Innovation and productivity across four European countries[1]

Rachel Griffith*
Institute for Fiscal Studies London (IFS) and University College London

Elena Huergo†
Universidad Complutense de Madrid

Jacques Mairesse‡
CREST-INSEE Paris

Bettina Peters¶
Centre for European Economic Research Mannheim (ZEW)

This version: March, 2005

Preliminary and incomplete. Please do not quote!

Abstract

There is a considerable number of national firm-level studies analysing the relationship between innovation and productivity. But, cross-country comparisons using micro data are still rare. This paper contributes to the literature by investigating the innovation-productivity nexus at the firm-level for the four major European countries France, Germany, Spain, and the UK using the internationally harmonized CIS 3 data. We apply a structural model that describes the link between R&D expenditure, innovation output and productivity (CDM model). Our econometric results show some interesting heterogeneity across the four countries. Using different innovation output indicators, we found that the innovation output is significantly determined by the innovation effort in the four countries. In contrast to that, productivity effects of innovation showed up only for France, Spain and the UK, but not for Germany.

JEL: D24, L6, O3.

Keywords: innovation, productivity.

Contact:
* E-mail: rgriffith@ifs.org.uk
† E-mail: ehuergo@ccee.ucm.es
‡ E-mail: Jacques.Mairesse@ensae.fr
¶ E-mail: b.peters@zew.de

[1] We thank Laura Abramovsky, Rupert Harrison, Jordi Jaumandreu, Tobias Schmidt, Helen Simpson.
This paper is part of the European research project "Innovation and Employment in European Firms: Microeconometric Evidence (IEEF)", funded by the European Commission under the Fifth Framework Programme. All errors and omissions remain the responsibility of the authors.

1 Introduction

The poor productivity performance of European countries relative to the US has been an important focus for government policy. Value-added per capita in EU countries has long lagged behind the US despite widespread reforms across EU countries aimed at increasing growth.[2] EU (2003) emphasizes the fact that post-war growth in Europe was largely based on imitation, driven by capital accumulation, while what is needed now is for European countries to shift towards growth based on innovation. Academics and policy-makers have emphasised the importance of investment in research and development (R&D) as a contributor to long-term productivity growth. In response to these concerns, the European Union has set itself the target of increasing R&D expenditure to 3% of GDP by 2010 (this is part of the "Lisbon Agenda").

Yet, despite the importance of the topics, and the attention they have receive, little is know about the links between R&D expenditure, innovation and productivity at the firm level. Does the EU's poor performance lie primarily in low investment in R&D[3], or is the main problem that EU firms do not exploit innovations as well? In this paper, we use a new data source, which provides comparative data across European countries at the firm level, to estimate a structural model that directly links R&D to innovation outcomes and then links innovation to productivity. This allows us to disentangle the contribution of R&D intensity from the productivity of innovative effort in producing innovations in their effects on overall productivity.

We compare firm performance in France, Germany, Spain and the UK. Our econometric results show some interesting heterogeneity across the four countries. Using different innovation output indicators, we found that the innovation output is significantly determined by the innovation effort in the four countries. In contrast to that, productivity effects of innovation showed up only for France, Spain and the UK, but not for Germany.

The paper is organized as follows. Section 2 presents the theoretical framework. Section 3 describes the data. Section 4 presents the results and some robustness checks. Section 5 concludes.

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[2] See, for example, EU (2003).

[3] R&D intensity in the four major EU countries (France, Germany, Spain and the UK) lies behind US and Japan (as measured by GERD over GDP).

2 Theory and Econometrics

The model draws largely on Crépon, Duguet and Mairesse (1998). Traditionally R&D is entered directly into the production function. From this the rate of return or elasticity of output with respect to R&D is estimated. What we do here is model (i) firms' decisions to engage in R&D, (ii) the intensity within which they undertake R&D, (iii) the knowledge production function, allowing for different types of knowledge output including process innovation, product innovation and the extent of novelty of new products, (iv) the output production function where knowledge is an input.

Let $i = 1,\ldots,N$ index firms, $j = 1,\ldots,J$ index industries, $c = 1,\ldots,C$ index countries, $s = 1,\ldots,S$ index size categories. The basic structure of the model is: firms decide whether and how much effort to put into innovation; knowledge is produced as a result of this investment (along with other inputs and uncertainty); output is produced using knowledge (along with other inputs). More formally we can write this as follows.

