpar and should focus on growing the use of AI in their economy. Germany, France, and the United Kingdom perform very well. Australia, Poland and Russia however would need to improve their

ICT spending, the value of their Data Market now and in the future and their overall use of ICT as a share of their GDP. The overall competitiveness is very high amongst all countries, and only China, Russia and Poland should focus on improving this by improving their efficiency and thus directly influence their GDP per hour worked and labour productivity growth. In addition to this, their IT industry competitiveness and their global innovation rate could also be improved.

Interestingly, the United Kingdom and Russia are the only two countries with a negative labour productivity growth. Research & Education are again ruled by China and the United States and Germany is placed 3rd for this category. China and the USA publish far more AI papers than their competitors and their weighted citation measure are the highest. They also spend much more on R&D. Other countries could learn from these examples. China, the United States, Japan, and to a lesser extent the Republic of Korea and Germany, clearly stand out when it comes to technological performance. These countries have the highest stock of industrial robots and the largest base of internet users to train AI with. Even when it comes to robot density, which is a relative measure, the other countries do not come close and as such should focus on increasing their automatization to decrease the gap. Getting enough data to train their own AI is also an area that could be done better. In general, the larger economies outperform the rest, however when we take size into consideration the Netherlands and Canada perform very well. An overview of the detailed results can be found in Appendix B.



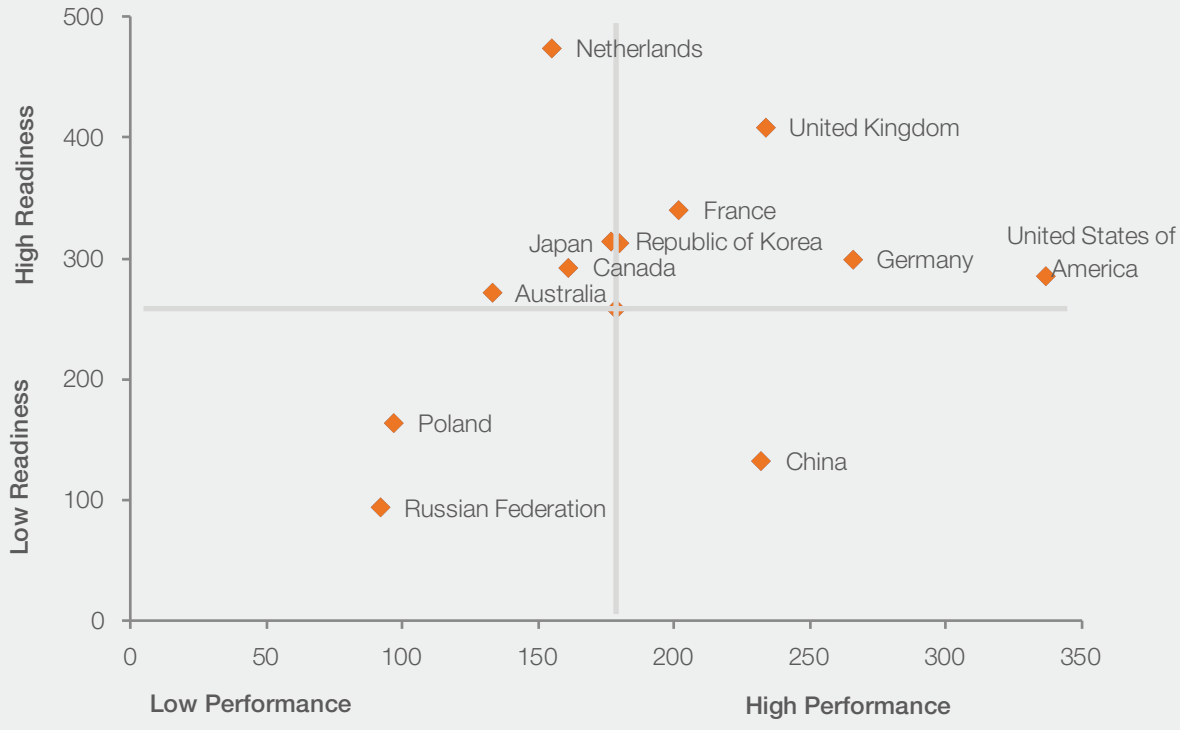
Conclusion

By combining both benchmarks and splitting the graph into four quadrants based on the median, the following categories of countries can be established:

- High readiness, high performance
- High readiness, low performance
- Low readiness, high performance
- Low readiness, low performance

Needless to point out, is that countries falling under the low-low category should put the most effort in a transformation, if they wish to be able to compete and benefit from Artificial Intelligence. Countries that fall in the high-high category should continue in a similar fashion. The easiest gains can be realised by countries in the low-high category, as they perform well but are unable to reap the full benefits of AI. The reverse holds for countries in the high-low category, as they can take the advantage of AI, but they don't have the best performance in the field. They have a big incentive to increase their performance as they are already able to reap all the associated benefits of AI.

