AI Adoption and Its Impact on Business Performance

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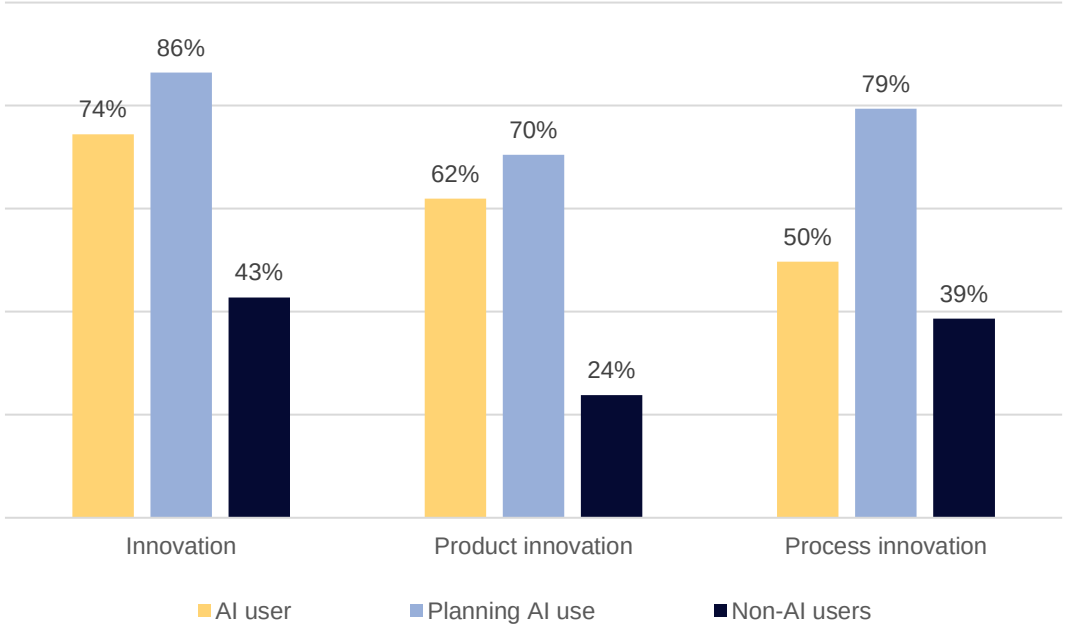
Motivating Evidence (1/3)

Figure 1 Firms that adopt AI technologies are notably more likely to innovate

Share of firms that reported innovation by usage or planned usage of AI technologies (percent)



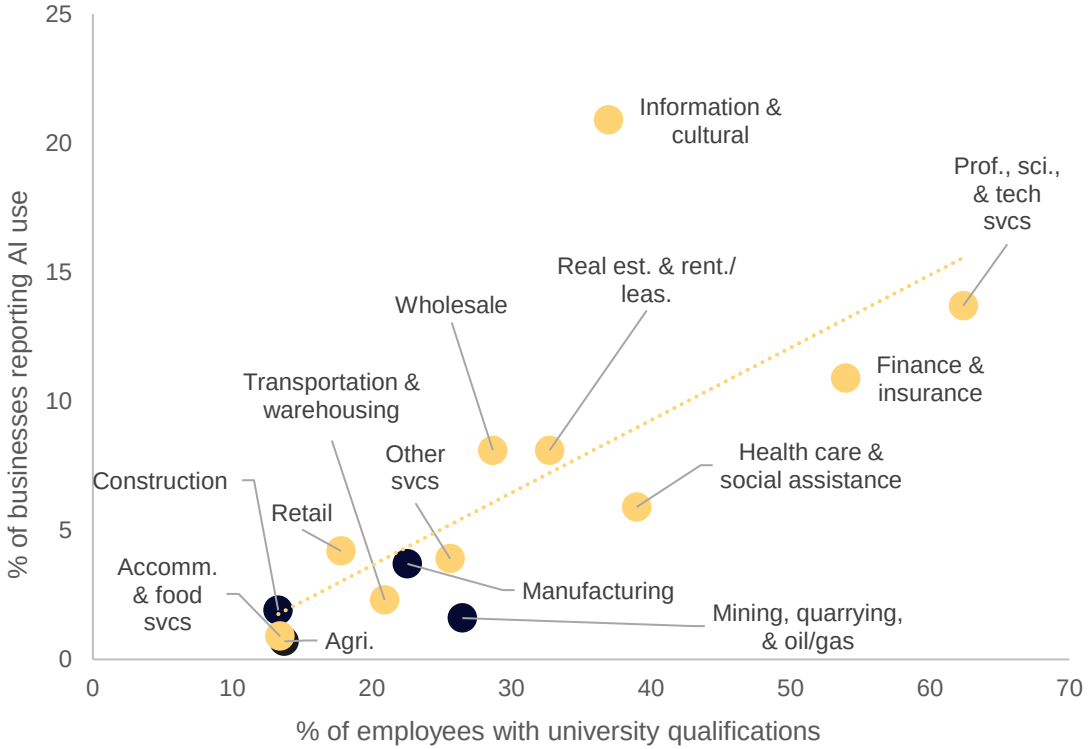
Note: Incidence of innovation is measured by the share of firms that reported innovation by usage or planned usage of AI technologies.
Source: Authors' calculation, Survey of Advanced Technology (SAT) 2022.