Firms innovative effort is described by the latent variable r_i^*

$$r_i^* = z_i'\beta + e_i \tag{2.1}$$

where z_i is a vector of determinants of innovation effort. However, we only observe effort (reported R&D expenditure, which is denoted r_i) above a certain threshold level c. We therefore estimate a selection model for observed effort and use the predicted value to proxy innovation effort in the knowledge production function. The selection equation describing whether a firm is reporting R&D or not, is given by

$$rd_i = \begin{cases} 1 & \text{if} \quad rd_i^* = w_i'\alpha + \varepsilon_i > c \\ 0 & \text{if} \quad rd_i^* = w_i'\alpha + \varepsilon_i \le c \end{cases} \tag{2.2}$$

where rd_i is the observed binary endogenous variable being zero for non-R&D and one for R&D reporting firms and w_i is a vector of variables explaining the R&D decision. On condition that firm i reports R&D activities, we can observe the amount of resources devoted to R&D

$$r_i = \begin{cases} r_i^* = z_i'\beta + e_i & \text{if} \quad rd_i = 1 \\ 0 & \text{if} \quad rd_i = 0 \end{cases} \tag{2.3}$$

The error terms e_i and ε_i are bivariate normal with zero mean, variances $\sigma_\varepsilon^2 = 1$ and σ_e^2 and correlation coefficient $\rho_{e\varepsilon}$.

In contrast to Crépon et al (1998) we do not concentrate on innovate firms, but we consider all firms.[4] We model innovation effort in this way because we believe that all firms exert some innovative effort. For example, production workers may well spend a small part of their day considering how the process they are working on could be achieved more efficiently. However, below a certain threshold a firm will not collect data explicitly on this effort and therefore will not report this effort. An alternative interpretation is as an instrumental variables equation, where we may concerned that innovative efforts is endogenous to the knowledge production function - that is, there may be unobservable (to the econometrician) characteristics of firms that make them both invest more in innovation effort and also make more productive use of this effort. This would induce spurious correlation and mean that the coefficients in (2.4) below would be biased upward.

The output of this effort produces knowledge g_i. In general, the knowledge production function takes the form

$$g_i = r_i^* \gamma + x_i' \delta + u_i \tag{2.4}$$

where the latent innovation effort enters and where x_i is a vector of determinants of knowledge production. We measure knowledge output in producing both process and product innovations. Effort is a public good within the firm, so it can be used to produce several outputs without depletion. Therefore, we model g_i as a vector of innovative outputs (see section 4.3 for more details).

Finally firms produce output using the following production function

$$y_i = \pi_1 l_i + \pi_2 k_i + \pi_3 g_i + v_i, \tag{2.5}$$

where output y_i is measured as labour productivity. Besides labour l_i and physical capital k_i, knowledge – now measured in terms of the output of innovation activities – g_i enters the production function. One diverging point compared to the original CDM model is that we

[4] According to the Oslo manual R&D activities are only one out of several innovation activities. The latter also comprises the acquisition of machinery and equipment in the context of innovations, the acquisition of other external knowledge, training activities related to innovations, market introduction of innovations, design and other preparation activities for the production and delivery of new products (Eurostat and OECD, 1997).

estimate the elasticity of productivity with respect to innovation not only for innovative but for all firms in the last part of the model.

The specification of the model and the identification strategy is explained in more detail in the next section.

3 Data and Measurement

The data comes from the third wave of the Community Innovation Survey (CIS 3), launched in European countries in 2001.[5] The cross section provides information for the period 1998-2000. In Germany, UK and Spain, the CIS 3 covers all enterprises with 10 or more employees. In France, however, the target population for manufacturing covers firms with 20 or more employees, only. To compare the four countries, we thus restrict the analysis to firms with at least 20 employees

[Table 1 here]

The whole structure of the model, including the exclusion restrictions made for identification of the model, can be gathered from Table 1. Descriptive statistics of the main explanatory variables in the model are reported in Table 2.

[Table 2 here]

As mentioned before we believe that all firms exert some innovative effort implying that we estimate the model for the whole sample and not only for the innovating firms. This further implies that we are only able to use variables which we can observe for all firms to explain the selection equation. Unfortunately, only a few variables are available for innovating and non-innovating firms in CIS 3 data. Thus, besides size and industries dummies only three other variables enter the R&D selection equation. The first one is an indicator of whether the international market is the firm's most important market. The second one is the exports as a share of total turnover at the beginning of the period (1998). And we include also measures of appropriability conditions. We have more explanatory variables available to explain the R&D intensity because R&D performers have to answer several additional questions in the CIS.[6] We consider demand conditions, an indicator whether the enterprise had some co-operative arrangements on innovation activities during 1998-2000, a set of

[5] For a more detailed description of the data sets, their comparability across the four countries under consideration and some basic results, see Abramovsky, Jaumandreu, Kremp and Peters (2004).

[6] The CIS questionnaires in France, Spain and Germany include a filter question, i.e., only firms with innovation activities are requested to answer to a lot of other questions, like questions on co-operations, sources etc. R&D performers are by construction firms with innovation activities.

categorical variables reflecting the sources of information for innovation and indicators of public support.

