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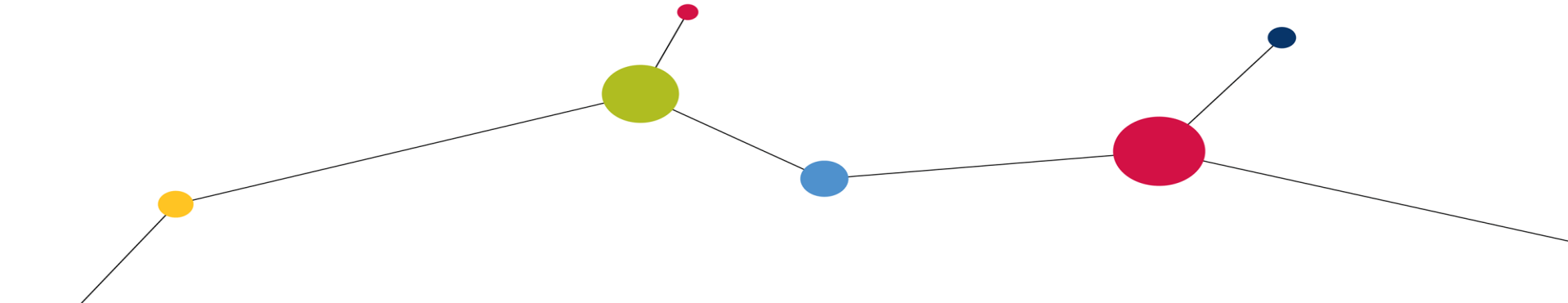
Technology at Work:
The Future of Employment

Carl Benedikt Frey & **Michael A Osborne**



William Lee invented the stocking frame knitting machine in 1589, and approached Queen Elizabeth I for patent protection.

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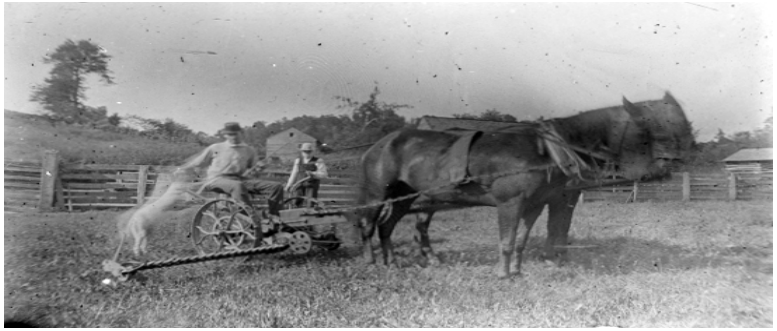
"Consider thou what the invention could do to my poor subjects. It would assuredly bring to them ruin by depriving them of employment, thus making them beggars."

- Queen Elizabeth I

William was forced out of England by the guilds' opposition to his invention.



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In 1900, 40% of US workers were farmers; in 1999, the figure was 2%.

In 1900, unemployment was 5%; in 1999, it was 4.2%.

Will new technologies threaten the historical pattern of employment resisting technological change?

We also consider the question of which jobs are most vulnerable to technological change.

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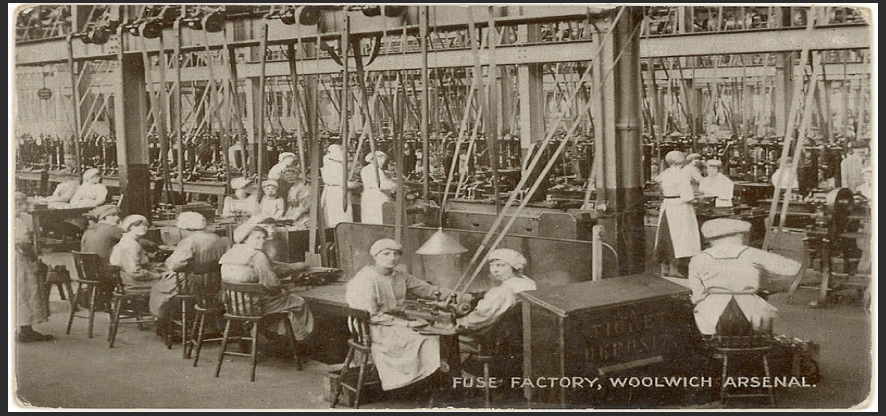

"the idea that technological advances favor more skilled workers is a twentieth-century phenomenon." - Acemoglu (2002a, p. 7)

What's different now? Machine Learning is the study of algorithms that can learn and act.