- AI is among the fastest growing technology adopted (SAT 2022)
  - Of them, 77% also reported to start using it in the last three years
- AI adopters – using and planning to – are significantly more innovative than non-adopters
  - Incidence of innovation among AI users is about twice that of non-users, and nearly thrice in product innovation
- AI adoption is also more likely alongside the adoption of other advanced technologies
  - More than 70% of heavy adopters – firms integrating more than three tech domains – reported innovation, in contrast to 20% of non-adopters

Motivating Evidence (2/3)

Figure 2 AI adoption is positively linked to skills

Correlation between %businesses reporting using AI and %employee with a university qualification



Source: Authors' calculation. Labour Force Survey (Public Use Microdata File) and the Canadian Survey of Business Conditions (CSBC) 2024 Q2.

- Canadian businesses have middling, or low adoption rates, but AI may present an exception
  - AI adoption among Canadian businesses is ~6% in 2023 – growing from 3% in 2021 (SDTIU 2022; SAT 2022; SIBS 2022; CSBC 2024)
  - While comparable to the U.S. adoption rate of 4-5% in 2023 (Bonney et al. 2024) albeit low other digital adoption across OECD countries like cloud computing, internet of things, and big data analytics (OECD-ICT Access and Usage by Businesses 2021)
  - Predominantly in service-providing industries – far more than that of the goods sectors – likely reflecting industrial skills composition as high-skilled industries tend to adopt AI at a higher rate
- Large and small innovative firms predominate early adoptions of AI
  - 92% of large AI adopters and 69% of small AI adopters are firms with innovative activities

Motivating Evidence (3/3)

- Gains from AI are uneven, with the most gains expected in
  - Service sectors like travel, transport and logistics, ICT and finance (McKinsey Global Institute 2018)
  - Larger firms, as well as productivity leaders in their respective sectors, with intensive AI skills and significant digital assets (Brynjolfsson et al. 2023; Calvino and Fontanelli 2023; Filippucci et al. 2024)
  - Tech centres and urban/research centres (Conference Board of Canada 2024)
- The impact of AI on innovation and skills is mixed
  - Enhance the productivity of research (Mullainathan and Rambachan 2024), and accelerate scientific discovery and product innovation (Toner-Rodgers 2024)
  - Level up productivity by reducing differentials between the skilled and the less-skilled (Noy and Zhang 2023; Peng et al. 2023; Brynjolfsson et al. 2023; Autor 2024)
  - Bring on new risks (Dell'Acqua et al. 2023) and undermine expertise (Fugener et al. 2021; Agarwal et al. 2023; Hui et al. 2023)
- Productivity gain varies widely and can take decades to realize and requires complementary capacities
  - Canada: No conclusive evidence of AI adoption and short-run productivity gains (Dais 2025), but potentially reaching a 0.6% annual increase in TFP (Filippucci et al. 2024) and a 1.1% annual LP growth over the next decade (OECD 2025)
  - United States: AI is negatively linked to manufacturing performance in the short run while improving over time and among early adopters (Brynjolfsson et al. 2025), and +0.55–0.71% increase in total factor productivity over the next 10 years (Acemoglu 2025)
  - Translating AI potential into long-term benefit growth also hinges upon considerable digital investment and skills (Brynjolfsson et al. 2021; Dernis et al. 2023; Calvino and Fontanelli 2024; Gu 2024)

Research Questions

1. What types of firms, in terms of business characteristics, are more likely to adopt AI?

2. What is the impact of AI adoption on productivity and its growth, in the short and longer run?
   - How does such impact differ across businesses?

Overview

- Empirical Framework
- Data
- Empirical Results
- Concluding Remarks

Empirical Framework (1/2)

- **Probit regression**: (1)-Firm Characteristics of AI adopters

- **IV estimation**: (2)-AI's Impact on Productivity

$$y_j = \alpha_1 + \beta ai_j + \sum_{i=1}^{K} \gamma_i x_{ij} + u_j, \text{ where } ai_j = \alpha_2 + \delta z_j + \sum_{i=1}^{K} \phi_i x_{ij} + e_j$$

  - y_j is $log(lp)$ or $\Delta\, log(lp)$; ai_j denotes AI adoption by firm (1/0); instrument z_j is ict_{share}; and $\sum_{i=1}^{K} x_{ij}$ is a set of firm-level controls
  - Pooled cross-sectional data (3 years) with sampling weights and 2011 ICT occupations share at 4-digit NAICS as an instrument
    - No reversed causality before AI adoption taking place
    - Highly correlated with AI adoption (Fontanelli et al. 2024)
    - Unlikely related to firm-level productivity after 2019

