BIS | Department for Business Innovation & Skills

Investigating the links between innovation and productivity: an analysis of UK firms

"The raw materials that we use have not changed, but as a result of trial and error, experimentation, refinement, and scientific investigation, the instructions that we follow for combining raw materials have become vastly more sophisticated."

daniel.hodges@bis.gsi.gov.uk

Theory: Foundations

- Macro:
  - Exogenous (Solow) and endogenous (Romer) growth theory

- Micro:
  - Neo-Schumpeterian approach: Firms search for ‘novelty’
  - Novelty may be represented by new hiring & firing procedures, new policies for investment, R&D or advertising; similar to innovation

Theory: Innovation and Productivity

- CDM (1998) use structural model to investigate the links between productivity, innovation and research at firm level
- Accounts for the fact that it is innovation outputs that increase productivity, not inputs.
- Consistent with earlier studies; probability of engaging in R&D rose with size, market share, diversification. R&D intensity rose with same factors apart from size.
- Innovative output increased with input intensity. Productivity positively correlated with innovative outputs.

Theory: Innovation and Productivity

- OECD (2009) uses 2004 CIS to produce CDM model for 18 countries.
- Found firm size positively correlated with R&D engagement, along with operating in foreign markets and belonging to a group. Positively correlated with experiencing high barriers to innovation.
- Higher investment associated with co-operation, financial support and operating in foreign market (for UK).
- Innovation outputs positively correlated with inputs. Mixed picture for firm size.
- Strong correlation between product innovation and productivity; 1% increase in innovation sales associated with 0.55% increase in productivity for UK.

Data

- Sample restricted to those firms with positive turnover, more than 9 employees and from manufacturing and most non-public services. Once observations with missing values are dropped, leaves sample of 9,651.

- A firm is defined as innovative if:
  - Strict: positive innovation expenditure and positive innovative sales (2,561)
  - Wide: positive innovation expenditure (8,514)

- Innovative activities include internal & external R&D, acquisition of machinery, equipment & software, acquisition of knowledge (and training, design, market introduction)

Data: Descriptive statistics

	Median	Mean
Strict innovator	0	0.265
Wide innovator	1	0.882
Product innovator	0	0.322
Process innovator	0	0.188
Wider innovator	0	0.397
Innovation intensity	0.005	0.196
Proportion of sales from innovative products	0	0.109
IPR protection	0	0.157

Data: Descriptive statistics

	Strict Innovators		Non Innovators	
	Median	Mean	Median	Mean
Employees (2008)	58	313	50	360
Turnover (2008, £000s)	5017	47159	3800	50659
Distance from NTF	112.27	141.64	118.44	151.35
Concentration ratio	9.2	15.75	9.2	16.21
Is the firm part of a group? (Y/N)	1	0.558	0	0.479
Operate in foreign markets? (Y/N)	1	0.579	0	0.339
High barriers to innovation? (Y/N)	1	0.567	0	0.377
Set up in the last three years? (Y/N)	0	0.060	0	0.073
Staff with science degree (%)	2%	11.5%	0%	4.7%

Model - 1st Stage: The investment decision

- First, a Probit regression to model whether or not a firm is an innovator;

$$Innov\_active_i = \alpha_i + \beta_i x_{1i} + \varepsilon_i$$

$$X_{1i} = (size, group, cr4, DNTF, foreign, barriers, newfirm)$$

- Then, an OLS regression to model investment intensity;

$$Intensity_i = \alpha_i + \gamma_i x_{2i} + \varepsilon_i$$

$$X_{2i} = (size, group, cr4, DNTF, foreign, newfirm, cooperate, support)$$

Model – 2nd Stage: Knowledge Production

- An OLS regression to model innovative outputs;

$$Innov\_sales_i = \alpha_{3i} + \rho_i x_{3i} + \varepsilon_{3i}$$

- x_{3i} = (size, group, cr4, DNTF, Process, Skills, IPR, collaborators, Intensity, Newfirm)

Model – 3rd Stage: Productivity

- A 2SLS model of productivity. 1st stage is the knowledge production function, 2nd stage is;

$$Productivity_i = \alpha_{4i} + \varphi_i x_{4i} + \varepsilon_{4i}$$

- x_{4i} = (size, group, cr4, DNTF, Process, IPR, newfirm, *Innov_sales*)

BIS Department for Business Innovation & Skills

Results – 1st stage

- Which firms innovate?