In practice this means that China, and to a lesser extend the United States, both have the most to gain, scoring subpar on indicators such as bandwidth, the usage of ERP's and CRM's, the percentage of portable devices and cloud uptake. Furthermore, they should focus on educating their specialists. Germany, France, Japan, the Republic of Korea and to a lesser extent Australia, Canada and the Netherlands especially when size is considered, perform well in both readiness as well as performance. They all score well on e-Government measures, infrastructure measures and population measures, and should focus on further developing their IT Skill Advancement to create more and better specialists in the field of AI to enhance their performance. Poland and Russia should focus both on increasing all their performance indicators as the two score the lowest compared to the measured countries. Parallel to this, they should develop a solid state of readiness by improving their basic IT infrastructure, their institutional readiness and by educating the population.



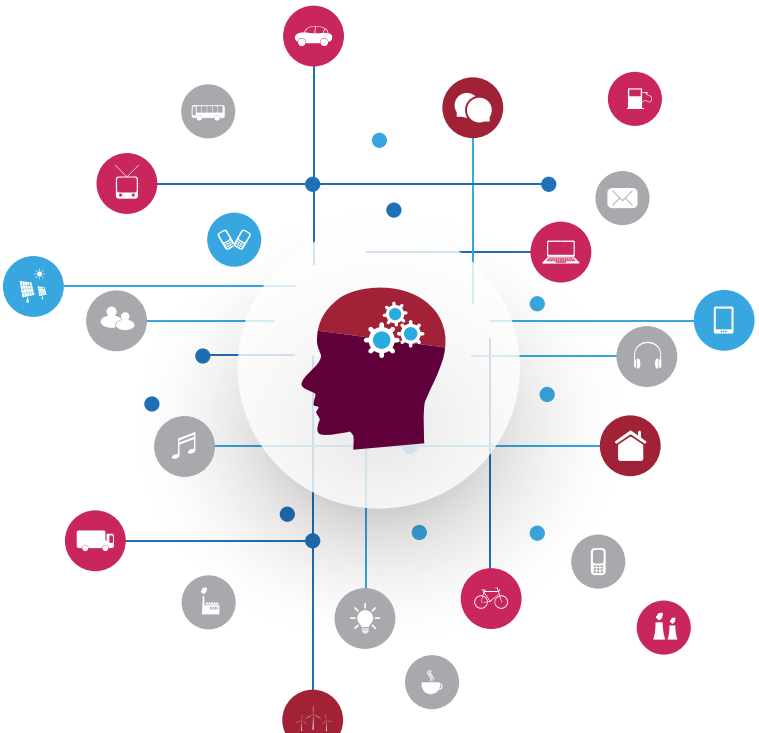
What are the benefits of AI and why is falling behind so detrimental to a country's economy?

The number of studies and academic papers on the topic of AI has steeply risen by more than a factor of 9 since 1996, vigorously trying to forecast the beneficial and possible harmful effects the AI revolution may bring along. Although there is a lot of contradiction among these papers, there is one thing they all agree on: AI is not just a trend or a timely phenomenon. On the contrary, AI is happening and will change life as we have come to know it.

The uncertainties of the future are something we are often concerned about. Thinking about the future is deeply embedded in the core of our human nature and intertwined with that is our ongoing imagination of what the future will look like. Now that we are at the early stages of the digital age, it is no surprise that with our core tendency to imagine the future, discussions about AI have jumped into the public eye over the past year. Back in the days when the term Artificial Intelligence was first introduced by Turing (1950) as 'machines that can think', this did not raise any concerns. It simply seemed too far from reality and restricted within its form. However, now that organizations are focusing increasingly on automating their businesses to stay competitive and scientists predicted that AI will exceed human intelligence by the early 2030s, it suddenly does not seem that far-fetched anymore. Imagine a world with self-driving vehicles, robots that have taken over the job of your housekeeper and online purchases that will be brought to you through a flying drone. In the 1950s, this would have seemed like a futuristic portrayal in the form of a good sci-fi movie and hence completely fiction. Today however, this 'fantasy' is not far from becoming reality.

AI is expected to bring profound positive impacts to our society and economy in a large breath of markets. To give an example, the transportation sector could soon be disrupted by the advent of self-driving cars. This new technology will, for one, greatly reduce road deaths as cars equipped with sensors ensure a timely break. Secondly, when it is possible to simply summon a car, the necessity to own one diminishes and the number of vehicles on the roads will as well. Generally, AI can lead to a strong acceleration in scientific breakthroughs, as with a growing body of digital data, it will be easier to find missing pieces, crucial for example to tackle climate issues, or to find targeted medical treatments for a range of diseases. Regardless of the precise outcome, AI will generate new insights.6

It is forecasted that the investment in AI will triple and the augmentation of AI will generate $2.9 trillion in business value by 2021. Quoting from a 2017 Gartner report on this:



"AI is expected to unleash remarkable benefits across countries, countering dismal economic growth prospects and redefining the new normal as a period of high and long lasting economic growth".10

Indeed, the economic potential of AI is enormous. As Capgemini found out, three-quarters of firms have linked the AI implementation to a 10% uplift in sales.12 Secondly, AI is likely to transform operations by increasing productivity, as AI can replicate labour activities at much greater scale and speed. Thirdly, AI will allow organizations to offer higher quality products and services. False-positives will be reduced and time for repetitive tasks will be freed up which creates room for more value-adding and meaningful tasks. As a result, the customer journey is expected to be massively improved, leading to reduced churn and an increase in customer satisfaction.