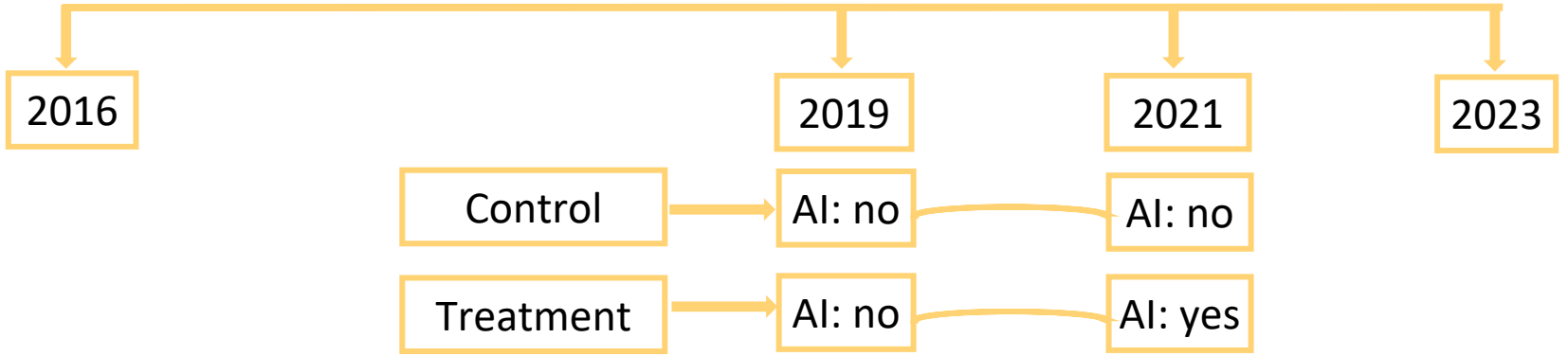
Empirical Framework (2/2)

- **Diff-in-diff estimation with IV**: (2)-AI's Impact on Productivity

$$y_{jt} = \alpha_2 + \beta did_{jt} + \sum_{i=1}^{N} \varpi_i x_{ijt} + \varepsilon_{jt}, \text{ where } did_{jt} = \alpha_3 + \pi\theta_{jt} + \sum_{i=1}^{N} \nu_i x_{ijt} + \nu_{jt}$$

  - did_j is the diff-in-diff indicator = $treat * post$ where $treat = 1$ if $ai_j^{2019} = 0$ and $ai_j^{2021} = 1$; and 0 if $ai_j^{2019} = 0$ and $ai_j^{2021} = 0$; $post = (year \geq 2021)$
  - Instrument, $\theta_{jt} = ict_{share} * post$, where 2011 ICT occupations share by 4-digit NAICS industry
  - Panel structure without weights

Figure 3: Difference-in-Difference Design



Source: Authors' illustration based on Survey of Digital Technology and Internet Use (SDTIU) 2019, 2021, and 2023.

Data (1/2)

Linked business microdata using SDTIU & NALMF

- **AI adoption**: Survey of Digital Technology and Internet Use (SDTIU), 2019, 2021, and 2023
  - AI adopter, by type / purpose / obstacles
  - Complementary/substituting capacities: Cloud computing, big data analytics, advanced robotics, ICT specialists/training

- **Business characteristics and performances**: National Account Longitudinal Microdata File (NALMF), 2011-2023
  - Characteristics: size, age, industry
  - Performances: labour productivity and growth, capital intensity, R&D, foreign ownership, internaitonalisation

Data (2/2)

Survey questions includes

- AI (ICT) use
- Type of use
- Purpose of use
- Reasons not to use

Use of information and communication technologies (ICTs)

Q35: Which of the following Information and Communication Technologies (ICTs) did this business use in 2023?

Information and Communication Technologies (ICTs) consist of the hardware, software, networks and media for the collection, storage,processing, transmission and presentation of information (e.g., voice, data, text, images), as well as related services.

