ECONOMIC STATISTICS CENTRE OF EXCELLENCE

Digital opportunity: how cloud computing changes the shape of the UK economy

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Background: what is the cloud and historical overview

1960s	1970s	1980s	1990s	2000s	2010s

Mainframes

- Centralized computing
- Batch processing
- Terminal Access
- Virtual Machines

Client Server

- Personal Computer
- Early Networks
- Packet Switching
- Local Area Networks

World Wide Web

- Web browsers
- Enhanced Networks
- Service Oriented Architecture

Cloud Computing

- Broadband Networks
- Large Data Centers
- Advanced Virtualization
- Mobile Clients

Cloud is a **service** that enables **on-demand network access** to a **shared pool** of **configurable** computing resources (e.g. networks, servers, storage, applications, and services) that can be **rapidly provisioned and released** with **minimal** management **effort** or service provider interaction

Source: Hrishikesh (Rishi) Trivedi "Cloud Adoption Model for Governments and Large Enterprises", Figure 1

Motivation:

- Solow paradox (Solow 1987) and no ICT impact (Doms, Dunne and Troske 1997, Morrison 1996, Brynjolffson 1993)
- Slowly emerging positive impacts of ICT on productivity (Jorgenson and Stiroh, 1995, 2000)
- As cloud is still at the implementation process*, the question about its effectiveness is important
- Cloud computing is related to a boost in company productivity (Acemoglu and Restrepo, 2018, Bloom and Pierri, 2018, Ewens et al. 2018)
- Helps to cut down R&D costs, leverage existing best practices in using ICT, achieve better time use thanks to automation of internal processes (Jin and McElheran, 2018)

*Reuters (2011), “Cloud computing disappoints early adopters: survey”

What is different about Cloud

- Productivity impact
  - Cloud for SMEs (Jin and McElheran (2018))
  - Automation (medicine(Wang et al., 2011), physics (Sevior et al., 2010) autonomous vehicles (Yadan, 2019), conversational AI (Mead, 2017))
  - New jobs (European Commission (2017))
- Intangible impact
  - Learning and R&D (Jin and McElheran (2018))
  - Ease of communications, knowledge sharing (Bloom et al (2018), OECD (2015), Mohamed and Pilutla (2014))
  - GPT (AI, IoT)
- Financial impact
  - ICT substitution (Jin and McElheran (2018), Coyle et al. (2018))
  - Reducing business uncertainty (Decker et al. (2014))
  - Demand non-rigidity (DeStefano et al. (2018),Palmer (2012))
  - Lower barriers for entry (Ewens et al. (2018), OECD (2015), Etro (2009))
  - Standardization, interconnection, security (IDC (2014))

The main differences between Cloud and ICT:

- technology cost reduction
- decreasing barriers
- cancellation opportunity
- network effects
- complementary investments
- ICT substitution

The study

Research question:
What is the impact of cloud technologies on the performance of enterprises in the UK?

Topics:
- Understand the role of cloud technologies for enterprises
- Empirically verify the impact on the productivity of companies
- Understand the role cloud plays for firms' resilience to the COVID-19 disruption

Contribution to the literature:
- Derive empirical quantitative estimates of the cloud productivity
- New method for collecting the data about the modern economy

What is the impact of cloud technologies on the productivity of enterprises in the UK?

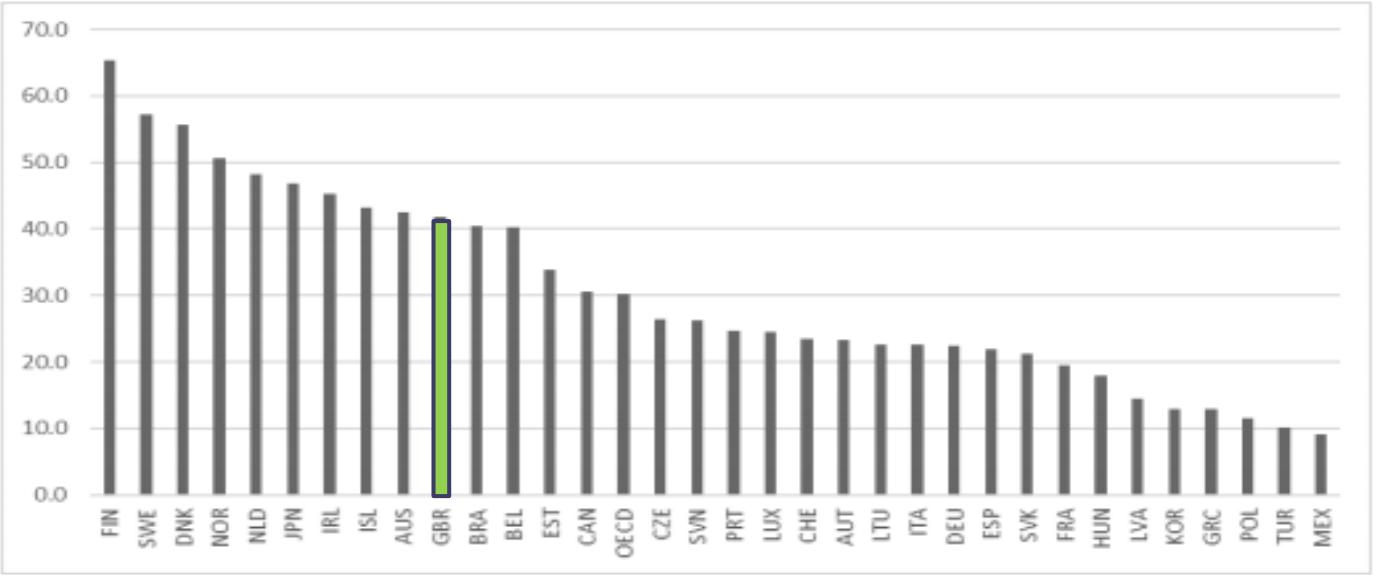
Source: Coyle et al.(2018)

Public sector:
from 7 m GBP to 1.7 bn GBP expenditures
Private sector:
from 24% to 41%, 1/3 of IT infrastructure investments*
Biggest players:
Rackspace, IBM, Amazon, Azure, Google ,Oracle, Alibaba, UKCloud (government)**

*(Forbes, 2017)
** https://www.techradar.com/uk/news/best-cloud-computing-service

What is the impact of cloud technologies on the productivity of enterprises in the UK?

As a percentage of enterprises with ten or more persons employed



Source: OECD, ICT Access and Usage by Businesses Database, http://oe.cd/bus, December 2018.

OECD, ICT Access and Usage by Business Database, indicator G3: Businesses purchasing cloud computing services

Incentives to implement cloud

Business perspective common roles

- *CAPEX to OPEX shift*
- *Solving of underutilization issues*
- *External compliance issues*

People perspective common roles

- Additional cloud roles and skills
- *Cloud direction conflicts*
- *Management issues*

Governance perspective common roles

- *Scorecards impact*
- *Software licensing*

Security perspective common role

- *security policies compliance*

- *Information Leak Prevention (ILP) problems*

Operations perspective common roles

- *Data recovery (DR) / Business continuity (BC)*
- *Cloud management and audit*
- *Cloud Single Sign-On opportunities*
- *Cloud mobility*
- *Cloud inventory management*

Platform perspective common roles

- *Continuous Integration (CI) and Continuous Development (CD)*
- *Cloud architecture patterns*
- *Auto resource provisioning*
- *ML and AI tools*

Sources: The AWS Cloud Adoption Framework: Creating an Action Plan 2017,
Berkley et al (2014) “A HEURISTIC MATHEMATICAL DECISION-SUPPORT MODEL FOR SMES CLOUD ERP SYSTEM ADOPTABILITY”

Dataset construction: where to get cloud usage statistics

- E-commerce survey
- Direct cloud statistics
- Own dataset construction

Domain name service (DNS) is a register of companies' websites.

