

Impact case study (REF3)

Institution: University of Oxford		
Unit of Assessment: 12 – Engineering		
Title of case study: Informing policy by raising awareness of the societal and economic effects of automation		
Period when the underpinning research was undertaken: Sept 2013 – Jan 2017		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Prof. Michael Osborne	Professor of Machine Learning	2012-present
Period when the claimed impact occurred: Sept 2013 – Jul 2020		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact		
<p>Prof. Osborne’s novel inter-disciplinary collaboration with economist Dr Frey (University of Oxford – Oxford Martin School) rekindled a worldwide debate about automation that transformed public and policy considerations of the future of work. The collaboration led, in September 2013, to a working paper (later published in 2017 in <i>Technological Forecasting and Social Change</i>) titled “The Future of Employment: How susceptible are jobs to computerisation?”. The BBC’s Rory Cellan-Jones has called their paper one of the most influential studies of our time.</p> <p>Frey and Osborne’s paper has been influential in shaping policy at governmental levels. The paper was the first to quantify the potential employment impact of new technologies from within Machine Learning, Computer Vision and Robotics. Unlike previous literature, the research by Frey and Osborne provided quantitative, actionable information to policymakers, particularly on the scope of automation’s potential impact on employment, and on the skills most needed to safeguard jobs against automation. The paper’s methodology was employed by President Obama’s Council of Economic Advisors to inform policymakers decisions to update and strengthen policies to respond to the economic effects of AI. The prime minister, Theresa May, commissioned the Taylor Report, which used the paper’s methodology to highlight the risk of automation to the UK labour market, shaping Britain’s industrial plan “The Good Work Plan”. The paper has also been built upon by international institutions, including the OECD, the World Bank, and the International Monetary Fund. Businesses such as McKinsey have also utilized the research. These institutions have used the paper to investigate how automation will affect developing countries, and how future generations will be affected. Prof. Osborne’s expertise has been called upon in roundtable discussions, and in providing evidence to global leaders. Finally, the BBC used the paper to raise public awareness of the risk of automation via the “Will a robot take your job?” tool on its website, which has seen a high number of visitors since it went live in 2015.</p>		
2. Underpinning research		
<p>The paper utilised Prof. Osborne’s expertise in Bayesian machine learning to introduce a machine-learning approach to measure the exposure of jobs to future automation, such as may be possible using emerging AI technologies. [R1, R2] It asked: in which occupations do human workers still hold the comparative advantage over technology? To answer this question, the paper presented a training set of seventy canonically automatable and non-automatable occupations, informed by AI experts. In a second step, this training set was enriched with quantitative occupational features from the US Bureau of Labor Statistics. In addition to data on education and wage, the data described each occupation’s average reliance on nine skills linked to potential automatability, including ‘Manual Dexterity’, ‘Social Perceptiveness’ and ‘Originality’. This enriched training set</p>		

was used to train a machine learning algorithm to classify the (binary) automatability of occupations as a function of its skills.

Prof. Osborne chose a Bayesian Gaussian process classifier for its efficient use of the small (N=70) training set. The Gaussian process classifier also provided transparency, in that it gave both a quantitative assessment of the importance of the nine skills to automatability and estimates of the uncertainty in the automatability of occupations. The approach treated expert labels as uncertain. For example, the algorithm disagreed with the training set's label of 'non-automatable' for 'Waiters & Waitresses': the algorithm's judgement has been somewhat borne out by the subsequent use of Ziosk tablets to automate ordering in US restaurants. In a validation exercise, the classifier proved able to accurately predict held-out members of the training set, thereby establishing the results as at least self-consistent.

Frey and Osborne's results suggested that 47% of current US employment was at high risk of automatability. Results also indicated that both highly-paid and highly-educated workers were more resistant to automatability, as were occupations requiring high originality.

Although there already existed a wealth of research on automation prior to Dr Frey and Prof. Osborne's study, the existing literature was inadequate to forecast the impact of new technological trends, which might lead to the automation of non-routine tasks. In particular, the Frey and Osborne study considered the risk to jobs of recent developments in engineering science, particularly within Machine Learning, Computer Vision and Mobile Robotics. This assessment was built on the expertise of Osborne within Machine Learning.