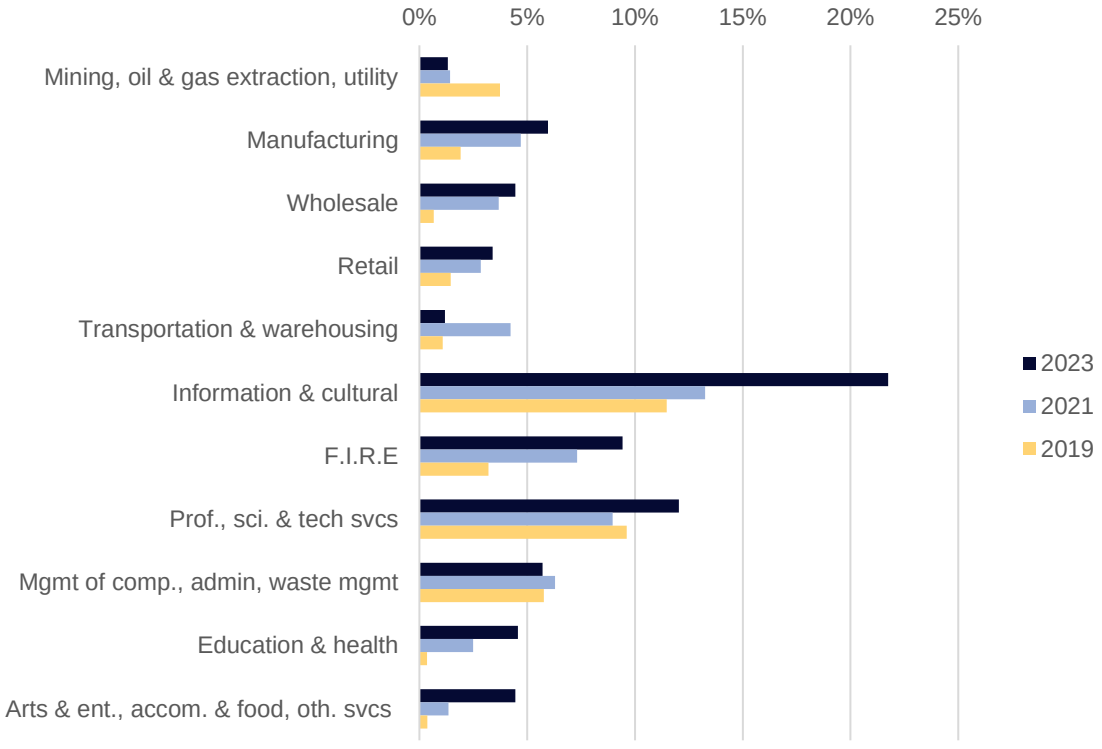
Select all that apply.

1: Company-wide computer networks
2: Industry-specific software
3: Software not specific to this business's industry
4: Customer Relationship Management (CRM) software
5: Electronic Data Interchange (EDI) on the Internet
6: Enterprise Resource Planning (ERP) software
7: Radio Frequency Identification (RFID) tags
8: Cloud computing
9: Internet-connected smart devices, or Internet of Things (IoT)
10: Software or hardware using artificial intelligence (AI)
11: Advanced robotics
12: 3D printing
13: Blockchain technologies
14: Open source software
15: Quantum technologies
: OR
16: None

Empirical Results #1

Summary Statistics (1/4)

Figure 4a. AI Adoption by Industry



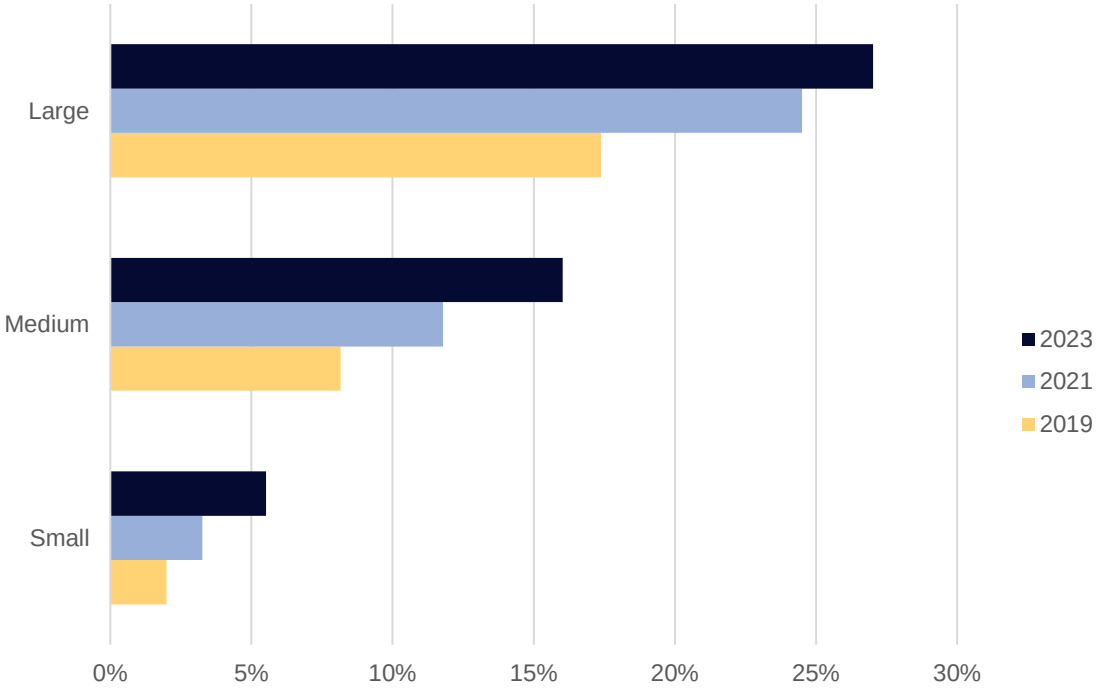
Source: Survey of Digital Technology and Internet Use (SDTIU).