Variable	Coefficient	Std. Error			
constant	-0.855***	0.094		**No. of obs**	9651
Log employment	0.022*	0.011		**Wald chi²(25)**	906.53
Group	0.052	0.034		**Prob > chi²**	0.0000
Cr4	0.005***	0.002		**Pseudo R-squared**[1]	0.0860
DNTF	-0.0001	0.00010		**Log pseudoliklihood**	-5111.4359
Foreign	0.472***	0.031			
Knowledge barriers	0.322***	0.050			
Market barriers	-0.098**	0.042			
Cost barriers	0.362***	0.032			
Regulatory barriers	0.083	0.052			
New Firm	-0.059	0.058			

BIS Department for Business Innovation & Skills

Results – 1st stage

- How much do they invest?

Variable	Coefficient	Std. Error			
constant	0.543***	0.217		**No. of obs**	2343
Log employment	-0.372***	0.030		**F(23,4585)**	25.87
Group	0.472***	0.080		**Prob > F**	0.0000
Cr4	0.029***	0.0105		**R-squared**	0.2081
DNTF	-0.00099***	0.00024		**Root MSE**	1.6511
Foreign	0.620***	0.080			
Cooperation	0.379***	0.086			
Financial Support	0.538***	0.080			
New Firm	-0.141	0.147			

BIS Department for Business Innovation & Skills

Results – 2nd stage

- Innovative sales

Variable	Coefficient	Std. Error			
constant	3.272***	0.169		**No. of obs**	2343
Log employment	-0.073***	0.024		**F(26,2316)**	21.2
Group	0.360***	0.061		**Prob > F**	0
Process Innovator	0.184***	0.054		**R-squared**	0.2183
Prop. of staff with science degree	0.322**	0.141		**Root MSE**	1.2631
Market collaboration	0.053***	0.018			
Knowledge collaboration	0.006	0.025			
DNTF	-0.00136***	0.00027			
Cr4	-0.007*	0.004			
Investment in innovation per employee	0.249***	0.018			
IPR	0.101*	0.058			
New Firm	0.023	0.114			

Results – 3rd stage

- Productivity

Variable	Coefficient	Std. Error			
constant	2.955***	0.172		**No. of obs**	2343
Innovative sales per employee	0.535***	0.042		**F(24,2318)**	51.61
Log employment	0.027**	0.014		**Prob > F**	0
Group	0.239***	0.040		**R-squared**	0.49
Process Innovator	-0.214***	0.033		**Root MSE**	0.70244
DNTF	-0.001***	0.000			
Cr4	-0.001	0.002			
New Firm	-0.191***	0.074			
IPR	-0.072**	0.034			

Conclusions

- Larger firms more productive & more likely to innovate but invest proportionately less and yield proportionately less returns to innovation.
- The probability of innovating also rose with exporting and experiencing high barriers to innovation.
- Higher innovation intensity associated with exporting, cooperating on innovation, receiving public financial support, being part of a larger enterprise group and being closer to the NTF.
- Innovation outputs rose with inputs, collaboration, proximity to the frontier, belonging to a wider enterprise group, a more skilled workforce, being process (“dual”) innovators and IPR.

Conclusions continued… and next steps

- Productivity was higher for firms who had higher innovative sales. Larger firms and more technologically capable firms were also more productive. Being a process innovator and applying for formal IPR protection was associated with lower productivity with the opposite being true for firms which were part of a group.

- Surprisingly, competition was not correlated with productivity, suggesting problems with the variable used in this study.

- Further analysis of sensitivity to industrial sectors

- Panel data analysis for causation questions