Firm Capabilities and Cooperation for Innovation: Evidence from the UK Regions

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Abstract This chapter focuses on the relationship between firms' technological competencies and capabilities and different forms of cooperation for innovation by combining the analysis of both micro and meso levels, i.e. the level of the firm and of the geographical region. Our findings, based on the Fourth UK Community Innovation Survey (CIS), provide new insights regarding the relationship between cooperative linkages for innovation and firms' technological status. Firstly, the distinction between competencies and capabilities adopted in this chapter seems appropriate for going beyond the rather simplistic dichotomy of 'innovative' versus 'non-innovative' firms commonly used in interpreting CIS data. Secondly, we find that the analysis for the UK as a whole masks stark regional differences in terms of intra- and extra-region collaborative linkages and firms' technological status.

Keywords Cooperation for innovation • Firms' technological competencies and capabilities • UK regions

JEL Classification: O30, R12

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1 Introduction

Following evolutionary views of technical change, technological capabilities can be considered as the outcome of in-house technological competences and of complex interactions among individuals, firms and organisations within a specific socio-economic and institutional framework. Among these interactions, a crucial role is played by the cooperation in R&D and innovative activities, where such a cooperation can involve other firms in the same sector, suppliers, customers, consultants and scientific institutions like universities and public labs.

A shortcoming of most previous studies that have investigated technological capabilities is that these latter are seen at the same time as inputs and outcomes (among others Westphal et al. 1990; Romijn 1999; Wignaraja 2002). In this chapter it is argued that, in order to evaluate firms' technological capabilities, variables related to outcomes such as the introduction of new products and processes are more appropriate. This distinction comes mainly from the differentiation between competences and capabilities introduced by von Tunzelmann and Wang (2003). Whilst competences are understood as enhanced inputs to produce goods and services, capabilities generally involve learning, the accumulation of new knowledge, and the integration of behavioural, social and economic factors, as adapted to specific contexts. Consequently, capabilities are to be taken as the results of adaptive learning processes that are sustained through a variety of external connections and sources for innovation (von Tunzelmann and Wang 2003, 2007), at least partially embedded in the regional environment of the firm. As capabilities directly promote better and/or cheaper goods and services, we can index them by their embodiment in new products and processes (von Tunzelmann 2009a).

This chapter investigates the relationship between firms' technological status – in terms of its competences and capabilities – and different forms of cooperation for innovation by combining the analysis of both micro and meso levels, i.e. the level of the firm and of the geographical region. In particular, the aim is to provide an answer to the following questions: To what extent are the patterns of inter-organisational cooperation for innovation associated with firms' technological status? And is such a relationship influenced by the regional location of firms?

The chapter is structured into five sections. The following section briefly summarises the literature on firm-level technological capabilities, innovation linkages and sources external to the firm, emphasising the relevance of the regional environment as an appropriate dimension to study such relationships. Section 3 provides an overview of the data, methodology and assumptions underlying our empirical analysis. Section 4 discusses the results at the firm level, taking into account both the overall national context and the specific regional environments. Section 5 offers some concluding remarks and implications of the research here carried out.

2 Technological Competences and Capabilities, Firms and Regions

Over the last three decades, following Nelson and Winter' s seminal book (1982), contributions in the area of firm-specific capabilities have proliferated in and around resource-based views, evolutionary economics, the economics and history of technical change, strategic management and, more recently, evolutionary economic geography. The term capabilities has been used variously across different levels of systems from individual to global, to describe a large variety of processes (e.g. 'social capabilities' for growth, see Abramovitz 1986) and a variety of functions. In this chapter, technological capabilities at the micro-level are defined as the knowledge and skills that the firm needs in order to acquire, use, adapt, improve and create technology, interacting with the external environment (e.g. Lall 1992; Malerba 1992; Bell and Pavitt 1993, 1995). The main extensions to traditional static notions of capabilities involve both interactive and dynamic capabilities. Formally, the interactive dynamic capabilities of firms represent the extent to which the change in their productive capabilities influences or is influenced by the change in the capabilities of other external actors – i.e. consumers, clients, suppliers, universities, etc. – in real time or over historical periods (von Tunzelmann and Wang 2007; von Tunzelmann 2009a).