Company can host its website:

- Using own premises
- Using conventional hosting vendor
- Using cloud vendor

DNS metadata

Parameter	Value
Name	King's College London
Domain	kcl.ac.uk
Domain registered on	2007-01-01
Expires on	2020-01-01
Last update	2018-11-24
DNS	*.kcl.ac.uk, *ja.net
Servers	Apache, Varnish
Additional services	Outlook.com Mailchimp

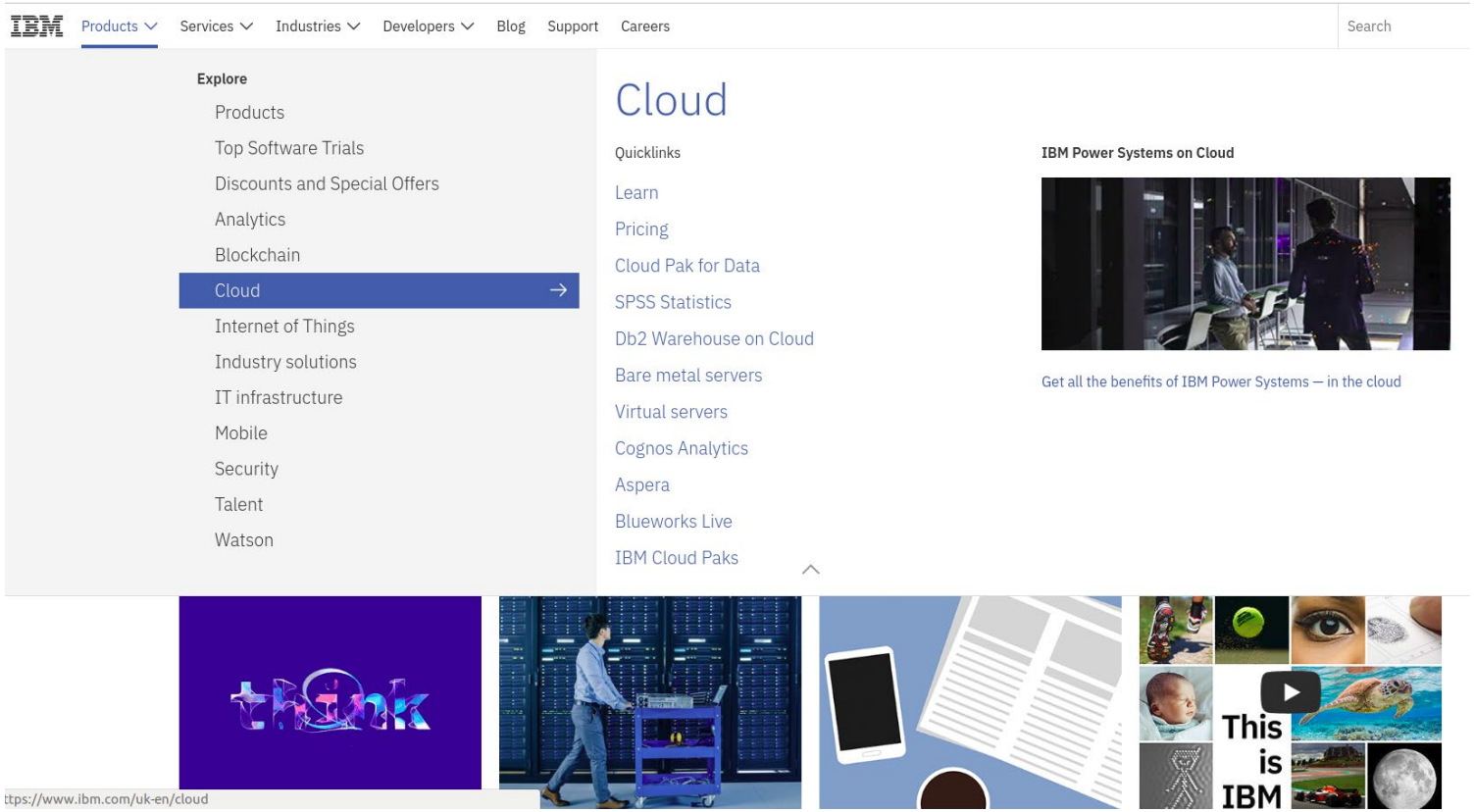
if company uses cloud vendor => means it utilizes cloud technologies

Cloud indicator and web scraping

1. Get list of web addresses from the FAME dataset. We use all companies that have a website
2. Do a parsing of DNS records (historical). Use Security Trails – worlds largest database of historical DNS records (2010 +)

Cloud indicator and web scraping

3. Find websites of SPs using google search and scrape websites of vendors (using wayback machine: web.archive.org)



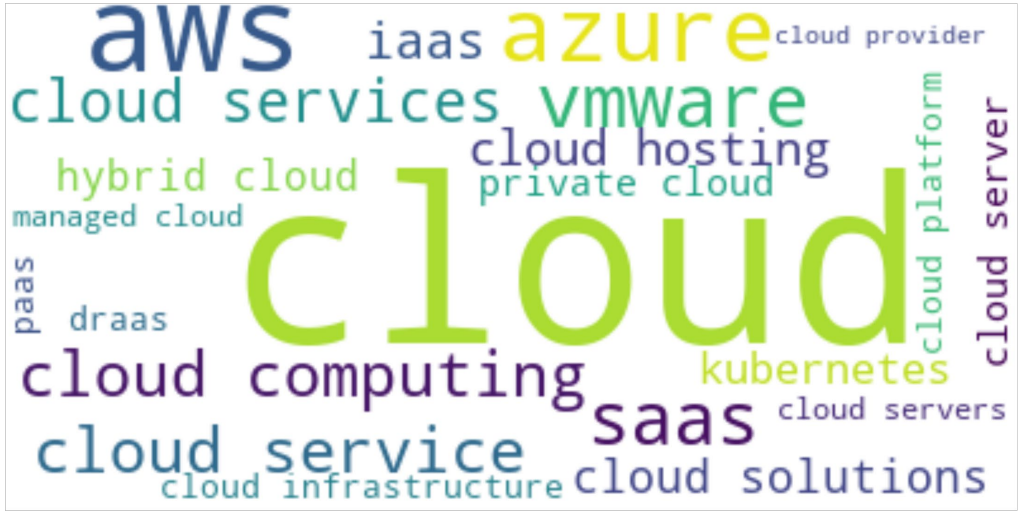
Limitations:

- First entry in google search is not always accurate (=> wrong website)
- Some websites block scraping (need more advanced scraping technique)

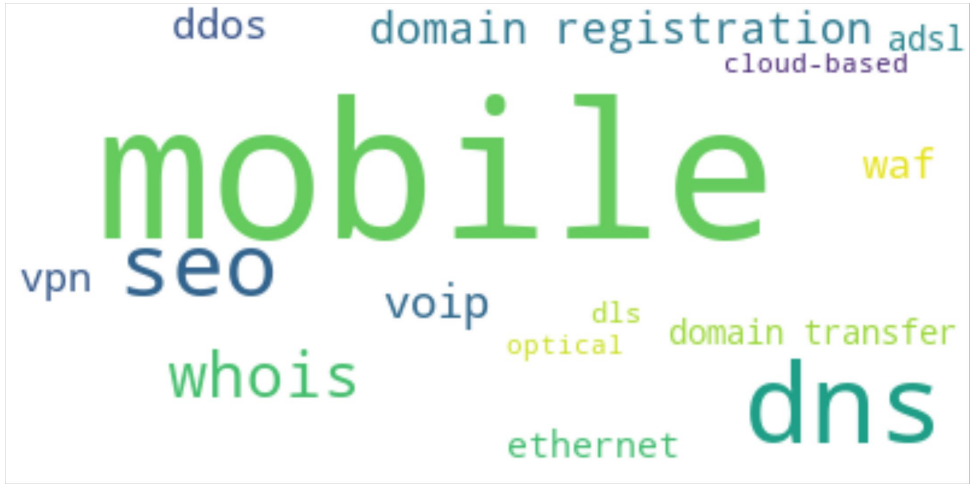
Cloud indicator and web scraping

4. Extract cloud related words

Cloud



Non cloud



Cloud indicator and web scraping

5. Assign cloud indicator to website hosting providers

A) Calculate number of keywords mentioned on the website – both cloud related and non-cloud related
B) If there are more cloud words than non-cloud, assign indicator = 1

