# Robots and the origin of their labour-saving impact

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# Outline

# Motivation

- the impact of automation upon employment has become a major topic of discussion both in policy and academic debate

**Brynjolfsson and McAfee (2011, 2014)** the root of current unemployment is not the Great Recession, but rather a 'Great Restructuring' characterised by an exponential growth in computers' processing power having an ever-bigger impact on jobs, skills, and the whole economy (*"This time is different"*)

**Frey and Osborne (2017)** 47% of the occupational categories are at high risk of being automated, including services and highly cognitive jobs

# Motivation (cont'd)

> *"Automated systems, such as robotic systems, are used in a variety of industries to* ***reduce labo[u]r costs and/or increase productivity****. Additionally, the use of human operators can involve increased cost relative to automated systems."* [US20170178485A1]

> *"The use of [robotic] technology results in improved management of information, services, and data, increased efficiency, significant reduction of time,* ***decreased manpower requirements****, and substantial cost savings."* [US2010022313 4A1]

# Our contribution

- we use natural language processing and probabilistic topic modelling techniques on the universe of 2009–2018 patent applications at USPTO, matched with ORBIS (BvD)
- we investigate the presence of explicit labour-saving heuristics among robotic patents
- we include not only patents entailing robotic artefacts as a *product* but also as *process* and complementary technology
- we analyse innovative actors engaged in robotic technology and their economic environment (identity, location, industry)
- we identify the technological fields that are particularly exposed to labour-saving innovations
- we pinpoint the technological bottlenecks underlying the search efforts inspiring robotics inventors

# Outline

# Original data

- universe of USPTO patent applications from 1st January 2009 to 31st December 2018
- 3,557,435 full-text applications (hereafter, patents)

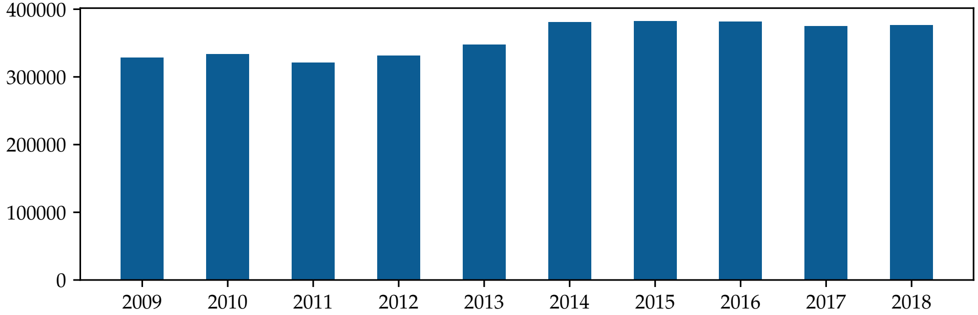



Figure: # of patents by year

# Robotic patents

- identification of robotics[-related] patents
  1. via CPC codes
     - USPTO concordance table with USPC class 901
     - purely robotic technology
     - 10,929 `‘CPC’` patents
  2. via keyword search
     - multiple occurrence ($\times 10$) of morphological root *‘robot’*
     - process implementation and complementary technology
     - 18,860 `‘K10’` patents (once those already in 1 have been discarded)
- 29,789 total robotic patents

# Robotic patents (cont'd)

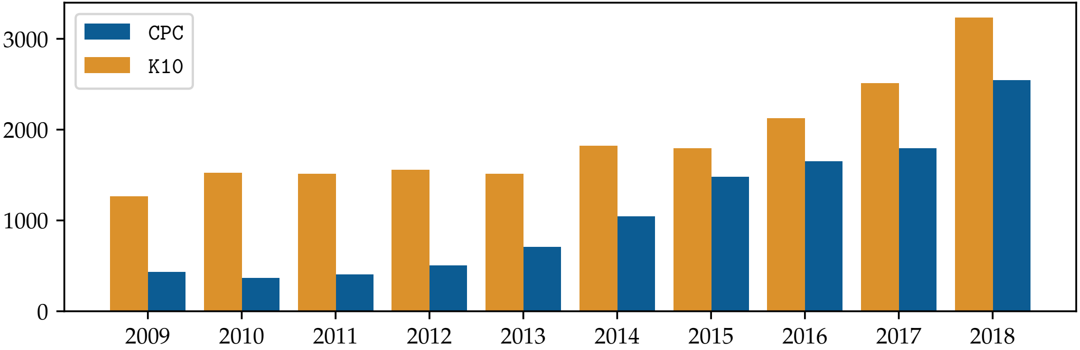



Figure: # of **robotic** patents by year

# Text preprocessing

## tokenisation

- each patent textual body is divided into *sentences* by means of a punctuation regexp
- patent text $\Longrightarrow$ list of sentences
- sentence $\Longrightarrow$ list of words

