Are digital-using UK firms more productive?

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Introduction

- Slowdown in productivity growth in many developed countries since the mid 2000s (eg Lafond et al., 2021);
- Growing productivity gap between frontier firms and the rest (eg Andrews, Criscuolo and Gal, 2019; Haldane, 2017).

But we might have expected digital tools increasingly used in production (data usage, cloud services, platform business models….) to increase firm-level and aggregate productivity.

Possible resolutions?

- Fewer new ideas or important innovations compared to previous periods of high productivity growth (Bloom et al., 2020; Gordon, 2017);
- ‘Productivity J-curve’: intangible aspects of digital adoption mean time is needed to achieve productivity gains (Tambe et al., 2020).

A few firms improve their productivity, but it takes time to spread gains to most firms.

How does digital use by UK firms relate to their productivity?

Our approach

Why not standard aggregate growth accounting approach to estimating TFP?

- Any additional accounting for inputs will reduce estimated TFP (residual a 'measure of our ignorance'). Omitted inputs imply an upward biased TFP estimate.
- Assumes perfect competition and constant returns to scale. Not applicable in the context of digital markets. Deepens the productivity puzzle.

Role of firms' expenditure on innovation and digital inputs:

- Economies where firms spend on innovation have higher social returns (Jones and Summers, 2020).
- High productivity firms are those with a high level of digital capital, highly concentrated among few firms (Tambe et al., 2020, for US, Cathles et al for EU).
- Strong link between firms' proprietary IT, rising industry concentration, and higher productivity among the leading firms (Bessen, 2020; Pelzman, 2020).
- Investment in organisational capital, apart from IT investments and purchases, to make the most of digital technology (Brynjolfsson and Hitt, 2020; Li and Hall, 2020).

Focus on UK firms and a large number of digital inputs. Production function estimation approach to the largest UK dataset to date, using TFP estimates based on physical and digital capital stocks.

Data

We merged three ONS firm-level datasets :

- Annual Business Survey (ABS) – 62,000 businesses annually
- Annual Purchases Survey (APS) – 33,000 firms. Business expenditure on energy, goods and materials.
- E-Com Survey – 11,000 firms per year. Use of and expenditure on ICT.

Bias towards larger firms, with a final dataset of around 2,000 firms per year (2015-2018), not representative of the universe of UK businesses. In the merged data the average firm in 2018:

- 1,900 workers.
- £267 million of output and around £119 million of GVA (basic prices).
- £64 million of total employment costs.
- £1.3 million spent on telecommunication services, £2.7 million on programming services and £1.6 million on information services.

Data & estimation

- Create stocks of physical and intangible capital flow variables per firm and year.
- Perpetual Inventory Method (PIM) by ONS until 2014 from ABS: land, vehicles, machinery.
- Carried them forward for 2015-2018 using firms' annual expenditure on "land and existing buildings", "vehicles" and "other fixed capital", using EUKLEMS depreciation rates by industry.
- Similar method for capital stock using APS expenditures on R&D, programming, information, telecommunication, education and training services, with EUKLEMS depreciation rates, assuming 5 years average life.
- Baseline TFP, regressing GVA against ABS capital stock, employment and production costs
- Alternative TFP measure controlling additionally for APS capital stock variables.
- Several standard approaches: Olley and Pakes (1996), Levihnson and Petrin (2003), Wooldridge (2009) w/ and w/o GMM.
- Preferred approach: Wooldridge (2009) with GMM, 3rd degree (IV approach with lagged values as instruments)