- Service-providing sectors more likely to adopt AI than goods-producing sectors
  - Top adopters include [51] info and cultural, [54] prof., sci. and tech services
- AI adoption generally increases over time
  - Exceptions include [21-23] mining, oil/gas extractions, and utilities

Empirical Results #1

Summary Statistics (2/4)

Figure 4b. AI Adoption by Firm Size



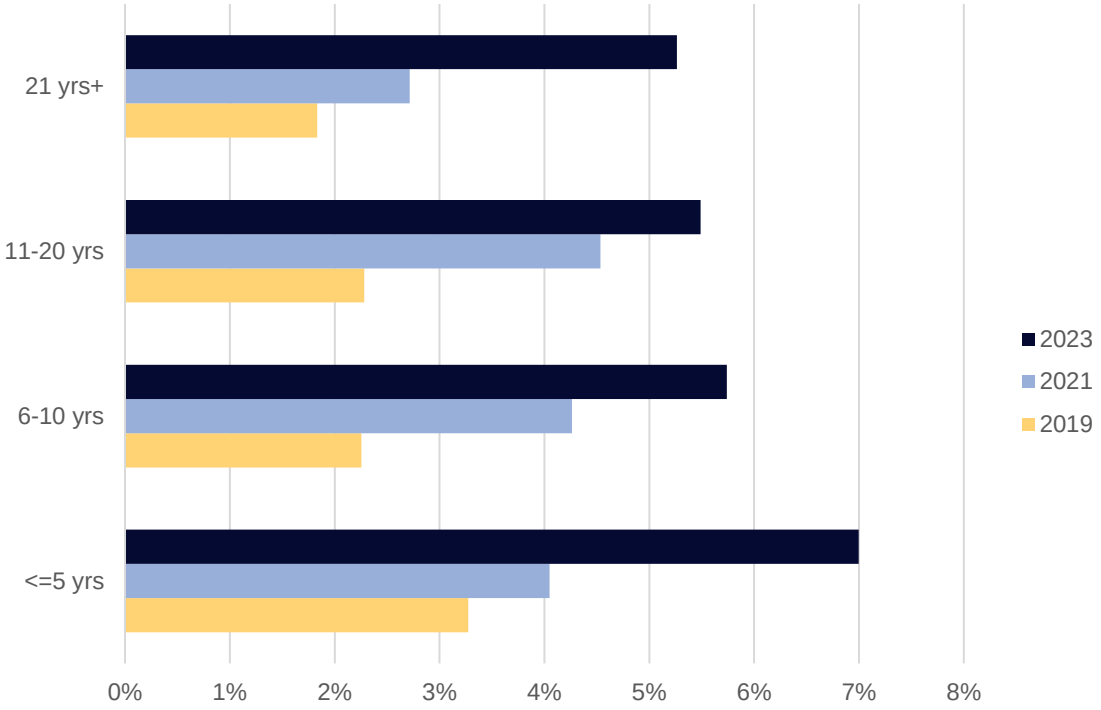
Source: Survey of Digital Technology and Internet Use (SDTIU).

- Larger firms are consistently top adopters of AI
- AI adoption increases over time, regardless of firm size
  - Yet small firms experience accelerated growth in adoption, compared with a slowdown among medium and large firms

Empirical Results #1

Summary Statistics (3/4)

Figure 4c. AI Adoption by Age



Source: Survey of Digital Technology and Internet Use (SDTIU).

- Younger firms are more likely than older firms to adopt AI
- AI adoption increases over time, regardless of firm age
  - Firms aged 5- yrs or 21+ yrs experience accelerated growth in adoption, compared with a slowdown among firms aged 6-20 yrs

Empirical Results #1

Summary Stats

AI-adopting firms are

- Persistently more productive, with better-paying jobs
- More likely to be foreign owned, exporters, and most distinctively, importers
- Larger but younger
- Considerably more likely to have complementary capacities