A crucial distinction between competences and capabilities has been introduced by von Tunzelmann and Wang (2003). Competences are understood as stemming from inputs to produce goods and services – in this sense they are pre-set attributes of individuals and firms, with the enhancements typically produced either in-house or by a different organisation. For example, one may think of firm's endowment of adequate skills as the necessary internal competences to obtain value from R&D and innovation investments (see Piva and Vivarelli 2009). By the same token, the recruitment of university graduates may be intended as the necessary internal competences for small and medium enterprises (SMEs) and new technology-based firms (NTBFs) that want to obtain values from external spillovers (see Acs et al. 1994; Audretsch and Vivarelli 1994; Arrighetti and Vivarelli 1999).

Capabilities instead involve both internal and external learning, accumulation of new knowledge on the part of the firm, and the integration of behavioural, social and economic factors into a specific set of outcomes. Consequently, capabilities are to be taken as the results of adaptive learning processes that, in their collective dimension, can be highly localised, giving rise to 'system' capabilities, i.e. referring to a specific spatial and industrial setting such as a regional innovation system (von Tunzelmann 2009b). For instance, an endowment of highly qualified human resources is not a capability per se, but a resource that, through learning, may become a source of technological capabilities for the firm or the system as a whole.

In other words, while technological competences are prerequisites or resources for innovation activity, technological capabilities correspond to knowledge that, through learning and processing, is ready to be incorporated into new products and processes (von Tunzelmann and Wang 2003, 2007). Thus, a firm with technological capabilities does possess competences, though a firm with competences does not necessarily have technological capabilities. For example, a pharmaceutical firm endowed with an adequate R&D lab and performing research on a new vaccine is a firm with technological competences, while a competitor already testing a new vaccine on patients is a firm with technological capabilities.

The study of technological capabilities at the micro-level, as pursued by the data in this chapter, sets the firm at the centre of the analysis (Bell 1984; Bell and Pavitt 1995; Hobday 1995). In addition to interactions and organisational behaviours within the enterprise, the micro-level approach focuses on one-way knowledge and resources flows from external sources of knowledge into the firm. Firms can learn horizontally, that is from spillovers from other producers and competitors, or vertically, by interacting with upstream suppliers and downstream users, as well as from independent research carried out in the regional, national or international science and technology system by universities and research institutes. Such an external learning will need to be absorbed in various ways through the firm's 'absorptive capacity' (see Cohen and Levinthal 1990).

The empirical estimation of such complex internal and external learning processes would require panel micro data with detailed characteristics of firms' internal routines and practises across time, still rarely available in firm-level innovation surveys such as the Community Innovation Survey (CIS) used here. Therefore, the simplifying assumption is that of a sequential logic between the categories of competencies and capabilities: in other words, the know-how accumulated through actual learning and experience in the production of outputs has to lie beyond mere 'potential' – or competencies; hence capabilities are associated with 'realisations' – or the ability of firms to handle change (von Tunzelmann 2009a).

On the other hand, the importance of contextual factors and systemic interactions in the process of generation and diffusion of innovation has long been recognised as a key determinant of the technological and economic performance of firms, countries and regions (see for example Lundvall 1988; von Hippel 1988; Cooke et al. 1997). The significance of the regional dimension of innovation systems has emerged as the logical consequence of the interactive model of innovation (Kline and Rosenberg 1986), which indeed puts the emphasis on the relations with knowledge sources external to the firm. More recently, the 'open innovation' model (Chesbrough 2003; Laursen and Salter 2006) has complemented the innovation system perspective by reinforcing the view that innovative firms draw knowledge from a variety of external sources and linkages, integrating them into their own routines and learning processes, thus achieving more advanced technological capabilities. In this approach, the latest applications of the capabilities framework to regional innovation systems have emphasised that regions can be considered as spatial congregations of actors – i.e. suppliers, producers, consumers, public organisations, etc. – each with its own unique level of competences and capabilities, and all embedded in a specific regional institutional setting (von Tunzelmann 2009b).

