Innovation, IP Choice, and Firm Performance

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(based on joint work with Christian Helmers, Vania Sena, and the late Mark Rogers)

UK IPO Study

Looked at firms' use of patents and alternative IP protection methods

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Outline of our study

1. Facts about UK firms use of various kinds of IP

Hall et al. (2011). *The importance of patents and other formal intellectual property in comparison to informal protection methods.* Report to the UKIPO.

1. Survey of theory and evidence on IP choice

Hall et al. (2014). The choice between formal and informal intellectual property: A literature review. *Journal of Economic Literature*, forthcoming.

1. Impact of IP choice on performance
    a. Firm productivity and employment growth

Hall et al. (2013). The importance (or not) of patents to UK firms. *Oxford Economic Papers* 65 (3): 603-629.

    a. Adding IP choice to the CDM model; Innovation spending variation

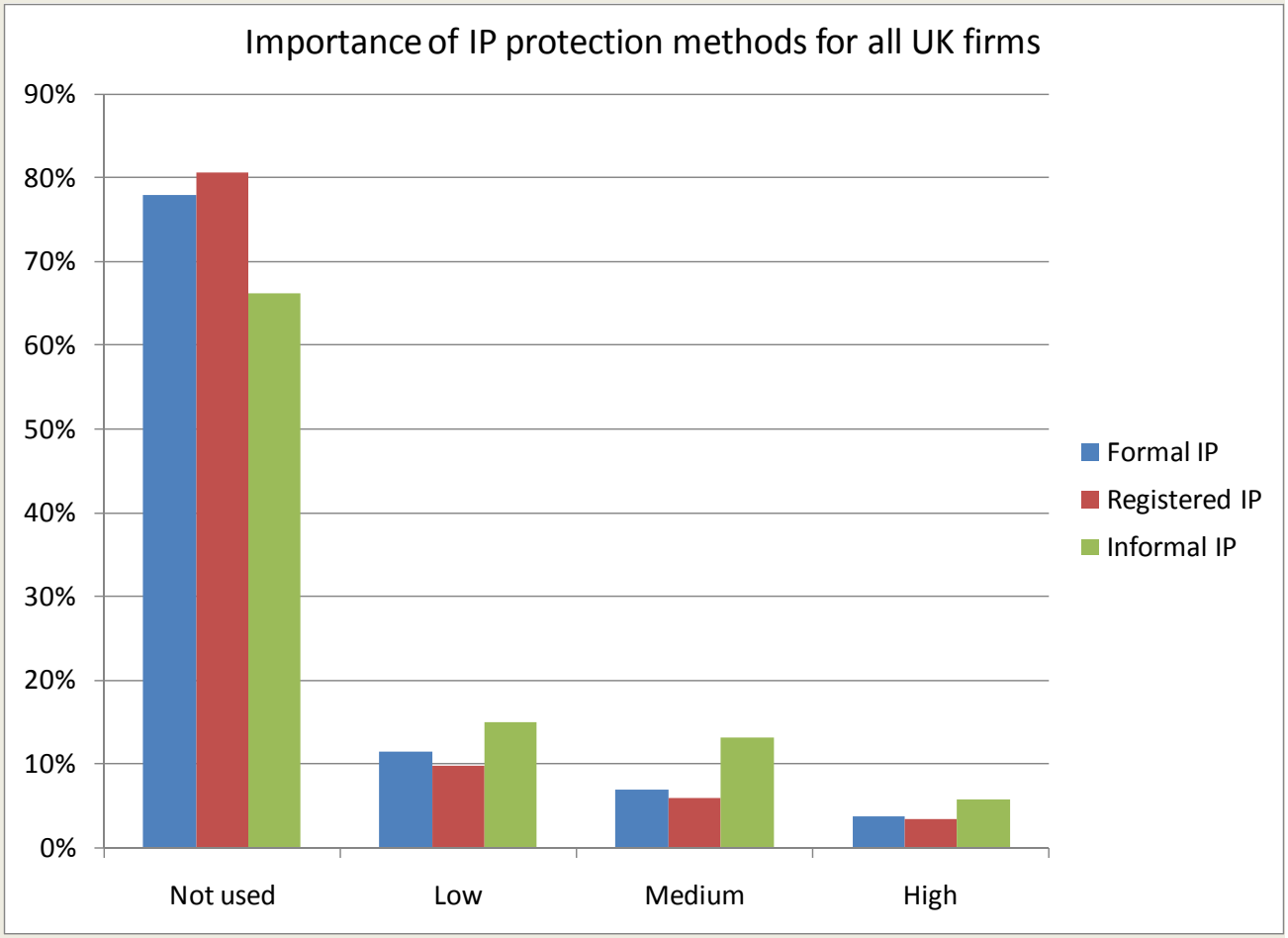
Hall and Sena (2014). Innovation, IP choice, and productivity: Evidence from UK firms. (*Draft for a CDM conference in October*).