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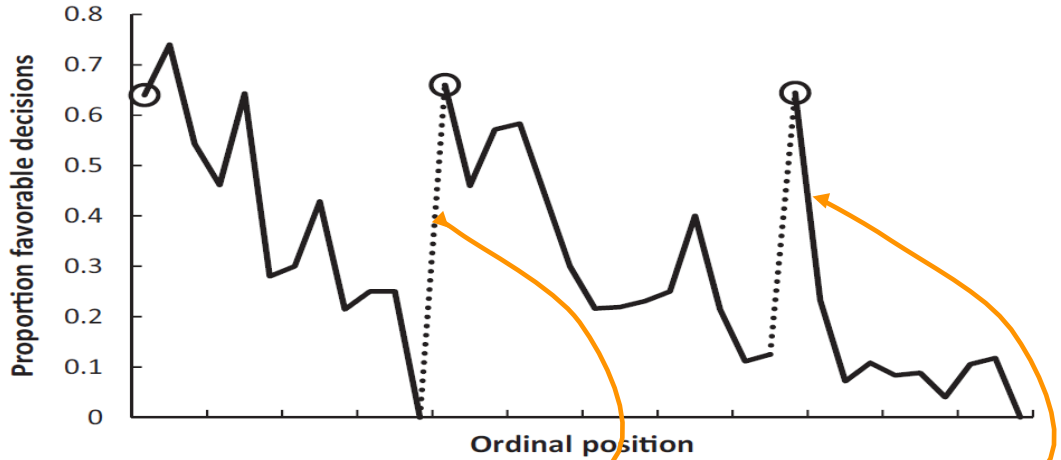

Judges are significantly more lenient after a food break (Danziger et al 2011).

Algorithms are increasingly a cheaper alternative to human work.

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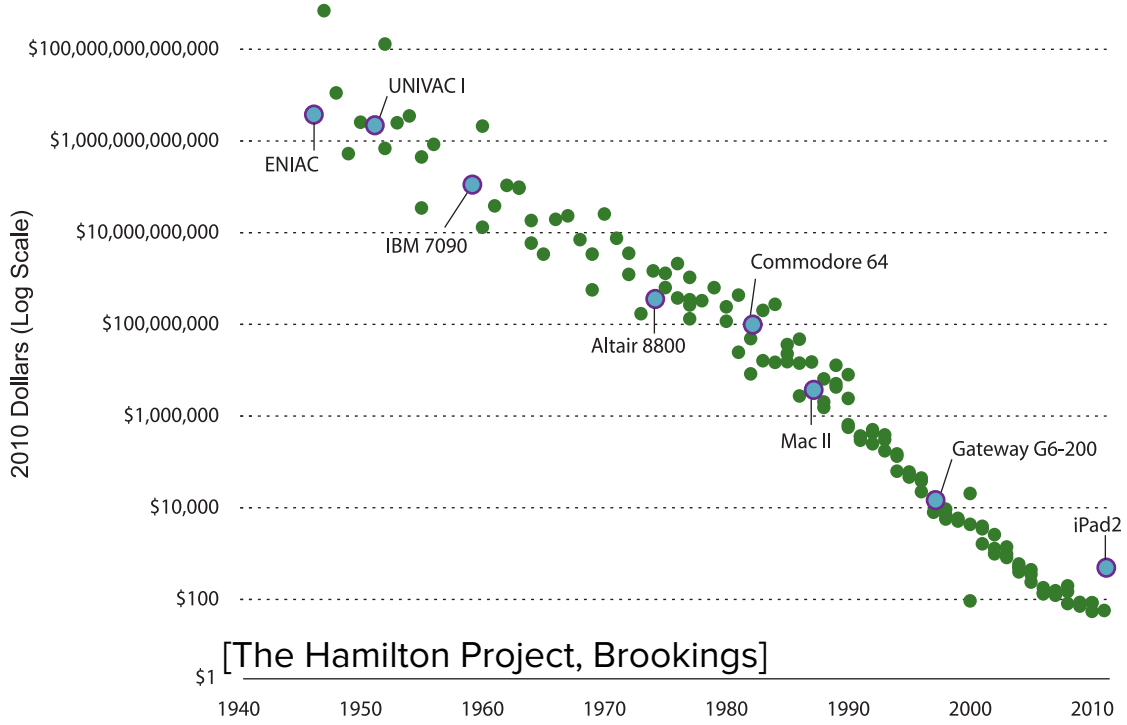

We live in the age of big data.

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All printed material in the world	200 petabytes (2×10^{17} bytes)
All words ever spoken by human beings	5 exabytes (5×10^{18} bytes)
Predicted internet traffic in 2015	960 exabytes (1×10^{21} bytes)

Source: UC Berkeley School of Information, 2003; Cisco Visual Networking Index, 2011

Big data is leading to algorithms for increasingly sophisticated tasks, including translation.

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Google Translate

Break through language barriers.

Retail and sales jobs will be increasingly affected by automation.