Descriptive Results

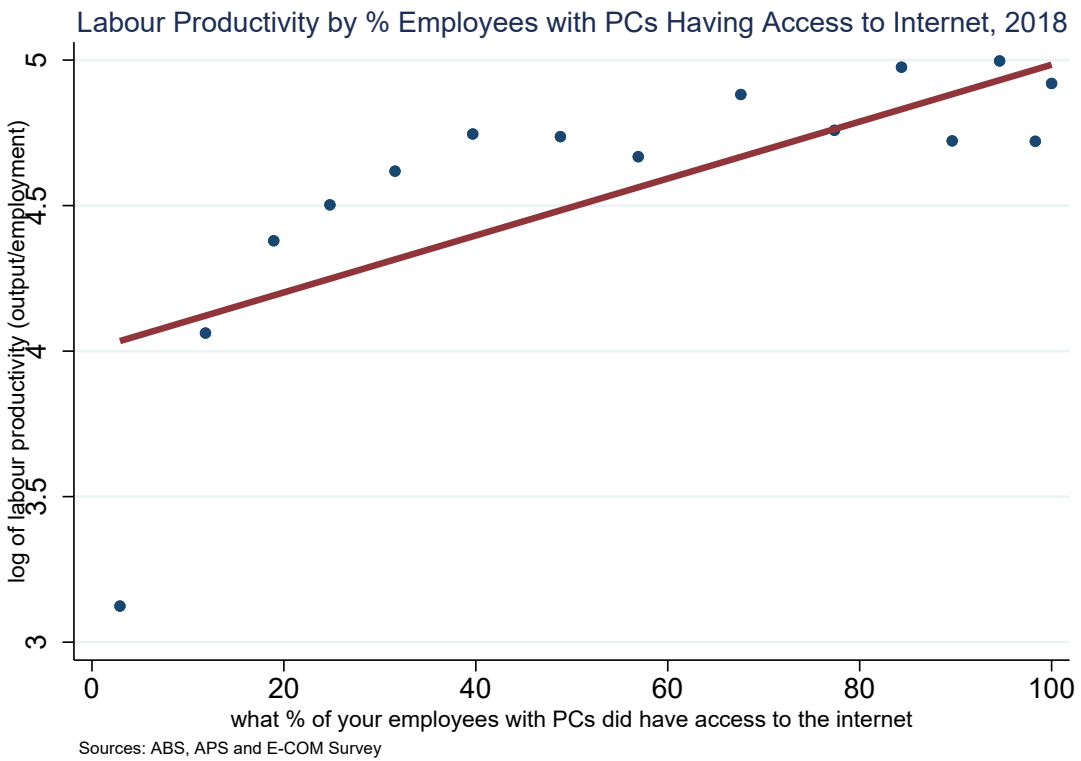
Weighted summary statistics 2018, by year and firm size (means and frequencies)

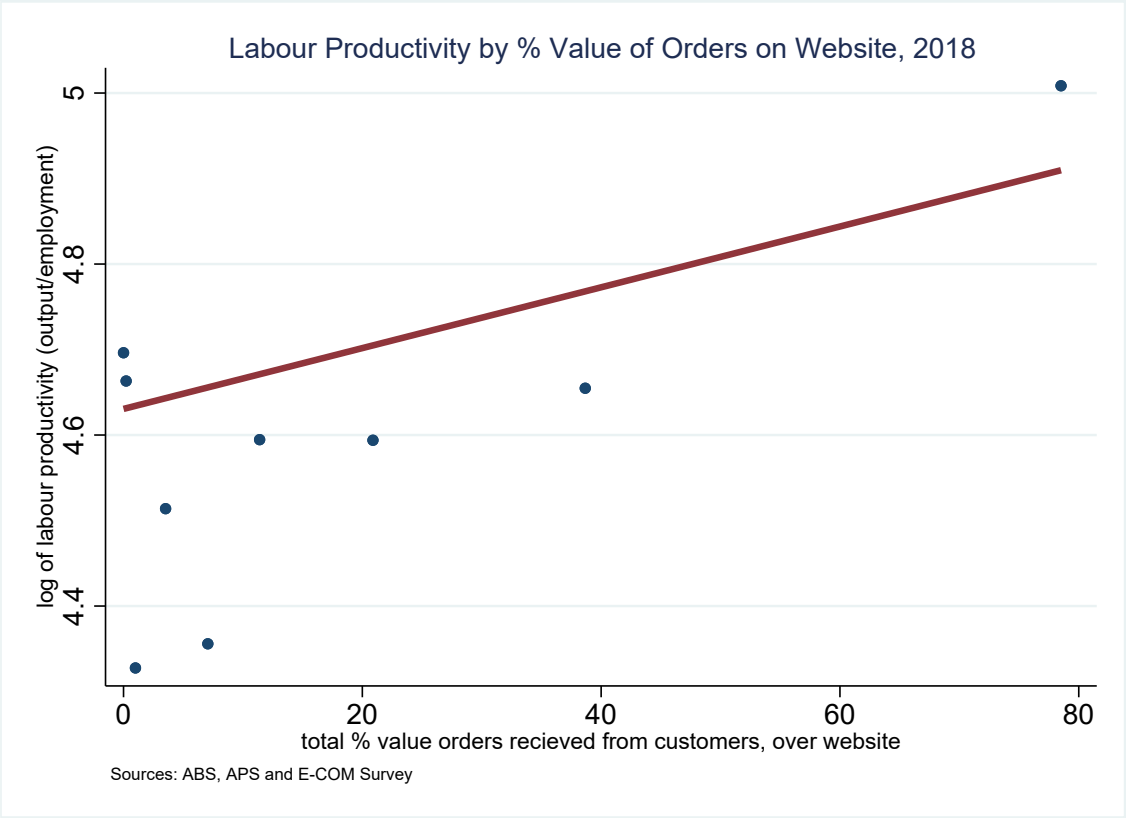
Indicator	Mean / Frequency	Employment sizeband						Total
		0-9	10-19	20-49	50-99	100-249	250+	
Computer software developed in-house (£ thousands)	mean	0.15	0.81	1.56	5.97	28.98	393.73	1.85
	freq.	2151712	138487.9	73324.93	23768.37	12814.57	8632	2408740
Investment in purchased software (£ thousands)	mean	0.28	4.91	7.6	26.35	43.44	751.13	3.95
	freq.	2151712	138487.9	73324.93	23768.37	12814.57	8632	2408740
Expenditure on scientific R&D services (£ thousands)	mean	0.73	0.05	0.39	3.12	35.85	307.46	83.49
	freq.	4127.55	7139.47	3407.61	1690.61	1192.41	6309.34	23867
ICT purchases, % total purchases (ABS)	mean	0.069	0.078	0.061	0.076	0.058	0.141	0.07
	freq.	1587660	127667.4	68932.15	22193.03	12186.35	8501.319	1827141
ICT services, % total expenditure on services (APS)	mean	0.154	0.149	0.16	0.196	0.126	0.143	0.152
	freq.	4127.55	7139.475	3407.613	1690.608	1192.414	6302.044	23859.71