## stemming

- each word in each sentence is reduced to its morphological root with the Porter2 stemming algorithm (an improved version of the original Porter (1980) algorithm)
- patent text $\Longrightarrow$ list of lists of stemmed words

- identification of labour-saving (LS) patents by means of a word-level text query per sentence

# Labour-saving patents

$$
\underbrace{\begin{bmatrix} \text{`reduc'} \\ \text{`replac'} \\ \text{`elimin'} \\ \text{`save'} \\ \text{`lower'} \\ \text{`substitut'} \\ \text{`autom'} \end{bmatrix}}_{\text{verbal predicate}} \times \underbrace{\begin{bmatrix} \text{`labor'} \\ \text{`worker'} \\ \text{`human'} \\ \text{`employe'} \\ \text{`manpow'} \\ \text{`job'} \end{bmatrix}}_{\text{direct object}} \times \underbrace{\begin{bmatrix} \text{`cost'} \\ \text{`expenditure'} \\ \text{`expens'} \\ \text{`hour'} \\ \text{`intens'} \\ \text{`task'} \\ \text{`time'} \\ \text{`skill'} \end{bmatrix}}_{\text{object attribute}}
$$

- 336 combinations of triplets (**not** *trigrams*, as we do not require adjacency)
- a patent is flagged as *potentially* LS if contains at least one triplet within a sentence
- 1,666 potentially LS patents

# Labour-saving patents (cont'd)

- all matched sentences are manually examined and flagged as *explicitly* LS if appropriate
- 1,276 explicitly LS patents ($\approx$ 77% of potentially LS; $\approx$ 4.3% of robotic patents)
- of which 461 ($\approx$ 36.1%) are `CPC` and 815 ($\approx$ 63.9%) are `K10`