Introduction

- Overview
  - Innovation represents 'knowledge'/intangible asset – which implies an appropriability problem
  - So how can the firm capture the returns?
  - Available options:
    1. Intellectual Property— registered and unregistered (formal)
    2. Range of "alternative" protection strategies (informal)
  - Choice among formal and informal IP protection methods is an endogenous decision by firm
    - Some can be used simultaneously, but not all

Among all firms, IP not very important; most important is informal IP

- Formal IP
  - Registered:
    - Patents
    - Trademarks
    - Design rights
  - Unregistered:
    - Copyright
- Informal IP
  - Secrecy
  - Lead time
  - Complexity



Theory: patents vs. secrecy

- Modeling of trade-off between the benefits from using registered IP and its costs
- Focus on patents vs secrecy because these are clearly substitutes, at least to some extent
  - Other informal IP mechanisms tend to complement patents
  - E.g., software: copyright, trade secrecy, & trademarks (Graham and Somaya 2004)

Factors affecting the choice to patent vs. to keep secret

- 'Exogenous' differences in technologies
  - Process vs. product (process innovation easier to keep secret)
  - Expected commercial life of innovation
  - Expected value of innovation
  - Composition of innovation: tangible vs. intangible components
  - Complexity of research (difficult to codify knowledge => secrecy)
  - How effectively do patent(s) protect the innovation (as opposed to the invention)
  - Difficulty of reverse-engineering

Factors affecting the choice to patent vs keep secret

- Industry demographics/characteristics & strategic/competitive considerations
  - Strong competition for same or similar innovation may encourage patenting (e.g. a patent race)
  - Patent as 'strategic signal' of profitable innovation
  - Technology gap between lead innovator and followers
    - Whether competition is 'neck and neck', with each firm building on others' innovations
  - Firm size
    - Large – lower cost per patent
    - Startups – helps obtain financing
  - Appropriability regime in industry

Factors affecting the choice to patent vs. keep secret

- Institutional aspects:
  - Patent system
    - Initial fixed costs (higher initial costs reduce patent use, especially for smaller firms)
    - Maintenance and enforcement costs (higher costs reduces patent use)
    - Division and addition (ability to delay and amend patent increases their strategic value)
    - Disclosure requirements
  - Trade secrecy system
    - Costs of confidentiality agreements
    - Internal monitoring and active knowledge management
    - Enforcement issues

Empirical challenges

- Multiple and overlapping IP use
- Impossible to determine what exactly is protected by which protection instrument
- Different protection tools may be used at different stages of the innovative process (secrecy protects work in progress)

Data Overview

- New firm-level dataset for UK firms - components:
  - Business Structure Database (BSD)
  - Annual Respondents Database (ARD2)
  - UK Community Innovation Survey (CIS) 3, 4, 5, 6, and 7
  - Patent data (UK & EPO – includes PCT)
  - Trade-mark data (UK & OHIM)
  - Business Enterprise Research & Development expenditure (BERD)
- Linked from 'scratch'
  - Unified and recoded CIS surveys
  - Cleaned and modified/adapted BSD, ARD2, and CIS
  - Database at enterprise level due to patent and trade-mark data
  - When necessary, aggregated local unit up to enterprise level
- Limitations and problems:
  - No real panel structure (due to CIS sampling)
  - Enterprise aggregation may be incomplete for CIS
  - Patent/TM match no longer available due to move from VML to SDS
  - IP questions on CIS changed over time, limits us to 1998-2006

Dataset structure

CIS-based firm panel (1998-2006), highly unbalanced (stratified sampling & changing sampling frame)

# Firms	Share (%)	Sample*	CIS 3	CIS 4	CIS 5
533	2.0%	109	X	X	X
436	1.7%	163	X	X	
5,321	20.4%	1,174		X	X
235	0.9%	81	X		X
6,740	25.9%	1,942	X		
6,694	25.7%	3,576		X	
6,101	23.4%	2,479			X
26,060	100.0	9,524			

