Occupational Trends and the Future of Work

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All views expressed in this paper are those of the author and do not necessarily reflect the views or policies of the U.S. Bureau of Labor Statistics.

Will artificial intelligence and robots cause massive job loss/disruption?

Unprecedented rate of technological advance?

Current wave ≠ prior waves?

The AI Revolution

2004: First DARPA Grand Challenge, 0 driverless cars complete race

2005: Second race, 5 driverless cars complete 132-mile, off-road course

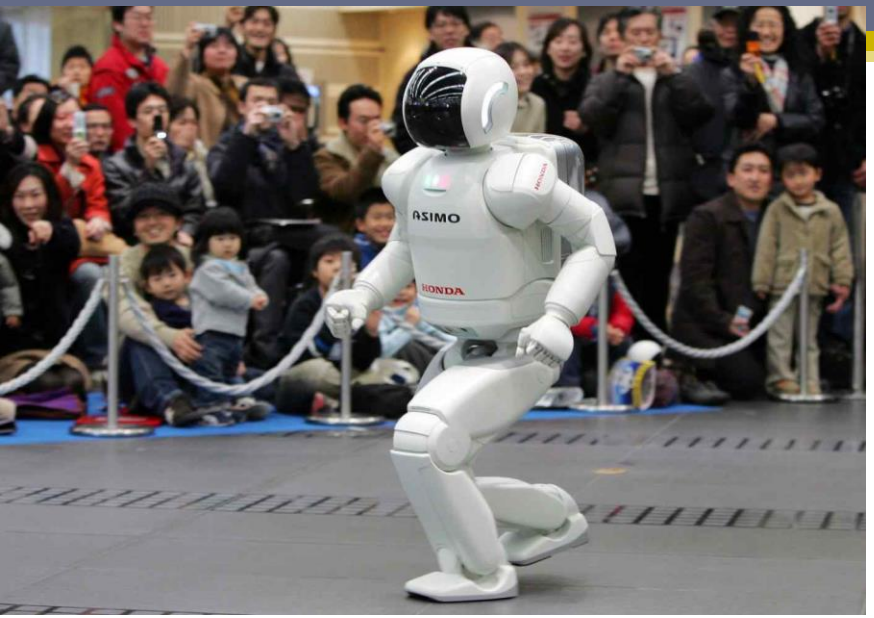
Winner used machine learning (ML), not hand-coded rules (*if-then*)

Pattern recognition algorithms → remarkable series of AI breakthroughs

- **Image recognition**
- **Machine vision**
- **Speech recognition**
- **Natural language processing**
- **New robotics**

Key developments—robots

1. **Honda's humanoid robot ASIMO walks, runs, climbs stairs, serves food, responds to voice commands, navigates complex environments** (2000-on)
2. **BigDog** (2005)**, Cheetah, Atlas, Spot, highly agile field robots from Boston Dynamics**
3. **Roomba vacuum** (2002) **from iRobot**
4. **Baxter factory "co-bot" inexpensive and works safely with humans** (2011)
5. **Robots in warehouses, delivering packages, patrolling malls, checking store shelves for inventory, cleaning floors, laying bricks, sewing garments, cooking food, mowing lawns, fold laundry, assisting surgery**
6. **Autonomous vehicles—cars, taxis, shuttles, minibuses, freight trucks, mining trucks, delivery robots**

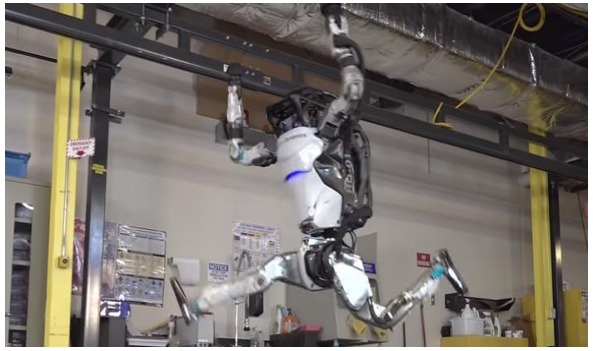


Asimo

Baxter

BigDog (2011)