Early adopters of AI are already starting to take advantage of these benefits. To avoid missing out on this potential and to remain competitive, companies need to make fundamental changes to integrate AI holistically into their strategies and operations.11

Organizations should be ready for the adoption of AI not solely for the benefits it brings. Major threats have also been identified. Firstly, people fear that if AI gradually eliminates jobs, this development will lead to widespread unemployment. Investigating this, Capgemini found that amongst nearly 1000 organizations who were implementing AI, 63% said that AI has not eliminated any jobs in their firm. On the contrary, 83% of these organizations reported AI instead has generated new roles. This research has been backed up by Gartner,10 who forecasts that by 2020 AI will create more jobs than it eliminates. Furthermore, as the Economist suggests,7 to find an answer to the question whether AI will eliminate our jobs, we might see if history provides any clues. They suggested that in many ways, AI resembles the 1st industrial revolution. At that time, people feared mechanization would make workers redundant. Instead, the opposite turned out to be true: more jobs were created, on an unforeseen large scale.

A second major threat of AI has been formulated regarding its possible singularity, which entails that humans will lose control over their own inventions. Stephen Hawking has been quoted saying "the development of full Artificial Intelligence, could spell the end of the human race". This opinion is further shared by Elon Musk stating that "with Artificial Intelligence, we're summoning the demon".

In other words, AI's large economic potential is intertwined with risks and possible pitfalls. Therefore, it is necessary for institutions, companies (SMEs and multinationals), governments and entire societies to become aware of its AI readiness. This will define whether they are ready to reap the benefits, or whether they are vulnerable to the dangers that need to be considered.

Becoming AI ready

Elaborating on what countries can do to stimulate their AI readiness; three components have been defined as the foundation of AI readiness: namely the (1) Institutional Environment, the (2) Technological Maturity and (3) IT Skill Advancement. 19 indicators were subdivided and clustered into these three components, to create a comprehensive overview of AI readiness.

Based on the interplay of these components and their indicators, a country's weaknesses and strengths regarding AI readiness can be assessed. Altogether they form a realistic baseline that allows countries to compare their AI readiness and yield insights regarding strengths and bottlenecks. However, it should always be kept in mind that these different components each have their own forces and thus in a myriad of ways can influence one another. The components, their definitions and some sample indicators are as follows:

I. Institutional Environment

Creating the right climate for AI is necessary to support and stimulate AI adoption. Digitalization can be fostered by providing a stable environment, in which consumers are protected and investments are encouraged. A country's government is responsible for managing the risks and challenges for building an AI-enhanced society. Therefore, it should adapt its policies and regulations in such a way that the benefits of AI can be harvested. The OECD acknowledges the driving force of the government in this:

> ***Governments play a key role in fostering a sound environment for innovation, in investing in thefoundations for innovation, in helping overcome certain barriers to innovation, and in ensuring that innovation contributes to key goals of public policy.***

To stimulate AI adoption, governments should adjust their legal environment for a twofold reason. Firstly, the legal environment should stimulate and facilitate the digital transition. An environment that encourages innovation should be created, by altering regulations around data access and transparency. Existing regulations should be revised in case they slow down innovation or unnecessarily increase costs.

Secondly, the legal environment should be adjusted to protect the public safety of the risk aspects of AI. In policy discussions, it should be debated whether the regulations that are in place are already adequately addressing these risks, or whether an alteration is needed. When the right safety measures are taken, it will translate into an environment of trust.

A country's current institutional environment can be assessed based on several indicators. For instance, the number of large firms within a country indicates how ready firms are to start adopting new technologies, as large enterprises are the driving force behind IT developments. In the same way, the number of IT firms and the rate at which firms create new technologies provide an idea of how welcoming and facilitating the current policies are with respect to AI adoption.

II. IT Maturity

With the right institutional environment in place, AI-based technological implementation and further sophistication can emerge. However, there are other key factors that are holding organizations back from embracing AI. These can be further subdivided in (1) the quality of the infrastructure (2) the access and management of data and (3) the extent to which IT is embedded and used.

Firstly, the infrastructure should facilitate the digital transformation. Therefore, the higher its existing quality is, the easier embedding new AI technologies will be. Essential for the implementation of AI is a profound level of connectivity and the availability of certain preconditions, such as internet bandwidth.

Secondly, one of the hygiene aspects for automation is proper data management. Correct data management facilitates the use of massive amounts of data to train algorithms. Hence, the availability of big data and the ease of accessing big data are key indicators of an institution's readiness for AI.

Thirdly, the extent to which IT is already embedded within business processes and people's day to day life, tells us how equipped and hence open companies and countries are for a radical change in the digital era. By looking at IT reliance, an estimate can be derived from the likeliness that a further digitalization will be embraced. To be more specific, enterprises that are already using software solutions and certain ERP software packages, have more mature infrastructures and hence will have fewer difficulties with AI deployment.

Once these three requirements are fulfilled, the maturity and sophistication of a company's current technology can be further developed.

