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ABSTRACT

This paper explores the link between different types of training and innovation outcomes using the Longitudinal Small Business Survey. Much of the evidence on innovation and the link to the capabilities of the workforce is based on evidence from the Community Innovation Surveys and as a result emphasis is on larger businesses and on formal skills acquired in Higher Education Institutions. This paper adds to the literature by focusing on a) micro businesses and b) on- and off-the-job training and manager vs. employee training. The main findings are that: a) there is a positive relationship between training and, in particular product innovation; b) that this relationship is strongest among micro-businesses with 1 to 9 employees; c) that the strength of the effect of on- and off-the-job training is similar; and that d) specific manager training in IT and 'financial management' shows relatively strong correlations with product and process innovation. Training leading to formal qualifications is not significantly associated with innovation. Novel – new-to-market – product innovation is also significantly enhanced by leadership training of managers, but not by other forms of training.

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CONTENTS

1. INTRODUCTION

This paper explores the role of investment in different types of on- and off-the-job training on different types of innovation outcomes in micro-businesses and SMEs. This is important because of the relevance of the small business sector to the economy and the relative lack of empirical evidence that stems from this part of the economy. The paper analyses the Longitudinal Small Business Survey panel for the years 2015, 2016 and 2017.

Innovations and innovation related activities and investments are major determinants of business and economic performance. The innovation literature, as well as public policy on innovation, emphasises the role of technology and knowledge, especially connected with or measured as business and national expenditures on research and development (R&D). Alongside this type of investment, theory and evidence also emphasises the important role of human capital and investment in relevant skills. Skills are mainly referred to, and measured as, formal qualifications of staff, specifically the number of staff with university degrees in science and engineering (e.g. Tether et al. 2005, Toner 2011, Frenz and Lambert 2014).

This focus on measuring skills as the share of the workforce with university degrees is possibly data driven. Much of the large-scale empirical evidence draws on Community Innovation Survey type data (e.g. Leiponen, 2005, Tether et al. 2005, Frenz and Lambert, 2014). This has two important consequences. Firstly, much of the literature overlooks other types of skill, such as marketing or those at intermediate level, while also taking no account of businesses developing their own skill base through different types of on- and off-the-job training. Secondly, the underpinning survey data excludes evidence from micro-businesses with 1 to 9 employees. We know much less about these businesses and their innovation drivers than we know about SMEs and, in particular, large businesses.[1]

This report seeks to address some of these gaps in the evidence by analysing data on SMEs and micro businesses from the whole of the UK from the LSBS survey. The

[1] For example, the LSBS reports that far fewer micro businesses with 1 to 9 employees engage in training - 50% of micro businesses with 1-9 employees funded training, compared with ca. 75% and 85% of small and medium sized businesses - BEIS, 2018.

analysis utilises an extensive range of variables to capture the relationships between innovation indicators and training, taking account of time lags from the longitudinal aspects of the LSBS data. It is organised as follows: Section 2 covers the relevant literature on the role of human capital and skills in innovation and the empirical evidence. Section 3 sets out the research objectives with respect to general employee training, manager compared to employee training, and on - and off-the-job training. Section 4 introduces the LSBS dataset and the methods used to analyse the data. Section 5 presents the results and Section 6 concludes with the key findings, main limitations and implications for policy and areas for future research.

2. THEORY AND HYPOTHESES

The role of human capital in innovation is widely covered in the literature, largely through studies of skills in businesses and their availability in the labour market. Training as an alternative, or supplement to, recruitment has been less extensively covered. In the following section we start by briefly touching on the importance of human capital based on UK national level, macro studies, before summarising the firm-level evidence on the importance of human capital, skills and different types of training.

2.1 National level evidence on expenditure on training

Recent work, in the tradition of innovation production functions, at the national economy level, has drawn attention to the potential importance of training as a determinant of innovation performance. Studies using innovation production functions estimate the combination of capital, skills and knowledge that generate new knowledge and new products and processes, analogous to traditional output production functions. Training is part of knowledge development. An instance of this approach is a model of innovation that emphasises investment in intangible assets as the aggregate sources of innovation, and which underpins an Innovation Index, developed under the auspices of NESTA. This model estimated national (market sector) expenditure on innovation production function components (Goodridge, Haskel, and Wallis, 2014). Own account training in the market sector accounted for around 20% of intangible innovation investment of £127 bn in 2014.

2.2 The link between training and innovation – firm level evidence

The published literature on the link between training and innovation has included discussion of training as derived demand, generated by firms' perception that their ability

to adopt technologies or to develop innovation internally is limited by the skills and knowledge of their staff and managers (Freel 2005). Others have analysed training as a factor that determined or enhances innovation capacity or achievement (Dostie 2018). Taking a balanced view, the relationship is likely to be reciprocal:

"In the long term, the relationship between skills and innovation must be circular. The skills of the workforce and management will help determine the innovation that takes place, which will then help determine the changed demand for skills in the firm, which will influence the innovation that takes place and so on." (Tether, Mina, Consoli, and Gagliardi, 2005)

Although framed in respect of workforce skills, this summary is also apposite to developing skills internally through training and any resultant changes in the level or intensity of innovation.

One approach to the importance of human capital in innovation stems from the body of research under the heading of "absorptive capacity." Building on the seminal work of Cohen and Levinthal (1990), this posits the importance of in-house capabilities and complementary knowledge for identifying, accessing and applying technological or other external knowledge. Cohen and Levinthal themselves emphasise human capital and the role of team work in effectively applying external knowledge. Much of the empirical literature has, though, used R&D spending in the acquiring firm as a proxy for absorptive capacity. Data on the employment of skills and on training activity, where available, can be argued to offer better measures of absorptive capacity. In a study using Canadian survey data, Leiponen (2005) reports that training does enhance absorptive capacity and is strongly complementary to undertaking R&D, the take up of new technology and to innovation.