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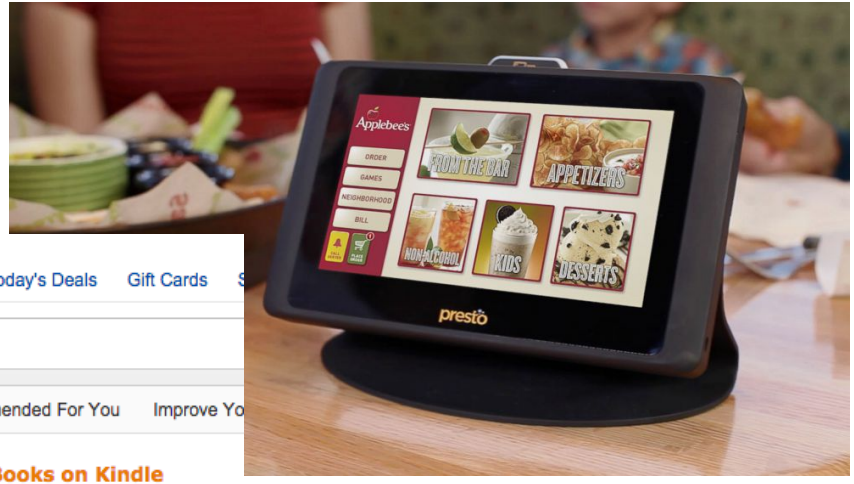

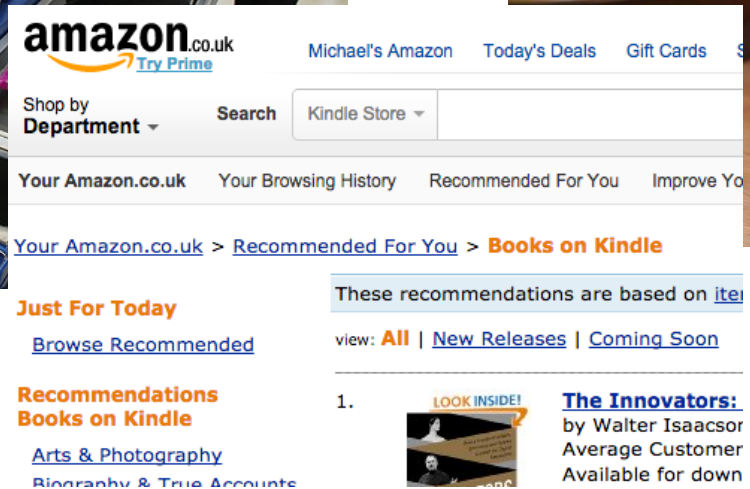

Levy and Murnane (2004): *"it is hard to imagine discovering the set of rules that can replicate a driver's behaviour".*

In 2012, Nevada issued a driving license to a fully autonomous Google car.

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The automation of mass-market cars just requires the right algorithm.

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```
module GPyFITC
import PyCall
PyCall.@pyimport GPy
export FITCModel, observe!, infer!, predict
type FITCModel
    model
    n::Int
    X::Array{Float64, 2}
    y::Array{Float64, 1}
end
function FITCModel(lb, ub, n=10)
    u = linspace(lb, ub, n)
end

function observe!(m::FITCModel, X, y)
    if size(m.X) == (0,0)
        m.X = X
        m.y = y
    else
        m.X = vcat(m.X, X)
        m.y = vcat(m.y, y)
    end
    n = size(m.X, 1)
    m.model = GPy.models[:SparseGPRegression](m.X, reshape(m.y, (n, 1)),
        num_inducing=m.n)
end

function infer!(m::FITCModel)
    m.model[:constrain_positive](" ")
    m.model[:optimize]("tnc", max_f_eval=1000)
end