3. References to the research

Publications

[R1] Frey, C., Osborne, M. "The Future of Employment: How susceptible are jobs to computerisation?". <https://www.oxfordmartin.ox.ac.uk/downloads/academic/future-of-employment.pdf> (Working Paper) (Sept. 2013)

[R2] Frey, C., Osborne, M. "The future of employment: How susceptible are jobs to computerisation?", *Technological Forecasting and Social Change*, Volume 114, pp. 254-280, (2017) doi: 10.1016/j.techfore.2016.08.019. Cited 7,625 times as of 22 August 2020. (Journal article)

4. Details of the impact

Frey and Osborne's working paper in 2013 [R1] had immediate impact on public perceptions; its subsequent publication in *Technological Forecasting and Social Change* in 2017 (with only minor changes) [R2] only cemented this impact. The significance of the paper is underlined by how it has shaped the debate. Since publication it has repeatedly been featured in most major media outlets around the globe, becoming high-profile even before being formalised into a published paper, including in: The Economist (**cover feature**, 2018), the Guardian (2017), The Times (2017), Huffington Post (2017), Foreign Affairs (2015), and Nature (2018). [S1]

In 2015, to improve public understanding of automation, Frey and Osborne worked with the BBC to develop the "Will a robot take your job?" web tool. This tool allows users to select their occupation to learn more about its exposure to automation. The tool relied on the estimates from [R1], supplemented by figures on UK job numbers and average wages from the Office of National Statistics and Deloitte UK. The BBC site has had significant impact on informing the public about the issue of automation of work. On the site's first day of going live, it received 1,300,000 views, which increased to 2,000,000 views within a week; the BBC regarded this as "a really big success". Further demonstrating the impact on informing the public, on the day of release, traffic via social media made up 200,000 page views, with the metrics showing the page was being shared and engaged with by members of the public via their personal accounts, not just via the BBC social media. The interactive was also publicized on websites, such as IFLScience and Business Insider, further disseminating information. [S2]

Unlike the existing literature, the research by Frey and Osborne drew the attention of policymakers by providing quantitative, actionable information. It has offered policymakers a valuable methodology regarding i) the potential scope of automation; ii) the types of skills that the educational system needs to provide in response; iii) a framework for understanding some of the impacts of new technologies on labour markets going forward.

Frey and Osborne's methodology has subsequently been cited and used by governments in open discussions about automation and creating policies regarding the future of work, thereby enhancing state capability. Examples are listed below.

- "Good Work: the Taylor Review of modern working practices" was commissioned by Prime Minister Theresa May in 2017 and was the first review of its kind internationally. The review had a designated section regarding automation in the UK and explicitly cited Frey and Osborne's work [R1]; the review highlighted the resurfacing discussions on the automation of work and recommended that automation in UK labour should be an area to watch. Using Frey and Osborne's data the report recognizes that the rapid pace of change around automation and machine learning means that the next step for UK policy makers regarding their labour force is to ensure they are ..."equipped for a modern labour market" and prepared for new jobs that are being created through automation, or prepared for roles requiring skills that are more difficult to automate, such as non-cognitive skills. The Taylor Review guided the writing of the subsequent "Good Work Plan", published in 2018, which set out the UK Government's vision for the future of the UK Labour Market. [S3]
- The approach was also employed by President Obama's Council of Economic Advisors (CEA) to examine the potential impact of automation on U.S. income distribution; the CEA cited Frey and Osborne's paper [R1] and engaged with their research to "better understand the relationship between automation and wages at the occupational level, CEA matched an occupation's median hourly wage to the occupational automation scores from Frey and Osborne (2013)" [S4]. "These data demonstrate the need for a robust training and education agenda, to ensure that displaced workers are able to quickly and smoothly move into new jobs" [S4]. The Executive Office of the President (EOP) further built upon the CEA's suggestions and used Frey and Osborne's work to better understand the effects of AI on the work market. Their conclusions recognize that: "AI-driven automation stands to transform the economy over the coming years and decades. The challenge for policymakers will be to update, strengthen, and adapt policies to respond to the economic effects of AI." EOP proposed three strategies to strengthen the economy and prepare for the shifts that may arise as a result of AI in the future of work: "1. Invest in and develop AI for its many benefits; 2. Educate and train Americans for jobs of the future; and 3. Aid workers in the transition and empower workers to ensure broadly shared growth." [S4].
- The German Bundesministerium für Arbeit und Soziales (Federal Ministry of Labour and Social Affairs) has also engaged with and expanded upon Frey and Osborne's work, by applying the study to Germany and its labour force. The German study takes the research further and looks at individual employees' activities, not just their professions as a whole. The study calculates the probability of automation and job losses, but also explores the potential new jobs automation can create. The German Federal Minister Andrea Nahles' White Paper "Work 4.0" (2016) cited both Frey and Osborne's research and the more detailed Bundesministerium für Arbeit und Soziales study to answer questions raised by an earlier Green Paper regarding work in the age of digital and societal change. Nahles presents several scenarios based on long-term forecasts, but in all cases, much as in Britain and the US, upskilling labourers to safeguard employment forms a critical aim. [S5]

