AI Adoption in Denmark and Productivity

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Big picture (Brynjolfsson, Rock & Syverson, 2017)

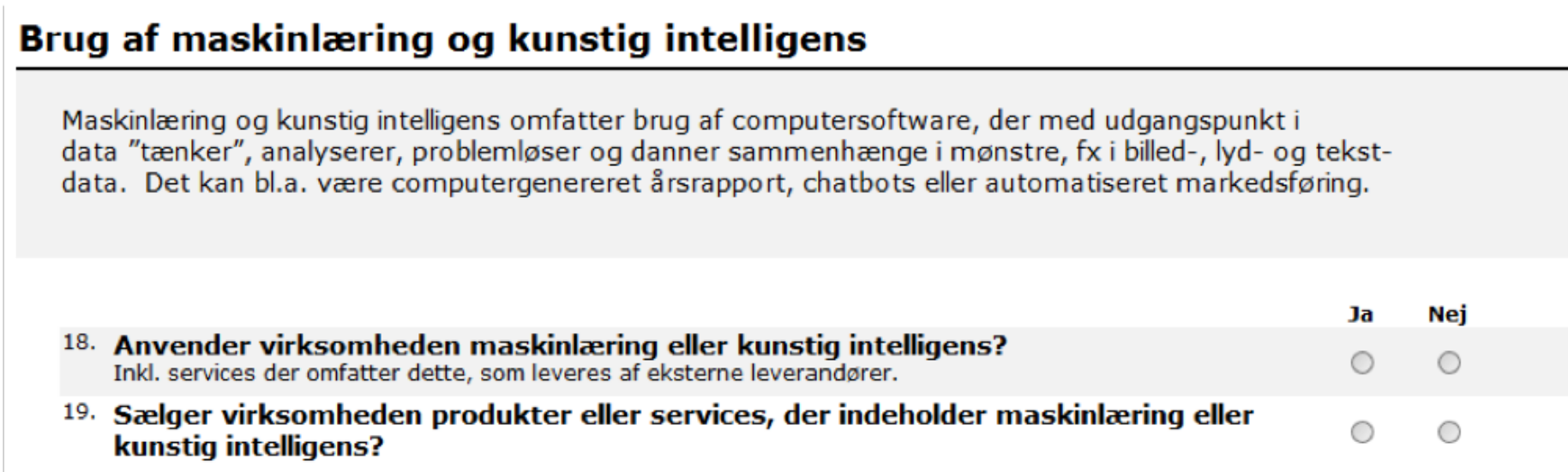
- General belief that AI/machine learning can generate substantial productivity gains in the near future
- AI as a General Purpose Technology (GPT)
- yet, productivity slowdown. Productivity paradox (Solow old quote)
- reasons for mismatch? false hopes? too early? (implementation lags) mismeasurement?
- how do we measure AI? Hard, but have to start somewhere
- once we have a measure: what does AI correlate with? Focus on productivity and workforce composition

Contribution

- use three (five?) waves of recently released surveys in ICT use to identify firms adopting AI in Denmark
- merge this information with standard datasets about workforce composition and accounting variables (productivity)
- document (i) an extremely rapid diffusion of AI in 4 years; (ii) a strong selection effect into AI (more productive firms more likely to adopt AI)
- find evidence of dramatic change in workforce composition, as AI adopting firms hire more tech workers (especially in IT and other information services - JC NACE 62+63)
- so far: (preliminary) evidence of improvement in productivity in the short run
- (preliminary) evidence of complementarity between AI and skilled (tech) workers in AI intensive industries

Measuring AI

- Every year, Danmarks Statistik surveys firms about their use of IT.
- Questions evolve every year to keep track of recent advancements and practices.
- In 2017, two additional questions were included about the use of AI. Firms were simply asked whether they were using AI, or selling AI tools.



Brug af maskinlæring og kunstig intelligens

Maskinlæring og kunstig intelligens omfatter brug af computersoftware, der med udgangspunkt i data "tænker", analyserer, problemløser og danner sammenhænge i mønstre, fx i billed-, lyd- og tekst-data. Det kan bl.a. være computergenereret årsrapport, chatbots eller automatiseret markedsføring.

		Ja	Nej
18.	**Anvender virksomheden maskinlæring eller kunstig intelligens?** Inkl. services der omfatter dette, som leveres af eksterne leverandører.	○	○
19.	**Sælger virksomheden produkter eller services, der indeholder maskinlæring eller kunstig intelligens?**	○	○

Summary statistics

AI adoption increases rapidly and is concentrated in a few sectors

- fast diffusion of AI use: from **6.62% in 2017 to 23.89% in 2021** of sampled firms
- the vast majority of firms were operating in the service industry, in particular information service activities (NACE 63), computer programming, consultancy and related activities (NACE 62); wholesale (NACE 46) and retail (NACE 47); and legal and accounting activities (NACE 69), activities of head offices, management consultancy activities (NACE 70) and architectural and engineering activities; technical testing and analysis (NACE 71)
- the only significant manufacturing industries were computer, electronic and optical equipment (NACE 26) and machinery (NACE 28).