function predict(m::FITCModel, Xp)
    mean, variance = m.model[:predict](Xp)
    variance = max(variance, 0)
    mean, variance
end
end
```

Cars will be recording their environment constantly, having consequences for insurance, law, and meteor detection.

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Many logistics tasks are now being automated with the use of machine learning and mobile robotics technologies.

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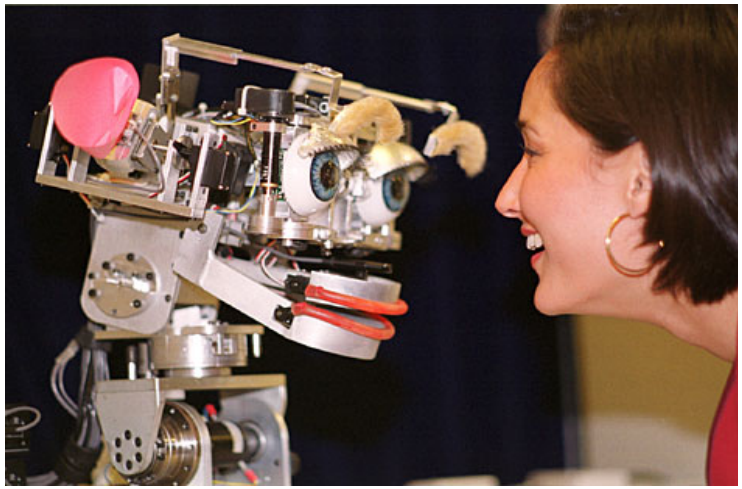
So, if machines can drive, serve customers, and look through data, for what are humans still good? In short,

creativity



and social intelligence.

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Autonomous manipulation is also hard, largely due to the difficulties involved in perception.

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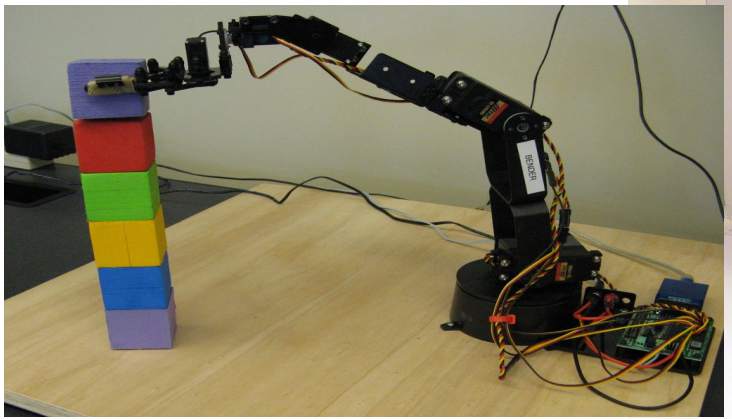

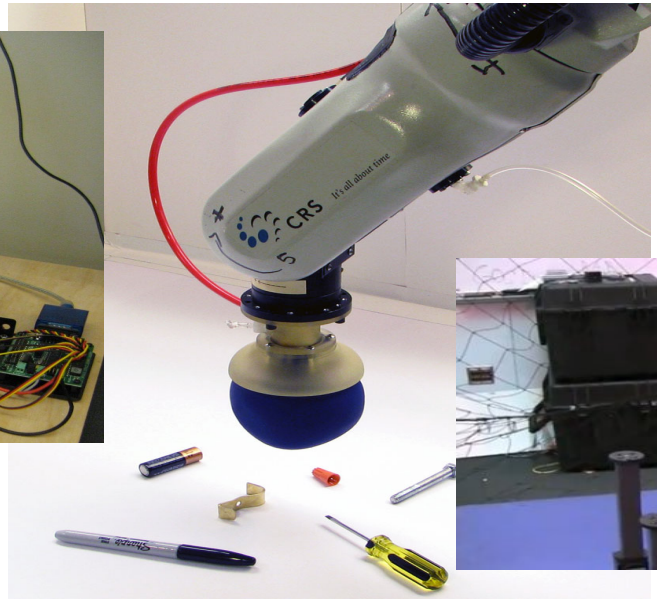