Accuracy:

- Based on manual verification of top 200 providers, the misclassification rate is 10% (6% FP, 4% FN)
- POWER LAW: top 200 web hosting providers serve 97% of users
- So, final error is 0.3% on 10000+ hosting providers

Cloud indicator and web scraping

6. Assign cloud indicator to companies (based on web hosting provider used).

Problems:
A) companies change hosting providers(some do several times a year). Thus, assign cloud indicator just to those who use cloud provider more than 6 months a year

B) ex. Some of AWS users went to cloud hosting just out of curiosity (based on the marketing campaign). Those who do not benefit from cloud solutions, usually switch back within a year

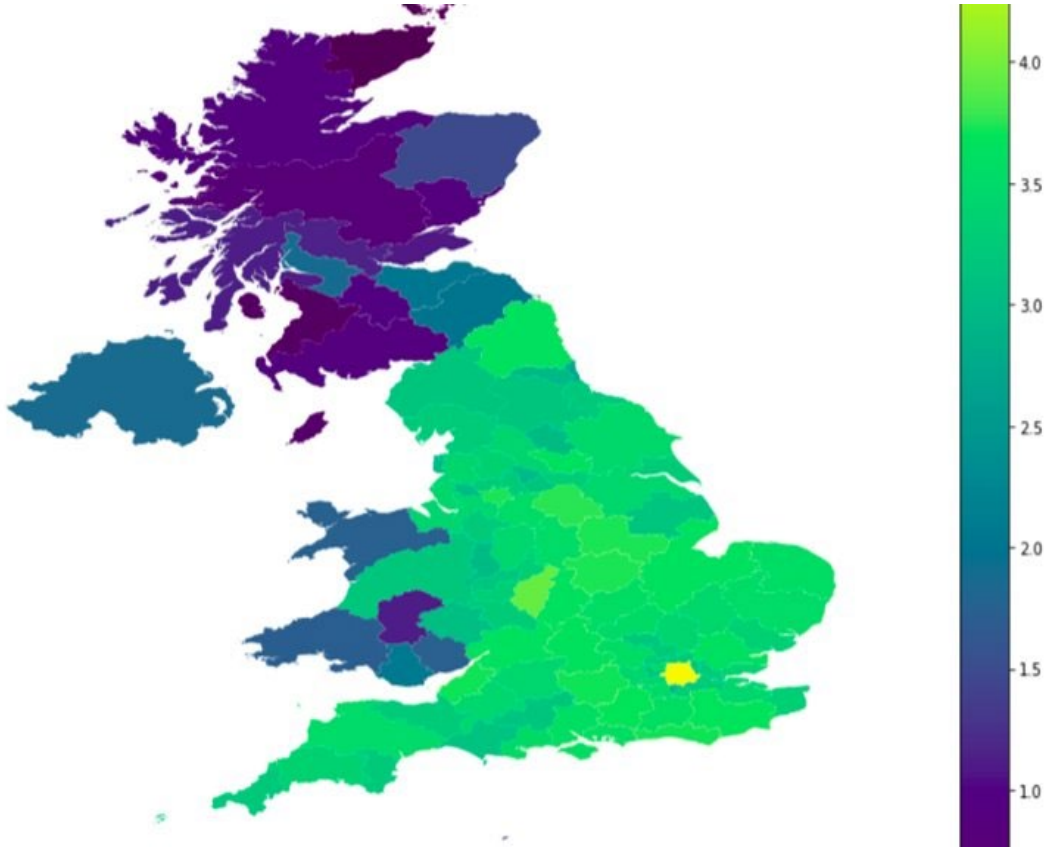
Cloud indicator and web scraping

1. Get list of web addresses
2. Do a parsing of DNS records (historical) and live
3. Scrape websites of vendors
4. Extract cloud related words
5. Assign cloud indicator to website hosting providers
6. Assign cloud indicator to companies

website	2010	2011	2012	2013	2014	2015	2016	2017	2018
www.guinnesspartnership.com	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0
www.gywop.org	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0
www.korewireless.com	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
www.mtgsolicitors.com	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0
www.oasisgroup.com	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
www.realtree-eu.com	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	0.0
www.tenalps.com	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
www.thecookingrooms.com	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0

Fame dataset

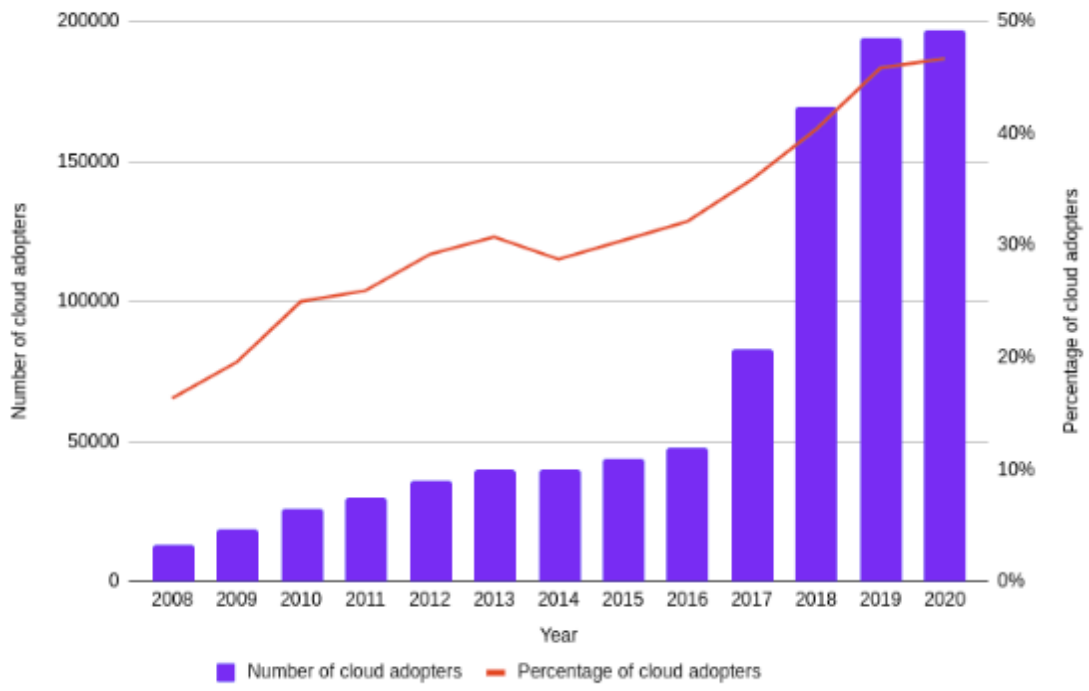
- Financial Analysis Made Easy (FAME) dataset, that covers a population of businesses in the UK and derives information from Companies House records
- 313,721 firms over the period from 2010 till 2018
- There are financial indicators, employment statistics and other important indicators of business performance contained in the dataset.