III. IT Skill Advancement

AI skills are a prerequisite for the implementation of an AI infrastructure. Therefore, to transform an organization in such a way that it can leverage the new opportunities offered by AI, a shift in the company's capabilities is necessary. Existing IT skills must be augmented, and new skills developed. In line with our research,12 AI will not diminish jobs, but will act as a job creator, mainly for people with the proper capabilities. Consequently, the required skill sets will shift towards people who can use AI. In general, as technology continues to re-shape the needs of the labour markets, the demand for individuals with a broader knowledge base and more specialized skills continues to rise. Thus, the percentage of the population that has completed the highest education indicates the flexibility of the current population to adopt IT skills.

We found that 64% of the organizations that implement AI, lack the appropriate skills and talent to do so. Therefore, one of the biggest hurdles in the use of AI is developing or acquiring the right AI talents. In general, three broad approaches exist for companies to improve their AI skill sets. Firstly, AI related tasks can be outsourced to companies who do possess the right capabilities. However, regardless of the reliance on external parties to fully embrace AI, a company needs its own expertise on how to perform the 'number crunching' and to understand the technical implications of AI. Hence a second option is to hire the people with the right skills. Unfortunately, these people are limited and hard to find. Thus, a third option is to train the own workforce in a variety of skills, ranging from the ability to collect relevant data to the ability to create the right algorithms. Furthermore, the use of AI for a business process requires leaders who can guide the team while thoroughly understanding AI and its impact on the business.

How to develop these three foundations is discussed in the following section.

Policy recommendations

I. AI awareness should be increased through intensive experimentation

The first step towards AI readiness is creating awareness. Currently, many citizens are not aware of what AI means and what its implications are. Creating awareness forms the foundation towards a better understanding and eventually the building of trust in AI. As the EU has emphasized, it must be ensured that all citizens are aware of the AI-enabled changes and our education and learning systems need to be adapted accordingly. Thus, a concrete path towards increasing this awareness starts by educating people on what AI means, beginning in schools and universities.

Courses on AI, IoT, machine learning and data science should be embedded within the current curricula, emphasizing topics such as ethics and safety. Moreover, organizations and institutions should experiment more intensively with AI to grow awareness and experience. By means of experimental utilization and implementation of pilots, the benefits AI can bring will become salient. Only once awareness is incited through experience, trust can grow, which is essential for the adoption of AI.

II. Existing legal frameworks need to be revised to create a favourable AI-enabled environment

AI is a very powerful technology. Therefore, caution in its development and deployment must be taken. Governments should lead by example and take responsibility to assure safety while enabling a favourable entrepreneurial environment.

Building on awareness, a vigorous and informed debate should be encouraged about how best to steer AI in ways that enrich our lives and society. Furthermore, there are several concerns that need to be addressed. Privacy concerns related to the increased accessibility of data, including personal data, should be tackled. The current fear regarding the impact of AI on the labour market, as it is commonly believed it will take jobs away, needs to be addressed. In a similar vein, the possibility that AI may lead to decreased tax incomes as processes are increasingly automatized should be studied. In addition, debates relating to liability concerns need to be held (e.g. 'was it the human's fault or the AI machine that was used?').

More specifically, a recent concern has been raised regarding discriminatory outcomes of AI. One of the purposes of AI is to eliminate human bias in decision-making. However, because of several reasons (e.g. insufficient or outdated data sets), deployment could reinforce bias or discrimination, for instance because AI systems are trained based on historical data.

Several measures should be taken to prevent discriminatory outcomes in AI. Above all, human rights principles and obligations must

always apply and should be embedded in the architecture of AI machines. Furthermore, visible avenues for redress should be incorporated in AI systems, the development of AI applications should involve a vast diversity of input sources and the systems must be able to provide an explanation of their decision-making.17

The driving mechanism and fuel behind an informed debate, is research. A country's government should invest heavily in AI-based R&D to gain more knowledge on the risks and implications of AI adoption. The European Union is already doing this and recently increased its investment in this field to €1.5 billion for the period 2018-2020 under the Horizon 2020 research and innovation programme. Public and private funding should be increased for interdisciplinary study of the societal impacts of AI. To facilitate this research, professionals from various disciplines and functional areas should be working together towards a better understanding of AI.

For businesses specifically, it is important to be aware of how AI can benefit, but also disrupt a company. By researching other businesses that are already using AI, best practices can be determined.

Furthermore, by leveraging research it should be determined how AI will potentially challenge existing legal frameworks. Several alterations in existing regulations, regarding topics such as cyber security or the free flow of data, have already been proposed by the European Commission.16 By further revising current policies, a strengthened AI-enabled environment should be created. Policies need to be installed to lower regulations and bureaucracy, thereby empowering the private sector to innovate.

III. SMEs and large companies should collaborate and prioritize the low complexity and high benefit projects to create quick wins

SMEs face the challenge of lacking the big data sets required to incorporate AI solutions. However, their processes are often of a low complexity compared to bigger organizations, making it easier for them to make the switch to AI.

Larger organizations, on the other hand, have a different challenge to overcome. In general, their processes are very complex due to their size and when they try to implement AI for highly complex projects, they miss the low-hanging fruits. Instead, they should focus on projects with low complexity, but with a high benefit12 as for big organizations as well, large benefits can be gained.