In all equations we control for size and industry characteristics.

4 Results

4.1 Estimation Procedure

The model equations (2.2)-(2.5) make clear that we assume a recursive model structure, i.e. we neglect possible feedback effects, e.g. from productivity on innovation effort. For estimation purposes, we do not estimate all equations simultaneously, but apply a consistent although less efficient three step estimation procedure. In a first step the generalized Tobit model, comprising the selection equation (2.2) and the innovation effort equation (2.3), is consistently estimated by full maximum likelihood techniques. In the second step we estimate the knowledge production function using the predicted value of the innovation effort as one explanatory variable. As already mentioned innovation effort can be used to produce both new products and processes. We consider four different innovation outputs and the applied estimation technique depends on the nature of the outcome variable (see section 4.3). In the last step we estimate the output production function allowing the endogeneity of the knowledge input variable.

4.2 R&D equation

We start by estimation (2.1). As described above, we want to allow for the fact that firms only collect data on and report R&D when it is above a threshold level. Yet many firms in the CIS report innovating without undertaking any innovative effort.

[Table 3 here]

Table 3 shows the estimated coefficients of this model. Columns (1)-(5) show the probit for whether firms report continuous R&D or not, while columns (6)-(10) show the equation for R&D intensity, where this has been estimated using full maximum-likelihood. Looking at column (1) we see that French firms are 30% less likely to do continuous R&D than UK firms, West Germany firms are 48% less likely, while East German firms are 80% more likely. This seems surprising given the descriptive statistics shown in Table 2, which clearly indicate the opposite pattern. Table 3b shows that this is due to industry composition. In column (1) of Table 3b when we just include country dummies we see a similar pattern as in

Table 2. In column (2) we include size dummies. This reduces the size of the France and West Germany effects (so to some extent the estimates in column 1 were capturing the fact that firms in the French and Germany sample are on average larger, and therefore more likely to innovate) and increases the size of the coefficient for East Germany. In column (3) of Table 3b we include country specific industry effects. This further reduces the effects for France and West Germany, and further increases the effect for East Germany. The results in Table 3 additionally include controls for firms exposure to international markets, which further amplify the country specific coefficients.

In addition, columns (2)-(5) of Table 3a resume the individual country results. As it is expected from economic theory, in all countries the export intensity enlarges the propensity to engage in R&D. This propensity increases also if the international market is the most important for the firm.

The estimates of the R&D intensity equation in columns (7)-(10) show a higher degree of heterogeneity. Having some co-operative arrangement on innovation and the exposure to international markets increase R&D intensity in France, Germany and Spain, but not in UK.

We use the predicted value of innovation effort from column (6) of Table 3 as an input into knowledge production. Table 3c compares the predicted with the actual value.

4.3 Innovation production function

We now turn to the knowledge production function described by equation (2.4). We estimate this for four separate forms of innovation output: (a) discrete indicator of whether or not the firm has introduced a process innovation, (b) discrete indicator of whether or not the firm has introduced a product innovation, (c) the share of the firms' output that correspond to products that are innovative and new to the firm, (d) the share of the firms' output that correspond to products that are innovative and new to the market. Given the different nature of the innovation outputs, we estimate probit models only for binary indicators (a) and (b). In the case of innovative sales measures (c) and (d), we use generalized Tobit models, comprising a selection equation for being a product innovator, and the share of innovative sales equation.

[Table 4 here]

The predicted value of the innovation effort is markedly significant as explanatory variable of process and product innovation (Table 4a and 4b). However, the results are not so clear in the innovative sales equations. The predicted R&D intensity does not render a statistical

coefficient for France, in the case of innovative sales new to the firm, and for Germany and UK, in the case of innovative sales new to the market.

4.4 Output production function

To provide a comparison we start by estimating a baseline specification of standard production function with R&D intensity included.

$$\ln\left(Y/E\right)_i = \theta_0 + \theta_1 \ln\left(I/E\right)_{it} + \theta_2 \ln\left(R/E\right)_i + c_c + s_s + \eta_j + \upsilon_{it}\,, \tag{2.6}$$

where Y: sales, E: number employed, I: investment, R: R&D expenditure, c: country effects, s: size effects, η: industry effects, υ: ideosyncratic effects.

Estimates of this are shown in Table 5.

[Table 5 here]

As we expected, in all columns R&D intensity appear to be significantly associated with labour productivity. Tables 6 and 7 include alternatively actual and predicted values of the innovation variables analysed in previous steps.

[Table 6 and 7 here]

The results in Table 7 are specially interesting. In France, Spain and UK the four predicted innovation outputs increase labour productivity. This regularity is not present when we use actual values instead, pointing out the relevance of taking into account the endogeneity of the knowledge input variable. In the case of Germany, only the R&D intensity appears as a significant source of productivity improvements.

