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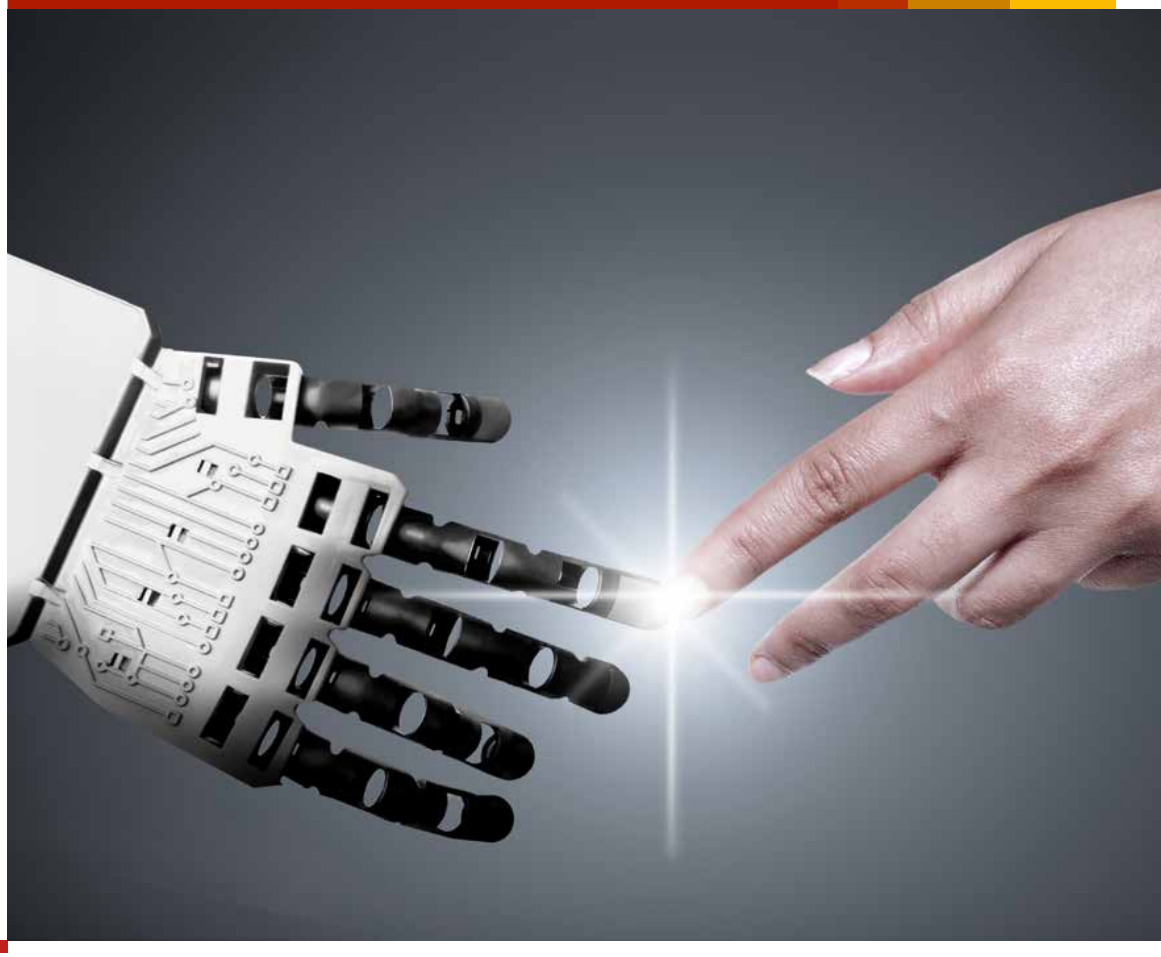
# *Impact of Artificial Intelligence in Germany*

*June 2018*



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# A *Executive Summary and recommendations:* Five steps to becoming an AI champion

The present study shows that artificial intelligence (AI) holds enormous potential for the German economy: according to our forecasts, by 2030 AI alone can increase the German gross domestic product (GDP) by 11.3%, generating around €430 billion of value.

In terms of percentage, this potential is greater than in most other European economies. However, the amount of growth will vary according to industry – our forecast predicts rates of between 7% and 28%. Artificial intelligence is likely to have a particularly large impact on the areas of retail and consumer goods, hotels, restaurants, education, health and the public sector. Compared to the economies of China and the US, however, it is predicted that Germany will have a greater need to catch up in terms of using artificial intelligence to innovate in the further development of business models.

What we find particularly telling is that GDP growth will primarily be driven by new innovative companies, products and services: at 6.71 percentage point, they constitute almost 60% of total growth and consequently play a greater role than using AI to increase productivity (4.56 percentage points).