Closely related to the literature on absorptive capacity - the ability to identify valuable external knowledge, assimilate it, diffuse and use knowledge from outside the business - are studies that focus on the joint effects on business performance of training and other inputs. Bauernschuster, Falck, and Heblich (2009) using German establishment level data for 1997-2001 find strong complementarity between continuous training of staff and undertaking R&D and the propensity to incremental innovation, although the training variable is not significant in explaining novel innovation.

A paper based on a panel of Spanish manufacturing firms from 2001 to 2006 also found complementarity, with R&D the main determinant of innovation while training was also significant but with a smaller scale of impact (González, Miles-Touya, and Pazó, 2016). For larger firms, only the combination of R&D and training was important but training on its own had a significant positive effect on innovation for smaller firms (10-200 employees). A study of Canadian small firms using one period (1992) survey data found training to be complementary to R&D and other sources of technological change and innovation (Baldwin and Johnson, 1995). The effect was reinforced where there was a focus on quality and a conscious human resources policy.

2.3 Evidence from micro firms on the link between training and innovation

Evidence from micro firms is scarce and often conflated with that from larger firms. For example, Bauernschuster et al. (2009) use establishment level data with size bands starting at 0-4 but also including large establishments with 2,000+ employees. However, in their paper the authors use size to explain innovation performance but not to investigate if size affects the relationship between training and innovation. Cosh, Hughes and Weeks (2000) explore the 1997 Cambridge Centre for Business Research (CBR) SME Survey. They examine the impact of training on employment growth in British SMEs including businesses with 1 to 9 employees arguing for the desirability of longitudinal data.

The study by Freel (2005) is another exception. Using a cross-sectional dataset of Northern British businesses, and including micro firms, skills and training are measured with a wide spectrum of indicators. His results tentatively point to the following: a comparatively low relevance of science and engineering degrees in innovation outputs in much of the British economy, and greater importance of intermediate skills. He further finds that the relationship with training is important, concluding that “the most innovative firms train more staff” (2004, p.132).

The Community Innovation Surveys - arguably the most authoritative and widely cited innovation surveys - include a question about expenditure on training directly connected with innovation, addressed to the respondents who were active in innovation. The LSBS instead addresses the more general question of the provision of any form of training for employees and managers. This enables us to address the issue of how far broad training, not explicitly tied to innovation investments or projects, might support or enable a higher scale or intensity of innovation activity.

Research question 1: *Does general employee training enhance innovation capability and is the strength of this relationship influenced by firm size?*

2.4 Different types of training

On/off job training

A longstanding theme in the economic analysis of training activity is the balance between sending staff for external training, or formal classroom learning, and the more informal training on-the-job or learning from colleagues or supervisors.[2] This theme is reflected in some recent publications. A paper using data from Korean enterprises finds a positive and significant relationship between on-the-job training and innovation performance, but a negative effect of financial support for formal, external training (Sung and Choi, 2014). The authors hypothesise that, as the latter is selective amongst employees, there could have been a negative incentive effect on those not selected.

A study using longitudinal data from the Canadian Workplace and Employee Survey for the years 1999–2006 finds positive and significant innovation impacts from both on-the-job and classroom training (Dostie, 2018). The research has a battery of control variables to condition on factors other than training that affect innovation. These include workplace level fixed effect. Despite all the controls, the training effects are well defined and important.

The LSBS surveys seek information separately on informal or on-the-job and on classroom training, offering the possibility of new insights into the comparative impacts on business' innovation activities.

Research question 2: *Do any innovation impacts vary according to whether the training was on- or off-the-job?*

This issue has been the subject of some empirical research, summarised above and the information from the LSBS on how training is provided is an opportunity to investigate further this interesting question.

[2] An ex colleague used to refer to "sitting by Nellie'.

Staff or manager training

This topic has not generated much empirical research. One study of data on Irish firms from a survey in 2009, argues that employing managers with specific characteristic: - including training and willingness to change - show a higher innovation propensity (McGuirk, Lenihan, and Hart, 2015). The study's data supports the view that the effect of training itself is positive and significant. Interestingly, the level of initial education is not significant, implying that later training and development of staff and managers can be more important for innovation performance than recruiting skills from the labour market.

Research question 3: *Does manager training enhance innovation capability? Do effects vary by type of manager training?*

The survey includes manager training as distinct from employee training and also breaks this down by type. This enables us to approach the issue of how far training of the business's leaders might support more innovation activity and whether one or more particular types of such training have larger or more extensive effects on innovation.

The LSBS includes more a more extensive line of questioning on manager training than other surveys, including a range of subjects and disciplines involved, which allows us to investigate more extensively the particular contributions of manager training to innovative behaviour.

3. DATA AND METHODOLOGY

3.1 The Longitudinal Small Business Survey (LSBS)

The LSBS is conducted on behalf of the UK Department for Business, Energy and Industrial Strategy. The 2017 wave was collected by BMG Research Ltd. The LSBS is a survey of owners or managers of UK businesses conducted in 2015, 2016 and 2017. The sampling method was specifically designed to create a balanced panel. 4,165 businesses replied to all three waves. The 2015 wave is individually the largest wave with 15,502 responses, followed by 9,248 responses in 2016 and 6,619 responses in 2017 (BEIS, 2018).