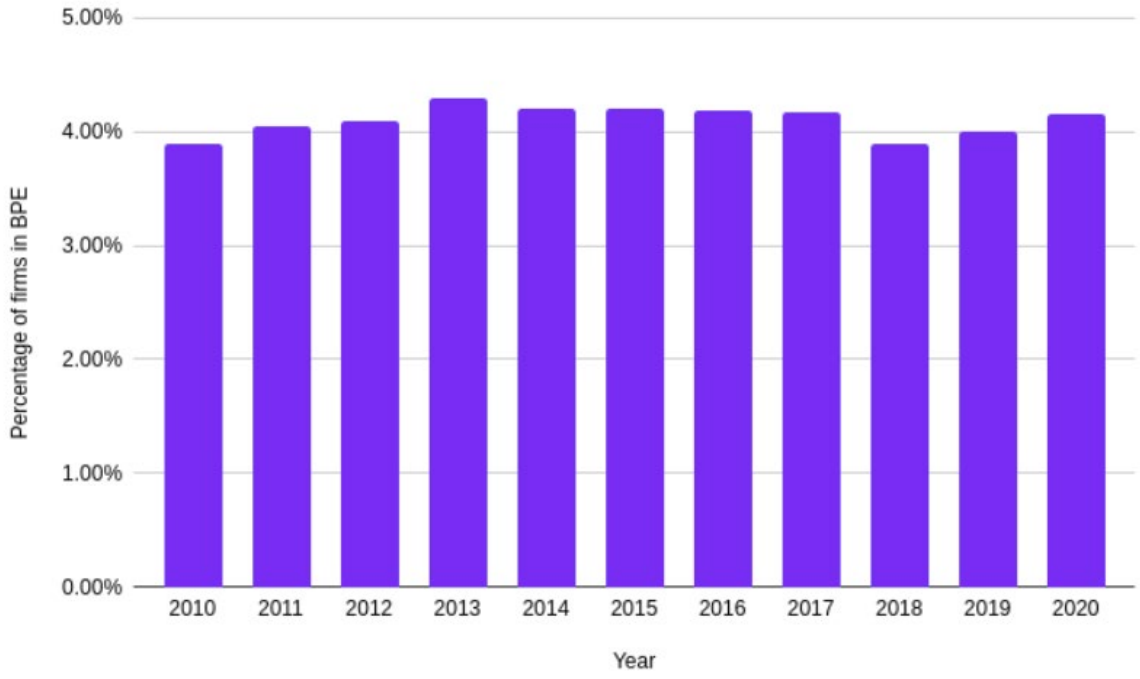
Number of companies depending on region (logs)

Sample analysis

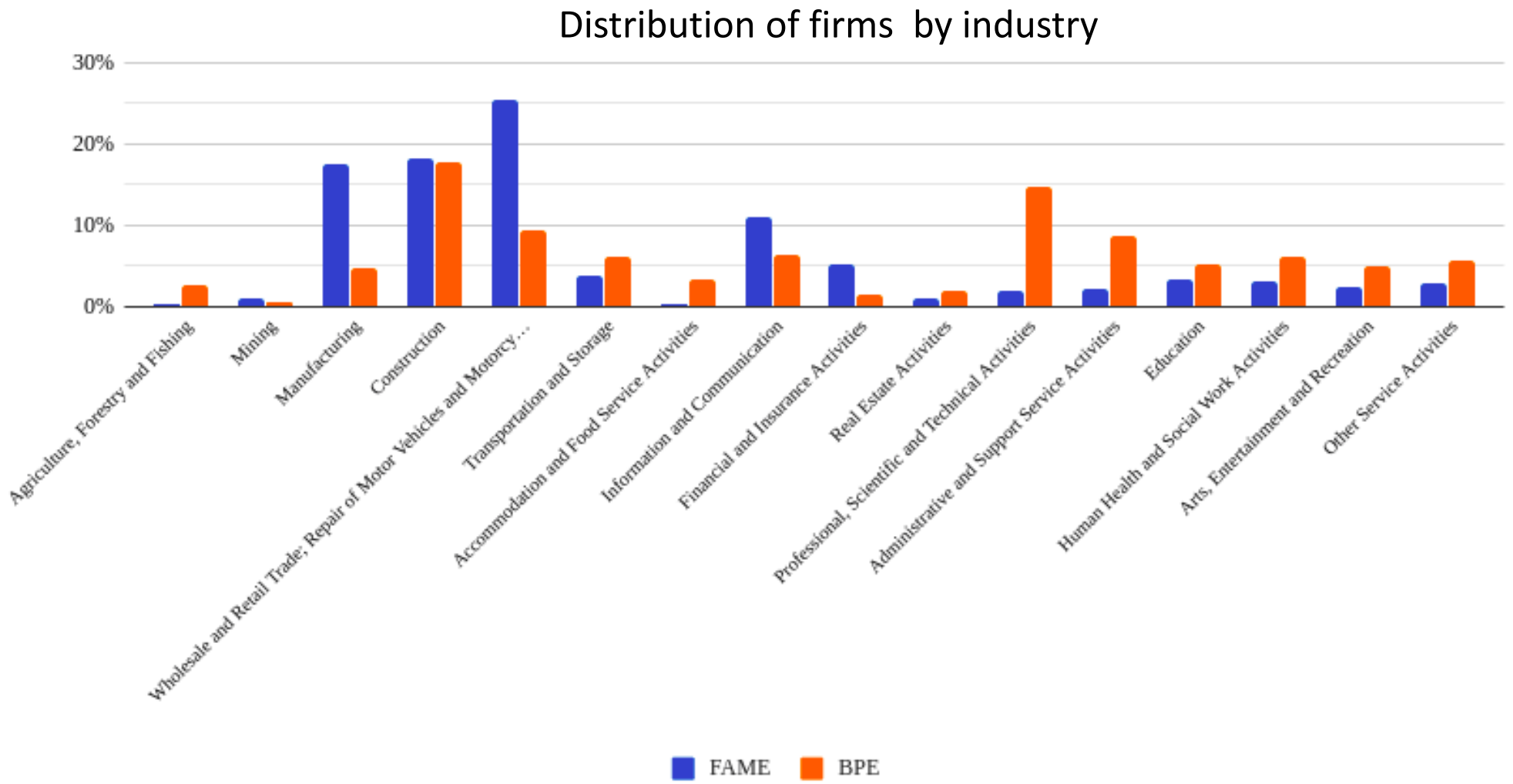
Number and percentage of cloud adopters by year