**Regression sample is innovating firms only, cleaned*

Sectoral distribution (%)

Sector	CIS 3	CIS 4	CIS 5	Total
High-tech	2.7	1.6	1.5	1.9
Medium tech	5.6	3.7	3.5	4.1
Other manufacturing	17.0	16.3	15.3	18.7
Non-manufacturing	63.9	76.3	78.9	74.1
R&D services	0.7	2.1	0.9	1.3

High-tech: pharma 2423; aircraft & spacecraft 353; scientific instruments 33; radio, TV , & comm eq 32; office, acctg, & comp machinery 30
Medium-tech: elec machinery 31; motor vehicles, etc. 34; rail & transport equipment 352/359; chemicals 24 (excl. 2423); machinery 29
R&D services: SIC 73
(international SIC Rev. 3)

Innovation and IP use in the UK 1998-2006 (self-reported)

	Product innovators	Process innovators	Patenters
All firms	22.4	14.1	1.4
R&D-doers	37.6	24.3	2.1

IP mechanism	Not used	Low	Medium	High
Formal IP	78.0	11.4	6.9	3.7
Registered IP	80.7	9.8	6.0	3.5
Patents	83.8	5.9	4.4	5.9
Informal IP	66.2	14.9	13.1	5.8
Secrecy	67.8	11.2	11.5	9.5
From CIS 3,4,5 –shares of firms, population weighted (38,760 obs)				