Cheetah (2015)



Atlas (2020)

"In 2009, robots developed by Boston Dynamics were barely able to walk. In 2019, they were doing gymnastics" (BI, 2020)

Key developments—software

1. IBM Watson beats *Jeopardy!* champion (2011) → healthcare field
2. AlphaGo beats world champion decade before expected (2016)
3. Image recognition error rates fall from 28% in ImageNet competition's first year (2010) to 2% (2017), some surpass humans
4. Machine translation
5. Digital assistants, call center software communicate with humans, answer verbal questions with informed responses
6. Legal document processing
7. Text generation for news stories, press releases

Many surprising, rapid gains after decades of meager progress in AI and robotics—burst of change

Some aimed at skilled white-collar tasks—unlike earlier technology

Abrupt increase in 3 critical inputs:

- **training data** (internet, social media)
- **hardware** (GPUs from video game industry)
- **improved algorithms**

Many concluded we are entering a new era.

Moore's Law + AI → exponential change

"stuff of science fiction" Brynjolfsson and McAfee (2011, 2014)

Mass displacement possible for jobs at all skill levels in near future

Frey and Osborne AI expert panel(2013, 2017)

"…already possible to automate almost any task with sufficient amounts of training data"

47% of U.S. jobs in 2010

"…are potentially automatable over some unspecified number of years, perhaps a decade or two" **[i.e., 2020 or 2030].**

Very influential—press coverage, widely cited and emulated globally

Summary

- Real-world rapid breakthroughs → structural break in job trends?
- Expert judgment on job automatability in near-future (FO)
- Widespread acceptance and replication

Congress notices. Asks BLS:

> "develop a strategy to better understand how automation, digitization, and artificial intelligence are changing the employment landscape" (2018, 2020)

But there are reasons for skepticism….

Reasons for caution

1. Past fears of technological displacement and jobless futures
2. AI's history of large claims/predictions
3. Practical problems and delays
4. Methodological issues with Frey/Osborne study

Past forecasts of mass technological displacement wrong

Era	Years	Issue	Outcome
Great Depression	1930s	Record productivity ↑ (1920s)	Record job market WWII
Mainframe computers, automation	1950-1964	Periods of recession BLS automation studies begin	Boom (1965-69)
Personal computers	1980s	"Jobless recovery" (early 1990s)	Boom (late 1990s)
		End of Work Jeremy Rifkin (1995)	
		The Jobless Future, Aronowitz and DiFazio (1994)	
Financial crisis	2010s	Slow recovery, skills mismatch, automation (Brynjolfsson/McAfee 2011)	Boom (2017-Feb. 2020)

Common mistake: cyclical downturn = new trend in technological change

Solow Commission (1965) and Cyert/Mowery (1987): macro forces > tech.

AI has history of overoptimism and grandiosity

	YEAR	FORECAST
AI founding conference	1956	"significant advance" in machine intelligence over summer
Herbert Simon	1958	Computer will beat #1 chess player in 10 years (actually 40)
Herbert Simon	1960	"machines will do any work" humans can do by 1980 (1985)
Marvin Minsky	1967	AI ≈ human intelligence "within a generation"
Hans Moravec	1988	"general-purpose robot usable in the home within ten years"
Hans Moravec	1988	$1,000 computer = human intelligence by 2030
Shane Legg (Deep Mind)	2009	"roughly human-level AI" around 2028
Pew expert canvas	2013-4	robots/software displace sig. BC and WC workers (48%)
Pew respondent		"AI will pass adult reading comprehension test by 2020"
Elon Musk	2019	"Sometime next year, you'll be able to have the car be autonomous without supervision."