For SMEs, it is therefore advisable to work collaboratively with larger organizations to ensure data accessibility and to unleash the benefits of AI. The European Commission is supporting this approach by actively taking away the obstacles to data mobility. The 'free flow of data' initiative allows companies and institutions to store and process non-personal data wherever they choose in the EU. Regarding personal data, free movement is already provided by the General Data Protection Regulation (GDPR).

Furthermore, for bigger organizations and SMEs alike, creating a strategy and implementation plan that starts with an MVP (minimal viable product), would be beneficial, as organizations are able to leverage the power of AI quicker. Therefore, prior to deployment, SMEs and larger firms should

execute a detailed internal analysis to identify the areas within their company where AI can create the quickest advantages. By focusing on the use cases that are easy to implement and have high benefits, learning within the organization will be sped up. Furthermore, once quick wins are created, it becomes easier to deploy AI implementations for more complex areas, as knowledge of previous AI projects can be built upon. Thus, scalability will be ensured. Lastly, quick wins will create an AI-friendly mindset among employees since an earlier positive experience will increase acceptance and trust in AI.

IV. Data sharing and accessibility should be stimulated in initiatives and innovation hubs

To accelerate research, both access and availability of data should be improved, as big data forms a crucial prerequisite for AI. An entire data ecosystem should be built, in which the focus lies on data quality and -management. An ecosystem, composed of several initiatives on digitizing the industry, should be created in which businesses and institutions share their data and work collaboratively towards gathering rich sets of data. These initiatives should not be restricted to within a country but should be extended internationally to unlock the full potential of AI. The EU has launched many initiatives to create such an ecosystem. By establishing a coordinating forum for all Member States, the EU is facilitating the building of a critical mass of initiatives around AI.16 Furthermore, as mentioned above, the European Commission is actively addressing the current regulations restricting the free flow of data, to ensure easy data accessibility within the EU.

An indispensable prerequisite to data sharing is the availability of a qualitatively high infrastructure. Important facts that should be part of a well-designed infrastructure are the utilization of cloud storage, broadband internet speed, and large computing resources to enable the retrieval, storage and transportation of data across several institutions and countries. Furthermore, thorough security procedures should be incorporated into the infrastructure to prevent data leaking or hacking.

Another way to stimulate knowledge sharing and innovation is by building and encouraging innovation-focused networks and innovation labs, as has been proposed by the European Commission.16 A benefit of such initiatives is that a safe environment is created to enable idea sharing. This directly stimulates innovation, as interdisciplinary approaches are brought together. In the end, when utilizing richer data sets, better policy decisions can be made, and best practices can be shared.

V. The skills gap between the general workforce and the one that can work with AI needs to be decreased

Currently the skills gap between the general human workforce and the one that can develop and work with AI continues to grow. To bridge this gap, talent and skills should be fostered as has been listed as one of the top priorities by the OECD (2015) Innovation Strategy for policy action.15

The focus regarding the skills gap is concentrated heavily on hard skills such as Artificial Intelligence, data science and computer science. However, a Capgemini study found that, contrary to what one might expect, the talent gap in soft digital skills such as collaboration and change management is more pronounced. For a digital professional, soft digital skills are an increasingly vital characteristic. More specifically, the most required digital soft skills are customer-centricity and passion for learning, while the largest gap exists in the soft skills comfort with ambiguity and collaboration.

Initiatives such as the 'digital skill and jobs coalition' take action to help bridge the gap in digital skills.14 Besides this, there is a myriad of ways towards the improvement of the current state of digital skills. Firstly, our education and learning systems should be adapted. Starting at school, IT and coding should become an integral and mandatory part of the curriculum. To be able to do so, public institutions should invest heavily in IT equipment.

Secondly, a culture that celebrates innovation should be stimulated by creating incentives for developing IT skills. This might be achieved by launching marketing schemes for technological universities to encourage the enrollment for IT-related studies. Furthermore, innovation awards should be created to increase people's interest in developing innovative skills. Lastly, we should work towards the attitude that skill development does not stop at graduation but continues throughout the work life. This could be incentivized by a scoring system that assigns bonuses to people who successfully finish certain courses. The workforce should be prepared for a lifetime of reskilling and learning, motivated by a regular course offering on trending and evolving topics.

Thirdly, the accessibility of certain skills should be increased, by adjusting government policies regarding international mobility programs. When lowering barriers, such as visa restrictions, and creating more open borders, new skills can be brought in more easily.

