Capital Incentives and Cloud, Big Data & AI Diffusion

Jonathan Timmis – World Bank

joint with Tim DeStefano, Nick Johnstone and Richard Kneller

Summary

- Traditionally, digital adoption = **tangible investments in hardware, software**. Policies often incentivize tangible investment.

- Instead, via the cloud, firms buy access to data storage & processing ***services***. Complementary to big data and AI.

- Use **UK tax incentive for tangible capital investment** as quasi-natural experiment to examine firm adoption of cloud computing, big data and AI.

- Tax incentive leads to:
  - Increase investment overall and in IT capital (as expected)
  - **But *reduces* adoption of cloud computing, big data and AI.**

1. Motivation

What is cloud computing?

- Change way in which firms access IT…
  - from investment in fixed IT capital
  - to paying variable cloud services expenses
- Beginning with Amazon Web Services in 2006 - access for data storage, computing or software services via the internet

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Why cloud matters?

- Cloud - flexible, “pay as you go” cost
  - Scale & productivity gains for SMEs and startups (Bloom & Pierri, 2018; DeStefano et al., 2023, Jin & McElheran, 2018)

- Cloud matters for use of Big Data and AI:
  - Big data requires big storage & processing power, often only available via the cloud.
  - AI needs data and processing to train algorithms - cloud computing as pre-requisite for AI (Zolas et al., 2020; DeStefano et al 2022)

Policy environment

- Policies often target tangible capital investment (PCs, servers…) rather than digital services (OECD, 2018)
  - Tax allowances, subsidies, grants, training programs
- Every OECD country has some form of tangible capital incentive (Tax Foundation, 2018).
  - IT services are usually excluded from these incentives

- We use a UK tangible capital incentive, introduced in 2008, and modified thereafter.
- If own-IT investment and cloud services are (partial) substitutes….capital incentives may discourage cloud use

2. Data & Empirical Approach

Data

- UK firm-level data on investment, cloud & big-data & AI from Office of National Statistics
- Baseline analysis focuses on 2007-2013.
- Annual Business Survey
  - Annual investment data (total, ICT, hardware)
  - ICT investment only available 2008 onwards

- E-commerce survey
  - Unbalanced panel
    - Cloud available 2013,15,19; Big-Data in 2015,19 and AI in 2019.
  - Assume zero use in 2007, following DeStefano et al. (2023)

Summary Statistics

- 34% of firms have cloud, but varies a lot by type. 26% use big data, but only 1% use AI.
- Size of treatment groups - £ 50,000 total investment is 19th percentile, £250,000 is 35th percentile

Variable	Mean	Standard deviation	Observations
Cloud (any type)	0.344	0.475	3,953
Cloud Data Storage	0.209	0.407	3953
Cloud Processing	0.095	0.293	3953
Cloud Email	0.170	0.376	3953
Big Data Analytics	0.259	0.438	3544
AI - Machine learning	0.014	0.119	1748
AI - Natural language	0.010	0.101	1748
(log) Investment	6.661	2.356	27,095
Multi-plant	0.753	0.431	29,625
Number of plants	52.948	278.088	29,550
Foreign owned	0.341	0.471	29,625
(log) Age	3.349	0.384	29,625

UK Annual Investment Allowance (AIA)

- Introduced in April 2008, changed several times
- Eligible investment: tangible capital used to produce / sell products – IT capital, machinery (***but not land & buildings***)
- Tax incentive: Deduct capital investment, up to allowance, from profits
- Allowance calculation: based on table below and firm's precise financial year (e.g. Jan to Dec vs March-April)

	Annual Investment Allowance
Before April 2008	No Allowance
April 2008 – March 2010	£50,000
April 2010 – March 2012	£100,000
April 2012 – December 2012	£25,000
January 2013 – March 2014	£250,000
April 2014 – December 2015	£500,000
January 2016 – December 2018	£200,000
January 2019 onwards	£1,000,000

Use Changes in Allowance over Time

- Follow literature using changes in eligibility ceilings to estimate R&D tax incentive impact (e.g. Bjuggren, 2018; Saez et al., 2019; Bøler et al. , 2015)

- Intuition:
  - Firms with investment ***below*** AIA threshold have lower marginal cost of additional investment => receive a rebate equal to corporate tax rate
  - Use within-firm ***changes*** in AIA threshold as quasi-natural experiment.
    - i.e. AIA threshold increases, new firms fall below AIA threshold, which reduces their marginal cost of investment.