FAME-to-BPE data ratio



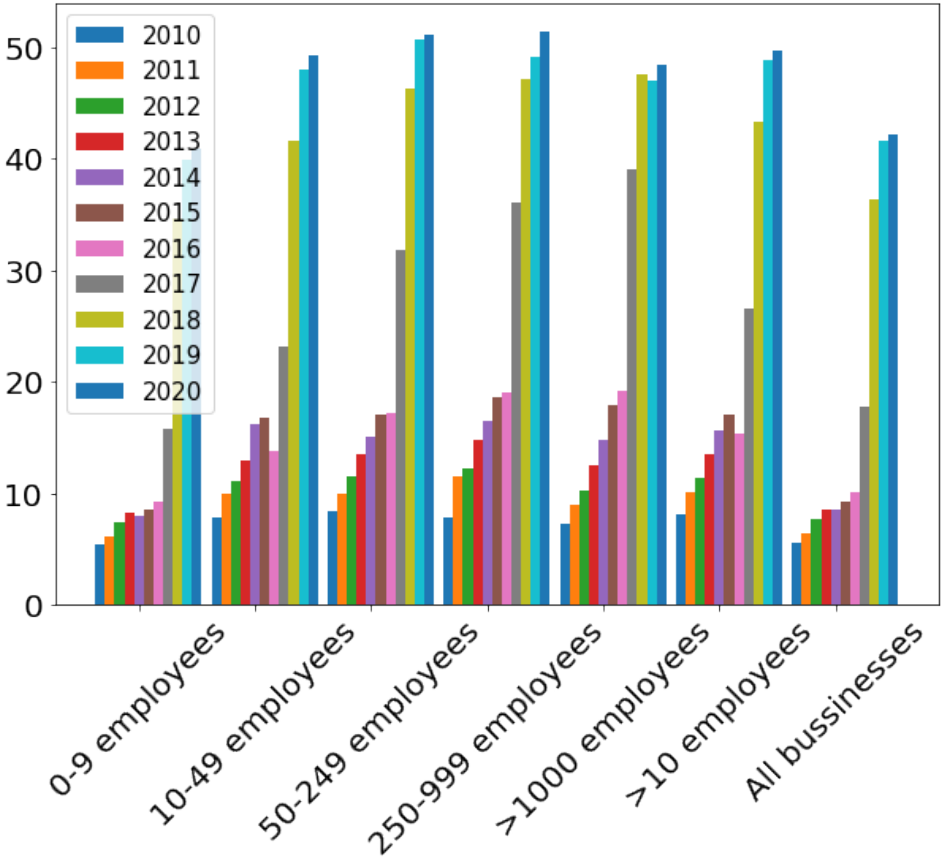
Sample analysis



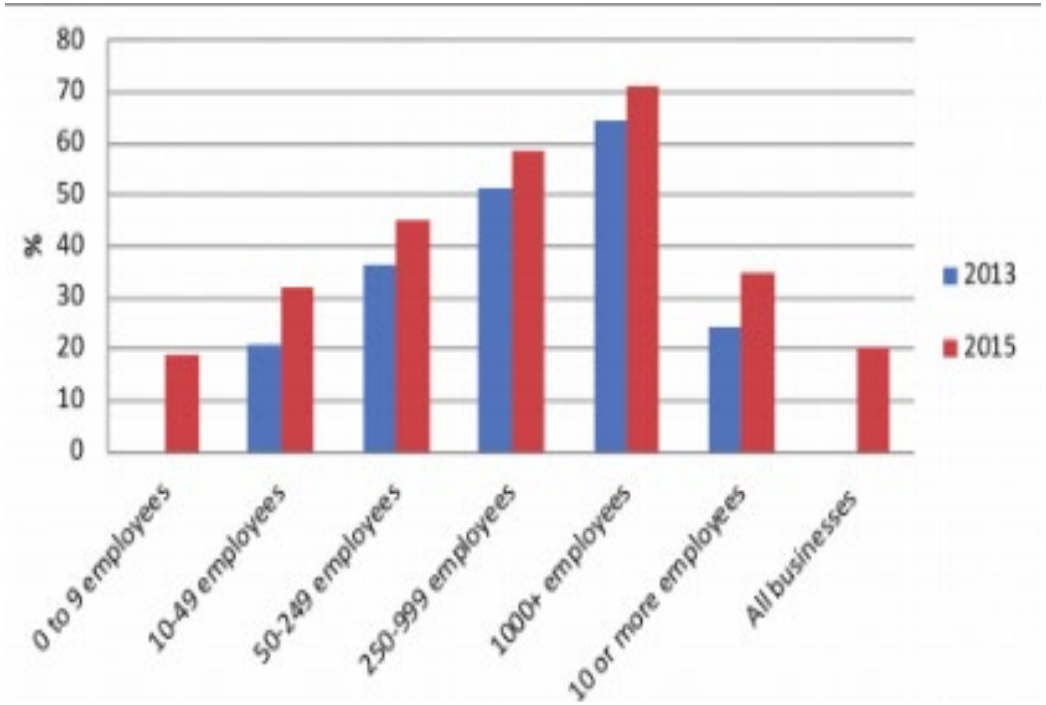
Sample analysis

Percentage of cloud users

Our sample



E-commerce survey



Modelling

$$p_{it} = a_0 + a_1 * l_{it} + a_2 * k_{it} + a3 * g_{it} + a_4 * f_{it} + a_5 * c_{it} + a_6 * h_{it}$$

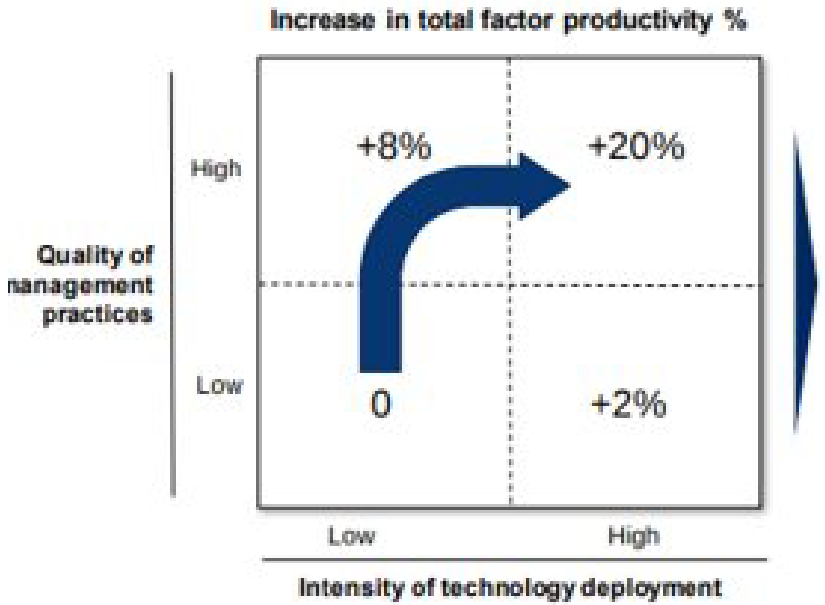
where p is a productivity per worker, l is a number of employees in the company, k are fixed assets per employee (a substitute for capital per worker), g is an age of the company (number of trading years since registration day till current year), f is a broadband connection speed based on Offcom's data, c is an indicator when the company started to use cloud services, h - historical usage of cloud facilities(amount of previous years when company used cloud, 0 in the first year of the cloud usage), i, t are entity and time subscripts.

Regression results

	(1) p b/se	(2) p b/se	(3) p b/se
k	0.230***	0.230***	0.230***
	(0.006)	(0.006)	(0.006)
l	-0.076***	-0.077***	-0.077***
	(0.002)	(0.002)	(0.002)
g	0.038***	0.038***	0.038***
	(0.003)	(0.003)	(0.003)
f	0.058***	0.058***	0.058***
	(0.003)	(0.003)	(0.003)
n	0.005**	0.005**	0.005**
	(0.002)	(0.002)	(0.002)
c	-0.035***		-0.022***
	(0.006)		(0.006)
h		0.010***	0.009***
		(0.001)	(0.001)
nobs	140072	140072	140072
R-sqr	0.185	0.185	0.185
dfres	140031	140031	140030
BIC	294812.43	294732.55	294733.24

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: all regressions include year, industry and region dummies



we obtain results similar to another independent study by Grous (2019), where it was found that cloud effect on productivity could vary from 0 to 20 per cent depending on the quality of management practices and intensity of technology deployment

Grous (2019). The Transformative Effect of Cloud on Firm Productivity and Performance: Defining the benefits and impact of cloud as a 21st Century digital enabler

Results depending on firm size and industry

Firm size	Cloud effect (h)
Micro	0.022***
Small	0.009***
Medium	0.003***
Large	-0.026