The survey is stratified first by the four UK nations, then within each nation by four employment size bands (0, 1-9, 10-49 and 50-249), and within each employment size

band by industry sector (base on SIC2007). Businesses with four or fewer employees are substantially under-represented (BEIS, 2018).

3.2 The variables

We summarise here the variables from the LSBS data to be used in the analysis, covering innovation, training and any control variables that are used in the report.

Innovation variables

The LSBS collects data on a range of innovation variables, essentially the same categories as those applied in the UK Innovation Survey. Like the UK Innovation Survey, the reference period is frequently the last three calendar years. Our analysis uses a set of innovation indicators as dependent variables – taken from the 2017 wave of the LSBS – in modelling the relationship between innovation outcomes and training activities.

Table 1: Dependent (innovation) variable names, description and measurement scales

Variable name in the report	Innovation description	Measurement scales
Product innovation	Summary of firm level product innovation	1– Any new or significantly improved goods and/or services 0 – No
New-to-market product innovation	Were any of these goods and services new to the market?	1 - At least some new to the market 0 - All just new to the business
Process innovation	Business introduced any new or significantly improved processes for producing or supplying goods and services in the last three years.	1 – Yes 2 – No
New-to-industry process innovation	Were any of these processes new to your industry	1 – At least some new to the market 0 – All just new to the business

Training Variables

The LSBS has a very good range of questions on training: general training for employees and some more specific types of training for managers and also whether these take the form of 'on the job' or more formal 'off-the-job' training. Unlike the innovation variables, the training variables refer to the last 12 months and not the last three years. We use

training variables taken from the 2015 wave of the LSBS, to allow for some degree of time lag between training and any response in innovation performance.

Table 2: Explanatory (training) variable names, description and measurement scales

Variable name	Variable description	Measurement scales
General training	Has your organisation arranged or funded any on- or off-the-job training	1 – Yes 0 – No
Off-the-job training	Over the past 12 months, has your organisation arranged or funded any off-the-job training or development for employees?	1 – Yes 0 – No
On-the-job training	Has your organisation arranged or funded any on-the-job training	1 – Yes 0 – No
Manager training	Did any of the managers in the business receive this off-the-job or informal on-the-job training or development during the last 12 months?	1 – Yes, formal off-the-job 2 – Yes, informal on-the-job 3 – Yes, both 4 – No 5 – Don't know
Leadership and management skills	Thinking now about the training or development that managers received, what subjects or discipline did that training or development cover: Leadership and management skills	1 – Yes 0 – Not
IT skills	IT skills	1 – Yes 0 – Not
Health and safety	Health and Safety	1 – Yes 0 – Not
Technical, practical or job-specific skills	Technical, practical or job-specific skills	1 – Yes 0 – Not
Financial management	Financial management (not available in 2015)	1 – Yes 0 – Not
Team working skills	Team working skills	1 – Yes 0 – Not
Proportion of staff receiving training	Proportion of staff receiving training in last 12 months	1 – All 2 – 75 to 99% 3 – 50 to 74% 4 – 25 to 49% 5 – 10 to 24% 6 – under 10%
Training leading to formal qualification	And thinking about all staff, not just managers, was any of this training and development designed to lead to a formal qualification? (2015)	1 – Most 2 – Some 3 – No
Training leading to formal qualification	Whether training leading to qualifications is for management or other staff. (2015)	1 – Managers 2 – Other staff 3 – Both 4 – None

Control variables

The following variables are used to break the data into different segments of the business population. These are mainly taken for the years 2017. Over and above the controls listed in Table 3, the regressions also control for lagged innovation activity.

Table 3: Control variable names, description and measurement scales

Variable name	Variable description	Measurement scales
Size-band 1	Interviewers recoded this also into grouped data	1 - Zero unregistered 2 - Zero registered 3 - Micro 1 - 4 4 - Micro 5 - 9 5 - Small 10 - 19 6 - Small 20 - 49 7- Medium 50 - 99 8 - Medium 100 - 249 9 - Large 250+
Size-band 2	Interviewers recoded this also into grouped data	. – No employees 2 - Micro 1 - 9 3 - Small 10 - 49 4 - Medium 50 - 249
Sector-1digit	Sector coded by interviewer into SIC2007	14 sector dummies – not listed here
UK Region	UK nations	1 – England 2 - Scotland 3 - Wales 4 - Northern Ireland

3.3 The LSBS sample

Our report uses mainly the panel dataset of 4,165 businesses, and, from within that panel, is based on businesses with one or more employees, amounting to 3,102 businesses (see Table 5). Businesses with no employees are excluded from this study, since we consider they are likely to exhibit systematically different patterns of behaviour with respect to innovation and training, so their inclusion could lead to biased results. This size group of business merits separate research.

Table 4: LSBS sample distribution across size-bands

	LSBS 2015	LSBS 2016	LSBS 2017
Number of observations	**15,501**	**9,248**	**6,619**
No employees	4,355	2,324	1,825
Micro 1-9 emp.	4,101	3,039	2,183
Small 10-49 emp.	4,066	2,488	1,660
Medium 50-249 emp.	2,979	1,370	928
Large 250+ emp.	0	27	23
Panel	**4,165**	**4,165**	**4,165**
No employees	1,063	931	905
Micro 1-9 emp.	1,205	1,385	1,425
Small 10-49 emp.	1,118	1,194	1,165
Medium 50-249 emp.	779	641	649
Large 250+	0	14	21

LSBS own calculations.