Share of AI firms by industry, 2017-2019

	2017	2018	2019
63: Information service activities	28.57%	51.16%	38.46%
# firms surveyed	42	43	52
58: Publishing activities (includes videogames and software)	15.63%	15.38%	34.44%
# firms surveyed	64	65	90
62: Computer programming, consultancy and related activities	15.94%	19.03%	24.57%
# firms surveyed	251	268	350
69: Legal and accounting activities	14.67%	29.33%	22.45%
# firms surveyed	75	75	98
26: Computer, electronic and optical equipment	9.26%	18.18%	16.95%
# firms surveyed	54	55	59
70: Activities of head offices; management consultancy activities	15.52%	21.88%	16.46%
# firms surveyed	58	64	79
47: Retail trade	6.94%	9.52%	13.43%
# firms surveyed	288	294	499
71: Architectural and engineering activities; technical testing and analysis	4.85%	11.40%	12.41%
# firms surveyed	103	114	137
28: Machinery	8.97%	9.43%	9.50%
# firms surveyed	156	159	179
46: Wholesale trade	6.72%	6.65%	8.98%
# firms surveyed	506	496	657

Industry distribution, 2019

AI adoption is more common in IT and other information services

	2019		
Sector	# AI firms	# firms surveyed	share AI firms
62: Computer programming, consultancy and related activities	86	350	24.57%
46: Wholesale trade	59	657	8.98%
47: Retail trade	67	499	13.43%
63: Information service activities	20	52	38.46%
69: Legal and accounting activities	22	98	22.45%
28: Machinery	17	179	9.50%
70: Activities of head offices; management consultancy activities	13	79	16.46%
71: Architectural and engineering activities; technical testing and analysis	17	137	12.41%
58: Publishing activities (includes videogames and software)	31	90	34.44%
26: Computer, electronic and optical equipment	10	59	16.95%

Industry distribution, 2018

AI adoption is more common in IT and other information services

	2018		
Sector	# AI firms	# firms surveyed	share AI firms
62: Computer programming, consultancy and related activities	51	268	19.03%
46: Wholesale trade	33	496	6.65%
47: Retail trade	28	294	9.52%
63: Information service activities	22	43	51.16%
69: Legal and accounting activities	22	75	29.33%
28: Machinery	15	159	9.43%
70: Activities of head offices; management consultancy activities	14	64	21.88%
71: Architectural and engineering activities; technical testing and analysis	13	114	11.40%
58: Publishing activities (includes videogames and software)	10	65	15.38%
26: Computer, electronic and optical equipment	10	55	18.18%

Industry distribution, 2017

	2017		
Sector	# AI firms	# firms surveyed	share AI firms
62: Computer programming, consultancy and related activities	40	251	15.94%
46: Wholesale trade	34	506	6.72%
47: Retail trade	20	288	6.94%
63: Information service activities	12	42	28.57%
69: Legal and accounting activities	11	75	14.67%
28: Machinery	14	156	8.97%
70: Activities of head offices; management consultancy activities	9	58	15.52%
71: Architectural and engineering activities; technical testing and analysis	5	103	4.85%
58: Publishing activities (includes videogames and software)	10	64	15.63%
26: Computer, electronic and optical equipment	5	54	9.26%

Merge ICT use survey with other datasets

Merge our two waves of ICT survey:

- with linked employer employee dataset (2010-2019): contains information about occupational code for each worker, so can compute number of workers by skill group and share of tech workers (workers with 2-digit code 25, "techies")
- with accounting data (2010-2019): contains information about value added, capital and employment, so can compute labor productivity and estimate TFP

Tech workers

25		**Arbejde inden for informations- og kommunikationsteknologi**
251		**Udvikling og analyse af software og applikationer**
2511		**Systemanalytikerarbejde**
	251110	Arbejde med overordnet IT-arkitektur
	251120	Design af IT-systemer og analyse af forretningsprocesser
2512		**Softwareudvikling**
	251210	IT-projektstyring
	251220	Rådgivning og programmering inden for softwareudvikling
2513		**Web- og multimedieudvikling**
	251300	Web- og multimedieudvikling
2514		**Vedligeholdelse og dokumentation af software**
	251400	Vedligeholdelse og dokumentation af software
2519		**Andet arbejde med software, herunder test og kvalitetssikring**
	251900	Andet arbejde med software, herunder test og kvalitetssikring
252		**Arbejde med databaser og netværk**
2521		**Design og administration af databaser**
	252100	Design og administration af databaser
2522		**Systemadministration**
	252200	Systemadministration
2523		**Arbejde med computernetværk**
	252300	Arbejde med computernetværk
2529		**Andet arbejde med databaser og netværk**
	252900	Andet arbejde med databaser og netværk

Stylized facts

Workforce composition changes and firms adopting AI have larger value added per worker