5 Summary and Conclusions

This paper contributes to the literature by investigating the innovation-productivity nexus at the firm-level for the four major European countries France, Germany, Spain, and the UK using the internationally harmonized CIS 3 data. We apply a structural model that describes the link between R&D expenditure, innovation output and productivity (CDM model). Our econometric results show some interesting regularities. Using different measures of innovation output, we found that this output is significantly determined by the innovation effort in the four countries, although the likelihood of doing continuous R&D differs among them. In contrast to that, productivity effects of innovation showed up only for France, Spain and the UK, but not for Germany.

References

Abramovsky, L., J. Jaumandreu, E. Kremp and B. Peters (2004) “National Differences in Innovation Behaviour: Facts and Explanations”, mimeo.

Aghion, Philippe, and Jean Tirole (1994a) “On the Management of Innovation”, *Quarterly Journal of Economics*, 102, 1185-1207.

Aghion, Philippe, and Jean Tirole (1994b): "Opening the Black Box of Innovation", *European Economic Review, Papers and Proceedings*, 38, 701-710.

Crepon, B., E. Duguet and J. Mairesse (1998) “Research and Development, Innovation and Productivity: An Econometric Analysis at the Firm Level”, Economics of Innovation and New Technology, 7(2), 115-158

EU (2003) “An agenda for a growing Europe: making the EU economic system deliver” Report of an Independent High-Level Study group established on the initiative of the President of the European Commission, July 2003.

Appendix: Variable Definition

Productivity: Sales per employee in 2000 (in log.).

Investment intensity: Gross investments in tangible goods in 1998, per employee (in log.).

R&D intensity: R&D expenditure in 2000, per employee (in log.).

Export intensity: Exports as a share of total turnover in 1998.

Continuous R&D engagement: Dummy variable which takes the value 1 if the enterprise reports continuous R&D engagement in intramural R&D activities during the period 1998-2000.

Process innovation: Dummy variable which takes the value 1 if the enterprise reports having introduced new or significantly improved production processes during 1998-2000.

Product innovation: Dummy variable which takes the value 1 if the enterprise reports having introduced new or significantly improved products during 1998-2000 (new to the market or only new to the firm).

Market novelty: Dummy variable which takes the value 1 if the enterprise reports having introduced new or significantly improved products during 1998-2000 which are new for the firms market.

Share of sales with new products: Share of turnover in 2000 due to new or significantly improved products introduced during 1998-2000.

Share of sales with market novelties: Share of turnover in 2000 due to new or significantly improved products introduced during 1998-2000 which are new for the firms market.

International Competition: Dummy variable which takes the value 1 if the enterprise's most significant market is international.

Cooperation: Dummy variable which takes the value 1 if the enterprise had some co-operative arrangements on innovation activities during 1998-2000.

Local funding: Dummy variable which takes the value 1 if the enterprise received local or regional funding for innovation projects during 1998-2000.

National funding: Dummy variable which takes the value 1 if the enterprise received central government funding for innovation projects during 1998-2000

EU funding: Dummy variable which takes the value 1 if the enterprise received EU funding for innovation projects during 1998-2000

Internal sources within the enterprise: Dummy variable which takes the value 1 if information from internal sources within the enterprise were of high importance during 1998-2000.

Internal sources within the group: Dummy variable which takes the value 1 if information from internal sources within the enterprise group were of high importance during 1998-2000.

Suppliers as source of information: Dummy variable which takes the value 1 if information from suppliers were of high importance during 1998-2000.

Customers as source of information: Dummy variable which takes the value 1 if information from costumers or clients were of high importance during 1998-2000.

Competitors as source of information: Dummy variable which takes the value 1 if information from competitors and other enterprises from the same industry were of high importance during 1998-2000.

Universities as source of information: Dummy variable which takes the value 1 if information from universities or other higher education institutes were of high importance during 1998-2000.

Government as source of information: Dummy variable which takes the value 1 if information from government or private non-profit research institutes were of high importance during 1998-2000.

Environmental, health and safety aspects: Dummy variable which takes the value 1 if improved environmental or health and safety aspects were of high / medium and low importance for innovation during 1998-2000.

Regulation and standards: Dummy variable which takes the value 1 if regulation or standards were of high / medium and low importance for innovation during 1998-2000.

Formal protection: Dummy variable which takes the value 1 if the enterprise used design pattern, trademarks or copyright to protect inventions or innovations during 1998-2000.

Legal protection: Dummy variable which takes the value 1 if the enterprise used complexity of design, secrecy or lead-time advantage on competitors to protect inventions or innovations during 1998-2000.