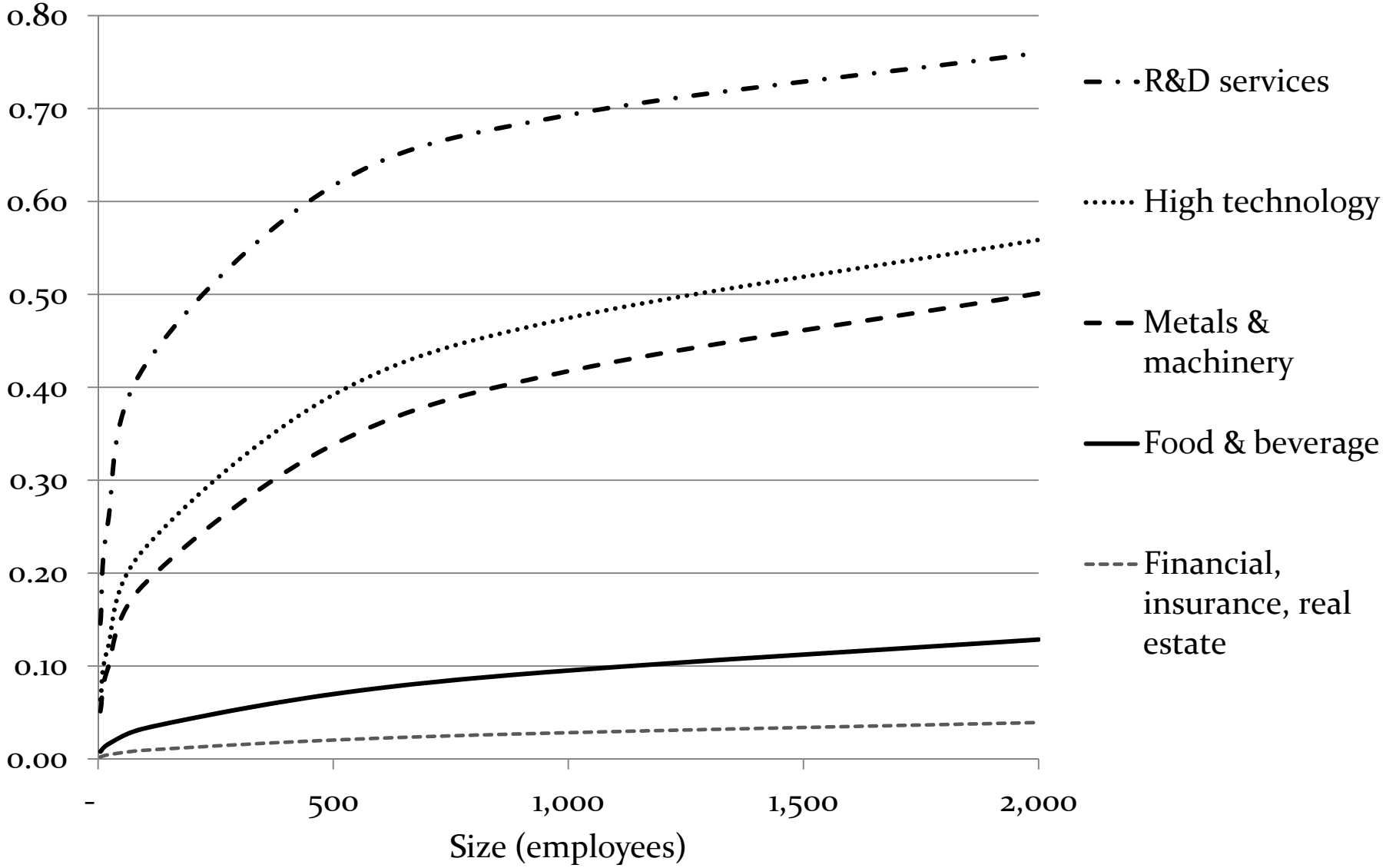
Initial regression analysis

- Determinants of firm's *decision* to patent
  - interpret innovating firm's decision not to patent as decision in favor of informal IP
- Determinants of firm's *preference* for patents relative to secrecy
- Sample is product and/or process innovators only
  - Look only at firms that innovate, since they clearly have an incentive to choose some form of IP

Summary (1) – patenting choice

- Enormous variation in patenting propensities across firms and industries explained by
  - Size (larger) – very important
  - Group membership
  - Sector (chemicals, high tech, metals & machinery, R&D services)
  - Doing R&D
  - New to market innovation

Figure 4: Probability of patenting - Innovating, R&D-doing firms aged 20 years



Summary (2) – firm attitudes

- Overwhelming share of firms does not consider patents to be important
  - 2.8%–5.0% (CIS 3–CIS 5) say they are crucial
- Importance attributed to formal IP varies depending on whether firm innovates and/or patents
  - 92% of non-product innovators regard patents as unimportant, but only 30% of innovators
  - Share of firms regarding formal IP as important substantially larger for patenting than for non-patenting firms
  - However, even patenting firms rely much more heavily on informal protection
- Within formal IP, trademarks most important
- Considerable variation across sectors in importance of informal IP (top is R&D services)

Summary (3) - performance

- Relation between decision to patent and performance:
  - No relation between sales due to innovation "new to the firm" and patents
  - Positive relation between sales due to innovation "new to the market" and patents
    - Having a patent associated with 30-50% increase in share of sales from products new to market
  - Slightly positive relation between employment growth and patents:
    - Having a patent associated with higher employment growth (by 12%) – but not significantly so

Summary (4) – IP use

- Heterogeneity in the use of IP is highly correlated across types of formal IP, even conditional on size, R&D, sector, region, export status, ownership, etc.
- Suggests "IP awareness" as a single left-out variable – or "does this firm use IP legal advice?"
- Relatedly, if a firm has an important innovation, using a package of IP types will be more appropriate

Augmented CDM model

- Augment the CDM model with equations for the choice of formal and informal IP.
- For simplicity in estimation and clarity of presentation we treat process and product innovation separately.
- Sample is 7,144 observations
  - Innovators with good measures of capital, labor, and value added from business survey data
  - 31% do R&D

Adding IP to the CDM model

1. Estimate simultaneously the decision to invest in R&D and the level of R&D.
2. Estimate the probability of innovation and IP choice simultaneously using trivariate probit.
3. Estimate a standard productivity equation with lagged innovation output (with and without IP protection) among the inputs.

- Assumptions:
  - IP choice affects a firm's productivity through the innovation it protects
  - Innovating and the IP choice precede temporally the production of output.
- Variation: use total innovation spending instead of R&D

Composition of innovation spending

	All firms	SMEs	Large firms
Acq. of mach. & comp. hardware/software	45.1%	48.0%	43.0%
Internal R&D spending	18.6%	17.7%	19.2%
Marketing expense	13.5%	11.8%	14.9%
Training expense	9.5%	10.2%	8.9%
Design expense	6.4%	5.9%	6.8%
External R&D spending	3.7%	3.5%	3.9%
Acq. of external knowledge	3.2%	2.9%	3.4%
Observations with nonzero spending	4,414	1,876	2,538
Share with nonzero spending	61.8%	57.1%	65.8%
The average shares shown are over firms that have some form of innovation spending reported.			