3.4 Comparison with UKIS and other datasets

The LSBS is usefully complementary to the UKIS in its coverage of sizes of business and of innovation related indicators. Our report seeks to utilise some of the comparability.

- The LSBS covers micro firms and those with no employees: the 0 to 9 size-band. Our report excludes business with zero employees, but compares on some indicators the results from the LSBS for SMEs with those from UKIS.

- The LSBS includes similar innovation variables to the UKIS: product, service and process innovations that are new to just the business or also new to the industry, giving a basis for comparative analysis.

The detailed comparisons are in Appendix 1. Here, we summarise the main findings.

The results reported for LSBS suggest a higher share of product and process innovators; more than double that reported from the UKIS. It is outside of the scope of this report to account for these differences in reported innovation propensities. However, we undertook a comparison of innovator shares broken down by industry, which did not show that the differences could be explained by the sectoral structure. Intuitively, the difference in survey method – the UKIS was a postal survey and the LSBS is telephone based – seems a plausible explanation for the differences, but we have not tried to explore the issue further.

3.5 LSBS Data Summary

Table 5 gives our base comparison table. We selected from the LSBS panel businesses with 1 to 249 employees for further analysis in this paper. The table below gives values based on size categories as classified in the LSBS 2015 wave and innovation variables reported in the 2017 wave (with a reference period for the innovation variables of 2015-2017).

Table 5. Share of product and process innovators by firm size. LSBS panel

Size band 2015	Number of observations	Percent of product innovators 2015-2017	of which new-to-market 2015-2017	Percent of process innovators 2015-2017	of which new to industry 2015-2017
Total	**3,102**	40	29	25	20
Micro 1-9	1,205	37	28	19	19
Small 10-49	1,118	39	26	28	18
Medium 50-249	779	44	33	31	24

Own calculations using the LSBS panel. Size variable from 2015 wave and innovation variables from the 2017 survey. Unweighted data.

In line with expectations, micro businesses report smaller shares of product and process innovators (37 and 19 percent respectively) compared with small (39 and 28) and medium sized businesses (44 and 31 percent).

3.6 Methodology

The report applies quantitative analytical techniques to the innovation relevant variables to add to knowledge on how far human capital development, through training of both staff and managers, can enhance the capacity of businesses, including micro-businesses, to innovate. This includes using the longitudinal nature of the survey data to investigate the lags between training and effects on innovation outcomes.

To address the research questions, we compile a summary of basic statistics for the selected variables: including the share of businesses that innovate and that engage in different forms of training. This is broken down by size-bands and by sector (1-digit level with 14 industry classes). In a second step we look at the relationship between training and innovation through cross-tabulations of the innovation variables with the training variables for different business sizes.

The main results section reports on regression models that relate innovation outcomes (for products and processes) to staff and manager training taking account of: a) a time

lag between training and innovation outcomes as well as b) past innovation activity while controlling for size-bands, sector and location (UK nations).

The main results use dynamic probit regressions (e.g. Duguet and Monjon, 2004; and Frenz and Prevezer, 2012). Our dependent variables are binary measured in the 2017 wave of the survey. The main independent variables are the training related variables measured in the 2015 wave of the survey with a time lag (Bauernschuster et al. 2009 use a similar lag). We control for past innovation activity, including a lagged dependent variable from the 2015 LSBS wave and for sector, size and region. We report marginal effects and robust standard errors. A limitation of the analysis is that the econometric models cannot include variables on R&D investments and on capital expenditures and therefore cannot test some of the propositions about complementarity of training with other innovation relevant investments that are found in the literature.

4. RESULTS: EXPLORING THE ROLE OF TRAINING IN INNOVATION USING THE LSBS DATA

In this section we present the empirical results from the analyses, starting with selected descriptive statistics, followed by the main regression results. Table 6 explores basic indicators pertaining to our first research question on the relationship between general training and innovation and whether the patterns vary by firm size.

Table 6. Percent of businesses with general training (column 1) and share who were innovators in 2015-2017 and percentage differences in the share compared to the LSBS panel reported in Table 5.

		Out of those with training in 2015			
	Percent of firms that had training 2015	Percent of product innovators 2015-2017	of which new-to-market 2015-2017	Percent of process innovators 2015-2017	of which new to industry 2015-2017
General training	77	43	29	28	20
Micro 1 - 9	56	44	27	21	19
Small 10 - 49	86	41	26	29	18
Medium 50 - 249	96	45	33	32	24
		Out of those with training in 2015: differences **in the**			
	Percent of firms that had training 2015	Percent of product innovators 2015-2017	of which new-to-market 2015-2017	Percent of process innovators 2015-2017	of which new to industry 2015-2017
General training	77	3	0	3	0
Micro 1 - 9	56	7	-1	2	0
Small 10 - 49	86	2	0	1	0
Medium 50 - 249	96	0	0	1	0

Own calculations using the LSBS panel. Training variables from the 2015 wave and innovation variables from the 2017 survey. Unweighted data. The top section gives the share of innovators, while the bottom section gives the differences in the share of innovators comparing the results in Table 6 with those reported in Table 5.

On average 77% of businesses offered some form of training. The comparison of training and non-training businesses indicates that those that offer some form of training are more likely to be product or process innovators over and above the propensity to innovate in each size band *per se* (the latter is reported in Table 5). The innovation propensity differences are largest for product innovation among micro business where the average share of innovators is 37%, (Table 5) and the average share of innovators among business with training is 44% (Table 6); a 7 percentage point difference. There is a modest difference of one or two percentage point for the two remaining size-bands and for process innovation. Table 6 shows no difference for novel innovators – those with new-to-market products or new-to-industry processes.