Frey and Osborne's work has been cited and has acted as a catalyst in the discussion around automation in major national and international policy reports, and by international organizations and think tanks.

- The 2017 "World Trade Report", the flagship report of the World Trade Organization, used the research to demonstrate the prospects of automation in the US. The report noted that Frey and Osborne's methodology had since been replicated by consultancy firms and

academics around the world providing analysis for automation on work in European countries, Australia, Canada, Japan, and New Zealand. [S6]

- The World Bank's "Development Report 2016" extended Frey and Osborne's analysis combining it with other extensive datasets to model the probabilities of work automation in different countries. Through this analysis, the World Bank showed that two-thirds of jobs in developing countries are also susceptible to automation, although the effects are moderated by lower wages and slower technology adoption. [S7]
- The International Monetary Fund's report "Technology and the Future of Work" (2018) uses Frey and Osborne's work and combines the findings with other leading works in the field to calculate the levels of automation using scenarios based around "substitutability" in labour. [S8]

The legacy of Frey and Osborne's work is that it was the first study to use AI and machine-learning to quantitatively examine the future automation potential of jobs, and kindled further research and discussion. According to the World Trade Organization Frey and Osborne's work "...reignited the debate about the new wave of technologies, in particular automation...". [S6] It has formed the basis for organizations to build upon the research, extending its impact to new groups, including the following:

- The OECD's "The Risk of Automation for Jobs In OECD Countries (2016)" furthered Frey and Osborne's work and examined individual jobs in OECD countries, rather than taking an occupation-level approach. The OECD concluded that low-qualified workers bore the brunt of adjustment to automation. [S9]
- The Bank of England built upon Frey and Osborne's work; their Chief Economist reported in a 2015 speech that, using Frey and Osborne's methodology, they had conducted their own extended exercise to estimate the potential impacts of automation on the UK and US labour markets, and estimated up to 15 million and 80 million jobs at risk of automation, respectively. [S10]
- McKinsey and Company used Frey and Osborne's research to form a part of their ongoing research into the future of work, analyzing the automation potential of the global economy, and concluded that 5% of occupations can be fully automated, while about 60% of jobs have at least 30% of activities that can technically be automated. This triggered a follow-up study which looked into the workforce transitions expected from automation and their implications for new employment opportunities. [S11]

As a result of the impact of the paper by Frey and Osborne, their activities also extend to providing evidence and acting as specialist advisors to policymakers in parliamentary committees and round-table discussions. For example:

- In 2016 Prof. Osborne was invited to provide oral evidence for the House of Commons Science and Technology Committee which was factored into their report on "Robotics and Artificial Intelligence" in 2016. The report investigated the potential value and capabilities of robotics and AI, as well as giving the Committee's perspective on problems and consequences that may require prevention, mitigation and governance. In particular Osborne's research and specialism in machine learning resulted in his contribution to section "2. Economic and social implications" of AI, highlighting the susceptibility of jobs in the UK. Whilst restating what his research had discovered, Osborne also voiced his concerns that in the long term even creative jobs may be at risk with the rapid rate of algorithms being developed, and that new occupations "might not be sufficiently well paid to substitute for those that are automated away [...] which might lead to exacerbation of inequality". The recommendations published were based around the transition and the new opportunities AI would offer, but also the potential losses in occupations. Osborne's research assisted the committee in recommending that the UK Government should commit to a Digital Strategy aimed to arm the nation with the ability to "...to re-skill, and up-skill, on a continuing basis [...] a standing Commission on Artificial Intelligence be established, based at the Alan Turing Institute, to examine the social, ethical and legal implications of recent and potential developments in AI [...] and the government should establish a Robotics and Autonomous Systems Leadership Council [...]". [S12]
- In 2016 Prof. Osborne attended roundtable discussions and acted as a specialist advisor