This shows that the current fears of massive job losses are excessive. Although a recent OECD study shows that just under 20% of jobs in Germany are threatened by AI, new products and services are emerging at the same – and with them new fields of activity. In addition, increased production volumes require an increase in the number of workers.

All in all, the results of the present PwC study underscore the enormous influence of AI and the fact that it will affect all areas of a company. To put it emphatically: AI will determine not only the success or failure of a company but also who works there, when and how.

For that reason it is high time to set off on the right course. To drive change rather than merely react to it, it is necessary to master five challenges.

## 1 *Understand artificial intelligence*

To find the right course, companies first have to analyse how AI affects their own organisation, industry and related areas. Only then can management identify risks and recognise opportunities – such as those arising through new business models. For instance, suppliers of raw material suppliers can become parts manufacturers more easily than ever before by leveraging AI and 3-D printing.

## 2 *Identify one's own strengths*

Goals should be ambitious but still attainable. Alongside a risk and opportunity analysis it is important to analyse one's own options – for example to check which data is available for training AI systems. In addition, there is the question of to what extent companies may use data – especially in light of the EU General Data Protection Regulation (GDPR), which entered into force at the end of May.

## 3 Develop a consistent AI strategy

An honest analysis will often show that data only exists in sufficient quantity and quality for the core business. Thus a company's own data from customer management and service systems can be more quickly and efficiently linked than external information, such as data from social media. Developing a consistent AI strategy starts with addressing this issue – defining how the business's core competences should be strengthened with AI systems and which innovative products, services or even business models are possible and useful.

## 4 Guarantee ethical behaviour and transparency

Innovative products and services will only succeed in the long term if they are trusted by customers. This is why ethical guidelines and transparency provisions are fundamental parts of any AI strategy. Companies can then have them certified by independent authorities (here we referring to trusted and explainable artificial intelligence).

## 5 Create an AI culture

In order to successfully implement the strategy, companies need to hire AI experts and train employees. Another decisive factor is a corporate culture that embraces innovation. Above all, it is important to cultivate a sense of team spirit, because silo mentalities, holding on to knowledge for the sake of control, and rigid hierarchies only serve to inhibit new ideas and quick responses.

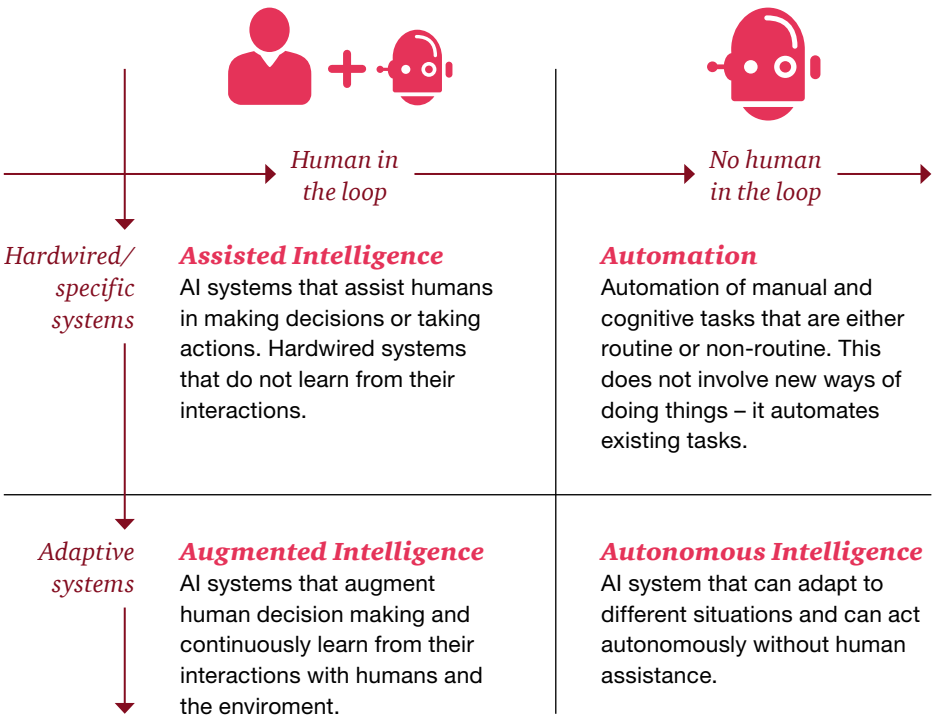
# B What is AI?

Almost all aspects of our daily lives have been increasingly digitised. Internet and mobile technologies have transformed the way we live and work. A new wave of technology is coming through, and it centres on data. AI will utilise data to assist us with the many tasks that we currently do ourselves today and will be able to do things that we have never even thought of before.

AI refers to computer systems that can sense their environment, think, learn and then can take action as a result. This ability to respond to the environment differentiates AI from automation of routine tasks. Machine learning algorithms and chatbots are examples of AI that are already used by businesses today.