Table 1: Identification strategy

	Continuous R&D	**R&D intensity**	**Knowledge production**		**Output production**
			process	product	
Selection term		x			
Predicted R&D intensity			x	x	
Predicted innovation outcomes					x
Investment intensity			x		x
Export intensity	x	x			
International Competition	x	x	x	x	x
Cooperation		x			
Demand Pull:					
Environmental, health and safety aspects		x			
Regulations or standards		x			
Public Support:					
Local funding		x			
National funding		x			
EU funding		x			
Sources:					
Internal sources within the enterprise		x			
Internal sources within the group		x			
Suppliers as source of information		x			
Universities as source of information		x			
Government as source of information		x			
Customers as source of information				x	
Competitors as source of information				x	
Appropriability conditions:					
Formal protection	x	x	x	x	
Legal protection	x	x	x	x	
Size	x	x	x	x	x
Industry	x	x	x	x	x
East Germany (only in Germany)	x	x	x	x	x

Table 2: Means of variables across countries

	France	Germany	Spain	UK
Observations	3579	1130	3539	1880
Productivity	164.545	145.409	137.217	142.284
Investment intensity	6.009	8.283	24.010	6.452
R&D intensity	4.841	2.343	1.097	1.617
Export intensity Exports as a share of total turnover	0.241	0.221	0.187	0.176
Share of firms with 20-49 employees	30.73	28.85	48.15	38.78
Share of firms with 50-99 employees	19.34	21.06	21.98	22.23
Share of firms with 100-250 employees	20.42	22.21	15.57	17.07
Share of firms with 250-999 employees	22.60	21.86	12.40	18.62
Share of firms with 1000 or more employees	6.90	6.02	1.89	3.30
Engage in R&D continuously (rdeng=1)	0.348	0.402	0.207	0.272
R&D intensity missing (rdl=.)	0.412	0.096	0	0.457
Process innovator (inpcs)	0.322	0.434	0.346	0.270
Product innovation	0.444	0.560	0.333	0.300
Share of sales with new products	0.073	0.160	0.109	0.088
Market novelties	0.269	0.376	0.196	0.152
Share of sales with market novelties	0.036	0.056	0.038	0.023
International competition	0.405	0.406	0.175	0.207
Environmental or health and safety aspects: low importance	0.135	0.188	0.066	0.214
Environmental or health and safety aspects: medium or high importance	0.271	0.257	0.263	0.226
Regulations or standards: low importance	0.115	0.161	0.058	0.169
Regulations or standards: medium or high importance	0.305	0.266	0.282	0.274
Local funding	0.056	0.162	0.139	0.046
National funding	0.154	0.215	0.125	0.036
EU funding	0.051	0.081	0.033	0.018
Cooperation	0.259	0.247	0.112	0.154
Internal sources within the enterprise	0.315	0.304	0.227	0.260
Internal sources within the group	0.094	0.115	0.083	0.087
Suppliers as source of information	0.091	0.127	0.126	0.135
Universities as source of information	0.015	0.077	0.024	0.018
Government as source of information	0.016	0.029	0.033	0.005
Customers as source of information	0.252	0.323	0.127	0.144
Competitors as source of information	0.125	0.118	0.057	0.061

Notes: Community Innovation Survey, Wave 3; covers the years 1998-2000. All values are in thousands of Euros, exchange rate for the UK is 1.6422 Euros per pound sterling.

Table 3a: R&D intensity equation

Dependent variable	**Engage in R&D continuously**					**R&D per employee**				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Sample	pooled - UK, France, Germany	France	Germany	Spain	UK	pooled - UK, France, Germany	France	Germany	Spain	UK
Observations	6,589	3579	1130	3539	1880	2,212	1247	454	731	511
Method	weighted					weighted				
Country dummies										
France	0.1400					0.5798				
	(0.0178)					(0.0710)				
West Germany	0.0344					0.2027				
	(0.0227)					(0.0929)				
East Germany	0.2389		0.2434			0.1963		0.0576		
	(0.0372)		(0.0383)			(0.1219)		(0.1389)		
ln(Export/Sales)$_{98}$	0.0136	0.0176	0.0099	0.0497	0.0133	-0.0045	0.0258	-0.0197	0.0212	0.0049
	(0.0027)	(0.0039)	(0.0055)	(0.0089)	(0.0035)	(0.0104)	(0.0196)	(0.0171)	(0.0161)	(0.0142)
International markets	0.1065	0.1120	0.1040	0.2534	0.1178	0.2237	0.2457	0.2864	0.3730	0.0209
	(0.0171)	(0.0208)	(0.0362)	(0.0701)	(0.0287)	(0.0648)	(0.0818)	(0.1238)	(0.0892)	(0.0977)
Appropriability cond.	x	x	x	x	x	x	x	x	x	x
Demand pull - regulation						x	x	x	x	x
Public support						x	x	x	x	x
Cooperation						0.3112	0.2739	0.3491	0.1909	0.1373
						(0.0602)	(0.0754)	(0.1207)	(0.0898)	(0.0990)
Sources of information						x	x	x	x	x
Size dummies$_{98}$	x	x	x	x	x	x	x	x	x	x
Industry dummies	x (by cty)	x	x	x	x	x (by cty)	x	x	x	
rho						0.5823	0.3582	0.6449	0.7521	0.8538
						(0.0428)	(0.0524)	(0.0798)	(0.0575)	(0.0320)
W_appropriability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W_demand pull						0.5637	0.2942	0.5409	0.5947	0.0688
W_public support						0.0088	0.0005	0.0098	0.0000	0.1218
W_sources						0.0220	0.0162	0.1930	0.1013	0.1826
W_size dummies	0.0000	0.0000	0.0000	0.0000	0.0000					
W_industry dummies	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Log-Likelihood						-6546.6	-3590.0	-1272.8	-2185.6	-1491.0