Table 1: Descriptive Summary, 2019, 2021 & 2023

	AI Adopters					Non-AI Adopters
	All	R&D	Cloud	Data	Robot	
Firm Attributes						
Labour productivity (VA per worker, log)	11.3	11.6	11.3	11.3	11.5	11.1
Initial labour productivity (2011-2013)	11.4	11.5	11.4	11.4	11.2	11.1
1-yr LP growth	0.3%	1.8%	0.8%	2.7%	-8.7%	1.9%
2-yr LP growth	-1.0%	1.9%	0.0%	0.8%	10.3%	1.0%
3-yr LP growth	2.1%	-5.0%	2.8%	2.5%	-7.2%	7.5%
Mean earning per employee	$55,482	$59,513	$57,834	$48,124	$72,333	$39,311
Tangible capital intensity (K/L, log)	10.2	10.1	10.2	10.2	10.7	10.4
Internationalisation						
Foreign-owned	4.0%	9.8%	4.0%	6.0%	17.0%	1.4%
Importer	23.3%	60.7%	23.4%	30.6%	61.9%	16.8%
Exporter	8.8%	29.8%	9.3%	14.4%	39.4%	5.8%
Size						
Small	90.5%	78.2%	90.1%	83.3%	67.8%	97.6%
Medium	5.0%	10.0%	5.1%	7.9%	10.5%	1.7%
Large	4.5%	11.8%	4.8%	8.8%	21.7%	0.7%
Mean employment	97	278	104	207	757	20
Median employment	8.0	19.8	8.3	11.7	29.7	6.5
Age						
< 5 yrs	25.0%	20.5%	25.0%	31.6%	39.9%	20.5%
6-10 yrs	22.9%	31.6%	23.1%	20.9%	12.4%	21.9%
11-20 yrs	26.7%	28.1%	25.2%	24.4%	25.8%	26.3%
> 21 yrs	25.5%	19.9%	26.8%	23.1%	21.9%	31.2%
Mean age	15	13	15	15	14	16
Median age	11	9	11	10	9	13
Complementary Capacity (indicator = 1)						
R&D	10.6%					2.4%
Cloud	90.8%					39.9%
Data	34.2%					7.2%
Robot	4.0%					0.4%
ICT training	33.8%					9.8%
#Observations	2,497	597	2,371	1,254	311	25,054
#Firms	2,247	524	2,132	1,122	276	22,590

Note: Summary statistics are adjusted for survey weights. *** p<0.01, ** p<0.05, * p<0.1

Source: Survey of Digital Technology and Internet Use (SDTIU) 2019, 2021 and 2023, linked to the National Account Longitudinal Microdata File (NALMF) 2011-2023.

Empirical Results #2

Which firms adopt?

Probit regressions show that

Adopters in any of the 3 surveyed years

- Non-exporters
- With complementary capacity
- Service industries

Adopters in a minimum of 2 out of the 3 surveyed years

- With complementary capacity in data
- Non-information/cultural industries

Table 2: Firm Characteristics of AI Adopters

Dep. Vars.: AI Adopters	Any Year		Min. 2 Years	
	Coeff.	(s.d.)	Coeff.	(s.d.)
Firm Attributes				
Labour productivity (VA/L, log)	-0.001	(0.005)	0.132	(0.119)
Earning per employee (log)	0.011	(0.007)	-0.004	(0.064)
Capital intensity (K/L)	-0.002	(0.002)	-0.075	(0.079)
Internationalization				
Canadian	0.004	(0.008)	0.003	(0.041)
Importer	0.005	(0.008)	0.042	(0.036)
Exporter	-0.010*	(0.006)	0.002	(0.029)
Size				
Employment (log)	-0.004	(0.005)	-0.273	(0.290)
Employment squared (log)	0.001*	(0.001)	0.045	(0.038)
Age				
Age (log)	0.029**	(0.012)	0.018	(0.095)
Age squared (log)	-0.006**	(0.003)	-0.019	(0.042)
Complementary Capacity				
R&D	0.034**	(0.014)	-0.128	(0.105)
Cloud	0.055***	(0.007)	-0.006	(0.026)
Data	0.048***	(0.013)	0.194**	(0.088)
Robot	0.095***	(0.023)	0.132	(0.082)
ICT training	0.032***	(0.010)	0.094	(0.057)
Industry (rel. to manufacturing)				
Info & cultural	0.046***	(0.012)	-0.248*	(0.131)
FIRE	0.034**	(0.017)	-0.133	(0.103)
Prof. sci. and tech svcs	0.018*	(0.010)	-0.053	(0.098)
Mgmt, waste/remediation svcs	0.025*	(0.015)	0.043	(0.118)
#Observations	22,352		4,943	
#Firms	19,847		2,442	
R-squared	0.233		0.147	

Note: For AI adopters appearing in any survey year, a pooled probit regression is run using cross-sectional sampling weights. For AI adopters appearing in at least two survey years, a fixed-effect panel regression is run using panel weights constructed by multiplying cross-sectional sampling weights by the inverse probability of firms being selected into the panel. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Source: Survey of Digital Technology and Internet Use (SDTIU) 2019, 2021 and 2023 linked to the National Account Longitudinal Microdata File (NALMF) 2011-2023.

Empirical Results #2
LP impact?

- AI's impact on labour productivity is limited in the short run
  - Increase contemp. productivity level, yet
  - No sig. impact on annual productivity growth
- Little impact on labour productivity in the medium term of 2 to 3 years