Source: ABS and APS

Descriptive Results

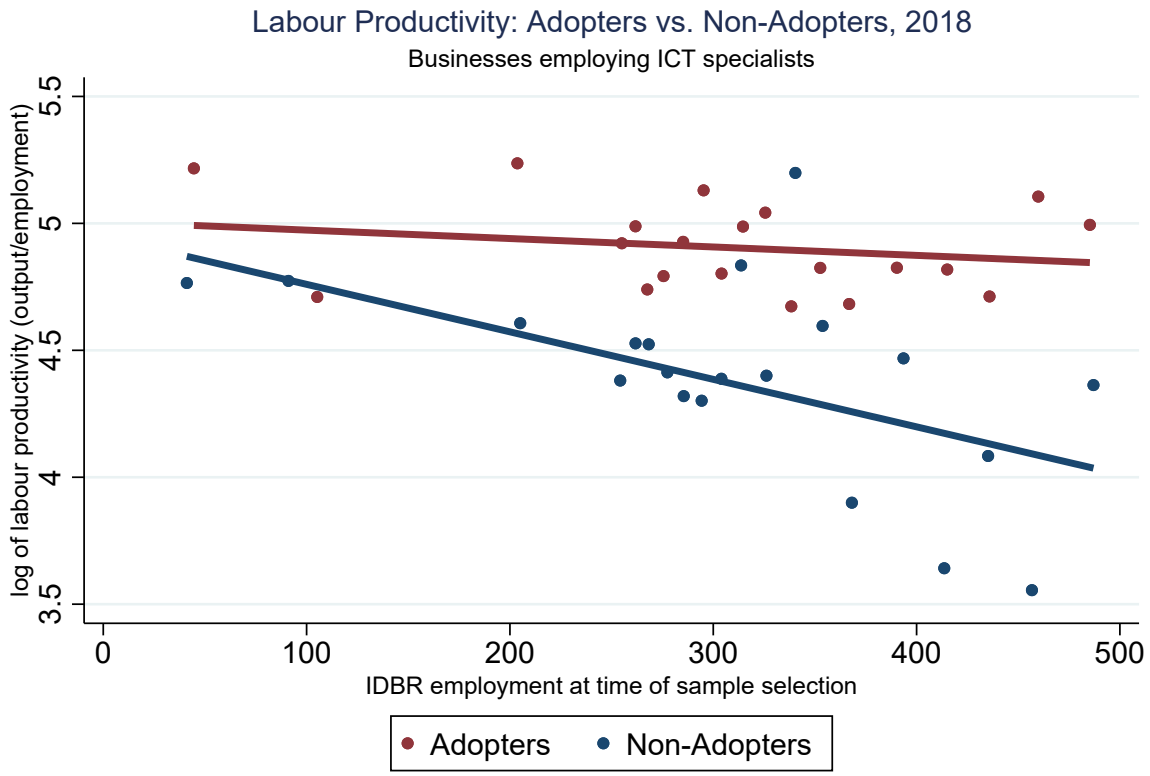
Correlation between labour productivity and indicators of digital adoption