Beyond the hype, some real setbacks and roadblocks

ASIMO discontinued	2018	Little profit after 18 years
Rethink Robotics	2018	Closed, sold assets to German automation group, relaunched
Robot vacuums	2022	Few other household robots after 20 years
Boston Dynamics	--	Robots not autonomous, almost no commercial products
Autonomous vehicles	~2019	Optimism cools
IBM Watson-Health	2022	Leading application, unprofitable, sold off (2022)

"…billed as a 'bet the ranch' move by Big Blue; now the company is prepared to throw in the towel" (WSJ 2021)

"How IBM Watson Overpromised and Underdelivered on AI Health Care" *IEEE Spectrum* (2019)

"IBM pitched its Watson supercomputer as a revolution in cancer care. It's nowhere close" *Stat+* (2017)

Technological change may be more gradual than anticipated

BLS occupational projections

- Conducted since 1960s
- Frey and Osborn data are BLS projections file for 2010-2020
- No sign anyone in debate has consulted them

Claim: New era is an inflection point, change is exponential
Traditional projections irrelevant, too backward-looking

BLS: Technical feasibility alone insufficient to impact projections
Projections do not get ahead of innovation cycle, differs from Frey and Osborne

Projections questioned in past, so their record needs clarification

Absolute job growth

Actual and projected job growth

	Absolute (millions)			Δ (percent growth)		
	Base year	Projected	Actual	Projected	Actual	P-A
Previous						
1978-1990	96.5	125.8	122.9	30.4%	27.4%	3.0%
1984-1995	106.7	122.8	130.0	15.0%	21.8%	-6.8%
1988-2000	118.1	136.2	143.8	15.3%	21.7%	-6.4%
2008-2018	150.9	166.2	161.0	10.1%	6.7%	3.4%
Current						
2019-2029	162.8	168.8	--	3.7%	--	--

Note: P-A = Projected value minus Actual value

Actual + projected 20-year job growth is 12% (2008-2029)

Not -47% → 80 million jobs in 2029

Projected composition of jobs 2019-2029

No structural breaks

Actual and projected occupational distribution, 2019-2029

	Employment		Δ shares
	2019 actual	2029 projected	2019-2029 projected
Managers	12.1%	12.3%	0.2%
Professional, technical	21.5%	22.2%	0.7%
All upper white-collar	***33.6%***	***34.5%***	***0.9%***
Sales	9.5%	9.0%	-0.5%
Admin. support, clerical	12.7%	11.7%	-1.0%
Service	21.4%	22.6%	1.2%
Agriculture	0.7%	0.7%	0.0%
Craft	8.3%	8.3%	0.0%
Production, transport	13.9%	13.4%	-0.5%

Index of dissimilarity (D)	**2019-2029**
1-digit occupation (n=8)	0.0207
Major group (n=22)	0.0214
Detailed occupation (n=790)	0.0299

Performance of projections for 2008-18

Trends in occupational distribution, actual (2008, 2018) and projected (2018)

	1 Actual 2008	2 Projected 2018	3 Actual 2018	4 Δ (proj.)	5 Δ	6 A-P (5-4)
1. Mgt, prof, tech	**31.0**	**32.3**	**33.0**	**1.3**	**2.0**	**0.7**
2. Service	**19.6**	**20.2**	**21.4**	**0.6**	**1.8**	**1.1**
3. Sales, clerical	**26.5**	**25.8**	**24.0**	**-0.7**	**-2.5**	**-1.7**
Sales 41	10.5	10.2	9.8	-0.4	-0.8	-0.4
Office support 43	16.0	15.6	14.3	-0.4	-1.7	-1.3
4. Farm	**0.7**	**0.6**	**0.7**	**-0.1**	**0.0**	**0.1**
5. Craft	**9.0**	**9.1**	**8.3**	**0.1**	**-0.7**	**-0.8**
6. Production	**13.2**	**12.0**	**12.6**	**-1.2**	**-0.6**	**0.6**

Index of Dissimilarity (occupation level)	**Projected 2008-18**	**Actual 2008-18**	**Difference (A-P)**
1-digit (n=6)	0.0199	0.0381	0.0182
Major (n=22)	0.0251	0.0470	0.0219
Detailed (n=770)	0.0349	0.0887	0.0538