Table 3: Estimates of AI's Impact on Productivity using Equations (2) with IV

Explanatory Variables	Labour Productivity		Period-specific Growth in Labour Productivity					
			1-year		2-year		3-year	
	Coeff.	(s.e.)	Coeff.	(s.e.)	Coeff.	(s.e.)	Coeff.	(s.e.)
AI Adoption								
Adopter	0.161**	(0.070)	0.052	(0.043)	0.005	(0.061)	-0.057	(0.084)
Firm Attributes								
Labour Productivity (VA/L, log), 2011-13	0.482***	(0.030)	-0.018	(0.014)	-0.009	(0.021)	-0.025	(0.029)
Capital intensity (K/L)	0.091***	(0.011)	0.003	(0.007)	-0.001	(0.009)	0.012	(0.011)
%Capital intensity (K/L), 1-year			0.309***	(0.031)				
%Capital intensity (K/L), 2-year					0.220***	(0.023)		
%Capital intensity (K/L), 3-year							0.170***	(0.025)
Internationalization								
Canadian	-0.248***	(0.037)	-0.031	(0.024)	-0.068	(0.047)	-0.103	(0.088)
Importer	0.139***	(0.024)	0.006	(0.015)	-0.012	(0.020)	-0.003	(0.026)
Exporter	0.050**	(0.024)	0.008	(0.015)	-0.004	(0.019)	-0.030	(0.024)
Size								
Employment (in log)	0.004	(0.043)	0.047	(0.029)	0.105***	(0.031)	0.119***	(0.044)
Employment squared (in log)	-0.007	(0.005)	-0.008**	(0.004)	-0.014***	(0.004)	-0.014**	(0.006)
Age								
Age (in log)	-0.107	(0.070)	-0.041	(0.041)	0.042	(0.026)	0.080	(0.049)
Age squared (in log)	0.017	(0.014)	0.010	(0.008)	-0.006	(0.007)	-0.018*	(0.011)
Complementary Capacity								
R&D	0.032	(0.031)	-0.028*	(0.016)	-0.004	(0.022)	-0.004	(0.034)
Cloud	-0.067	(0.066)	-0.038	(0.040)	-0.006	(0.056)	0.069	(0.078)
Data	-0.014	(0.051)	0.024	(0.032)	0.024	(0.045)	-0.005	(0.086)
Robot	-0.058	(0.062)	-0.070**	(0.035)	-0.085*	(0.049)	-0.064	(0.085)
ICT training	0.009	(0.032)	0.007	(0.020)	0.019	(0.028)	-0.017	(0.035)
Year-fixed Effect	Yes		Yes		Yes		Yes	
Industry-fixed Effect	Yes		Yes		Yes		Yes	
#Observations	12,821		12,722		12,341		6,083	
#Firms	11,474		11,384		11,047		6,083	
R-squared	0.555		0.256		0.176		0.142	

Note: The pooled-sample regression is run using survey sampling weights. The instrument variable is defined as the share of ICT occupation by 4-digit NAICS in 2011. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: Survey of Digital Technology and Internet Use (SDTIU) 2019, 2021 and 2023 linked to the National Account Longitudinal Microdata File (NALMF) 2011-2023.

Empirical Results #2a

Robustness Check

- Previous results hold
  - No sig. bearing on productivity level (and neg.)
  - Pos. but insig. on one-year growth

Table 4: Estimates of AI's Impact on Productivity using Equations (3) with IV

Explanatory Variables	Difference-in-Difference			
	Labour Productivity (LP)		Annual Growth in LP	
	Coeff.	(s.e.)	Coeff.	(s.e.)
AI Adoption				
Adopter	-0.087	(0.260)	0.085	(0.206)
Firm Attributes				
Capital intensity (K/L)	0.201**	(0.093)	0.080***	(0.022)
%Capital intensity (K/L), 1-year			0.206***	(0.050)
Internationalization				
Canadian	-0.185**	(0.092)	-0.021	(0.052)
Importer	-0.018	(0.022)	0.032	(0.026)
Exporter	0.049	(0.046)	-0.054	(0.043)
Size				
Employment (in log)	-0.071	(0.204)	0.384*	(0.228)
Employment_square (in log)	-0.027	(0.027)	-0.039	(0.031)
Age				
Age (in log)	-0.942	(1.558)	0.966	(1.464)
Age_square (in log)	0.229	(0.412)	-0.283	(0.355)
Complementary Capacity				
R&D	-0.033	(0.039)	0.035	(0.031)
Year-fixed Effect	Yes		Yes	
Industry-fixed Effect	Yes		Yes	
#Observations	10,691		9,308	
#Firms	1,372		1,369	
R-squared	0.29		0.207	

Note: The difference-in-difference (DiD) regression is run using panel weights that are constructed by multiplying survey sampling weights by the inverse of the probability firms being selected into either the control or treatment group. The instrument variable is defined by the share of ICT occupation by 4-digit NAICS in 2011. Standard errors in parentheses, clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1