Notes: Standard errors in parentheses are robust. Coefficients are marginal effects (at the sample means) for the probability of doing R&D continuously and for the expected value of the R&D per employee conditional on doing R&D, respectively. W reports the p-value of a test of the joint significance of the defined variables.

Table 3b: Engage in R&D continuously

	(1)	(2)	(3)
Sample	pooled - UK, France, Germany		
Observations	6,589		
	weighted		
Country dummies			
France	0.0807	0.0446	-0.0433
	(0.0140)	(0.0145)	(0.0541)
West Germany	0.1329	0.0723	-0.0893
	(0.0208)	(0.0213)	(0.0854)
East Germany	0.0023	0.1097	0.2778
	(0.0300)	(0.0336)	(0.1334)
Size		x	x
Industry			x (by cty)

Notes: Standard errors in parentheses are robust. Coefficients are marginal effects (at the sample means) for the probability of doing R&D continuously.

Table 3c

	France	Germany	Spain	UK
Actual R&D per employee	4.841	2.343	1.097	1.617
Predicted R&D per employee	1.180	1.010		0.494

Table 4: Knowledge production function

Dependent variable	**(a) Process Innovation (0/1)**					**(b) Product Innovation (0/1)**				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Sample	pooled - UK, France, Germany	France	Germany	Spain	UK	pooled - UK, France, Germany	France	Germany	Spain	UK
Observations	6,516	3,579	1,124	3,539	1,813	6,589	3,579	1,124	3,539	1,813
Method	weighted					weighted				
Predicted R&D intensity	0.2083	0.1889	0.1927	0.1611	0.0787	0.4411	0.3942	0.3001	0.3012	0.2576
	(0.0325)	(0.0268)	(0.0424)	(0.0301)	(0.0358)	(0.0375)	(0.0325)	(0.0470)	(0.0313)	(0.0362)
Predicted R&D intensity*France	0.0975					0.0794				
	(0.0288)					(0.0352)				
Predicted R&D intensity*West Germany	0.0028					0.0036				
	(0.0393)					(0.0499)				
Predicted R&D intensity*East Germany	0.0576					-0.0814				
	(0.0610)					(0.0710)				
France	-0.1951					-0.1860				
	(0.0637)					(0.0762)				
West Germany	-0.2272					-0.1390				
	(0.0846)					(0.1073)				
East Germany	0.0667		-0.0180			0.2694		-0.0158		
	(0.1712)		(0.0426)			(0.1483)		(0.0455)		
ln(Invest/L)$_{98}$	0.0420	0.0325	0.0381	0.0202	0.0525					
	(0.0052)	(0.0065)	(0.0129)	(0.0021)	(0.0076)					
Sources of information										
Appropriability cond.	x	x	x	x	x	x	x	x	x	x
Size dummies$_{98}$	x	x	x	x	x	x	x	x	x	x
Industry dummies	x (by cty)	x	x	x	x	x (by cty)	x	x	x	x
W_sources										
W_appropriability	0.1698	0.0000	0.5954	0.0000	0.0001	0.0074	0.0000	0.1347	0.0004	0.0462
W_size dummies	0.0000	0.0000	0.0000	0.0000	0.0007	0.0008	0.0001	0.0182	0.0000	0.8400
W_industry dummies	0.0000	0.0000	0.0002	0.0000	0.0538	0.0000	0.0000	0.0149	0.0000	0.1729
Log-Likelihood	-3518.4	-1868.0	-663.0	-1991.3	-944.9	-3219.5	-1769.5	-589.5	-1874.7	-887.8
Pseudo R2	0.1616	0.1698	0.1375	0.1274	0.1166	0.2862	0.2801	0.2395	0.1679	0.2138

Notes: Standard errors in parentheses are robust. Coefficients are marginal effects (at the sample means) from a probit. The omitted category is UK. W reports the p-value of a test of the joint significance of the defined variables.