Projections and progress report on high-risk jobs

Change in employment shares by automation risk group, 2010-2029 (%)

	Projections 2010-2020 and 2018-2028					Projections 2019-2029		
	A.	B.	C.	D.	E.	F.	G.	H.
	2010	2018 p	2018	Δ P	Δ	2019	2029 p	Δ
All occs								
Low risk	33.3	33.6	33.1	0.3	-0.2	33.4	34.1	0.7
Medium risk	19.4	19.5	19.9	0.1	0.5	21.8	22.4	0.6
High risk	47.4	46.8	47.0	-0.6	-0.4	44.8	43.5	-1.3
Total (%)	**100.0**	**100.0**	**100.0**			**100.0**	**100.0**	
Hand-labeled cases								
Low-Med risk	9.3	9.5	9.5	0.2	0.2	9.3	9.4	0.1
High risk	8.0	7.7	7.9	-0.3	-0.1	8.3	8.0	-0.3

2018 p = projected for 2018 (col. B)
2029 p = projected for 2029 (col. G)

D = B-A projected change, 2010-2018
E = C-A actual change, 2010-2018
H = G-F projected change, 2019-2029

Does the projections account for AI and robotics?

Technology-related drivers of changing occupational staffing patterns, 2019-2029

Category	% of jobs	N
Jobs researched	**59.5**	**298**
General	n.a.	
Capital/labor substitution	13.0	35
Productivity change	20.3	85
Technology	13.1	41
Electronic	2.1	5
Digital	1.2	6
Software	7.0	18
Automation, automatic	16.2	72
Production job automation	**4.3**	**36**
Robots	3.1	18
Programmable	0.6	20
Computer numerical controlled machine tools	0.6	17
Machining software	>0.0	1
Automated guided vehicle	0.7	3
Autonomous vehicle	>0.0	1
Artificial intelligence	**9.7**	**19**
Artificial intelligence	4.9	7
Machine learning	1.3	3
Smart	0.6	5
Chatbots	1.7	3
Language processing	5.2	3
Facial, handwriting, or optical character recognition	4.1	4
Robo-advisors	0.2	1

Yes, staff research uncovers many new and older high-tech drivers

Category	% of jobs	N
Tags and sensors	**2.0**	**4**
RFID	1.8	3
Barcodes	1.7	2
Sensors	1.9	3
Internet	**7.8**	**15**
E-commerce	0.6	1
Electronic shopping industry	2.8	4
Online	4.8	11
Electronic data processing, document management	**11.7**	**16**
Data processing	0.6	2
Electronic filing	1.9	2
Optical character recognition	3.3	2
Robotic process automation	3.3	2
Computer processing	0.1	1
Payment	6.5	4
E-signatures, e-delivery	0.1	1
Mobile apps	3.3	6
Any high technology from above	**31.3**	**118**
Self-service	**4.8**	**3**
Self-service	2.6	2
Self-checkout	2.2	1
Mechanical technology	**0.6**	**6**
Machines	1.1	23
Mechanize	0.6	5
Restructuring	0.3	
Outsourcing	2.9	8
Offshoring	0.2	3

Note: Categories are not mutually exclusive, and occupations may be represented by several indicators. The category "Any above high technology" excludes the generic keywords "Capital/labor substitution," "Productivity change," and "technology."

…they just affect fewer jobs and occupations than one might think

Projected to decline to 29.9% by 2029 (-1.4 pp)

Summary of BLS projections

1. **No structural break for 2019-2029**
   - **total number of jobs**
   - **occupational composition**
   - **skill and task content**
   - **Gradual changes, continuity with prior trends**
2. **Even accounting for new technologies** (AI, robotics)
   - **impacts smaller than often assumed**
3. **Projections reasonably accurate in first half of FO interval—did a better job than FO of predicting 8-year employment paths of their risk groups**
   A. **High-risk jobs likely to decline 2-4 percentage points 2010-2030**
   B. **Validity of FO scores widely taken for granted, but questionable**
   C. **Macroeconomy will be more influential for employment in 2030**