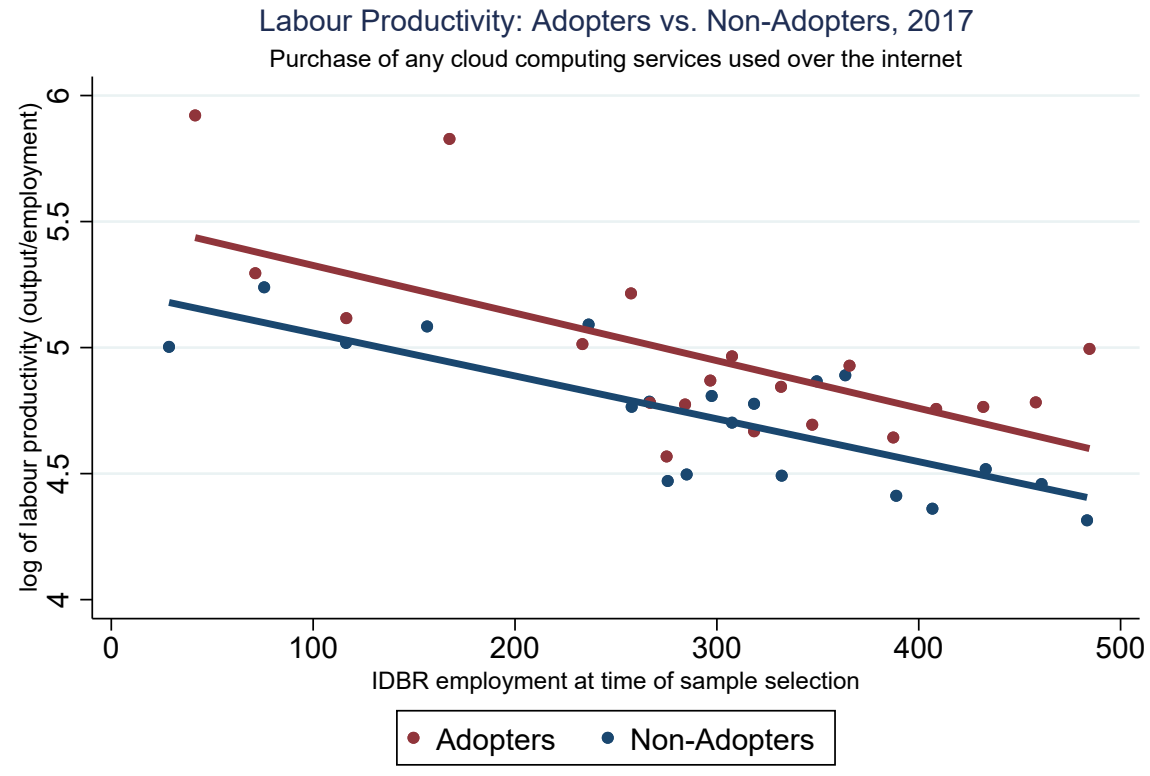


Descriptive Results

Correlation between labour productivity and firm size: digital adopters vs. non-adopters