First stage

- Models simultaneously the decision to invest in R&D and the intensity of R&D (Tobit type II).

$$rd_i = \begin{cases} 1 \text{ if } rd^* = w_i\alpha + \varepsilon_i > 0 \\ 0 \text{ if } rd^* = w_i\alpha + \varepsilon_i \leq 0 \end{cases} \qquad i = 1, \ldots, N$$

$$r_i = \begin{cases} z_i\beta + e_i & \text{if } rd_i = 1 \\ 0 & \text{if } rd_i = 0 \end{cases}$$

Second stage

- The choice(s) of IP method and the innovation production function are estimated simultaneously, but separately for product and process innovation.
- *INN* = product or process innovation dummy
- *IIP* = informal IP dummy; *FIP* = formal IP dummy

$$INN_i = \gamma_1 r_i^* + x_i^1 \delta_1 + d_s + d_r + u_i^1$$

$$IIP_i = \gamma_2 r_i + x_i^2 \delta_2 + d_s + d_r + u_i^2$$

$$FIP_i = \gamma_3 r_i + x_i^3 \delta_3 + d_s + d_r + u_i^3$$

Third stage

- A Cobb-Douglas production function is estimated with the innovation output from the previous stage included in the regression, along with indicators for the use of IP.
- *y, k, l* are the usual logs of VA, capital, labor
- Sectoral, survey, and regional dummies are included

$$y_i = a + b_k k_i + b_l l_i + \pi_1 \widehat{INN}_i + \pi_2 IIP_i + \pi_3 FIP_i$$
$$+ \pi_4 IIP_i \bullet \widehat{INN}_i + \pi_5 FIP_i \bullet \widehat{INN}_i + d_s + d_r + \nu_i$$

Results – R&D equation

	Invests in R&D (0/1)		Log R&D per employee	
Formal IP impt (3-digit industry)	0.26	(0.17)	1.05	(0.30)***
Informal IP impt (3-digit industry)	0.24	(0.19)	0.64	(0.32)*
D (foreign owned)	-0.10	(0.05)*	0.36	(0.09)***
D (exports)	0.31	(0.05)***	0.60	(0.10)***
D (collaborates)	0.42	(0.05)***	0.57	(0.10)***
Impt of reg & stds, H&S (3-digit ind)	N.S.		N.S.	
Impt of market risk, fin. constraints	N.S.		N.S.	
Other variables: size, information sources, age				
Year and sector dummies included in both equations				
Correlation of the disturbances			0.35	(0.10)***
Standard error of the residual			1.64	(0.05)***
Marginal effects and their HS-consistent standard errors are shown.				

Results – product innovation

	Formal IP	Informal IP	Product innovator
Predicted R&D intensity	0.84 (0.05)***	0.64 (0.04)***	0.30 (0.05)***
D (collaborates)	-0.19 (0.05)***	-0.03 (0.05)	0.43 (0.05)***
D (market risk)	0.32 (0.04)***	0.37 (0.04)***	0.17 (0.04)***
D (financial constraints)	0.12 (0.04)***	0.29 (0.04)***	0.02 (0.04)
D (impt of reg & stds)	0.14 (0.05)**	0.12 (0.05)*	-0.12 (0.05)*
D (impt of envir. concerns, H&S)	0.05 (0.05)	0.16 (0.05)**	-0.02 (0.05)
D (imitator)	-0.27 (0.06)***	-0.27 (0.06)***	
Other variables: size, information sources, purpose of innovation, age			
Year and sector dummies included in all equations			
Trivariate probit estimation; HS-consistent standard errors; Residuals are correlated (0.55, 0.20, 0.24).			