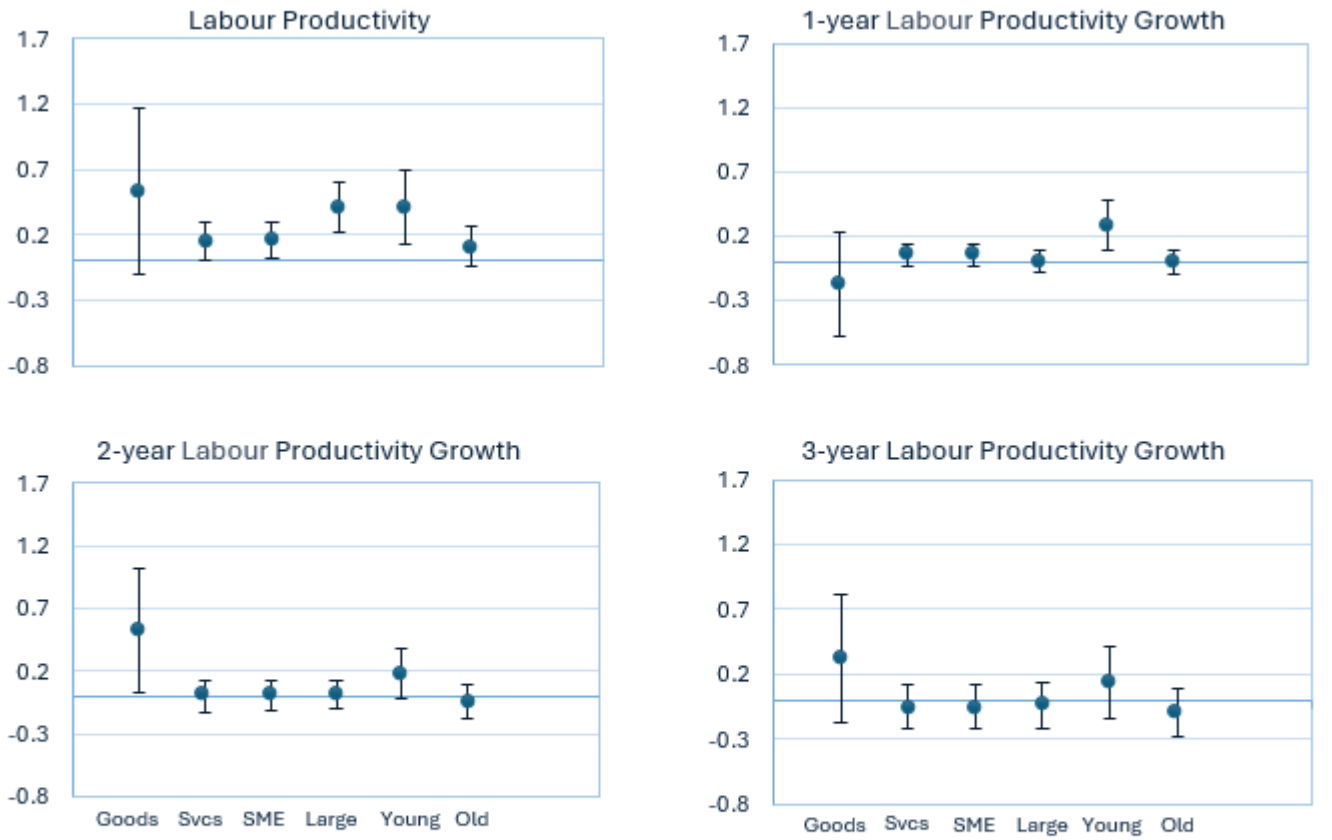
Source: SDTIU, 2019, 2021 and 2023 linked to the National Account Longitudinal Microdata File (NALMF) 2011-2023.

Empirical Results #3

Het. Impact

- Uneven productivity gains from AI adoption, benefiting most among
  - Large firms (250+ emp)
  - Younger firms (10yo or younger)
  - Productivity: level and one-year growth
  - Goods producing sectors (e.g., manu., mining, oil/gas) and young firms for 2-year LP growth

Figure 5: Estimates of AI's Impact on Productivity with 95% Confidential Interval in Subsamples



Note: These figures plot the coefficients of AI adoption in firm's productivity and productivity growth and their 95% confidence intervals for six subsamples. Goods refer to firms in Mining, quarrying, and oil and gas extraction, Utilities, Construction, and Manufacturing industries. Svcs refer to firms in the remaining services industries. SME refers to small and medium firms (with less than 250 employees) and large refers to firms with 250 and more employees. Young refer to firms aged 10 years or younger and old refer to firms older than 10 years. The coefficients are obtained by running the pooled IV regression described in equation (2) on the six subsamples. The instrument for the IV regression is 2011 ICT occupation share by 4-digit NAICS.

Source: SDTIU, 2019, 2021 and 2023 linked to the National Account Longitudinal Microdata File (NALMF) 2011-2023.

Concluding Remarks

- AI adoption is not uniform
  - More prevalent among firms in the service industries like information and cultural, and professional services
  - Non-linear with firm size (U-shape) and age (inverted-U)
  - Complemented by other advanced technologies, such as big data analytics
- AI adoption can boost labor productivity (LP) but its impact on LP growth remains limited in the short- and medium-term
  - Uniform impact, most pronounced among large and younger firms, and in the goods sector
  - Possible explanations
    - At an early stage, the potential of AI may require additional data to test a J-curve hypothesis
    - Translating AI's potential into economic gains may also require simultaneous organizational change, from business process, complementary technologies and skills
    - The COVID-19 pandemic may have confounded the observed effects on productivity growth

Questions?
Comments?
Suggestions?