Table 4: Knowledge production function (continued)

Dependent variable	**(c) Share of innovative sales new to firm (logit-transf.)**					**(d) Share of innovative sales new to market (logit-transf.)**				
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Sample	pooled - UK, France, Germany	France	Germany	Spain	UK	pooled - UK, France, Germany	France	Germany	Spain	UK
Observations	6,589	3,579	1,124	3,539	1,813	6,589	3,579	1,124	3,539	1,813
Method										
Predicted R&D intensity	1.357	0.0925	0.7232	1.2981	1.6501	1.0265	0.8533	0.4580	0.8787	0.4172
	(0.2184)	(0.1112)	(0.1673)	(0.1951)	(0.2830)	(0.2905)	(0.1875)	(0.2117)	(0.2111)	(0.3025)
Predicted R&D intensity*France	0.2303					0.1088				
	(0.1806)					(0.2364)				
Predicted R&D intensity*West Germany	0.4340					-0.0606				
	(0.2161)					(0.2765)				
Predicted R&D intensity*East Germany	0.0422					-0.2221				
	(0.2674)					(0.3644)				
France	-1.6708					-0.4922				
	(0.4404)					(0.5021)				
West Germany	-1.0248					-0.3826				
	(0.5577)					(0.5646)				
East Germany	1.2398		0.1099			0.1976		-0.2917		
	(0.6736)		(0.1868)			(0.7900)		(0.2058)		
$\ln(\text{Invest/L})_{98}$										
Sources of information	x	x	x	x	x	x	x	x	x	x
Appropriability cond.	x	x	x	x	x	x	x	x	x	x
Size dummies$_{98}$	x	x	x	x	x	x	x	x	x	x
Industry dummies	x (by cty)	x	x	x	x	x (by cty)	x	x	x	x
rho	0.8354	-0.1146	0.9154	0.9623	0.9430	0.8031	0.7380	0.7083	0.8911	-0.1524
	(0.0308)	(0.1454)	(0.0289)	(0.0065)	(0.0145)	(0.0516)	(0.0744)	(0.1439)	(0.0256)	(0.0445)
W_sources	0.0179	0.1692	0.0492	0.2266	0.4407	0.1878	0.1194	0.6875	0.1857	0.3030
W_appropriability	0.2166	0.7326	0.1822	0.0002	0.0126	0.0831	0.0032	0.0144	0.0025	0.5136
W_size dummies	0.0485	0.0510	0.5840	0.0080	0.4737	0.0083	0.4348	0.0005	0.2257	0.5875
W_industry dummies	0.0000	0.0000	0.0902	0.0000	0.0824	0.0000	0.0000	0.3389	0.0000	0.1378
Log-Likelihood	-7896.4	-4179.3	-1520.0	-4175.7	-1857.8	-2818.2	-3108.0	-1265.8	-2731.9	-1233.3

Notes: Standard errors in parentheses are robust. The omitted category is UK. W reports the p-value of a test of the joint significance of the defined variables. The coefficients are the estimated coefficients of the model with the logit-transformed dependent variable.

Table 5: Output production function with R&D

Dependent variable:	**Labour Productivity:** ln(sales/emp)00						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
sample	pooled - UK, France, Germany			UK	France	Germany	Spain
Obs	6,516	6,516	6,516	1,813	3,579	1,124	3,539
ln(Invest/L)	0.1134	0.1110	0.1120	0.0837	0.1347	0.1268	0.0604
	(0.0063)	(0.0063)	(0.0062)	(0.0096)	(0.0096)	(0.0135)	(0.0050)
ln(R&D/L)	0.0745	0.0803	0.0530	0.0618	0.1111	0.0770	0.1928
	(0.0093)	(0.0094)	(0.0182)	(0.0181)	(0.0098)	(0.0228)	(0.0327)
France*ln(R&D/L)			0.0714				
			(0.0206)				
Germany - west*ln(R&D/L)			0.0228				
			(0.0290)				
Germany - east*ln(R&D/L)			-0.0864			-0.0964	
			(0.0407)			(0.0404)	
country dummies							
France	0.0390	0.3333	0.3308				
	(0.0178)	(0.0686)	(0.0684)				
Germany - west	0.0296	0.2811	0.2876				
	(0.0247)	(0.1015)	(0.1014)				
Germany - east	-0.3328	-0.7715	-0.7882				
	(0.0350)	(0.1440)	(0.1433)				
Constant	4.4302	4.3398	4.3326	4.2969	4.7700	4.4207	3.5422
	(0.0365)	(0.0650)	(0.0646)	(0.0795)	(0.0558)	(0.0796)	(0.0639)
Dummy for ln(R&D/L) missing (by industry)	x	x	x	x	x	x	x
Size dummies$_{98}$	x	x	x	x	x	x	x
Industry dummies	x	x (by cty)	x (by cty)	x (by cty)	x (by cty)	x (by cty)	x (by cty)
R2	0.2521	0.2679	0.2716	0.2013	0.3022	0.3073	0.1909

Notes: Numbers in parentheses are robust standard errors. All pooled regressions are weighted by the inverse of number of firms in the sample so that each country has the same weight.