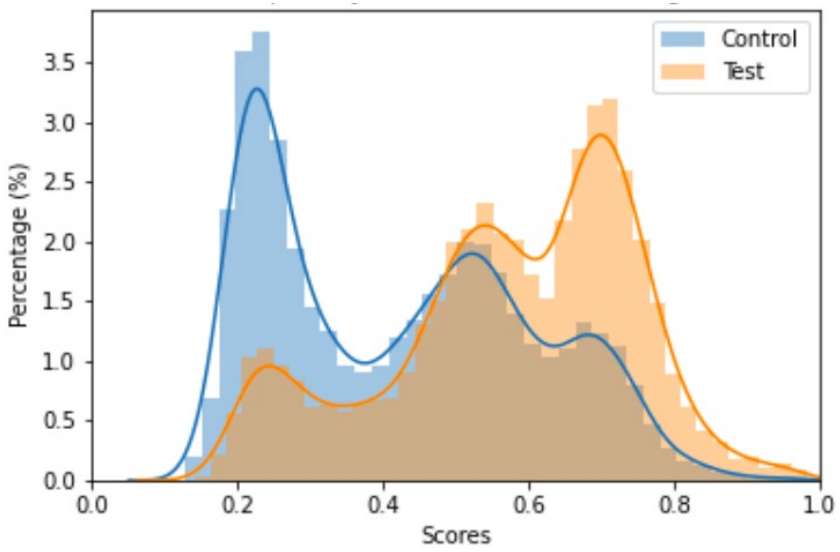
Micro and small firms face the highest yearly benefits from using the cloud

Sectors	Cloud effect (h)
Construction	-0.013
Manufacturing	0.006**
ICT and professional services	0.013***
Education and health	0.015**

Cloud provides the highest benefit for the ICT and professional services, education and health sectors, where information and tools that help to process it are one of the most crucial assets of the business

Propensity score matching

Propensity scores before matching



Dep. var	No. of treat	No. of control	ATT	Standard error	t-value	p-value
Outp. p. worker	62142	114129	0.65%	0.007	9.53	0.001

0.7% average productivity increase

we match 3 non cloud users to 1 cloud user, including financial indicators and year as a covariate

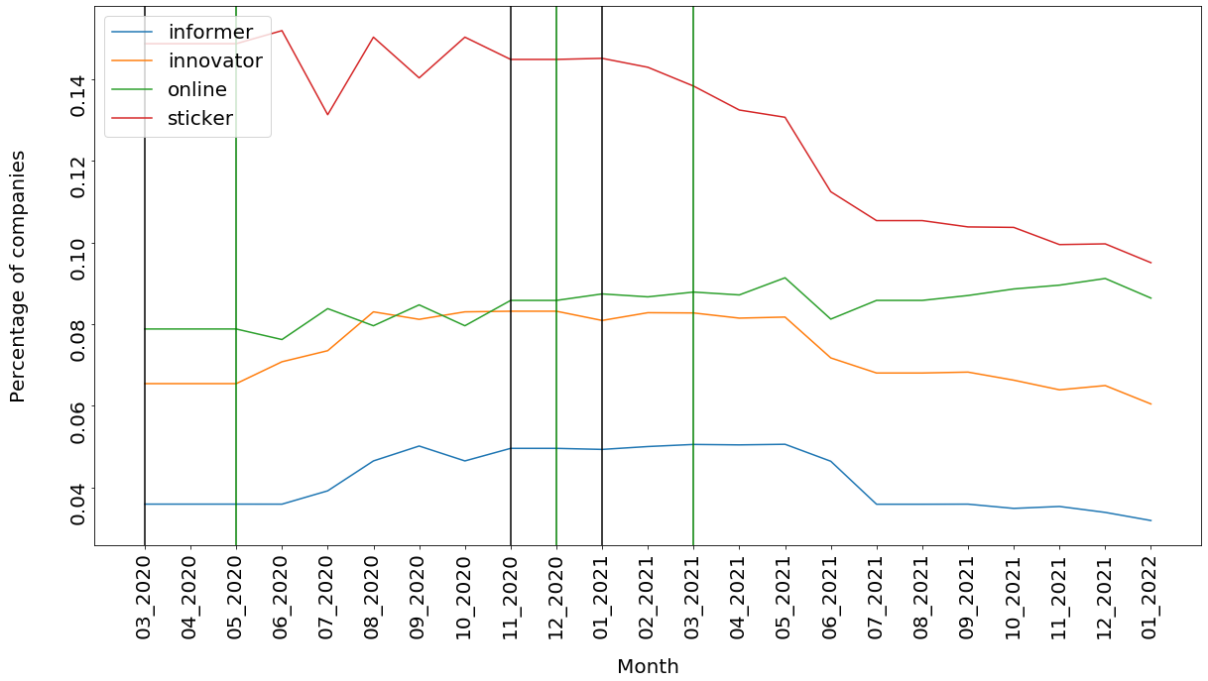
Propensity score matching results by firm size cohort

Group	Estimate	Standard error	t-value	p-value
Micro	0.8%	0.002	4.46	0.0003
Small	1%	0.001	7.28	0.0004
Medium	0.4%	0.001	3.96	0.0001
Large	0.08%	0.002	0.48	0.63

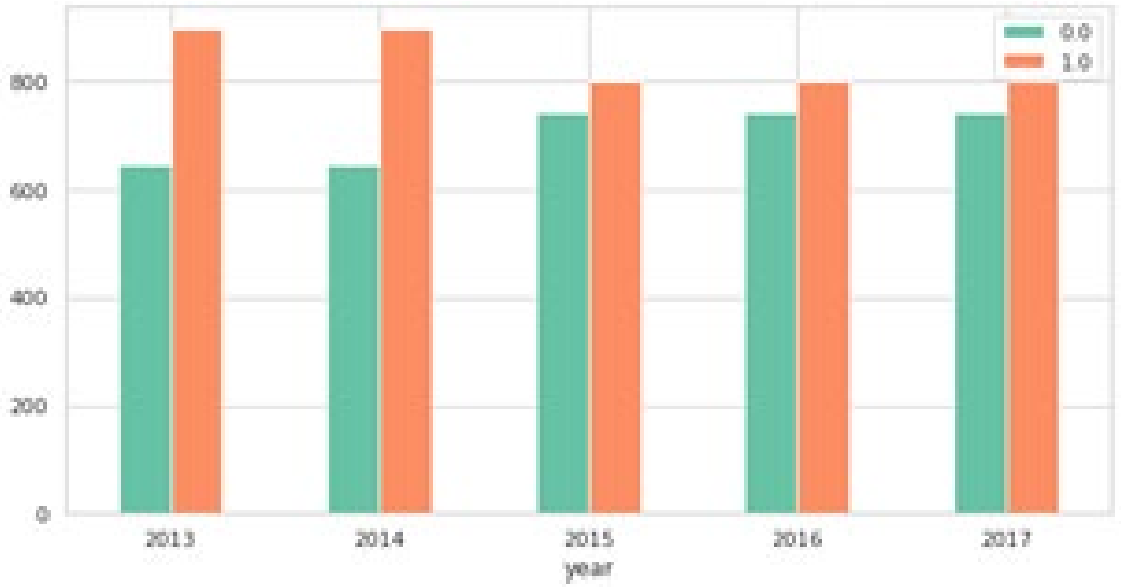
Further analysis: COVID-shock resilience

- Before-after analysis was performed, using pre-covid financial and technological, hiring background of the company, and it's after-shock resilience, ability to innovate.

- Results suggest that UK firms who use cloud technologies or even combine them with hiring of skilled employees have higher chances to innovate or to digitize their business. However, study revealed that bigger firms were still better able to innovate.



Further analysis: cybersecurity threats



- We utilized data about vulnerabilities, security threats and exposures of businesses (NVD, VERIS databases)
- Results revealed that cloud users are more vulnerable to security threats (higher vulnerability score, higher number of attacks on the company)

Thank you for your attention!