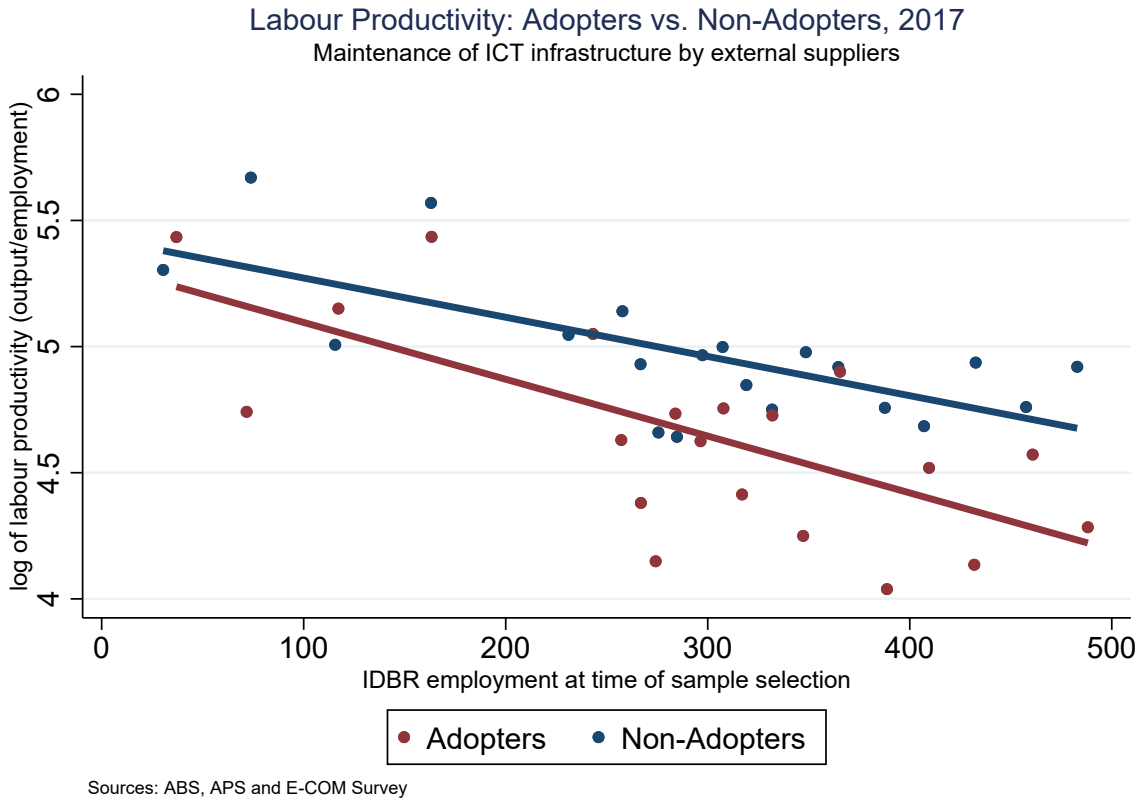
Sources: ABS, APS and E-COM Survey

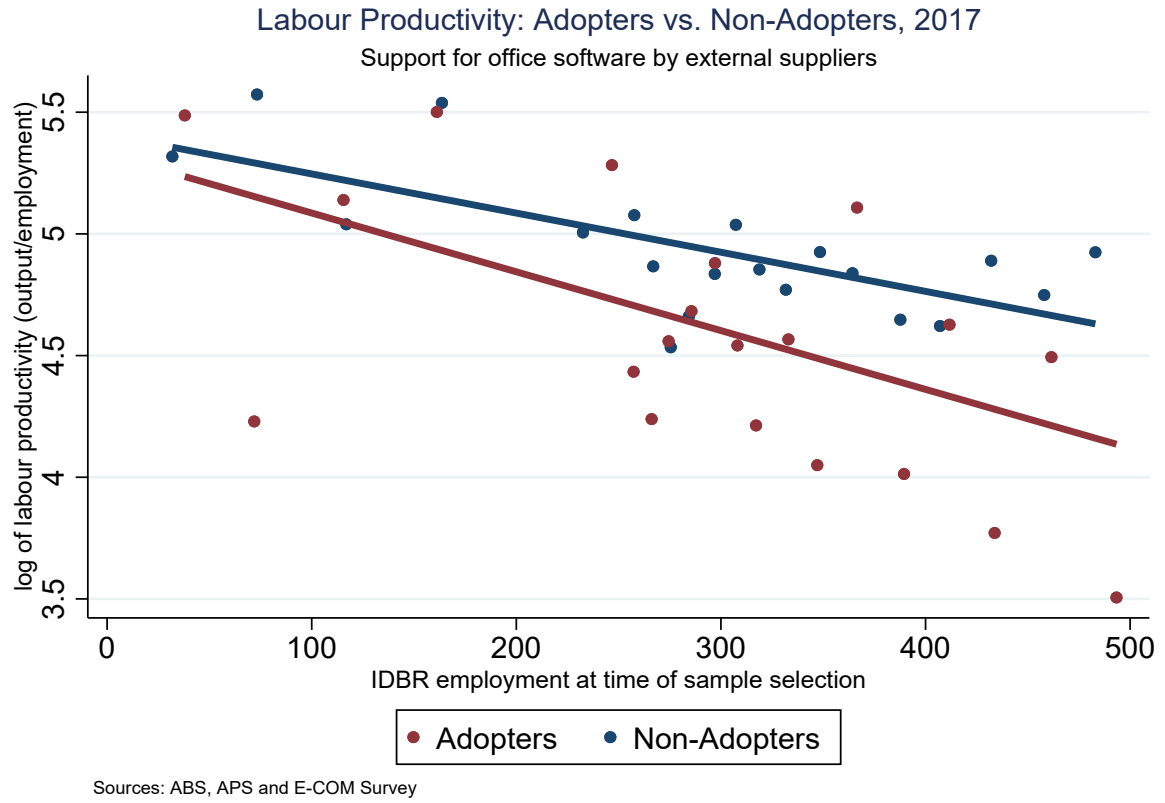


Sources: ABS, APS and E-COM Survey

Descriptive Results

Correlation between labour productivity and firm size: digital adopters vs. non-adopters