Our definition of AI, however, goes beyond this. We also include automation, the replacement of repetitive manual and cognitive tasks by machines that are not necessarily "intelligent" and that instead have basic rule-based capabilities. We include these as we recognise that they are a key step in the progress towards advanced intelligent technologies.

**Levels of AI**




*"We will be able to do things that we have never even thought before."*

# C AI in Germany

As the largest economy in the EU, Germany is consistently a country that is seen to be a leader of innovation in Europe. With a highly skilled labour force and a strong infrastructure, the conditions in Germany seem attractive for investment, particularly in emerging markets such as AI.

Therefore, it is no surprise that Germany is the home of Cyber Valley, a Baden-Württemberg sponsored initiative with the aim of boosting artificial intelligence research and development. The initiative has led to significant AI investment in Germany. For example in October 2017, when Amazon.com announced that they would be opening an AI research centre in the university city of Tübingen. Another example of the investment in this sector comes from the public-private venture capital firm High-Tech Gründerfonds, who have made 489 investments worth €886 million Euro in high tech start-ups, in sectors such as robotics, automation and virtual reality.[1] Investment activity such as this shows the high levels of confidence that both the government and private firms have in the economic potential of AI in Germany.

Previous PwC Germany reports give evidence of some of the practical uses for AI in the European economy. Sherlock in Health identified that €70 billion of healthcare costs could be saved in Europe in the coming decade with the use of AI's early health problem detection.[2] PwC Germany have also identified the opportunity that AI offers for German businesses investing in smart cities, which are cities that use smart technology and AI to improve the inhabitants' quality of life. The report claims that smart cities provide opportunities for the German industry such as providers of IT and digital solutions, transport or waste disposal.[3]

Due to the technical capabilities of domestic firms and workers coupled with the growing demand for AI services internationally, there is a large potential positive impact that AI can have on Germany's economy.

[1] https://high-tech-gruenderfonds.de/en/#facts-figures-2.
[2] https://www.pwc.de/de/gesundheitswesen-und-pharma/studie-sherlock-in-health.pdf.
[3] https://www.pwc.de/en/internationalisierung/smart-cities-an-overseas-opportunity-for-german-businesses.html.

# D The economics of artificial intelligence

With AI set to transform the way we live and work, it raises the inevitable question of how much it will actually impact businesses and the economy more generally. Despite discussion on social media about the things that AI will be able to achieve, the majority of studies that have sought to answer this question have focused on the risks of artificial intelligence to employment. More recently, some researchers have recognised the potential that this automation has to boost productivity,[4,5] leading to more efficient production of goods, more affordable products, and higher real incomes.

Our study aims to take further steps towards capturing the full economic potential of AI and the opportunities that it presents. In addition to the more traditionally examined productivity channel, we identify and measure impacts on the household consumption side of the economy through product enhancements resulting from AI.

In particular, we predict that AI will likely enhance available consumer products in three ways: increasing their quality, increasing consumer choice through more personalised and varieties of goods, and saving consumers time from being able to multitask better and delegate to AI technologies. As our study reveals, these product enhancements are expected to have a large impact on GDP. This is partially driven by increased consumer spending on more attractive products, but is most importantly the result of additional firms entering the market following the stimulation in consumer demand, leading to higher quantities of production and more affordable goods.

[4] McKinsey Global Institute (2017), "A future that works: Automation, employment and productivity."
[5] Accenture and Frontier Economics, "Why artificial intelligence is the future of growth".

# E Our approach

Our approach seeks to quantify the total economic impact of AI on the German economy via both productivity gains and consumption side impacts over the period 2017–2030. In June 2017, PwC published *Sizing the prize: What's the real value of AI for your business and how can you capitalise?*, a global report estimating the GDP impact that AI could have in various geographic regions and industrial sectors by 2030. In that study, we used a dynamic economic model of the global economy to evaluate the "net" impact of each channel on GDP.

We estimated that global GDP could be up to 13.8% higher in 2030 as a result of AI, and that these results are likely to vary by geographic region. Specifically, we found that GDP in the regions of Northern Europe and North America could be up to 9.9% and 14.5% higher respectively. Germany sits within Northern Europe in our global modelling, however, there is reason to believe that AI and its impact could vary across countries, and that the impact in Germany could look different from the average in the region.

In this study, we estimate the country-specific economic impact of AI in Germany. To do this, we use insights into the likely pace of adoption of AI in Germany as well as key differences between the German economy and that of other countries across Northern Europe and North America to understand (a) how big the impact of AI on productivity and product enhancements could be in Germany then (b) how much more or less these "first round" impacts could affect GDP over the period to 2030. We apply these insights to tailor the results from our global modelling to the German context. See Box 1 for details on the approach to estimating the global GDP impact of AI.