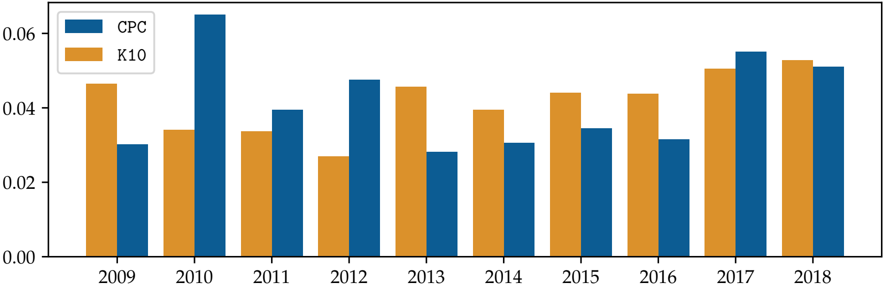


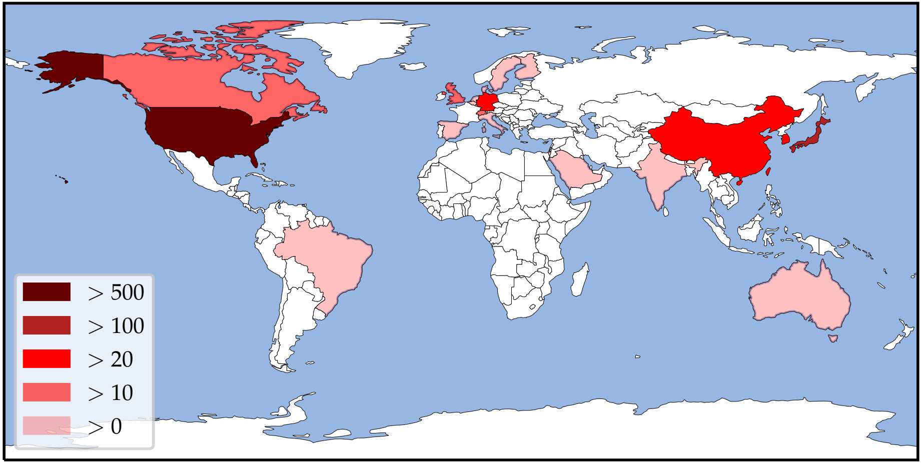

Figure: Fraction of **explicitly** LS patents over **robotic** patents by year

# Firm level match

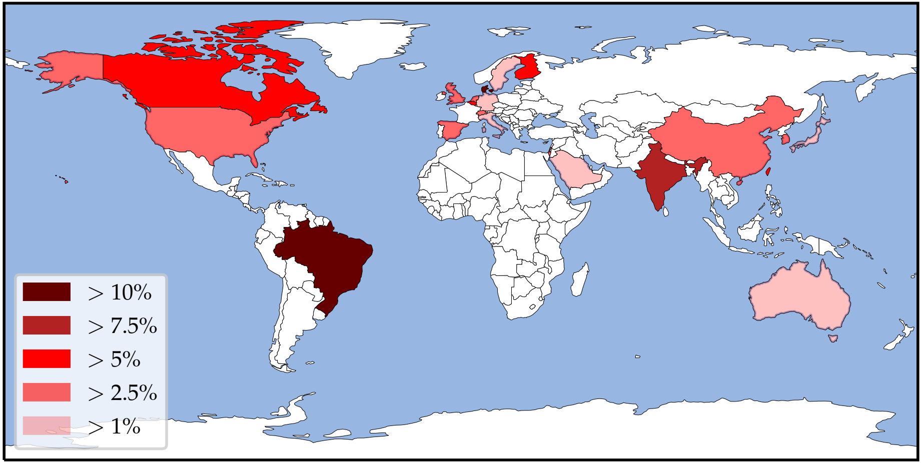
- LS patents are matched to their assignee via ORBIS (BvD)
- number reduces to 1,136 ($\approx$ 89%) due to truncation on 31st July 2018 (140 discarded)
- of these, 903 ($\approx$ 79%) are matched to at least one firm (233 find no match)
- there are 408 LS firms in total

# Outline

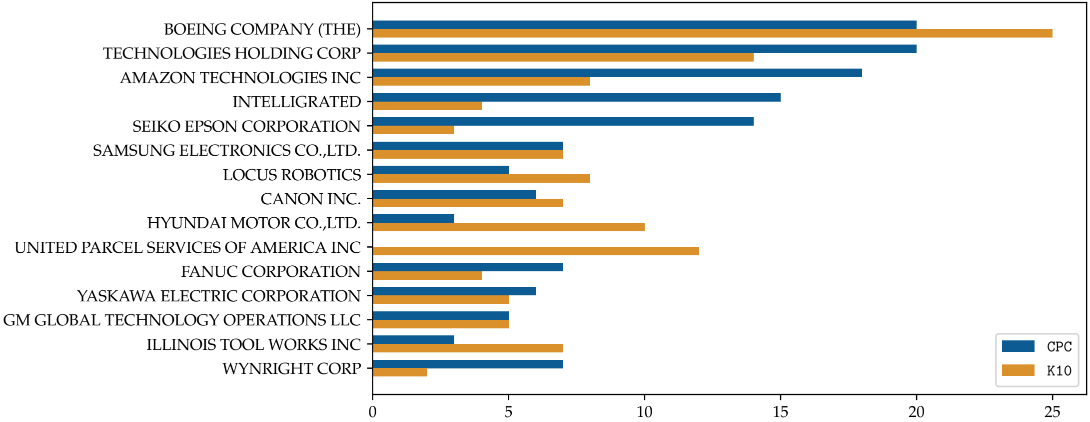
# LS patents by country – absolute value



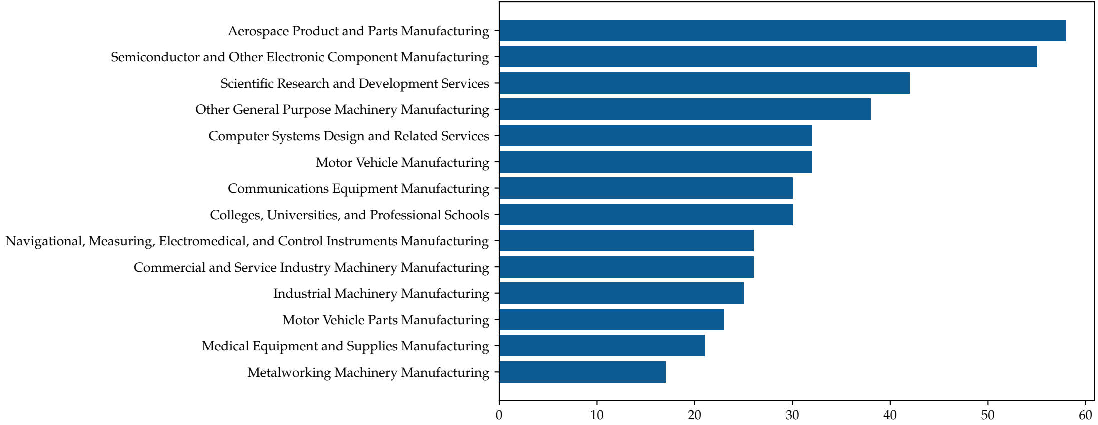
# LS patents by country – as % of robotic patents