Table 7 addresses our second research question by comparing off-the-job and on-the-job training patterns.

Table 7. Percent of businesses with off-the-job and on-the-job training that were innovators. Percentage differences from the LSBS panel reported in Table 5.

	Percent of firms that had training 2015	Out of those with training in 2015: changes in the			
		Percent of product innovators 2015-2017	of which new-to-market 2015-2017	Percent of process innovators 2015-2017	of which new to industry 2015-2017
Off-the-job	62	4	0	4	-1
Micro 1 - 9	42	7	-3	3	-4
Small 10 - 49	68	3	1	3	0
Medium 50 - 249	84	1	1	1	0
On-the-job	66	5	0	4	1
Micro 1 - 9	43	9	-1	2	3
Small 10 - 49	75	5	1	3	0
Medium 50 - 249	89	1	0	2	1

Own calculations using the LSBS panel. Training variables from the 2015 wave and innovation variables from the 2017 survey. Unweighted data.
Out of the 3,102 businesses with 1-249 employees, 3,096 businesses answered the question on off-the-job training, and 3,097 businesses answered the question on on-to-job training.

On-the-job training is marginally more frequent with 66% of businesses reporting on-the-job training and 62% of businesses reporting off-the-job training.

There is not much difference between on- and off-the-job training in terms of the shares of innovators, which varies from the evidence reported in Sung and Choi (2013) who found a positive relationship for on-the-job training, but a negative one for off-the-job training. Dostie (2018) using a Canadian dataset reports a positive effect for both.

We now turn to exploring our third research question on the relevance of manager training.

Table 8. Percent of businesses with manager training that were innovators. Percentage differences from the LSBS panel reported in Table 5.

		Out of those with training in 2015: changes in the			
	Percent of firms that had training 2015	Percent of product innovators 2015-2017	of which new-to-market 2015-2017	Percent of process innovators 2015-2017	of which new to industry 2015-2017
Manager training	72	5	-1	4	0
Micro	64	8	-2	5	1
Small	70	5	-2	2	-1
Medium	82	1	1	0	-1

Own calculations using the LSBS panel. Training variables from the 2015 wave and innovation variables from the 2017 survey. Unweighted data.
Of the 3,102 business with 1-249 employees, 2,380 answered the question on manager training: 677 micro businesses, 959 small businesses and 744 medium sized businesses.

72% of businesses reported manager training. The share of those with manager training who also report innovation is again higher for micro businesses and product innovators. In Appendix 2, Table A.4 the patterns are explored with reference to training in specific management skills. That table suggests that training of managers in 'financial management' and 'IT skills' is correlated with a higher propensity to innovate.

We now turn to our main findings and the regression models that relate innovation indicators to the various forms of training in the LSBS, but conditioned on a set of control variables that allow for past innovation performance, size, industry and national location of businesses. We run a sequential series of regressions relating the propensity to introduce products (goods or services) that are new to the business but not necessarily new to the market. The results, shown in Table 9, indicate that product innovation is positively and significantly related to offering some form of general training (column 1), including both on- and off-job-training (columns 2 and 3), manager training (columns 4 and 5) but with a weaker statistical significance.

Table 9. Regression results for product innovation in 2015-2017. Training and control variables are measured in 2015.

Independent variables 2015	(1) Product innovators 2015-2017	(2) Product innovators 2015-2017	(3) Product innovators 2015-2017	(4) Product innovators 2015-2017	(5) Product innovators 2015-2017
General training	0.12**				
	(0.02)				
Off-the-job training		0.08**			
		(0.02)			
On-the-job training			0.11**		
			(0.02)		
Manager training				0.04+	
				(0.02)	
Leadership skills					0.03
					(0.04)
IT skills					0.06+
					(0.03)
Health and safety					0.07*
					(0.04)
Job-specific					0.02
					(0.05)
Team working					0.01
					(0.03)
Financial Management					0.07*
					(0.03)
Product innovators 2013-2015	0.32**	0.33**	0.32**	0.32**	0.35**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)
Micro 1-9 empl.	Base comparison group				
Small 10-49	-0.01	-0.00	-0.01	-0.03	-0.01
	(0.02)	(0.02)	(0.02)	(0.03)	(0.04)
Medium 50-249	0.02	0.03	0.02	-0.01	-0.04
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)
14 industry dummies included					
4 regional dummies included					
Observations	3,100	3,096	3,097	2,380	1,254
Pseudo R-squared	0.130	0.128	0.130	0.115	0.134

Estimation methods: dynamic probit regression. We report marginal effects for a change of 0 to 1 in the independent variables and robust standard errors in parentheses.
** p<0.01, * p<0.05, + p<0.1

These results are generally consistent with the published literature summarised earlier. Some new results have emerged from including some of the specialised forms of training for managers only, variables that are not as far as we know, found in other datasets. Some of these also show a significant positive relationship with new to the firm product innovation, specifically: IT skills (though with a weaker statistical significance); health and safety; and financial management.

Another sequential series of regressions explore the relationship between process innovation – methods of making or supplying a business's outputs – and indicators of

training. The results are reported in Appendix 3 Table A.7. They are broadly similar to the case of product innovation, with process innovation positively and significantly related to offering: i) some form of general training; ii) both on- and off-the-job training.

The positive relationship with training of managers in financial management is common to product and process innovation, perhaps implying that all forms of innovation require a soundly managed financial framework so that 'firefighting' cash flow problems is less likely to distract the energies of staff and managers from developing the product range and means of delivery.