How much the "first round" impacts affect GDP – the economic multiplier – is determined by underlying economic factors, including how much capacity there is in the economy, as well as sectoral composition and how much sectors interact with each other. We compare some of these features of Germany with the same for North America and North Europe and find that the economic multipliers in Germany are likely to look more like North American economies, though with a small resemblance to North Europe. In our global modelling, the multipliers for North America were slightly higher for some of the reasons highlighted above. We used German data from the same sources as our global modelling to estimate the "first round" impacts.

### *Estimating the impact of AI on productivity in Germany*

On the production side, we focus on AI's impact on labour productivity through AI uptake for all sectors, as classified by OECD industry codes, between now and 2030. To estimate the sector-specific automation impact of AI in Germany, we first use German wage data[6] and job automation data to estimate the total labour reduction and cost savings associated with this. The estimates of job automation are calculated using a machine learning algorithm based on task composition and automatability of processes as in our study published in our March 2017 UK Economic Outlook.[7]

Further, we use key similarities related to GDP per capita, productivity and sector composition between the German economy and other economies in Northern Europe and North America to estimate the marginal impact on labour productivity for every unit of expenditure on AI in a sector. We combine these with the estimates of automated labour and projections of the scale of investment in AI by sector to estimate the total impact on productivity. Thus, we capture productivity that results from both businesses automating processes as well as businesses "augmenting" their existing work-force.

[6] We collected wage data from Statistisches Bundesamt (Destatis).
[7] PwC UK Economic Outlook March 2017, "Will robots steal our jobs: The potential impact of automation on the UK and other major economies".
[8] https://www.globalinnovationindex.org/.

### *Estimating the impact of AI on product enhancements in Germany*

On the consumption side, we focus on AI's impact on product enhancements which include increased quality, personalisation (i.e. product variety), as well as increased time available for leisure or work. The geographic variation in our estimates of the impact of AI on product enhancements is largely driven by the likely pace of adoption. We assumed that the potential uses of AI are homogenous across countries but that timeline for their introduction could vary.

We use the Global Innovation Index[8] scores as a proxy to understand Germany's current AI readiness relative to North Europe and North America. The score tells us that Germany's adoption rate is likely to be similar to most of Northern Europe's economies (e.g. Switzerland, Netherlands and United Kingdom) however marginally lower than that in many Northern American economies (e.g. USA, Mexico, and Canada). Germany performs particularly well on elements of the Index such as ICT access and use, R&D investment by companies and gross capital formation. However, it lags on new business density and cost of redundancy dismissal. In line with some of the sentiment highlighted in Section C of this report, Germany and German businesses have the foundations and potential to successfully adopt AI in the near term.

## Our approach to estimating the global and regional economic impact of AI

Here we outline the approach that we used to estimate the global economic impact of AI, the results of which we tailor to reflect the Germany context in this study.

### *Evaluating the impact of AI on productivity, jobs and product innovation*

We have completed a number of stages of analysis in order to ascertain the "first-round" impacts on jobs, productivity and product enhancements that would be inputted into the dynamic economic model in order to estimate the future size of the AI prize.

- On the production side, we focus on AI's impact on labour productivity through automation. This required estimating the marginal impact of AI on productivity, the scale of automation expected to take place, the amount of AI replacing and augmenting human labour for every industry between now and 2030.
- On the consumption side, we focus on AI's impact on product enhancements, which include increased quality, personalisation (i.e. product variety), as well as increased time available for leisure or work.

In line with this, we have brought together three key pieces of primary research undertaken by the global PwC network to estimate these impacts of AI on each channel:

### *Econometric modelling and machine learning to estimate the effect of AI on productivity*

We built econometric panel-data models, which estimates the impact of AI uptake on labour productivity. We used the World and EU KLEMS datasets which include detailed data on labour productivity and technology spending. The model accounts for productivity that results not only from businesses automating process but also from businesses "augmenting" their existing labour force with human-in-the-loop AI technologies.