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Appendix A: Readiness results

Countries: / Cluster:	Institutional Environment	IT Maturity	IT Skill Advancement	Total Score:	Rank:
Australia	133	115	24	272	17
Austria	93	142	56	291	15
Belgium	75	187	68	330	7
Bulgaria	36	51	5	92	35
Canada	125	138	30	293	14
China	48	84	1	133	32
Croatia	40	113	20	173	25
Cyprus	8	96	36	140	31
Czech Republic	48	110	24	182	24
Denmark	108	279	55	442	2
Estonia	67	133	32	232	20
Finland	112	222	69	403	5
France	121	171	49	341	6
Germany	102	143	55	300	12
Greece	44	76	21	141	30
Hungary	32	122	14	168	26
Ireland	68	177	52	297	13
Italy	92	85	16	193	23
Japan	134	151	28	313	10
Latvia	29	103	18	150	28
Lithuania	47	185	26	258	18
Luxembourg	28	230	62	320	8
Malta	32	181	28	241	19
Netherlands	124	293	58	475	1
Poland	68	80	16	164	27
Portugal	56	145	25	226	21
Republic of Korea	146	142	27	315	9
Romania	29	80	2	111	33
Russian Federation	43	22	29	94	34
Slovakia	30	98	19	147	29
Slovenia	45	125	48	218	22
Spain	108	171	34	313	10
Sweden	93	263	61	417	3
United Kingdom	152	207	50	409	4
United States of America	132	129	25¬	286	16
Median	68	138	28	258	-

Table 1 Readiness Benchmark Results

Appendix B: Performance results

Cluster: / Countries:	Personnel	Monetary Impact	Competitiveness	Research & Education	Technology	Total Score:	Rank:
Australia	14	18	46	18	37	133	10
Canada	28	35	56	14	28	161	8
China	11	34	26	66	95	232	4
France	37	52	46	22	45	202	5
Germany	31	56	57	52	70	266	2
Japan	10	12	53	18	87	180	6
Netherlands	13	40	63	20	19	155	9
Poland	12	30	29	10	16	97	11
Republic of Korea	10	23	51	22	71	177	7
Russian Federation	10	18	19	16	29	92	12
United Kingdom	48	69	56	32	29	234	3
United States of America	36	68	59	76	98	337	1
Median	13,5	34,5	52	21	41	178,5	-

Table 2 Performance Assessment Benchmark Results

Appendix C: Measurement methodology

All the data obtained is publicly accessible and available online, the complete source list is available in appendix E & F. The benchmark aims to construct measures for the “readiness” and “grade”, henceforth named readiness and performance respectively. This is done for 35 countries with the list being available in appendix A. Since no exact measurements of readiness and performance exist specifically for Artificial Intelligence these measures are constructed using proxies. A full list of these indicators can be found in appendix E for readiness and appendix F for performance.

The readiness benchmark aims to fill the measurement gap by quantifying the readiness state of countries at a national level. Benchmarking the 28 EU-member states, Australia, Canada, China, Japan, the Republic of Korea, Russia and the USA on their Artificial Intelligence readiness. This is quantified by using relative measures, adjusted for population size and other indicators that are directly comparable.

This benchmark aims to add an extra dimension to the readiness benchmark by assessing the level of performance in AI. Readiness and performance are not directly related. They do however have an indirect impact on each other. This benchmark therefore aims to complement the readiness measure by benchmarking 12 countries on their levels of performance. The countries that are compared are: Australia, Canada, China, France, Germany, Japan, the Netherlands, Poland, the Republic of Korea, Russia, the United Kingdom and the United States of America. Unlike the readiness benchmark, this is quantified by using absolute performance measures, unadjusted for population size as performance is here defined as an absolute and not a relative measure. This is done because the performance benchmark aims to assess the best performance, regardless of size, whereas the relative benchmark of readiness looks at entire nations.

To develop the benchmark a ranking system is created which works as follows: The indicators are clustered into groups. The three clusters for the first benchmark are used to assess the full readiness of a country by looking at the institutions, the infrastructure and skill set. The five clusters created for performance respectively look at the main categories in which AI could be measured as to have an impact on.

For each indicator in each group a reverse ranking is made, where a missing value is counted as having no value. The highest score is thus obtained by the country which has the highest original value of the indicator. The highest attainable score is No ofcountries – No of missing values. The sum of every indicator score is then taken for every cluster which yields the cluster score. The cluster scores summed form the total score for readiness and performance and these are used to create the final ranking. The clusters are not adjusted in weight for the number of variables to reflect on the importance of the clusters with a higher number of variables. A full list of the clusters can be found in appendix A for readiness and appendix B for a performance.

Each missing value is treated as having no score since this diminishes the total score by one per country for that indicator. This has a levelling effect and as such the effect of a missing value can be diminished. The impact of a missing value for a high scoring country is higher than that for a lower scoring country as they would have gotten a score closer to nothing regardless. To further decrease this effect, the maximum number should not exceed an amount such that the average value of an indicator times the number of missing values does not exceed the average gap between ranks. This way the expected value of the total missed score points is smaller than a deviation in rank. However, this is not feasible for the performance benchmark, and as such the missing values all get score 1 to level it even more. Furthermore, the country set is decreased to the most important players in the field of Artificial Intelligence to decrease the total number of missing values. For the full list of reduced countries see appendix B. Finally, if a tie occurs, the country with the most amount of missing values will get the higher ranking as it is deemed more likely that it would have scored higher to compensate for this.

Appendix D: Methodological comments

Since no true measurement of Artificial Intelligence readiness is available, the benchmarks had to be constructed from a set of indicators. The same holds for performance. The use of proxies however, leads to an imperfect measure as it does not capture the full effect, nor does it only capture the effect that needs to be estimated. For this paper this could largely be avoided by converting different measures to the same structure and limiting the data range to at most three years old.