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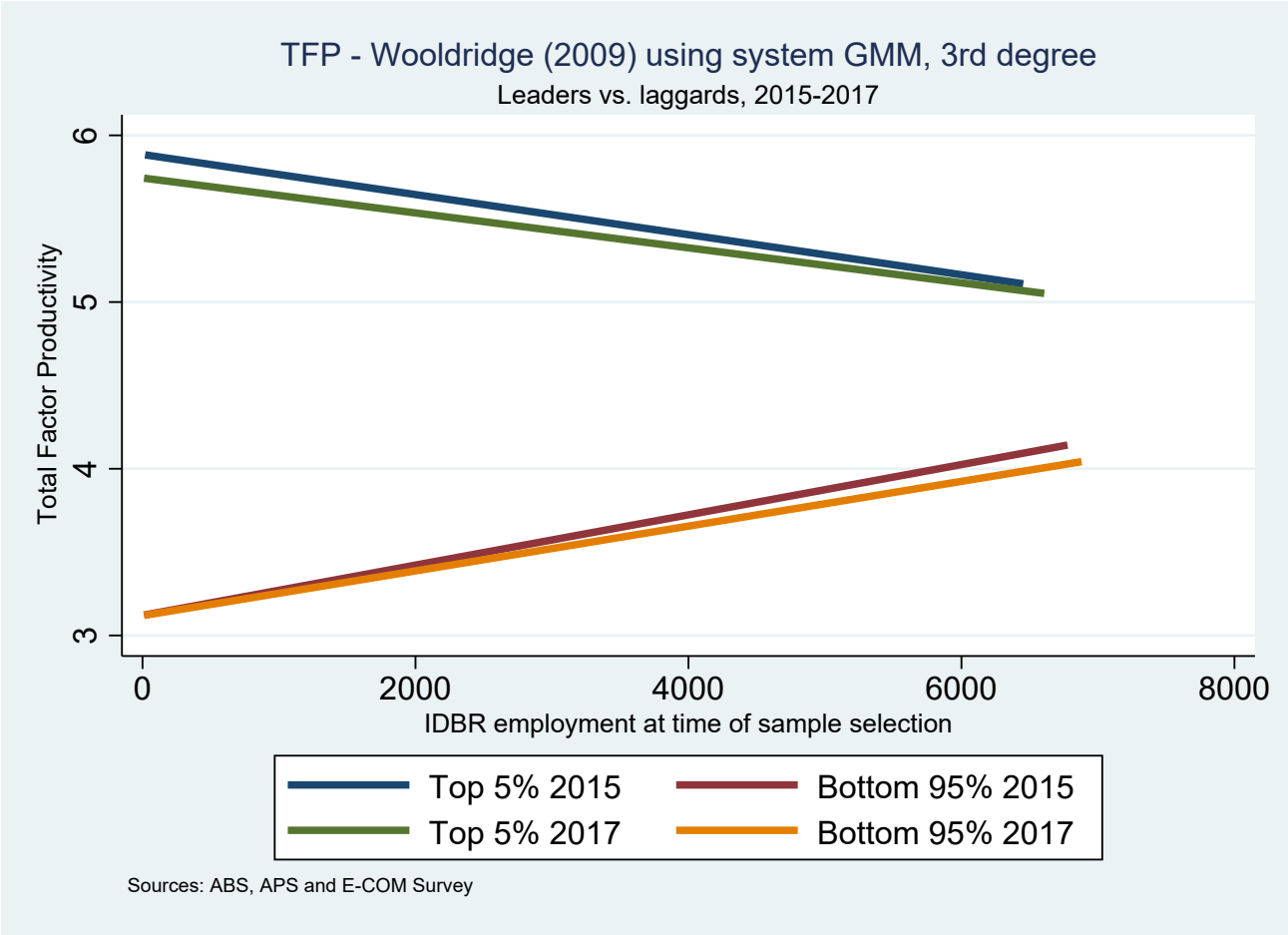
Descriptive Results

Productivity 'leaders' and 'laggards' by firm size



Estimation Results

IV approach:

- We instrument each of the E-Com Survey digitalisation variables by the share of firms (excluding the one of interest) adopting that technology at the year, industry and TFP quintile level.
- In case of ratio variables (% internet access, % orders via website), we take the average shares at those levels.