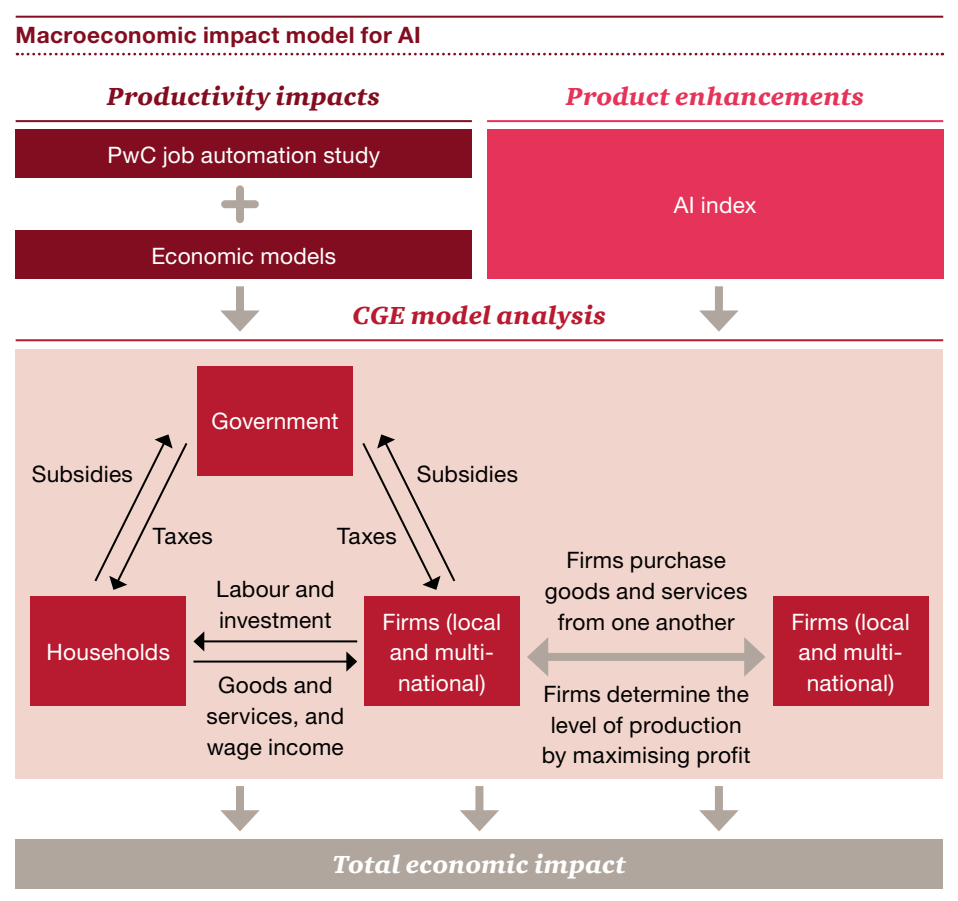
Our econometric model was used to evaluate the marginal impact of AI and was combined with our study on job automation and projections of investment in augmented intelligence to estimate the impact that expected AI uptake will have on productivity by 2030. The job automation study, which was published in our March 2017 UK Economic Outlook, used a machine learning algorithm to predict the fraction of jobs within UK industry sectors at high risk of automation from AI by 2030 based on their task composition and the automatability of those processes.

### *AI Index: Measuring the effect of AI on products and services*

We have also made use of the AI Impact Index which was created by PwC's Data Analytics team in the US. The index uses qualitative assessment from industry and AI experts to estimate the scale of product enhancements we will expect to see by 2030, by product line. The analysis sought to identify the most compelling examples of potential AI applications across industry sectors, and assessed almost 300 use cases in the process. We used measures from the index and quantified the affect that AI is likely to have on the variety of products available to consumers and the amount of utility that they would derive from them, as well the amount of additional labour supplied to the market. The AI index indicates the highest potential for product enhancements in the health, automotive and financial services sectors.

### *Bringing it all together: the S-CGE model*

In the final stage of our approach, we used each of these pieces as inputs into our dynamic economic model (known technically as a Spatial Computable General Equilibrium model (S-CGE)), to estimate the economic impact of AI on UK GDP by 2030. The S-CGE model captures all key interactions between households, firms and government in the economy, and also captures how different regions and sectors of the economy interact over time. This enables us to estimate the "net" effect of AI's impact on the economy, accounting for the creation of new jobs, a boost to demand from product enhancements and other secondary effects.