We examined via regressions, but do not report the results for, novel innovation. Novel innovation is defined as a product that is not only new to the business but also new to their market, or a process (for making or supplying) that is new to the industry. Most types of training show no significant relationship with novel product innovation (over and above the positive effect on innovation per se), the exceptions though are interestingly amongst specialised management training, with training in leadership skills and, less significantly, training in IT skills apparently supporting novelty in products.

We further examined whether to effect of training on innovation is moderated by firm size, in other words, if the relationship is stronger among micro firms. The results are in Appendix 3 Table A.8. We find some indication that this is the case. We also examined if training that leads to formal qualifications has a positive effect, but found no difference. The results are not reported in this paper.

5. CONCLUSIONS

We have analysed in some detail the data on innovation and types of training of staff and managers from the LSBS. Overall our results confirm the balance of evidence from the published economic literature that there is a positive and significant link between the provision of training that is not explicitly for innovation and several product and process innovation indicators. The relationship is stronger for product than for process innovations and for new to the firm rather than new to the market or industry innovation.

In our results, both on and off job training are positive and significant for new to firm innovation and with roughly the same coefficient values. For product innovations new to the firm, the link with training is more pronounced for micro-firms (1 to 9 employees). As

the economy includes very large numbers of such firms, this finding could have important implications for policy towards innovation.

However, training that leads to a formal qualification – which is likely to be less employment specific - is not positively linked to innovation propensity. The implication here may be that even training that is not tightly classified as specific to a particular job might be related to the activities of the business in a broader sense and not fully generic, whereas gaining a qualification is likely to be in more generic skills. So, training that "fits" the firm concerned may be more conducive to changes and improvements in products and processes.

A set of questions, unique as far as we know, to the LSBS, covers some particular types of training offered to managers rather than the workforce in general. The analysis finds positive and significant relationships between some of the types of manager training and innovation. In particular:

1. Manager training in financial management is significant for both new to the firm product and process innovation;

2. Manager training in leadership skills is significant for novel product innovation and also (but statistically more weakly) for novel process innovation.

These results on manager training are, we think, new to the literature.

The tentative policy implications are that promoting training both of workforce and managers seems likely to stimulate innovation, with the potential effects appearing to be more pronounced in micro firms than in other SMEs, although it is positive in all cases.

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APPENDIX

Appendix 1. Comparison of the LSBS with UK Innovation Survey

Do the LSBS data give broadly similar results to the UKIS for the common variables and sizes of business, for example, the shares who reported one or more types of innovation? We compare the estimates from LSBS on product and process innovations with the official statistics for UKIS data published by BEIS (2016 and 2018). To do so we, we select SMEs with 10 to 249 employees from the LSBS and produce the statistics for the waves 2015 and 2017, which align with the reference periods of the last two waves of UKIS. The statistics are: the shares of product innovators, new-to-market product innovators, process innovators and new-to-industry process innovators as these are the innovation variables common to both surveys.

Table A.1 Share of product and process innovators among UK SMEs (10-249 employees). Comparing LSBS and published UKIS data

	LSBS 2015 (full survey)	LSBS 2015 (panel)	UKIS 2015	LSBS 2017 (full survey)	LSBS 2017 (panel)	UKIS 2017
Product innovation	48	52	19	41	41	24
Of which new-to-market product innovation	31	30	32	28	28	35
Process innovation	33	35	13	29	29	16
Of which new-to-industry innovation	21	22	27	19	20	26

LSBS own calculations. Reference periods for the 2015 surveys – UKIS and LSBS – is the three year period 2012 to 2014 and for the 2017 waves of the surveys the three year period 2014 to 2016. The reported statistics are the share of innovators among SMEs (businesses with 10-249 employees).

The LSBS reports a higher share of product and process innovators, more than double that reported for the UKIS. We undertook a comparison of innovation rates by sector for the equivalent size groups in the UKIS and the LSBS but found that the differences were similar across sectors.

Appendix 2. Additional descriptive statistics on the differences in innovation rates for businesses who train compared to all business.

Table A.3 General training: share of staff receiving training in the last 12 months. Percentage differences from the LSBS panel reported in Table 5.

		Out of those with training in 2015: changes in the			
Share of staff receiving training	Percent of firms that had training 2015	Percent of product innovators 2015-2017	of which new-to-market 2015-2017	Percent of process innovators 2015-2017	of which new to industry 2015-2017
All of them	36	4	-6	3	0
75% to 99%	15	7	1	7	1
50% to 74%	18	3	7	1	0
25% to 49%	14	1	-5	-2	-4
10% to 24%	n/a*	n/a	n/a	n/a	n/a
Less than 10%	n/a*	n/a	n/a	n/a	n/a

The cell counts in the two final rows are below 30, so the figures are omitted to avoid the risk of disclosiveness.

The more staff – 50% and above – that have access to training the higher the reported share of innovators.

Table A.4 Percent of businesses with specific manager training that were innovators. Percentage differences from the LSBS panel reported in Table 5.

		Out of those with training in 2015: changes in the			
	Percent of firms that had training 2015	Percent of product innovators 2015-2017	of which new-to-market 2015-2017	Percent of process innovators 2015-2017	of which new to industry 2015-2017
Leadership and management skills	54	9	2	7	3
IT skills	40	12	2	9	2
Health and safety	72	6	-3	4	0
Technical, practical or job-specific skills	88	5	-1	4	1
Team working skills	45	9	0	8	4
Financial management	27*	15	3	12	3

Of the 3,102 businesses in the panel with 1-249 employees in 2015, 1,714 businesses answered the specific management skill training question in 2015 and 1,600 in 2016. Financial management skills data are from the 2016 survey.