- Use average investment in 2005/6 (before AIA policy) to determine eligibility

Estimation Approach

- Difference-in-difference estimation – changes in AIA as quasi-natural experiment:

$$y_{it} = \alpha + \gamma\ AIA\_Treatment_{it} + FE_i + FE_t + Z_{it} + \varepsilon_{it}$$

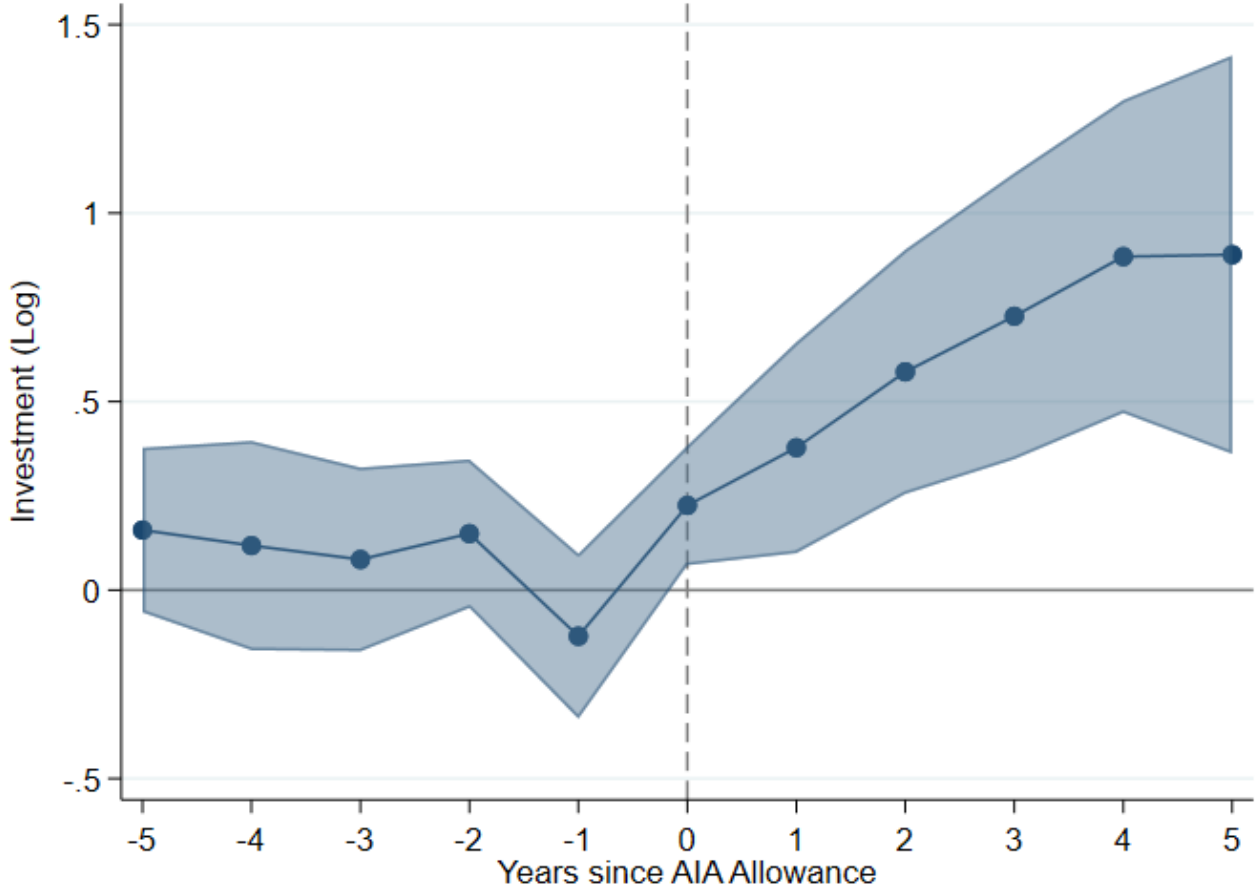
- y_{it} = investment, cloud, big data, AI
- Firm and Year Fixed Effects (FE_i, FE_t) – i.e. estimate changes *within* firms
- $AIA\_Treatment_{it}$ = 1 if lagged investment <= $AIA_{time \leq t}$,
  i.e. firm receives AIA incentive up to time t
  0 otherwise.