Precisely, manipulation in unstructured environments is difficult to automate.

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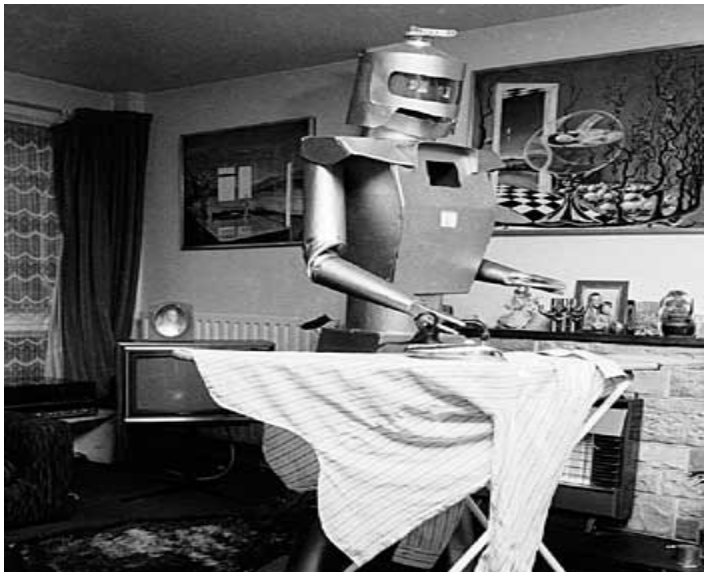
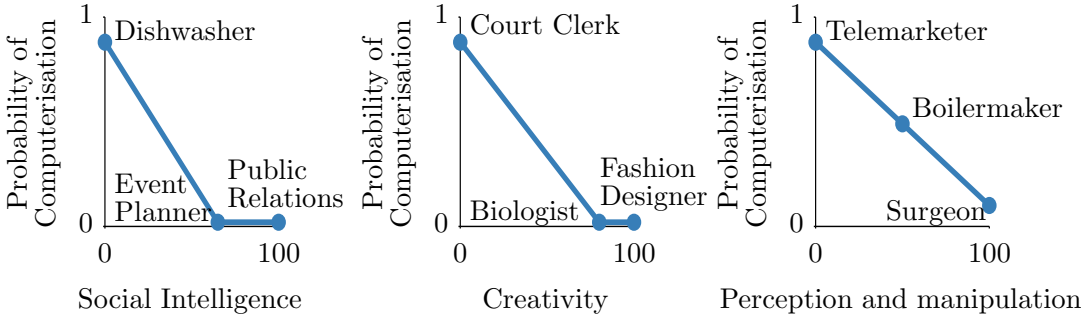
amazon.com



We expect social intelligence, creativity and perception to be bottlenecks to computerisation.



We used a dataset of 702 occupations, giving job features (e.g. requirements for finger dexterity and persuasion) to predict automatability by 2030.

Occupation	Label	Probability
Data Entry Keyers	1	0.99
Tax Preparers		0.99
Umpires and Referees		0.98
Industrial Truck Operators	1	0.94
Waiters and waitresses	0	0.94
Slaughterers		0.60
Economists	0	0.43
Funeral Attendants		0.37
Clergy	0	0.01
Choreographers		0.00

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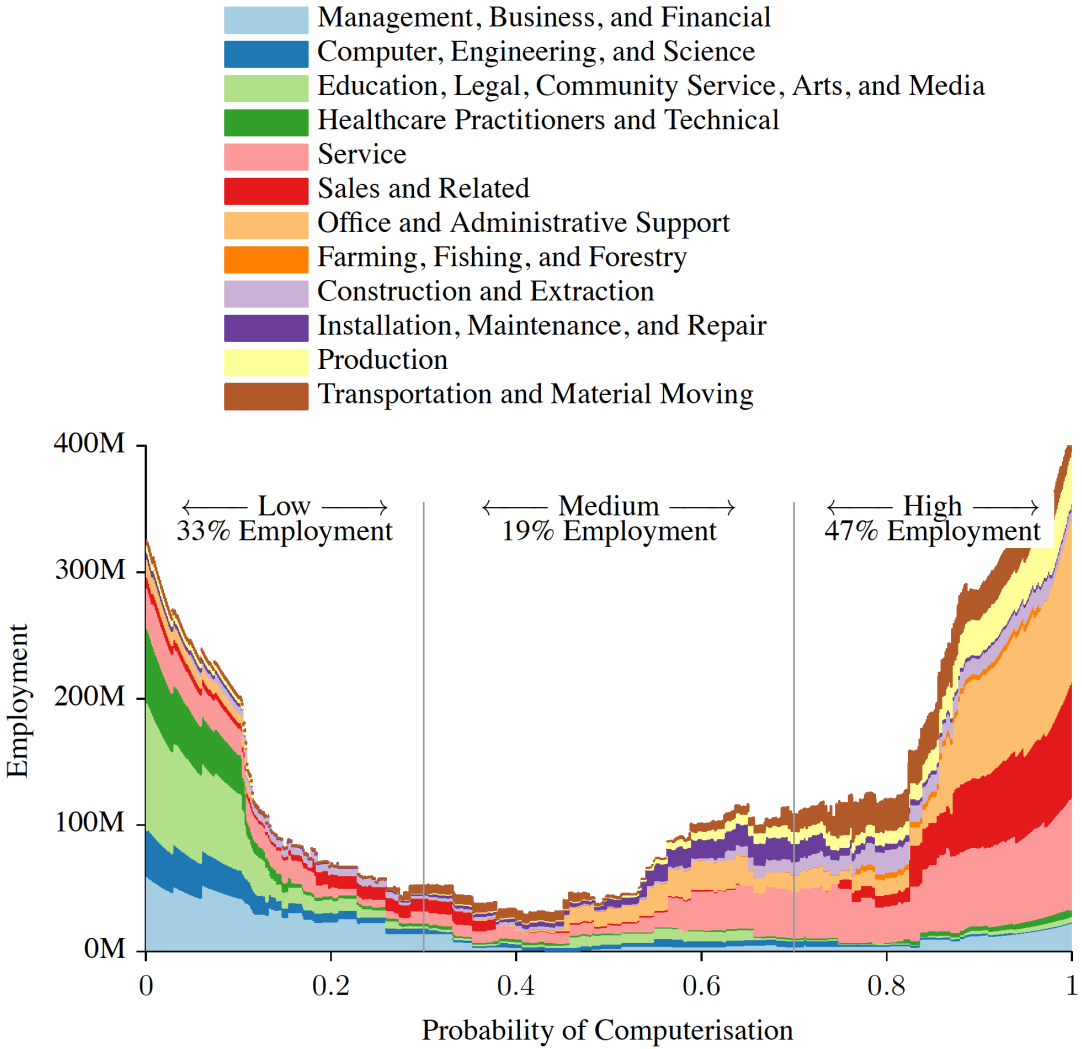

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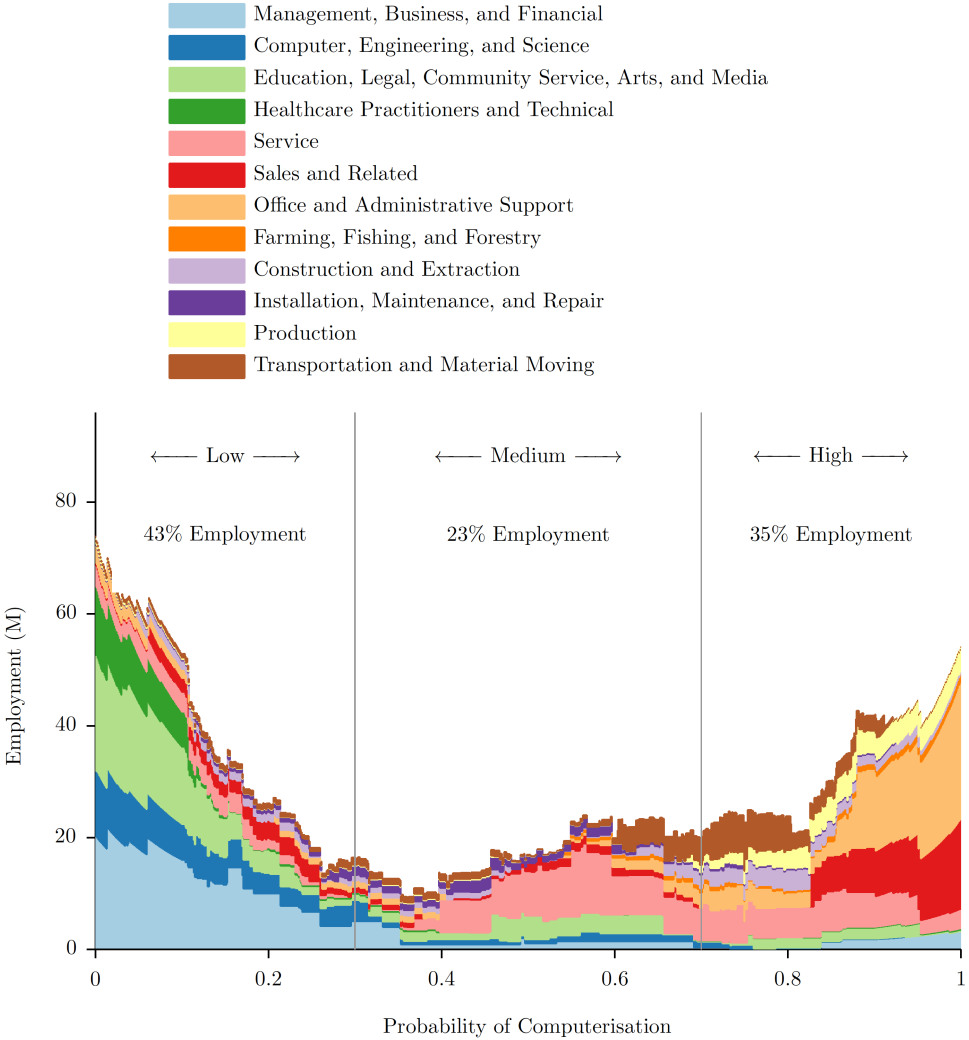
USA

UK



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We find creative jobs to be non-automatable.