Table A.5 Share of businesses with training leading to formal qualifications that were innovators. Percentage changes from the LSBS panel reported in Table 5.

Does training leading to formal qualifications lead to higher outcomes?

		Out of those with training in 2015: changes in the			
Training leading to formal qualification	Percent of firms that had training 2015	Percent of product innovators 2015-2017	of which new-to-market 2015-2017	Percent of process innovators 2015-2017	of which new to industry 2015-2017
Most	26	3	3	3	4
Some	34	6	-2	7	1
None	40	1	-1	-1	-3

Of the 3,102 businesses in the panel with 1-249 employees in 2015, 2,381 answered the question. Smallest cell size is 2,381 * 26% = 619.

		Out of those with training in 2015: changes in the			
Training leading to formal qualification	Percent of firms that had training 2015	Percent of product innovators 2015-2017	of which new-to-market 2015-2017	Percent of process innovators 2015-2017	of which new to industry 2015-2017
Yes, managers only	4*	0	2	-1	11
Yes, other staff only	43	3	1	4	2
Both managers and other staff	53	8	0	6	2

Of the 3,102 businesses in the panel with 1-249 employees in 2015, 1,420 answered the question. Smallest cell count is 4% * 1,420 = 57 observations.

Appendix 3. Additional regression results linking innovation and training

Table A.6 Regression results for product innovation in 2015-2017. Training and control variables are measured in 2015.

Independent variables 2015	(1) Product innovators 2015-2017	(2) Product innovators 2015-2017	(3) Product innovators 2015-2017	(4) Product innovators 2015-2017	(5) Product innovators 2015-2017
General training	0.12**				
	(0.02)				
Off-the-job training		0.08**			
		(0.02)			
On-the-job training			0.11**		
			(0.02)		
Manager training				0.04+	
				(0.02)	
Leadership skills					0.03
					(0.04)
IT skills					0.06+
					(0.03)
Health and safety					0.07*
					(0.04)
Job-specific					0.02
					(0.05)
Team working					0.01
					(0.03)
Financial Management					0.07*
					(0.03)
Product innovators 2013-2015	0.32**	0.33**	0.32**	0.32**	0.35**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)
Micro 1-9 empl.			Base comparison group		
Small 10-49	-0.01	-0.00	-0.01	-0.03	-0.01
	(0.02)	(0.02)	(0.02)	(0.03)	(0.04)
Medium 50-249	0.02	0.03	0.02	-0.01	-0.04
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)
Primary sector			Base comparison group		
Manufacturing	0.03	0.03	0.03	0.01	-0.02
	(0.06)	(0.06)	(0.06)	(0.07)	(0.11)
Construction	-0.17**	-0.17**	-0.16**	-0.21**	-0.26**
	(0.05)	(0.05)	(0.05)	(0.06)	(0.09)
Retail & wholesale	-0.04	-0.04	-0.04	-0.10	-0.19*
	(0.05)	(0.05)	(0.05)	(0.06)	(0.09)
Transport & storage	-0.12*	-0.12+	-0.12+	-0.16*	-0.28**
	(0.06)	(0.06)	(0.06)	(0.07)	(0.09)
Accommodation & food services	-0.06	-0.05	-0.06	-0.12+	-0.24**
	(0.06)	(0.06)	(0.06)	(0.07)	(0.09)
Information & communication	0.28**	0.28**	0.28**	0.24**	0.22+
	(0.06)	(0.06)	(0.06)	(0.08)	(0.12)
Financial & real estate	-0.03	-0.03	-0.03	-0.07	-0.20*
	(0.06)	(0.06)	(0.06)	(0.08)	(0.10)
Profess & scientific	0.05	0.06	0.05	-0.01	-0.13

	(0.06)	(0.06)	(0.06)	(0.07)	(0.10)
Administrative	-0.09+	-0.09	-0.09	-0.14*	-0.18+
services	(0.06)	(0.06)	(0.06)	(0.06)	(0.10)
Education	0.05	0.05	0.05	0.01	-0.12
	(0.07)	(0.07)	(0.07)	(0.08)	(0.10)
Human health	-0.06	-0.06	-0.07	-0.11+	-0.20*
	(0.05)	(0.05)	(0.05)	(0.06)	(0.09)
Arts &	0.10	0.10	0.10	0.08	0.02
entertainment	(0.08)	(0.08)	(0.08)	(0.09)	(0.13)
Other services	-0.03	-0.03	-0.03	-0.11	-0.11
	(0.06)	(0.07)	(0.06)	(0.07)	(0.12)
England			Base comparison group		
Scotland	0.04	0.05	0.04	0.04	-0.03
	(0.04)	(0.04)	(0.04)	(0.04)	(0.06)
Wales	0.02	0.03	0.03	-0.00	0.00
	(0.05)	(0.05)	(0.05)	(0.06)	(0.08)
Northern Ireland	-0.01	-0.01	-0.01	-0.02	-0.04
	(0.05)	(0.05)	(0.05)	(0.06)	(0.09)
Observations	3,100	3,096	3,097	2,380	1,254
Pseudo R-squared	0.130	0.128	0.130	0.115	0.134

Estimation methods: dynamic probit regression. We report marginal effects for a change of 0 to 1 in the independent variables and robust standard errors in parentheses.
** p<0.01, * p<0.05, + p<0.1

Table A.7 Regression results for process innovation in 2015-2017. Training and control variables are measured in 2015.