- Z_{it} are firm controls (log age, multi-establishment, foreign owned, fiber broadband availability)

3. Results

Capital incentive increased tangible investment (as expected)

- Event study plot of firm investment around timing of AIA changes (Callaway and Sant'Anna, 2021)



Capital incentive increased tangible investment (as expected)

- Firms that receive capital incentive….
  - increase overall investment, as well as investment in plant & machinery, vehicles, IT software..
  - But **not** land & building investment which was **ineligible** for capital incentive

	(1)	*(2)*	*(3)*	*(4)*	*(5)*
Outcome:	*Total Investment*	*Plant & Machinery*	*Vehicles*	*IT Software*	*Land & Buildings*
AIA treatment	0.201***	0.309***	0.093*	0.097*	0.002
	(0.064)	(0.059)	(0.051)	(0.055)	(0.056)
Observations	22,219	23,016	19,074	24,676	22,730

But capital incentive *slowed* cloud diffusion

- Firms that receive capital incentive are less likely to adopt cloud
  - *Especially* cloud services related to processing and storage of data

	(1)	*(2)*	*(3)*	*(4)*
Outcome:	*Cloud (Any Type)*	*Cloud Data Storage*	*Cloud Processing*	*Cloud Email*
AIA treatment	-0.165***	-0.097***	-0.095**	-0.045
	(0.04)	(0.04)	(0.04)	(0.03)
Observations	2,200	2,200	2,200	2,200

Especially among small firms

- The capital incentive slows cloud diffusion amongst all firm sizes, but the slowdown is much more acute for smaller firms.
  - Precisely the firms with the most to gain from flexible cloud services

	(1)	*(2)*
Outcome:	*Cloud (Any Type)*	*Cloud (Any Type)*
AIA treatment	-0.104**	-0.141***
	(0.046)	(0.042)
AIA treatment * SME	-0.235***	
	(0.075)	
AIA treatment * Small		-0.228**
		(0.103)
Observations	2,200	2,200

The capital incentive also *slowed* big data and AI diffusion

- Firms that received the capital incentive were less likely to adopt big data analytics or AI.
  - Consistent with cloud services (for data storage & processing) being a pre-requisite.

	(1)	*(2)*	*(3)*
Outcome:	*Big Data*	*Machine Learning (AI)*	*Natural Language Processing (AI)*
AIA treatment	-0.185*** (0.030)	-0.028** (0.011)	-0.013 (0.010)
Observations	2,262	1,746	1,746

4. Conclusion

The capital incentive also *slowed* big data and AI diffusion

- Every OECD economy has a (tangible) capital investment incentive program – many are targeted to IT
  - E.g. UK had IT specific incentive 2000 to 2004

- But businesses shifting from physical capital to intangibles & services
- Capital incentives increase investment in total capital & IT capital
  - but it **reduces** cloud adoption propensity

- Capital incentive also leads to a **lower** likelihood of using big-data analytics and AI
- Policies designed with a traditional view of capital & IT, may inadvertently be delaying new business models, including data and AI technologies.

Comments / suggestions are welcome!

Jonathan Timmis
jtimmis@worldbank.org

Robustness – Size of AIA Capital Incentive

- Firms with larger allowance ceiling increase their investment by more

	(1)	*(2)*	*(3)*
Outcome:	*Total Investment*		
AIA treatment dummy	0.201***		
	(0.064)		
AIA available allowance (continuous)		0.003***	
		(0.001)	
Allowance Quartile1			0.087
			(0.086)
Allowance Quartile2			0.124
			(0.081)
Allowance Quartile3			0.276***
			(0.103)
Allowance Quartile4			0.440***
			(0.116)
Observations	22219	22219	22219

Big Data Definition

- Ecommerce survey defines big data as:
- (1) vast amounts of data generated over time,
- (2) variety in terms of different formats of complex data, either structured or unstructured (for example text, video, images, voice, docs, sensor data, activity logs, click streams, coordinates).
- (3) velocity in terms of the high speed at which data are generated, become available and change over time.

- Big data analysis as the use of techniques, technologies and software tools for analyzing big data from our own business or other data sources.

AI Definition

Did this business use any of the following methods to analyse big data:

- **Machine learning**, for example deep learning. This involves 'training' a computer model to better perform an automated task, e.g. pattern recognition
- **Natural language processing**, natural language generation or speech recognition. This is the ability of a computer program to understand human language as it is spoken, to convert data into natural language as it is spoken and convert it to machine-readable format.