Results – process innovation

	Formal IP	Informal IP	Process innovator
Predicted R&D intensity	0.84 (0.05)***	0.64 (0.04)***	0.10 (0.05)*
D (collaborates)	-0.20 (0.05)***	-0.04 (0.05)	0.57 (0.05)***
D (market risk)	0.32 (0.04)***	0.37 (0.04)***	0.12 (0.04)**
D (financial constraints)	0.12 (0.04)***	0.29 (0.04)***	0.02 (0.04)
D (impt of reg & stds)	0.14 (0.05)**	0.12 (0.05)*	-0.18 (0.05)***
D (impt of envir. concerns, H&S)	0.05 (0.05)	0.16 (0.05)**	0.16 (0.05)**
D (imitator)	-0.08 (0.06)	-0.05 (0.06)	
Other variables: size, information sources, purpose of innovation, age			
Year and sector dummies included in all equations			
Trivariate probit estimation; HS-consistent standard errors; *Residuals are correlated (0.55, 0.04, 0.13).*			

Results – production function

Dependent variable = Log value added per employee

	Product innovation	Process innovation
Labour (log employees)	0.66 (0.01)	0.66 (0.01)
Log capital	0.10 (0.01)	0.10 (0.01)
Log materials	0.28 (0.01)	0.28 (0,01)
Predicted prob (innov)*Formal IP	0.11 (0.06)**	0.07 (0.06)
Predicted prob (innov)*Informal IP	0.02 (0.04)	-0.05 (0.05)
Predicted prob (innov)*Both	0.14 (0.03)***	0.13 (0.03)***
F-test for IP variables	3.6 (0.009)***	6.6 (0.009)***
Size, sector , year dummies also included		
H.S.-consistent standard errors, clustered on firms		

Summary

- Most surprising result:
  - Although firms seem to prefer informal IP as much as formal IP, the productivity contribution of innovation is associated only with the choice of formal IP protection.
  - A firm that innovates and attaches importance to formal IP achieves the same impact on its productivity as if it had doubled its capital stock.
- Variation by size:
  - Stronger IP impact for large firms than SMEs
- Variation by sector:
  - IP impact insignificant for manufacturing; highly positive for services
- Using innovation spending instead of R&D
  - Few differences; none in productivity equation

Conclusions

- Few UK firms patent, because most firms are SMEs or are in sectors where patenting is not important (services, for the most part).
- Firms that do patent or use other means of formal IP seem to achieve higher performance, in innovative sales, growth, and productivity
- Should more firms patent? Or is patenting associated with characteristics of successful innovation that we cannot measure?

BACKUP SLIDES

Results – Innovation spending eq.

	Invests in innov. (0/1)		Log IS per employee	
Formal IP impt (3-digit industry)	-0.28	(0.17)	0.35	(0.21)
Informal IP impt (3-digit industry)	0.38	(0.18)*	0.71	(0.32)***
D (foreign owned)	-0.07	(0.04)	0.29	(0.06)***
D (exports)	0.16	(0.04)***	0.42	(0.06)***
D (collaborates)	0.27	(0.06)***	0.39	(0.06)***
Impt of reg & stds, H&S (3-digit ind)	N.S.		N.S.	
Impt of market risk, fin. constraints	N.S.		N.S.	
Other variables: size, information sources, age				
Year and sector dummies included in both equations				
Correlation of the disturbances			0.06	(0.04)
Standard error of the residual			1.58	(0.02)***
Marginal effects and their HS-consistent standard errors are shown.				

Results – production function for innovation spending model

Dependent variable = Log value added per employee

	Product innovation	Process innovation
Labour (log employees)	0.66 (0.01)	0.66 (0.01)
Log capital	0.10 (0.01)	0.10 (0.01)
Log materials	0.28 (0.01)	0.28 (0,01)
Predicted prob (innov)*Formal IP	0.12 (0.06)**	0.07 (0.06)
Predicted prob (innov)*Informal IP	0.02 (0.04)	-0.05 (0.05)
Predicted prob (innov)*Both	0.14 (0.03)***	0.13 (0.03)***
F-test for IP variables	3.7 (0.009)***	6.7 (0.009)***
Size, sector , year dummies also included		
H.S.-consistent standard errors, clustered on firms		

Illustrating the selectivity of the data using the new sample

	Observations	Firms
Total CIS observations	**68,112**	**46,638**
Not matched to ARD	-20,005	
ARD-CIS match	**48,107**	
Drop missing industries, primary ind, ind 80-98	-26,092	
Drop non-profits, govt, missing legal status	-519	
Unable to construct capital stock	-5,040	
Potential ARD-CIS sample	**16,456**	**11,421**
Missing employment on CIS	-1,049	
Large estimation sample	**15,407**	**10,844**
Missing capital, turnover, or materials	-3,761	
Trim ratios for production function at 1%	-796	
Estimation sample (CIS 3-7)	**10,850**	**7,255**
Estimation sample (CIS 3-5)	**7,144**	**5,553**