Difference-in-difference model

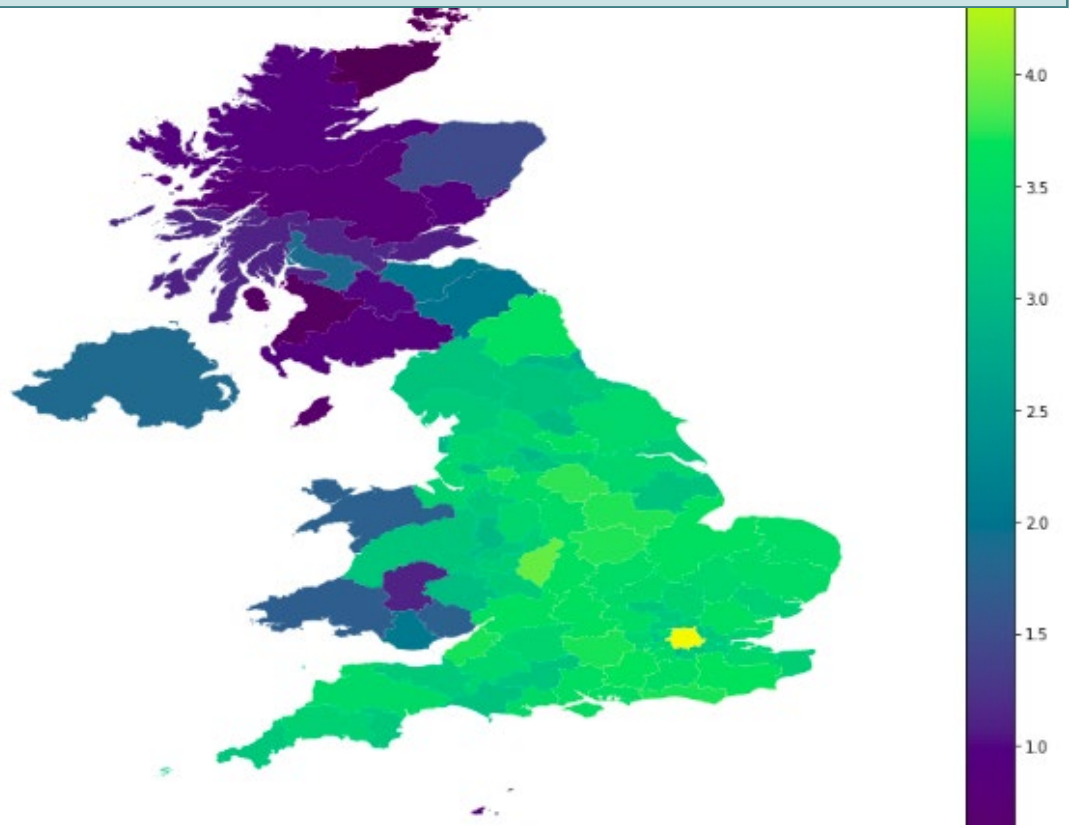
Dep. Variable:	sales_per_employees	R-squared:	0.1959
Estimator:	PanelOLS	R-squared (Between):	0.2217
No. Observations:	107097	R-squared (Within):	-0.3281
Date:	Fri, Mar 27 2020	R-squared (Overall):	0.1959
Time:	01:00:25	Log-likelihood	-1.535e+05
Cov. Estimator:	Unadjusted		
		F-statistic:	3727.0
Entities:	15298	P-value	0.0000
Avg Obs:	7.0007	Distribution:	F(7,107089)
Min Obs:	1.0000		
Max Obs:	10.0000	F-statistic (robust):	3727.0
		P-value	0.0000
Time periods:	10	Distribution:	F(7,107089)
Avg Obs:	1.071e+04		
Min Obs:	273.00		
Max Obs:	1.388e+04		

Parameter Estimates

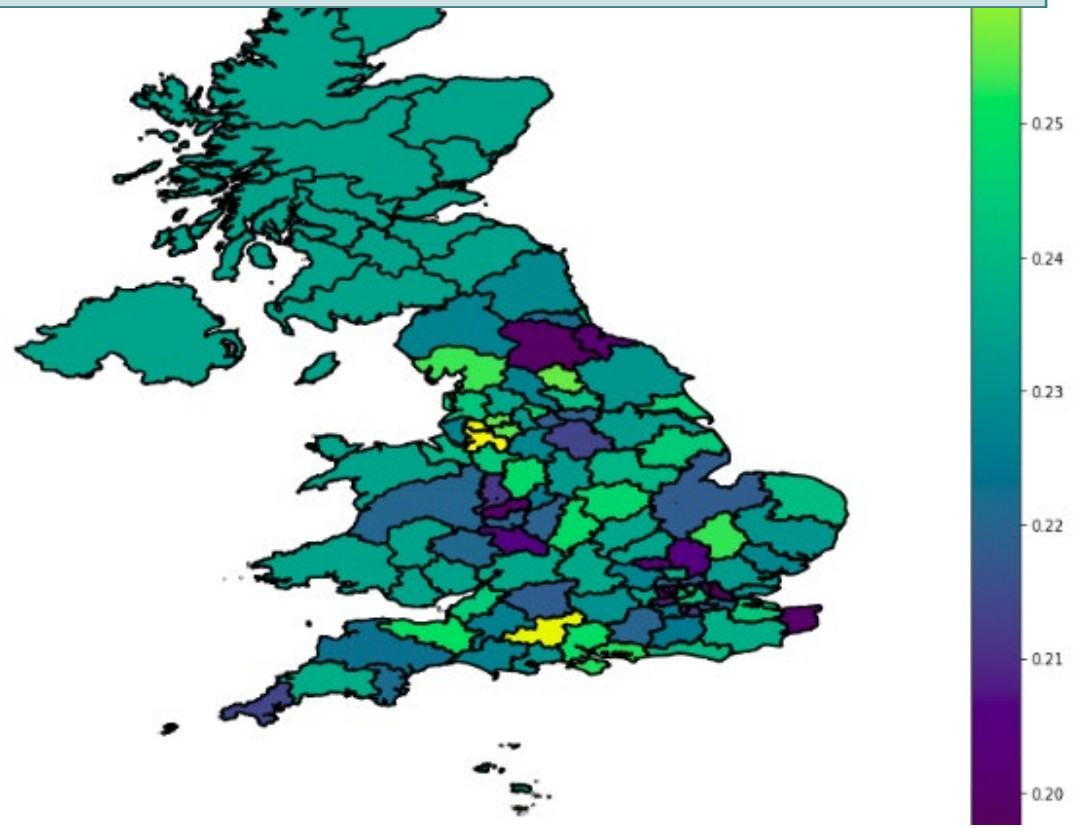
	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
const	5.6032	0.0130	430.71	0.0000	5.5777	5.6287
liquidity_ratio_x	-0.5460	0.0050	-109.80	0.0000	-0.5557	-0.5363
return_on_capital_employed_	0.1169	0.0012	95.599	0.0000	0.1145	0.1193
treated	0.0469	0.0084	5.5977	0.0000	0.0305	0.0633
policy	0.0198	0.0078	2.5424	0.0110	0.0045	0.0351
cross	0.0352	0.0142	2.4840	0.0130	0.0074	0.0629
shareholders_funds_	0.0625	0.0009	72.287	0.0000	0.0608	0.0642
number_of_employees	-0.1976	0.0026	-75.805	0.0000	-0.2027	-0.1925

Sample analysis

Number of enterprises in 2018 (in logs)