However, where this was not possible a missing value was denoted. The more countries in the set the larger the impact of having a missing data, thus the impact on the readiness benchmark is larger than that for the performance benchmark. To mitigate this the average value multiplied by the number of missing values per country could not exceed a threshold. This is however, a mitigating effect that does not consider that countries that would have scored could well miss more points than that. The range of countries that perform "well" must be increased to accommodate for this uncertainty, countries that perform poorly still perform poorly. This effect is a lot less for performance as the country set is a small subset of the total number of countries.

Furthermore, the readiness benchmark does not give an indication of how well prepared a country is ready for the benefits in the absolute terms, it only reflects on the relative position towards the other countries. Putting an absolute value on this would be valuable but impossible since all proxies are relative as well, and using absolute values gives a poor resemblance. Thus, it is unclear how well or poorly a country could theoretically be doing, it can only tell how well a country performs relative to another. This problem is not present for performance as this does not focus on the full country but on the best measures of a country.

This further alleviates the detrimental effect of missing data, as no absolute damage can be done to the benchmark, and even the relative benchmark is limited as a country that are within a broad range perform roughly equally. The measuring error for readiness between positions 1 and 5 is big enough to find this difference negligible, however the benchmarks still provide a very accurate estimation of how well a country is positioned globally, where this is seen as good, average or worse.

Appendix E: Readiness list

Indicator:	Cluster:	Source:
E-Government Development Index	Institutional Environment	https://publicadministration.un.org/egovkb/en-us/Reports/UN-E-Government-Survey-2016
E-Participation Index	Institutional Environment	https://publicadministration.un.org/egovkb/en-us/Reports/UN-E-Government-Survey-2016
Open Data Barometer	Institutional Environment	http://opendatabarometer.org/4thedition/data/
Number of firms with more than 250 employees per million inhabitants	Institutional Environment	https://data.oecd.org/entrepreneur/enterprises-by-business-size.htm http://www.chusho.meti.go.jp/sme_english/outline/07/01.html 13.000 http://www.mss.go.kr/site/
Digital Index Score Tuft's	Institutional Environment	https://sites.tufts.edu/digitalplanet/files/2017/03/Digital-Planet-Executive-Summary.pdf
International Bandwidth Rank	IT Maturity	https://www.weforum.org/reports/the-global-competitiveness-report-2016-2017-1
The percentage of enterprises that use an ERP software package to share information between functional areas and create and store internal data	IT Maturity	http://ec.europa.eu/eurostat/web/products-datasets/-/isoc_bde15dip https://www.statista.comstatistics701189japan-businesses-investing-erp-software/
The percentage of enterprises using software solutions, like CRM to analyse information about clients for marketing purposes	IT Maturity	http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tin00116&plugin=1 https://www.statista.com/statistics/701214/japan-businesses-investing-crm-software/
The percentage of persons employed provided with internet enabled portable devices	IT Maturity	http://ec.europa.eu/eurostat/documents/2995521/5155906/4-11122012-BP-EN.PDF/022f5cca-b1f5-4726-bb6f-4370f1184258
ICT technology birth-rate	IT Maturity	https://ec.europa.eu/growth/tools-databases/dem/monitor/data-explorer/ict-technology-birth-rate
The number of personal computers per household	IT Maturity	https://www.nakono.com/tekcarta/databank/personal-computers-per-household/
ICT Development Index	IT Maturity	http://www.itu.int/net4/ITU-D/idi/2017/
Networked Readiness Index	IT Maturity	http://reports.weforum.org/global-information-technology-report-2016/networked-readiness-index/?doing_wp_cron=1517318944.2009088993072509765625
Speedtest global index mobile	IT Maturity	http://www.speedtest.net/global-index

Speedtest global index fixed broadband	IT Maturity	http://www.speedtest.net/global-index
Percentage of firms that purchase medium-high sophisticated private servers, both ownership and rental	IT Maturity	http://english.yonhapnews.co.kr/news/2017/10/31/0200000000AEN20171031001400320.html
Percentage of the total working population that have specialist ICT skills	IT Skill Advancement	https://ec.europa.eu/growth/tools-databases/dem/monitor/data-explorer/ict-specialist-skills
Percentage of the population with tertiary degree education	IT Skill Advancement	https://data.oecd.org/eduatt/population-with-tertiary-education.htm
The percentage of firms that provide ICT training	IT Skill Advancement	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_ske_ittn2&lang=en