Single vs. Multiple digital technologies:

- *Single_digital*: 1 if the firm has adopted only one type of digitalisation.
- *Multiple_digital*: 1 if adopting more than one type.
- *Digital*: number of digital technologies adopted by a firm (from 0 to 6).
- We only consider the six digital technologies which got a positive and significant effect on TFP in our 1st stage regressions.

Estimation Results

Productivity vs. Digitalisation 2017. OLS estimation

Dependent Variable	TFP - Wooldridge (2009) using system GMM 3rd degree											
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
% internet access	0.123***											
	(0.0328)											
% orders via website		0.0400**										
		(0.0198)										
have a website			-0.243									
			(0.192)									
ICT especialists				0.261***								
				(0.0534)								
use of CRM					0.177***							
					(0.0455)							
cloud computing						0.0574						
						(0.0422)						
ICT maintenance (external)							-0.141***					
							(0.0396)					
office software support (external)								-0.168***				
								(0.0517)				
management software (external)									-0.0423			
									(0.0394)			
web solutions (external)										-0.0543		
										(0.0383)		
security data protection (external)											-0.225***	
											(0.0394)	
3D printing												0.0857
												(0.0702)
constant	2.391***	2.880***	3.051***	2.807***	3.259***	2.875***	2.947***	2.936***	2.905***	2.911***	3.012***	2.889***
	(0.330)	(0.325)	(0.366)	(0.324)	(0.490)	(0.326)	(0.325)	(0.326)	(0.326)	(0.324)	(0.323)	(0.324)
Firm Size, Sector and Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2193	2193	2193	2193	1183	2193	2193	2193	2193	2193	2193	2193
r2	0.104	0.0934	0.0926	0.102	0.132	0.0915	0.0959	0.0963	0.0912	0.0915	0.105	0.0915
r2_a	0.0889	0.0779	0.0770	0.0865	0.105	0.0759	0.0804	0.0808	0.0756	0.0759	0.0898	0.0759
ll	-2764.8	-2778.0	-2779.0	-2767.6	-1338.4	-2780.3	-2775.0	-2774.5	-2780.7	-2780.3	-2763.7	-2780.3

Standard errors in parentheses
* p<0.10 ** p<0.05 *** p<0.01

Estimation Results

Productivity vs. Digitalisation 2017. IV estimation

Dependent Variable	TFP - Wooldridge (2009) using system GMM 3rd degree											
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
% internet access	0.892***											
	(0.0666)											
% orders via website		0.367***										
		(0.0428)										
have a website			-1.563									
			(3.602)									
ICT especialists				3.427***								
				(0.309)								
use of CRM					2.064***							
					(0.282)							
cloud computing						5.280***						
						(0.893)						
ICT maintenance (external)							-2.610***					
							(0.571)					
office software support (external)								-3.055***				
								(0.785)				
management software (external)									-0.413			
									(0.271)			
web solutions (external)										-0.667		
										(0.441)		
security data protection (external)											-5.894***	
											(1.181)	
3D printing												0.876***
												(0.160)
constant	-0.0713	3.130***	4.923	0.615**	2.258***	-0.296	4.290***	4.046***	3.642***	3.802***	5.799***	3.291***
	(0.262)	(0.0370)	(3.502)	(0.261)	(0.172)	(0.631)	(0.192)	(0.161)	(0.157)	(0.262)	(0.482)	(0.0294)
Firm Size, Sector and Region FE	No	No	No	No	No	No	No	No	No	No	No	No
N	2203	2203	2203	2203	1180	2203	2203	2203	2203	2203	2203	2203
idstat	247.8	206.2	2.514	122.2	77.49	36.00	27.84	19.75	46.06	15.33	25.42	91.08
idp	7.65e-56	9.42e-47	0.113	2.14e-28	1.33e-18	1.97e-09	0.000000132	0.00000883	1.15e-11	0.0000904	0.000000462	1.38e-21
widstat	285.4	223.5	2.396	149.7	81.86	33.63	28.02	19.28	50.08	15.62	24.27	138.4

Standard errors in parentheses
* p<0.10 ** p<0.05 *** p<0.01

Estimation Results

Productivity vs. Single and Multiple Digitalisation. OLS estimation

Dependent Variable	TFP - Wooldridge (2009) using system GMM 3rd degree			
Year	2015		2017	
Column	(1)	(2)	(1)	(2)
single_digital	0.118		0.0678	
	(0.123)		(0.123)	
multiple_digital	0.373***		0.259**	
	(0.115)		(0.121)	
digital		0.132***		0.112***
		(0.0189)		(0.0196)
_cons	2.400***	2.449***	2.101***	2.122***
	(0.240)	(0.238)	(0.366)	(0.369)
Firm Size, Sector and Region FE	Yes	Yes	Yes	Yes
N	1850	1850	2193	2193
r2	0.172	0.184	0.0984	0.110
r2_a	0.154	0.167	0.0825	0.0951
F	13.49	14.27	7.608	8.554
ll	-2080.2	-2066.6	-2772.0	-2757.3