to inform Governmental policymakers on automation, its adoption and legal and ethical considerations, resulting in two reports citing Osborne and Frey: Professor Sir Charles Bean's "Independent Review of UK Economic Statistics" and Sir Mark Walport's (at the time, Chief Scientific Adviser to the UK Government) "Artificial intelligence: opportunities and implications for the future of decision making". [S12]

5. Sources to corroborate the impact

[S1] Portfolio of media coverage of Osborne and Frey's research, including: The Economist (**cover feature** (2018)), the Guardian (2017), The Times (2017), Huffington Post (2017), Foreign Affairs (2015), and Nature (2018)

[S2] Email correspondence with BBC colleague confirming the usage statistics of the website "Will a robot take your job?" (<https://www.bbc.co.uk/news/technology-34066941>) demonstrating the level of engagement from the public

[S3] UK Governmental policy documents demonstrating Osborne and Frey's research informing policy via being referenced in **a)** *Good Work: The Taylor Review of Modern Working Practices* (2017) which went to inform the **b)** *Good Work Plan* (2018)

[S4] **a)** Obama Administration's U.S. Council of Economic Advisers (CEA) annual report evidencing Osborne and Frey's research influencing the 2014 Acts introduced to prepare young people's skills for the future of work (2016) pp238-239 and **b)** the Executive Office of the President (EOP) report *Artificial Intelligence, Automation, and the Economy* using the CEA study and Frey and Osborne's data to further suggest strategies to prepare workers for automation pp13-25 (2016)

[S5] **a)** Bonin, et al, *Übertragung der Studie von Frey/Osborne (2013) auf Deutschland*, ZEW Kurzepertise, showing how the Federal Ministry of Labour and Social Affairs engaged with and built upon Frey and Osborne's research (2015) and **b)** White Paper demonstrating that Frey and Osborne's research was utilised by German Federal Minister of Labour and Social Affairs, Andrea Nahles, regarding automation's effect in Germany (2016)

[S6] World Trade Organization report *Trade, Technology and Jobs* (2017) using Frey and Osborne's work to demonstrate the prospects of automation on the US and noting how widely the methodology has been replicated for other countries

[S7] A World Bank report evidencing that Frey and Osborne's work has been built upon by The World Bank, extending the study to developing countries and how they are affected (2016)

[S8] International Monetary Fund report *Technology and the Future of Work* (2018) using Frey and Osborne's work to calculate levels of automation based around scenarios

[S9] OECD Working Paper *The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis* (2016) in which Frey and Osborne's work was expanded by the OECD, extending the study to individual jobs (2016)

[S10] A speech by the Chief Economist, Bank of England, to the TUC evidencing that Frey and Osborne's work has been expanded by the Bank of England using statistics from a Bank of England UK-US study (2015)

[S11] McKinsey Global Institute's two reports evidencing Frey and Osborne's research **a)** *A Future that Works: Automation, Employment, and Productivity* (Jan 2017) which led to a follow up study **b)** *Jobs Lost, Jobs Gained: Workforce Transitions in a Time of Automation* (Dec 2017)

[S12] Evidence of Prof. Osborne's contribution to Parliamentary Committees and roundtable discussions informing governmental reports: **a)** oral evidence given to the House of Commons Science and Technology Committee, subsequently published as the House of Commons Science and Technology Committee report on Robotics and Artificial Intelligence, 2016 and **b)** Professor Sir Charles Bean's *Independent Review of UK Economic Statistics* (Annex F: Stakeholder Engagement) and **c)** Sir Mark Walport's (at the time, Chief Scientific Adviser) *Artificial intelligence: opportunities and implications for the future of decision making*