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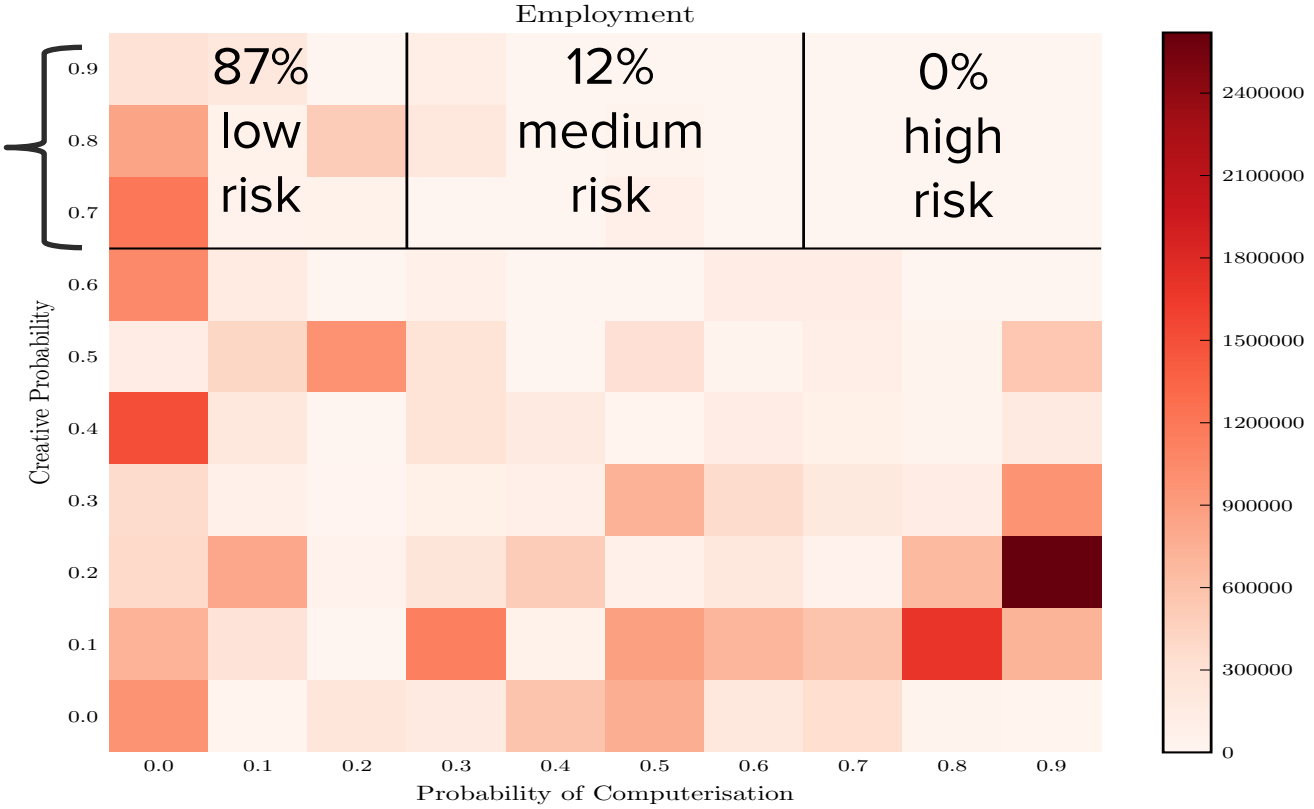
Creative jobs



Some industries are at high risk.

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	Low Risk (%)	Medium Risk (%)	High Risk (%)
Accommodation & Food Services	2.8%	10.5%	86.7%
Administrative & Support Services	1.6%	36.2%	62.2%
Agriculture, Forestry, Fishing & Hunting	75.6%	12.0%	12.3%
Arts, Entertainment & Recreation	47.9%	12.5%	39.6%
Construction	21.6%	19.8%	58.6%
Educational Services	63.1%	19.7%	17.2%
Finance & Insurance	28.9%	17.3%	53.7%
Government	46.2%	30.6%	23.2%
Health Care & Social Assistance	39.4%	25.0%	35.6%
Information	51.6%	38.3%	10.1%
Management of Companies & Enterprises	82.8%	6.2%	11.0%
Manufacturing	19.9%	18.4%	61.7%
Mining, Quarrying and Oil & Gas Extraction	7.8%	46.3%	45.9%
Other Services (ex Public Admin)	44.9%	24.7%	30.4%
Professional, Scientific & Technical Services	54.0%	10.9%	35.1%