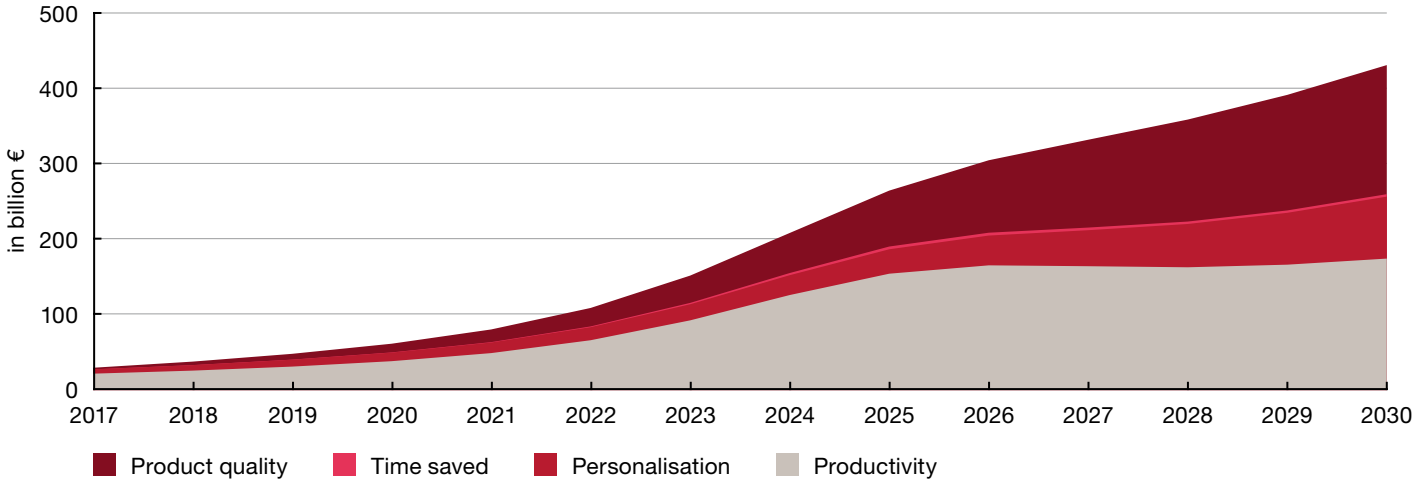
# F Results from our modelling

## 1 Headline impacts

Germany's GDP could be up to 11.3% higher in 2030 as a result of AI, equivalent to €430bn. The majority of the economic impact of AI in Germany is likely to come from consumption-side product enhancements – whereby AI would stimulate consumption but most importantly bring about more consumer choice and more affordable, bespoke goods over time as a result. Productivity enhancements are caused by efficiency gains for workers and will serve as a facilitator for the product innovation on the consumption side.

Our results suggest that the economic impact of AI in Germany could be higher than the average of the Northern European region. This is largely driven by the sectoral composition of the German economy, and the potential for productivity gains that this presents. The potential GDP gains associated with the replacement and augmentation of the workforce and the resulting productivity gains could be up to 4.6% in Germany, compared with 2.3% in the region more broadly. Capital intensive sectors, which make up a larger portion of Germany's economy relative to many other European economies, are expected to see the largest productivity gains. Furthermore, our previous research[9] found that the automation potential within Germany's capital intensive sectors was relatively higher than that of the UK due to the larger proportion of jobs that are manual or routine.

**Total GDP impact of artificial intelligence in Germany**




[9] PwC UK Economic Outlook March 2017, "Will robots steal our jobs: The potential impact of automation on the UK and other major economies".

## 2 Impact on labour

However, our analysis at the global level has found that the effects on GDP resulting from AI-enabled product enhancements are larger than those resulting from productivity gains. As shown in the graph here, the same is likely to be the case in Germany. Better quality goods, greater consumer choice and personalisation could result in GDP gains of up to 6.6% in Germany in 2030. AI is also expected to have an impact on the consumption side of the economy through the time that consumers could save. However, we find that many people use their additional time from AI enhanced products to relax and enjoy leisure time rather than work. This is partially explained by the fact that significant productivity and automation increases ensure large rises in the real wage, which in turn encourages workers to spend less time working as they can achieve their same income with less time spent. We would expect there to be a large welfare impact associated with this extra leisure time.

During the first phase of the impact (2017–2024), productivity growth could account for a relatively larger share of the gains than the period that follows when the consumption-side impacts are likely to dominate. This is due to the fact that it takes time for firms to enter the market place and supply AI enhanced products to consumers as a result of the AI-enabled product enhancements. As this takes place, competition within AI-goods producing markets increases dramatically, leading to further increases in the value of goods to consumers and therefore, greater expenditure on these products as their affordability and attractiveness rises.

On the topic of jobs, the adoption of "no-human-in-the-loop" technologies will mean that some jobs will inevitably become redundant, but others will be created by the shifts in productivity and consumer demand emanating from AI, and through the value chain of AI itself. Along with jobs in the development and application of AI, the technologies will need to be built, maintained, operated and regulated. In most cases, these jobs will be conducted by humans.

Furthermore, the extra demand generated in the economy as a result of AI increasing output and incomes, will lead to the creation of jobs not directly related to AI in non-AI intensive sectors. All of this will facilitate the creation of jobs that would not have existed in a world without AI.

In our analysis at the global level, we estimated that around 10% of jobs will to some degree be dependent on AI by 2030. By "dependent" we mean that these roles are either created through AI or rely on AI to the extent that the role would no longer exist without AI, holding all other aspects of the economy constant. Surprisingly, most of these jobs will be unskilled (though proportionally skilled jobs will be more positively impacted). 67% of the jobs in 2030 that will depend on AI will be the unskilled jobs, though this should be interpreted in the context of unskilled labour accounting for 69% of jobs in the baseline scenario. Our results therefore support the effect of skills-biased technological change. In practice, skilled labour would receive the bulk of the labour productivity gains, in which case the skills-bias in jobs would be more significant.