Table 3 Readiness Indicator, Cluster & Source List

Appendix F: Performance List

Indicator:	Cluster:	Source:
Percentage of firms that had hard to fill vacancies in ICT	Personnel	http://ec.europa.eu/eurostat/statistics-explained/index.php/ICT_specialists_-_statistics_on_hard-to-fill_vacancies_in_enterprises
Number of data workers	Personnel	https://a2528ba5-a-c3c32646-s-sites.googlegroups.com/a/open-evidence.com/download/repository/EDM_D8_Second%20Interim%20Report_June2016_v3.0_9thJune2016%20%281%29%20%281%29.pdf?attachauth=ANoY7crSH-6ml-lG1l2riChwam9f-vPt957eWXlwrq-AwvyS0gfDfXUebLjMUr1WalcpTY4mNdnx3lsLzhLZd9Eri_Orr_tJmyGrzdTUUv0U4AlwW7NJ_Ul8Vj9ASmEWMyXorMJyY0lV33iVXQolpkaKPFA4EZ6VDEqXUwb8hCW-4TrYgllf3l0FZBgD4MG-RmqZcpygND1QM52rpE4CFdVeJnPAFyG2VDEnA2joUk6Xw_nErAud2NQciwzoGnBN6qW_gQzPbLIMZ5hSLRWv3iGkkC8ASQmUgfSQBeLSK_TlJb-nbMcCimP_Qv5tgkXtrH-_K9yvyED9&attredirects=1
Number of Data Scientists	Personnel	https://www.deeplearningtrack.com/single-post/2017/08/27/Quantifying-the-current-demand-for-data-scientists
e-Skills Vacancies Estimate 1000's	Personnel	file:///D:/Users/ckraaij/Downloads/e-Skills%20in%20Europe%20Report%20-%20Feb%202014.pdf
Years of experience Data Scientists	Personnel	https://www.deeplearningtrack.com/single-post/2017/08/27/Quantifying-the-current-demand-for-data-scientists
Number of AI specialists	Personnel	http://www.chinadaily.com.cn/bizchina/2017top10/2017-07/13/content_30093900.htm
Percentage share ICT has of total GDP	Monetary Impact	http://ec.europa.eu/eurostat/web/products-datasets/-/tin00074
Data market value 2016	Monetary Impact	https://www.statista.com/statistics/499895/canada-big-data-services-market/ https://www.statista.com/statistics/796500/china-big-data-market-size/ http://mediaincanada.com/2018/02/07/whats-the-value-of-canadas-data-market/ https://www.idc.com/getdoc.jsp?containerId=prUS42371417 https://www.statista.com/statistics/661934/australia-big-data-business-analytics-revenue/ https://www.statista.com/statistics/499895/canada-big-data-services-market

Data market value 2020	Monetary Impact	https://www.statista.com/statistics/499895/canada-big-data-services-market/ https://www.statista.com/statistics/796500/china-big-data-market-size/ http://mediaincanada.com/2018/02/07/whats-the-value-of-canadas-data-market/ https://www.idc.com/getdoc.jsp?containerId=prUS42371417 https://www.statista.com/statistics/661934/australia-big-data-business-analytics-revenue/ https://www.statista.com/statistics/499895/canada-big-data-services-market/
ICT spending growth	Monetary Impact	http://eskills-lead.eu/fileadmin/LEAD/Working_Paper_-_Supply_demand_forecast_2015_a.pdf
Total computer software spending	Monetary Impact	https://knoema.com/GII2017Jun/global-innovation-index?
IT industry competitiveness index	Competitiveness	http://www.bsa.org/?sc_lang=en-US http://www.eiu.com/site_info.asp?info_name=eiu_Business_Software_Alliance_means_to_compete&rf=0
Cloud computing country ranking	Competitiveness	http://cloudscorecard.bsa.org/2016/
Global innovation index	Competitiveness	https://www.globalinnovationindex.org/analysis-indicator
Labour productivity growth	Competitiveness	https://data.oecd.org/lprdty/labour-productivity-and-utilisation.htm
GDP per unit of energy use	Competitiveness	https://www.theglobaleconomy.com/rankings/GDP_per_unit_of_energy/
GDP per hour worked in dollars	Competitiveness	https://data.oecd.org/lprdty/gdp-per-hour-worked.htm#indicator-chart
Dollars spent on R&D in AI or ICT millions	Research & Education	https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm
Publications in AI research, 2011 to 2015 Ranked	Research & Education	Elsevier/Scopus
Number of publications in AI	Research & Education	Elsevier/Scopus
Field-weighted citation impact	Research & Education	Elsevier/Scopus

Number of Top universities per country specialising in AI	Research & Education	Elsevier/Scopus
Robot density Rank	Technology	World Robotics Report, produced annually by the International Federation of Robotics.
Yearly shipments of multipurpose industrial robots in selected countries	Technology	World Robotics Report, produced annually by the International Federation of Robotics.
yearly shipments of industrial robots 2015	Technology	World Robotics Report, produced annually by the International Federation of Robotics.
yearly shipments of industrial robots 2018	Technology	World Robotics Report, produced annually by the International Federation of Robotics.
Operational stock of industrial robots 2015	Technology	World Robotics Report, produced annually by the International Federation of Robotics.
Operational stock of industrial robots 2018	Technology	World Robotics Report, produced annually by the International Federation of Robotics.
Number of High-Tech Patents	Technology	http://ec.europa.eu/eurostat/web/products-datasets/-/pat_ep_ntec
Operational stock of industrial robots 2018	Technology	World Robotics Report, produced annually by the International Federation of Robotics.
Number of internet users	Technology	http://www.internetlivestats.com/internet-users-by-country/

Table 4 Performance Indicator, Cluster & Source List

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