Independent variables 2015	(1) Product innovators 2015-2017	(2) Product innovators 2015-2017	(3) Product innovators 2015-2017	(4) Product innovators 2015-2017	(5) Product innovators 2015-2017
General training	0.05*				
	(0.02)				
Off-the-job training		0.05**			
		(0.02)			
On-the-job training			0.06**		
			(0.02)		
Manager training				0.03	
				(0.02)	
Leadership skills					0.02
					(0.03)
IT skills					0.03
					(0.03)
Health and safety					0.02
					(0.03)
Job-specific					-0.01
					(0.04)
Team working					0.04
					(0.03)
Financial Management					0.07*
					(0.03)
Product innovators 2013-2015	0.20**	0.20**	0.20**	0.22**	0.20**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)
Micro 1-9 empl.			Base comparison group		
Small 10-49	0.09**	0.09**	0.08**	0.10**	0.08*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)
Medium 50-249	0.12**	0.12**	0.11**	0.14**	0.07+
	(0.02)	(0.02)	(0.02)	(0.03)	(0.04)
Primary sector			Base comparison group		
Manufacturing	0.16*	0.16**	0.16*	0.13+	0.19
	(0.06)	(0.06)	(0.06)	(0.07)	(0.11)
Construction	-0.01	-0.01	-0.01	-0.02	0.02
	(0.06)	(0.06)	(0.06)	(0.07)	(0.11)
Retail & wholesale	0.06	0.06	0.06	0.05	0.11
	(0.06)	(0.06)	(0.06)	(0.07)	(0.11)
Transport & storage	-0.03	-0.02	-0.03	-0.05	-0.08
	(0.06)	(0.06)	(0.06)	(0.07)	(0.10)
Accommodation & food services	-0.03	-0.02	-0.03	-0.06	-0.10
	(0.05)	(0.05)	(0.05)	(0.06)	(0.09)
Information & communication	0.24**	0.24**	0.24**	0.19*	0.22+
	(0.07)	(0.07)	(0.07)	(0.08)	(0.13)
Financial & real estate	0.12+	0.12+	0.12+	0.12	0.11
	(0.07)	(0.07)	(0.07)	(0.08)	(0.12)
Profess & scientific	0.17**	0.17**	0.16**	0.14+	0.13
	(0.06)	(0.06)	(0.06)	(0.07)	(0.11)
Administrative services	0.03	0.03	0.04	-0.01	0.03
	(0.06)	(0.06)	(0.06)	(0.07)	(0.11)

Education	0.03	0.03	0.02	-0.01	-0.01
	(0.06)	(0.06)	(0.06)	(0.07)	(0.10)
Human health	0.04	0.04	0.04	0.02	0.03
	(0.06)	(0.06)	(0.06)	(0.06)	(0.10)
Arts &	-0.04	-0.04	-0.04	-0.08	-0.01
entertainment	(0.06)	(0.06)	(0.06)	(0.07)	(0.12)
Other services	0.01	0.01	0.00	-0.04	-0.08
	(0.06)	(0.06)	(0.06)	(0.07)	(0.10)
England			Base comparison group		
Scotland	0.04	0.05	0.04	0.05	0.02
	(0.03)	(0.03)	(0.03)	(0.04)	(0.05)
Wales	0.06	0.07	0.06	0.09	0.11
	(0.05)	(0.05)	(0.05)	(0.06)	(0.08)
Northern Ireland	-0.03	-0.03	-0.03	-0.01	-0.06
	(0.04)	(0.04)	(0.04)	(0.05)	(0.07)
Observations	3,100	3,096	3,097	2,380	1,254
Pseudo R-squared	0.102	0.102	0.102	0.0969	0.0952

Estimation methods: dynamic probit regression. We report marginal effects for a change of 0 to 1 in the independent variables and robust standard errors in parentheses.
** p<0.01, * p<0.05, + p<0.1

Table A.8 Regression results for product innovation in 2015-2017. Training and control variables are measured in 2015. Interaction term between business size bands and training included.

Independent variables 2015	Product innovators 2015-2017
General training	0.14**
	(0.03)
Micro 1-9 employees	Base comparison group
Small 10-49	0.02
	(0.05)
Medium 50-249	0.17+
	(0.10)
General training * micro 1-9 empl.	Base comparison group
General training * small 10-49	-0.05
	(0.06)
General training * medium 50-249	-0.15+
	(0.09)
Product innovators 2013-2015	0.32**
	(0.02)
Primary sector	Base comparison group
Manufacturing	0.03
	(0.06)
Construction	-0.17**
	(0.05)
Retail & wholesale	-0.04
	(0.05)
Transport & storage	-0.13*
	(0.06)
Accommodation & food services	-0.06
	(0.06)
Information & communication	0.28**
	(0.06)
Financial & real estate	-0.03
	(0.06)
Profess & scientific	0.05
	(0.06)
Administrative services	-0.10+
	(0.06)
Education	0.05
	(0.07)
Human health	-0.06
	(0.05)
Arts & entertainment	0.09
	(0.08)
Other services	-0.03
	(0.06)
England	Base comparison group
Scotland	0.04
	(0.04)
Wales	0.02
	(0.05)
Northern Ireland	-0.01
	(0.05)
Observations	3,100
Pseudo R-squared	0.131

Estimation methods: dynamic probit regression. We report marginal effects for a change of 0 to 1 in the independent variables and robust standard errors in parentheses.
** p<0.01, * p<0.05, + p<0.1

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