- number and share of tech workers significantly increases before we observe adoption, especially in industry 62; shares of tech workers for AI adopters increases from 57% to 63% between 2015 and 2017! in other sectors, increases by less than 1%
- firms adopting AI have on average 9.4% higher labor productivity than non adopters; the coefficient decreases over time (from 10.4% to 8.7%), suggesting the early adopters were the more productive firms (or sample selection)
- next steps: look at changes after adoption (with focus on productivity and labor composition) and estimate a simple production function (controlling for AI use and workforce composition)

AI Adoption Premia

	Level regressions:			
	logVA	*logEmp*	*logVAL*	*log(TechShare)*
AI Adopter	0.808***	0.698***	0.094***	0.110**
	(0.047)	(0.042)	(0.027)	(0.046)
Adj. R^2	0.15	0.13	0.20	0.59
# obs.	12,948	13,050	12,920	4,160

* p<0.10, ** p<0.05, *** p<0.01.

Methodology

- Run two simple specifications:
  - 1) forward looking (only 2 years after adoption, 2017-2019), "early" AI adopters (in 2017)

$$\Delta FirmAttribute_{f(t+2,t)} = \alpha + \beta_{AI} * AIAdoption_{ft} + Ind_{ft} + \varepsilon_{ft}$$

  - 2) production function estimation (panel, 2017-2019)

$$logVA = f(logK, logL^{Tech}, logL^{NonTech}, AI)$$

Results (I): forward looking growth rate, 2017-2019

Table: Firm Outcomes - Growth Rates and AI Adoption

	Growth Rate of:	
	log(Value Added / worker)	log(Tech Share)
AI Adopter	0.037*	0.071*
	(0.019)	(0.042)
R^2	0.03	0.07

* p<0.10, ** p<0.05, *** p<0.01.

Results (II): production function approach

Table: Production function estimation (OLS)

	Dep. var.: *logVA*			
	All industries		Industry 62	
	coeff	s.e.	coeff	s.e.
$logL^{Tech}$	0.163***	(0.008)	0.254***	(0.017)
$logL^{NonTech}$	0.504***	(0.011)	0.309***	(0.026)
logK	0.325***	(0.008)	0.396***	(0.021)
AI	-0.195	(0.140)	0.194	(0.333)
$AI * logL^{Tech}$	-0.007	(0.015)	0.085**	(0.042)
$AI * logL^{NonTech}$	0.037	(0.024)	0.047	(0.064)
$AI * logK$	-0.003	(0.018)	-0.068	(0.047)
# obs.	4,094		754	

2021 wave (courtesy of Statistics Denmark)

Table: Share of AI adopters by broad sector

All firms	Manufacturing	Construction & Installation/Repair	Trade & transportation	ICT	Business services
23.89%	27.29%	8.87%	19.8%	54.75	29.51%

- adds more questions about AI tools, aims and results:
  - what kind of AI technologies do firms use?
  - for which purposes?
  - what was the impact of AI on your company? (subjective but still)
  - how was AI acquired?

Does your enterprise use any of the following Artificial Intelligence technologies?

- The most common AI technologies used by Danish firms are:
  - technologies automating different workflows or assisting in decision making (Artificial Intelligence based software robotic process automation), 71% of adopters on average
  - machine learning (e.g. deep learning) for data analysis, 37% on average (61% in ICT industries)
  - technologies performing analysis of written language (text mining), 34% on average (82% in business services)

Does your enterprise use Artificial Intelligence software or systems for any of the following purposes?

- AI technologies are used mostly for:
  - the management of enterprises (48%)
  - ICT security (29%) - especially in ICT sector (37%)
  - organisation of business administration processes (27%)
  - marketing or sales (23%) - especially in ICT and trade and transportation sectors
  - production processes (20%) - 28% in manufacturing

Has the use of artificial intelligence technologies had a positive impact on the following in the enterprise?

- firms report that adopting AI led to:
  - streamlining workflows (71% on average)
  - improving the enterprise's products or services (52%)
  - greater earnings, e.g. increased revenue or reduction of costs (41%)

How did you enterprise acquire the Artificial Intelligence software or systems that it uses?

- Firms acquired their AI tools through various channels:
  - commercial software or systems ready to use were purchased (including examples where it was already incorporated in a purchased item or system) - 56%
  - commercial software or systems were modified by own employees (including those employed in parent or affiliate enterprise) - 53%
  - external providers were contracted to develop or modify them - 52%
  - they were developed by own employees (including those employed in parent or affiliate enterprise) - 32% (mostly in ICT sector, 60%)
  - open-source software or systems were modified by own employees (including those employed in parent or affiliate enterprise) - 32%

COVID and investment in digitalization

- Has the enterprise increased investments in advanced technology or digitization as a result of COVID-19? Eg AI, equipment, remote access and IT solutions for video conferencing
  - 20% of surveyed firms answered yes

Future work

- Better use of the panel dimension
- Endogeneity of production function estimation
- More general assessment of ICT as a sequential process (1999-2021): computers, ERP,..., AI
- two related/follow up projects:
  - COVID, digitalization and workforce composition
  - Relationship between offshoring and ICT use and spending (joint with Ray)