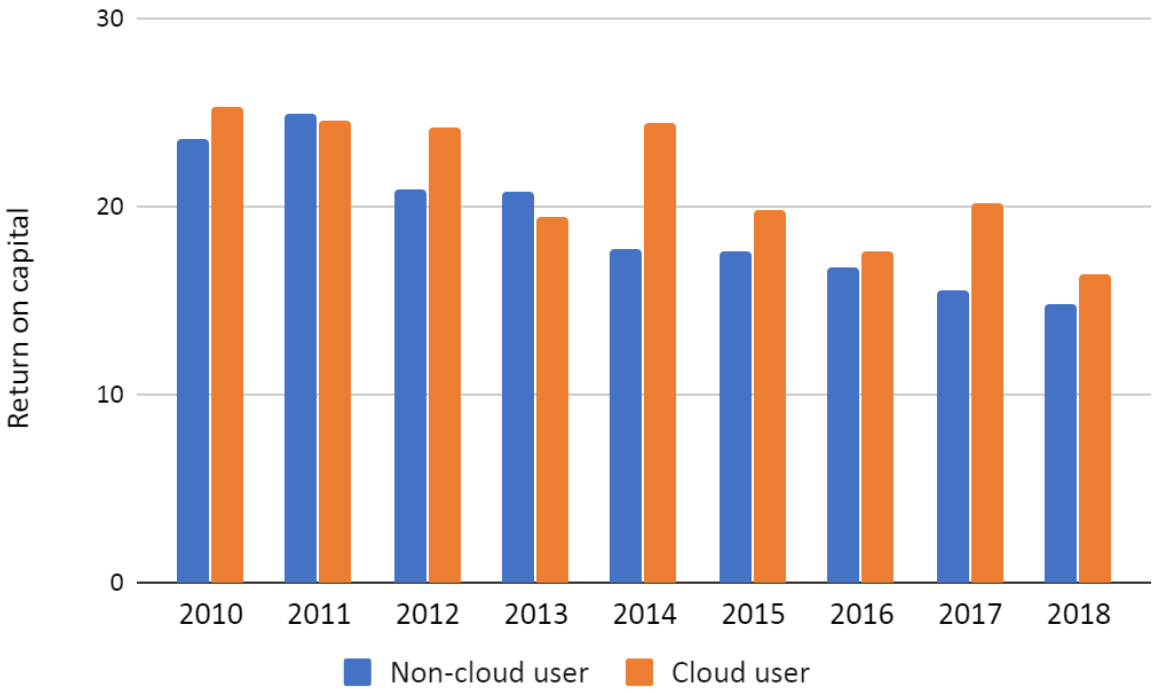
Cloud adoption in 2018 (in %)



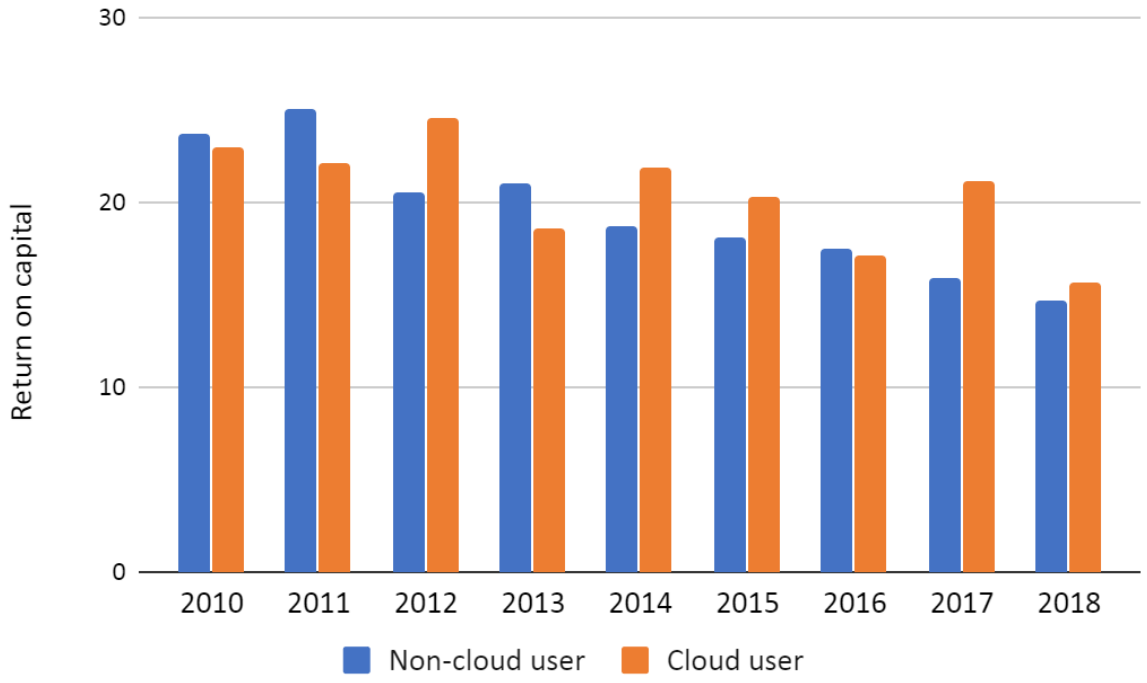
Cloud vs non cloud

Return on capital employed (%), all years, comparison between cloud and non-cloud users

Cloud adopted in 2012



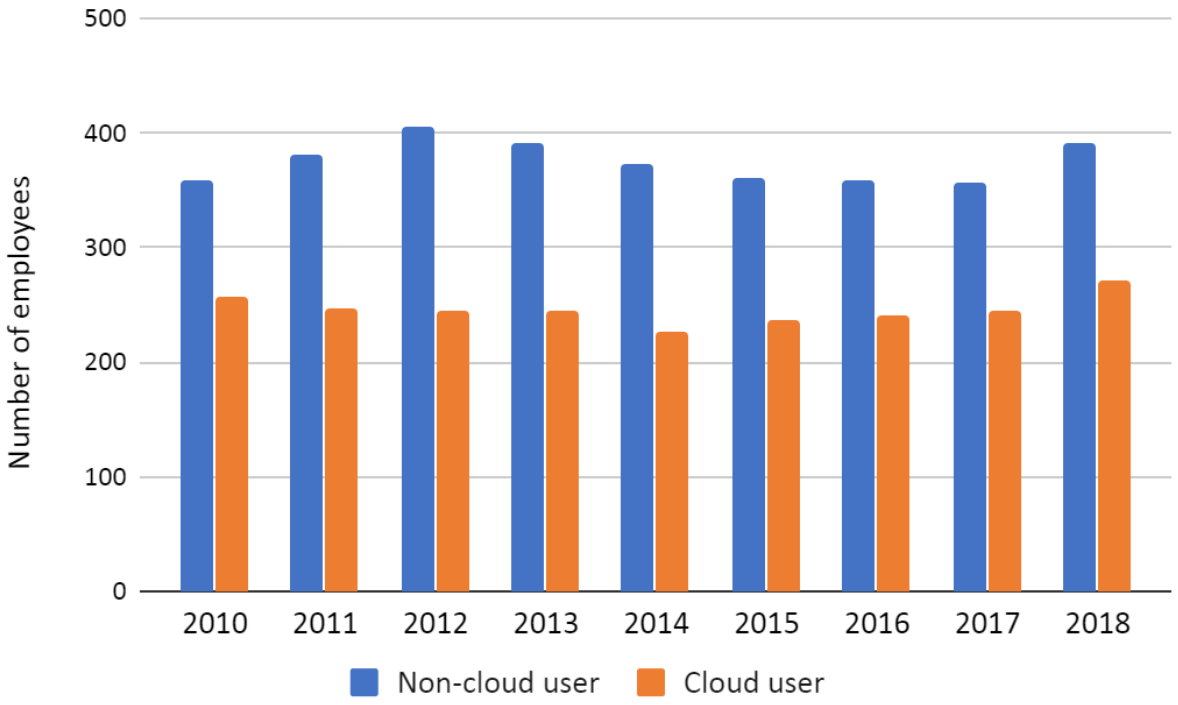
Cloud adopted in 2018



Cloud vs non cloud

Number of employees, all years,
comparison between cloud and non-cloud users

Cloud adopted in 2012



Cloud adopted in 2018