Table 6: Output production function with innovation: pooled results

Dependent variable:	**Labour Productivity:** ln(sales/emp)00							
Regression	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sample	pooled - UK, France, Germany							
Obs	6516	6516	6516	6516	6460	6516	6499	6516
ln(Invest/L)	0.1166	0.0927	0.1144	0.1092	0.1123	0.1095	0.1137	0.1098
	(0.0063)	(0.0070)	(0.0062)	(0.0062)	(0.0062)	(0.0063)	(0.0061)	(0.0062)
Actual process innovation	-0.0253							
	(0.0176)							
Predicted process innovation (4a)		0.1414						
		(0.0201)						
Actual product innovation			0.0354					
			(0.0177)					
Predicted product innovation (4b)				0.0863				
				(0.0121)				
Actual share of product innovation					0.0148			
					(0.0057)			
Predicted share of product innovation (4c)						0.0808		
						(0.0121)		
Actual share of new to market innovation							0.0142	
							(0.0081)	
Predicted share of new to market innovation (4d)								0.0781
								(0.0119)
France	0.3191	0.3788	0.3204	0.3053	0.3233	0.3558	0.3215	0.3106
	(0.0691)	(0.0688)	(0.0687)	(0.0680)	(0.0687)	(0.0684)	(0.0688)	(0.0681)
Germany - west	0.3463	0.4257	0.3510	0.3515	0.2862	0.3520	0.3508	0.3502
	(0.0977)	(0.0983)	(0.0971)	(0.0975)	(0.0938)	(0.0974)	(0.0974)	(0.0975)
Germany - east	-0.7801	-0.8269	-0.7979	-0.9028	-0.7701	-0.9153	-0.7871	-0.8452
	(0.1424)	(0.1405)	(0.1427)	(0.1424)	(0.1472)	(0.1428)	(0.1432)	(0.1421)
Constant	4.2457	4.3687	4.2349	4.4000	4.2959	4.5211	4.3023	4.6221
	(0.0582)	(0.0603)	(0.0579)	(0.0590)	(0.0619)	(0.0708)	(0.0675)	(0.0815)
Size dummies$_{98}$	x	x	x	x	x	x	X	x
Industry dummies	x (by cty)	x (by cty)	x (by cty)	x (by cty)	x (by cty)	x (by cty)	x (by cty)	x (by cty)
W_size dummies	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W_industry dummies	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R2	0.2530	0.2596	0.2533	0.2601	0.2526	0.2592	0.2513	0.2589

Notes: Numbers in parentheses are robust standard errors. All pooled regressions are weighted by the inverse of number of firms in the sample so that each country has the same weight.

Table 7: Output production function with innovation: single country results

Dependent variable:	**Labour Productivity:** ln(sales/emp)00			
	(1)	(2)	(3)	(4)
	France	Germany	Spain	UK
Obs	3,579	1,124	3,539	1,813
Actual process innovation	0.0227	-0.0348	0.0894	-0.0714
	(0.0213)	(0.0359)	(0.0381)	(0.0315)
Predicted process innovation (4a)	0.2531	-0.0159	0.2657	0.1167
	(0.0234)	(0.0494)	(0.0499)	(0.0447)
Actual product innovation	0.1241	-0.0437	0.2126	0.0157
	(0.0210)	(0.0369)	(0.0372)	(0.0331)
Predicted product innovation (4b)	0.1672	-0.0095	0.2047	0.0819
	(0.0145)	(0.0302)	(0.0366)	(0.0229)
Actual share of product innovation	0.0509	-0.0004	0.0448	0.0073
	(0.0069)	(0.0111)	(0.0080)	(0.0094)
Predicted share of product innovation (4c)	1.0794	-0.0178	0.1189	0.0412
	(0.1075)	(0.0277)	(0.0206)	(0.0116)
Actual share of new to market innovation	0.0568	-0.0145	0.0520	0.0125
	(0.0084)	(0.0142)	(0.0124)	(0.0178)
Predicted share of new to market innovation (4d)	0.2051	-0.0145	0.1476	0.0499
	(0.0181)	(0.0288)	(0.0294)	(0.0456)

Notes: Only the coefficients of the knowledge variable are reported. Coefficients are not estimated simultaneously but are based on eight different single country regressions. Capital, size and industry dummies were included in each regression but not reported here. The Numbers in parentheses are robust standard errors.