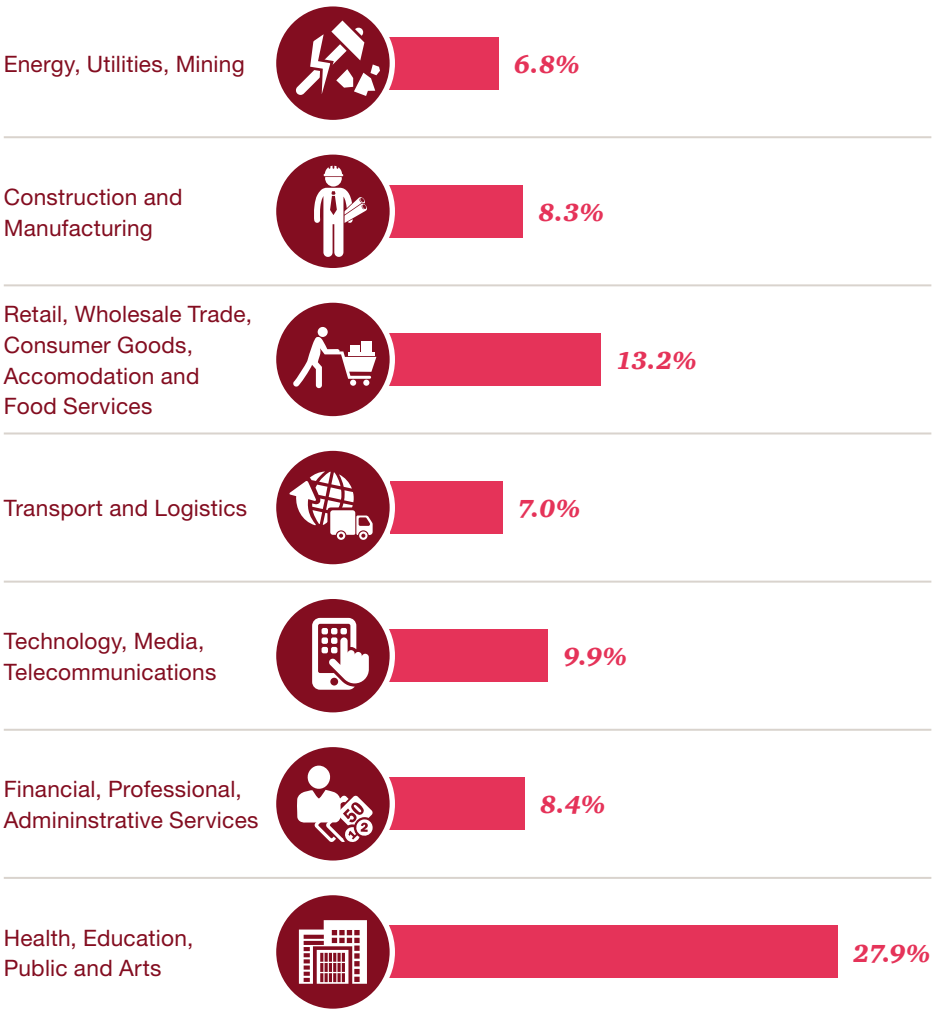
## 3 Sectoral impacts

All sectors of the German economy are likely to experience GDP increases as a result of AI by 2030, ranging from 7% to 28%. The graph below illustrates how the impacts will be distributed across sectors in Germany. It should be noted that all of these sectoral results are in percentages. Because of the relative sizes of sectors, some may experience larger absolute gains.

Labour-intensive sectors, such as retail and wholesale trade and accommodation and food services as well as health and other public services are likely to see the largest boosts to GDP, with gains of more than 13% and 28% respectively. The economic impact within these sectors is largely driven by consumption-side enhancements due to the front-end nature of the services provided. The effect within Germany's health and other public services sector is particularly high, however, as a result of likely productivity gains unmatched by any other region in the Western Hemisphere.

All of the other sectors are expected to see moderately high gains between 6.8% and 9.8%, in line with distribution across the Northern European region.

**GDP impact of AI by sector in Germany**




It is important to note that the impact of AI will not be concentrated in any one sector of the economy and will not be limited to the firms that develop and produce the AI technologies. The uptake of AI will have direct impacts in the sectors in which this uptake occurs, both through the automation and augmentation of processes and the enhancement of product offerings for consumers. Furthermore, the total economic impact includes the potential indirect and induced impacts that are likely to be felt by firms and consumers throughout the economy.