Standard errors in parentheses

* p<0.10 ** p<0.05 *** p<0.01

Conclusions

- Unique UK firm-level dataset, enabling us to explore links between a large set of digital inputs and investments and productivity.
- Large firms are more digital intensive than small ones.
- Digital adopters have higher productivity than non-adopters.
- Use of multiple in-house digital technologies strongly positively related to TFP.
- Some digital variables are positively related to TFP, and others negatively related. Difference driven by the use of in-house as opposed to bought-in capabilities.

Further research

- Role of digital technology taking account of organisational capabilities.
- Firms crossing from non-digital native / native threshold. Does organisational capital / management skills need to change first?
- Using the update of the E-Com Survey or other digital measures.

Thank you

Estimation Results

Productivity vs. Digitalisation 2015. IV estimation

Dependent Variable	TFP - Wooldridge (2009) using system GMM 3rd degree										
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
% internet access	0.829***										
	(0.0723)										
% orders via website		0.421***									
		(0.0427)									
have a website			8.563*								
			(4.380)								
ICT especialists				2.936***							
				(0.247)							
use of CRM					1.645***						
					(0.213)						
cloud computing						4.652***					
						(0.667)					
ICT maintenance (external)							-0.826**				
							(0.349)				
office software support (external)								-1.140**			
								(0.456)			
management software (external)									-0.735***		
									(0.250)		
web solutions (external)										-1.051*	
										(0.548)	
security data protection (external)											-3.952***
											(0.872)
constant	0.223	3.132***	-4.898	1.000***	2.476***	0.439	3.715***	3.668***	3.851***	4.071***	5.043***
	(0.284)	(0.0375)	(4.283)	(0.215)	(0.142)	(0.440)	(0.107)	(0.0850)	(0.136)	(0.324)	(0.355)
Firm Size, Sector and Region FE	No	No	No	No	No	No	No	No	No	No	No
N	1850	1850	1850	1850	1202	1850	1850	1850	1850	1850	1850
idstat	241.0	167.4	6.376	126.5	75.16	49.79	30.31	31.23	44.29	12.73	24.00
idp	2.38e-54	2.77e-38	0.0116	2.39e-29	4.34e-18	1.71e-12	3.68e-08	2.29e-08	2.83e-11	0.000359	0.000000962
widstat	303.5	188.0	5.549	143.1	102.8	49.67	28.26	30.38	45.03	12.85	23.18

Standard errors in parentheses
* p<0.10 ** p<0.05 *** p<0.01

Estimation Results

Productivity vs. Digitalisation 2015. OLS estimation

Dependent Variable	TFP - Wooldridge (2009) using system GMM 3rd degree										
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
% internet access	0.149***										
	(0.0265)										
% orders via website		0.0437***									
		(0.0149)									
have a website			0.0977								
			(0.149)								
ICT especialists				0.287***							
				(0.0630)							
use of CRM					0.163***						
					(0.0469)						
cloud computing						0.137***					
						(0.0414)					
ICT maintenance (external)							0.0235				
							(0.0433)				
office software support (external)								0.0313			
								(0.0562)			
management software (external)									-0.0428		
									(0.0377)		
web solutions (external)										-0.0158	
										(0.0367)	
security data protection (external)											-0.0608
											(0.0395)
constant	2.058***	2.522***	2.422***	2.420***	2.041***	2.466***	2.497***	2.506***	2.540***	2.527***	2.544***
	(0.239)	(0.243)	(0.274)	(0.246)	(0.382)	(0.240)	(0.247)	(0.246)	(0.244)	(0.244)	(0.243)
Firm Size, Sector and Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1850	1850	1850	1850	1212	1850	1850	1850	1850	1850	1850
r2	0.178	0.159	0.155	0.170	0.169	0.161	0.155	0.155	0.156	0.155	0.156
r2_a	0.161	0.141	0.138	0.152	0.142	0.143	0.137	0.137	0.138	0.137	0.138
ll	-2073.6	-2094.8	-2098.8	-2082.9	-1254.1	-2092.6	-2099.0	-2099.0	-2098.5	-2099.1	-2097.8

Standard errors in parentheses
* p<0.10 ** p<0.05 *** p<0.01