Real Estate and Rental & Leasing	0.7%	32.0%	67.2%
Retail Trade	14.5%	18.9%	66.6%
Self-Employed	60.4%	8.9%	30.7%
Transportation & Warehousing	5.5%	19.4%	75.0%
Utilities	40.3%	27.8%	31.9%
Wholesale Trade	15.9%	18.4%	65.7%

Source: Oxford Martin School

We predict that high-skilled jobs are relatively resistant to computerisation.

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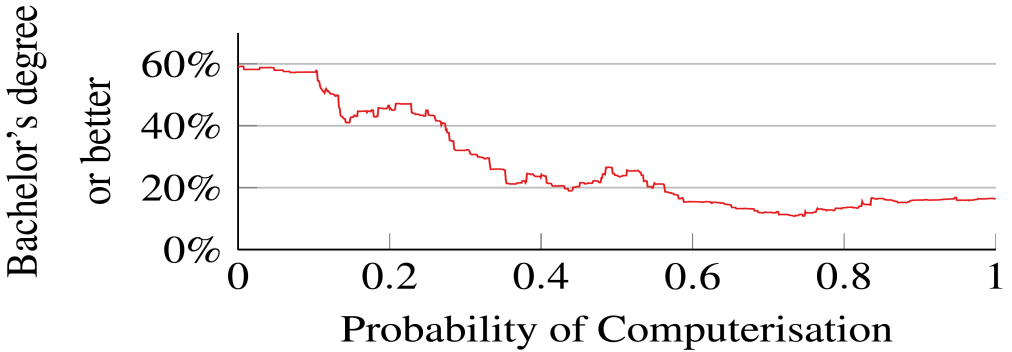

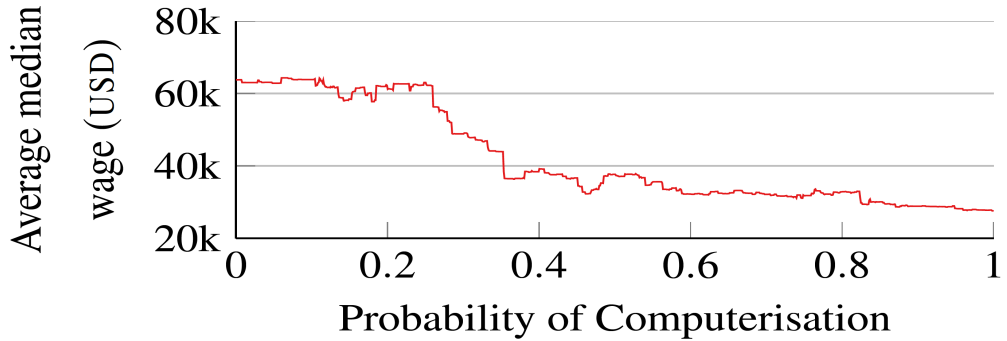

New jobs are being created.

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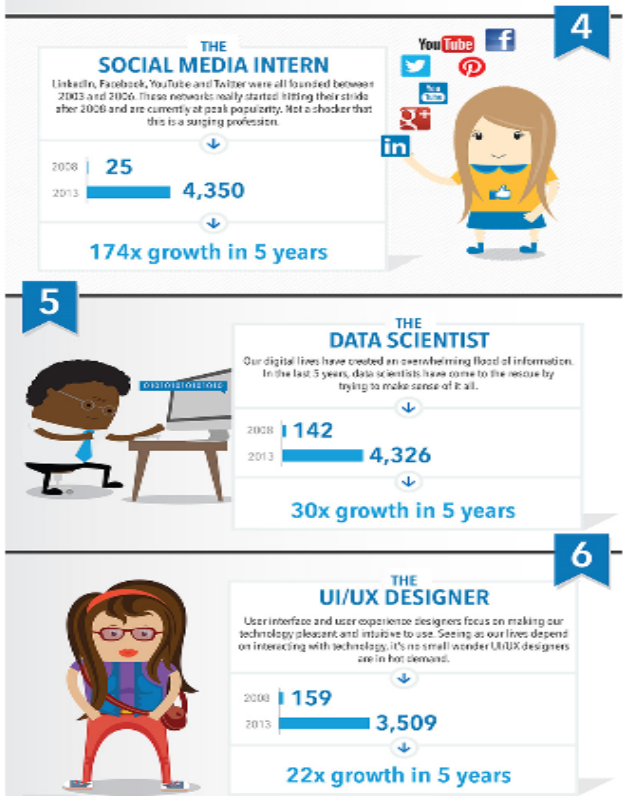

Source: LinkedIn

New jobs are being created.

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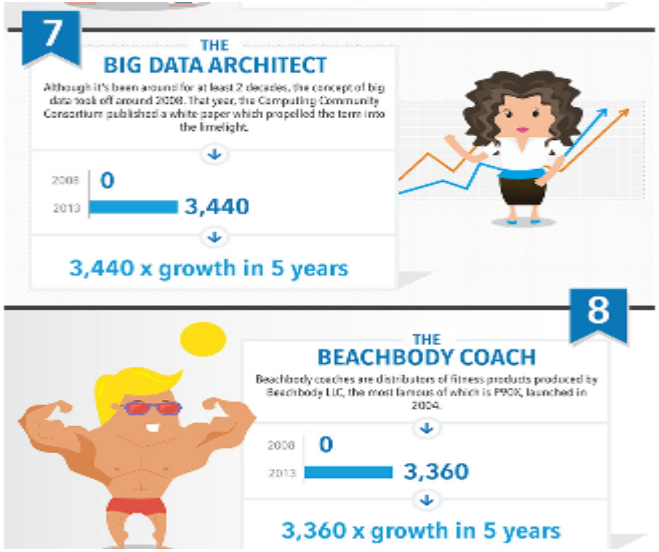

Source: LinkedIn

New industries have emerged.

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Detailed industry	% of US Employment	% with college degree	Avg. Wages ($)
Internet publishing and broadcasting	0.06	69.6	81,138
Electronic shopping	0.08	49.7	45,372
Data processing, hosting, and related services	0.08	48.0	64,729
Electronic auctions	0.01	52.2	47,257

Only 0.5% of the US workforce is employed in new industries created in the 21st century.

Source: Berger & Frey (2014)

Investment in skills and new job creation is essential for the long-run.

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Emerging occupations	Description	Current US employment	Projected new jobs by 2022
Wind energy engineers	Design underground or overhead wind farm collector systems	133,000	29,500
Solar energy installation managers	Direct work crews installing solar photovoltaic	546,000	187,100
Nanotechnology engineers	Implement production processes for nanoscale designs to produce or modify materials, devices, or systems	68,000	14,600
Informatics nurse specialists	Apply knowledge of nursing to assist in the design of computerized health care systems	521,000	209,600

Source: O*Net & BLS

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