*"Labour-intensive sectors, such as retail and wholesale trade and accommodation and food services as well as health and other public services are likely to see the largest boosts to GDP."*

# G Appendix

In this appendix we discuss some of the caveats to this study's conclusions as well as indicate the full list of key metrics calculated and assumptions used in the global study, and therefore used in these estimates for the economic potential of AI in Germany.


## 1 Caveats to the study's conclusions

Our results show the economic impact of AI only – our results may not show up directly into future economic growth figures, as there will be many positive or negative forces that either amplify or cancel out the potential effects of AI (e.g. shifts in global trade policy, financial booms and busts, major commodity price changes, geopolitical shocks etc.).

Our economic model results are compared to a baseline of long-term steady state economic growth. The baseline is constructed from three key elements: population growth, growth in the capital stock and technological change. The assumed baseline rate of technological change is based on an average of historical trends. It's very difficult to separate out how far AI will just help economies to achieve long-term average growth rates (implying the contribution from existing technologies phase out over time) or simply be additional to historical average growth rates (given that these will have factored in major technological advances of earlier periods).

These two factors mean that our results should be interpreted as the potential size of the economic impact associated with AI, as opposed to direct estimates of future economic growth.

## Key assumptions used

| Metric | Assumptions | Source |
|---|---|---|
| Uptake of workforce augmenting AI | • We estimated long-run trends in emerging technologies by industry uptake that are unrelated to labour force decisions (i.e. expansion periods or automation) using econometric models.<br>• We assume all firms will at least replace depreciating AI and ET so that the net stock remains constant at minimum. | PwC analysis |
| Uptake of workforce replacing AI | • All jobs that are of high risk of automation by 2030 as discussed in PwC's March 2017 UKEO report will be automated. These jobs have at least a probability of 0.7 of being automated by 2030.<br>• A fraction of labour cost savings from automation are spent on replacement AI; this fraction is determined by the current fraction of capital expenditure on AI and emerging technologies. | PwC UK Economic Outlook March 2017 |
| Speed of AI uptake | • We scale the rate of AI uptake in the UK based on the Global Innovation Index as a proxy for AI readiness.<br>• The highest scoring country's rate of uptake is based on the highest GII score.<br>• The UK-specific adoption rate is delayed in reaching full AI adoption based on the UK's score vs. the highest score. | WIPO, Cornell, INSEAD 2017 Global vInnovation Index |
| Profile of AI uptake | • We have assumed an "S-shaped" profile of AI uptake for the UK between 2017 and 2030, where some countries only reach the "end" of the s-curve many years later, depending on their rate of AI uptake from the GII.<br>• The uptake scale and rate refers to the conceived advancements between 2017–2030, and does not refer to all future AI advancements, the study does not make predictions about the impact and state of the world beyond 2030. | PwC analysis |
| Consumptionside impacts | **Personalisation:**<br>• We converted the AI index (AII) personalisation scoring to a percentage impact on variety of goods based on a number of Willingness-to-Pay and Welfare studies in the literature. Our conversion was as follows: 1 = 0%, 2 = 1.54%, 3 = 6.2%, 4 = 13.8%, 5 = 24.6%.<br>• We interpolated between these points using a second order polynomial.<br>• Personalisation captures both the increase in utility from existing goods and variety of new goods. This allows us to proxy personalisation with increased goods variety in the CGE model.<br>**Time Saved:**<br>• We used data on sleeping hours in the UK to estimate the increase in time saved as defined by the AII (in hours/year based on frequency of activity): 1 = 0:00 , 2 = 2:00, 3 = 8:00, 4 = 180, 5 = 730.<br>• Agents are given the "option" to work more in the model, but in reality are not taking it as the change in relative wage is not dramatic enough causing labour supply to shift.<br>**Utility:**<br>• This is the increase in marginal utility associated with a percentage increase in "quality" as defined by the AII.<br>• We have assumed the following scoring mechanism: 1 = 0%, 2 = 6.25%, 3 = 12.5%, 4 = 25%, 5 = 50% where the % increase is in marginal utility. We have interpolated between these points using a polynomial of order 4. | "Made-to-order: The rise of mass personalization," Deloitte 2015 Sleep alarm app data PwC analysis |
| Automation impact on productivity | • The marginal impact of automation on labour productivity is constant over the period per industry in the UK; where we proxy the AI impact using the available data on emerging (smart) technologies and productivity, as well as other data series used to isolate the effect of automation on labour productivity. | PwC analysis EU and World KLEMS data |

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### *About us*

Our clients face diverse challenges, strive to put new ideas into practice and seek expert advice. They turn to us for comprehensive support and practical solutions that deliver maximum value. Whether for a global player, a family business or a public institution, we leverage all of our assets: experience, industry knowledge, high standards of quality, commitment to innovation and the resources of our expert network in 158 countries. Building a trusting and cooperative relationship with our clients is particularly important to us – the better we know and understand our clients' needs, the more effectively we can support them.

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