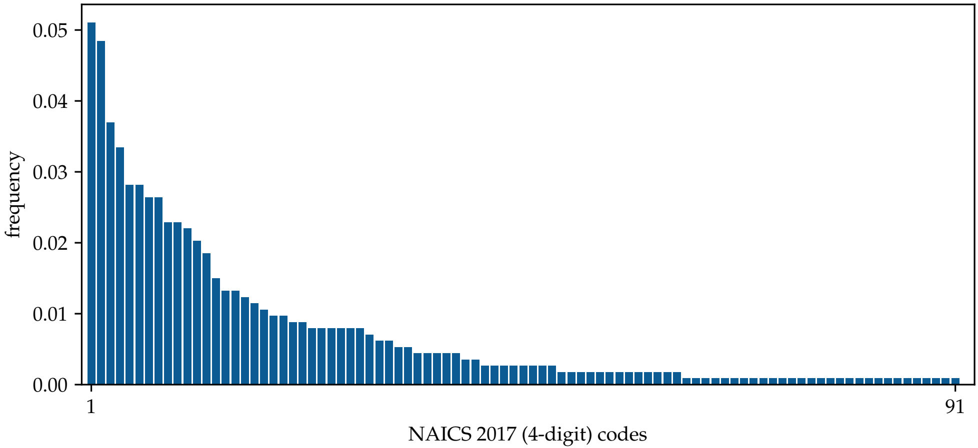
# LS patents by assignee



# LS patents by industry (cont'd)



# LS patents by industry



# Outline

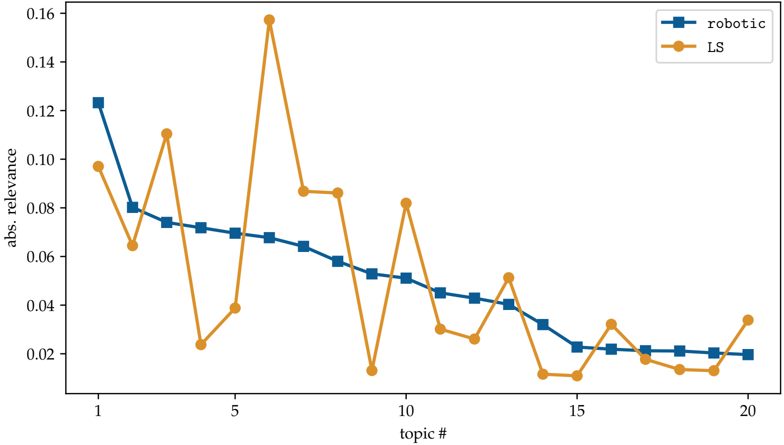
# Probabilistic topic model

1. we estimate a topic model with $K = 20$ topics on the whole collection of robotic patents $D$
   - each topic $k \in K$ is identified as a list of keywords ranked by frequency
   - each patent $d \in D$ is assigned a distribution $\theta_{d,k}$ over the $K$ topics
2. we assign a significance measure of CPC codes ($c \in C$) originally attributed to patents to each topic $k$ by leveraging on the *latent semantic structure* of the whole collection of patents, through relevance distributions $\theta_{d,k}$ obtained in 1

$$\varphi_{c,k} = \sum_{d \in D} \mathbf{1}_{\{c \in d\}} \cdot \theta_{d,k} \qquad \forall\, k = 1, \ldots, K; \quad \forall\, c \in C$$

   - this brings useful information for labelling the topics
3. we compare the relevance of the $K$ topics for robotic patents and the subset of LS patents

# Topic relevance for robotic and LS patents



# Technological taxonomy

| Topic # | LS relev. | Words | CPC | Weight | Description |
|---|---|---|---|---|---|
| 6 | +132.2% | carrier | B65 | 24.4% | Conveying; packing; storing; handling thin or filamentary material |
| | | conveyor | | | |
| | | item | H01 | 6.8% | Basic electric elements |
| | | gripper | G11 | 6.0% | Information storage |
| | | tape | Y02 | 4.6% | Technologies or applications for mitigation or adaptation against climate change |
| | | | B23 | 4.3% | Machine tools; metal-working not otherwise provided for |
| ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... |
| 9 | −75.2% | heater | H01 | 8.6% | Basic electric elements |
| | | hydrocarbon | E21 | 6.6% | Earth drilling; mining |
| | | pipe | B23 | 5.5% | Machine tools; metal-working not otherwise provided for |
| | | drill | Y10T29 | 4.4% | Metal working |
| | | gas | Y02 | 4.4% | Technologies or applications for mitigation or adaptation against climate change |

# Outline

# Main findings

- LS firms are not only robots producers, but mainly adopters (archetypical cases are Boeing, Amazon, and UPS)
- the overall number of robotic patents is rapidly expanding (3-fold increase in a decade)
- conversely, LS patents do not exhibit a clear trend, supporting the idea that labour-saving is a rather established heuristic
- LS robotic patents emerge along the entire supply chain, signalling pervasiveness
- LS patents are concentrated in labour intensive industries (e.g. logistics, healthcare)
- technological bottlenecks identified by Frey and Osborne (2017) (occupations requiring social and cognitive intelligence, finger dexterity and manipulation) are under active research efforts by innovative firms

# Thank you very much!

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this presentation available at www.staccioli.org/research