It follows that, at the meso-level, regional competences and capabilities cannot be considered merely as the sum of those developed in isolation by individual firms thereby located (Lall 1992; Iammarino et al. 2008; von Tunzelmann 2009b). A region embeds many systemic elements external to the firm that influence its technological capabilities and growth (e.g. Cooke et al. 1997; Howells 1999; Revilla Diez 2000; Cooke 2001; Evangelista et al. 2002; Iammarino 2005; Rodriguez-Pose and Comptour, in this book). While the individual firm can regard some of these as exogenous – for instance, the number of graduate students produced in the area – for the region itself this is not so. Nonetheless, the development of regional capabilities shares many of the features of the micro-level: regional learning is a long, uncertain and costly process, showing high path-dependence and cumulativeness. Thus, idiosyncratic regional structural and institutional features, networks and cooperative agreements emerge and have an influence on firms' R&D and innovative competences and capabilities, eventually resulting into a specific regional innovation pattern (Kleinknecht and Poot 1992; Cooke et al. 1997; Hassink 1997).

In spite of the rather copious empirical literature on cooperation linkages and innovativeness at the firm level (e.g. Cassiman and Veugelers 2002; Vanhaverbeke et al. 2002; Criscuolo and Haskel 2003; Belderbos et al. 2004a; Laursen and Salter 2004, 2006; Faems et al. 2005), surprisingly much less evidence has emerged on the relationship between different forms of collaborative innovative linkages and firms' technological status taking into account the environment of the firm, i.e. its regional location (for an exception, see Simonen and McCann 2008). In this chapter, the regional dimension of the relationship between cooperation for innovation and firms' technological status will be investigated in two ways. On the one hand, we will be able to distinguish between cooperation with local versus non-local partners; on the other hand, the aggregate empirical analysis for the UK will be split into macro-regions, in search for the possible territorial peculiarities that the literature suggests as very likely.

3 Data and Methodology

This paper uses data from the UK Innovation Survey 2005 (as part of the fourth iteration of the wider Community Innovation Survey – CIS4 – covering EU countries), which refer to the period 2002–2004. The survey sampled over twenty-eight thousand UK enterprises with 10 or more employees, had a wide sectoral coverage including both manufacturing and service sectors, and was stratified by Government Office Region in England, along with Scotland, Wales and Northern Ireland. The final representative sample consists of 16,445 firms.

Following the conceptualisation discussed above, technological capabilities at the firm level are signalled by the introduction of a product and/or process innovation. In other words, to identify firms with technological capabilities in the period of reference of the CIS4 we use the strict (output-oriented) definition of innovators, as in most of the previous literature on the CIS.[1] Such a definition (based on questions 5 and 9 of the UK questionnaire) applies if, during the period 2002–2004, the enterprise introduced a new or significantly improved product (either a good or a service) and/or new or significantly improved processes for the production or supply of its products. In such a case the respondent is here classified as a firm with technological capabilities.[2] If instead the enterprise has invested in innovative inputs (on the basis of question 13),[3] but without achieving any innovative output (new product or new process) in the relevant period, it is classified as a firm with technological competences. Finally, if the enterprise has declared neither innovative output nor investment in innovative inputs, it is classified as a technologically inactive firm in the period analysed by the UK CIS4.

Thus, our dependent variable – the firm's technological status – is a categorical ordered variable which assumes the following values: 0 in the case of a *technologically inactive firm*; 1 in the case of a *firm with technological competences*; 2 in the case of a *firm with technological capabilities*. Table 1 displays the regional distribution of the three categories of firms. It is interesting to note that the shares of firms belonging to each group are rather equally distributed across regions.

The patterns of cooperation for innovation – our main interest in analysing the factors influencing the technological status of firms – are based on question 18 of the UK questionnaire, which, in line with the Eurostat standardised questionnaire, is devoted to the types of cooperation partners used by the respondent firms, and their location. In fact, cooperation in R&D and innovative activities may imply a variety of different partners ranging from firms within the same corporate group, customers, suppliers, competitors and institutional partners such as universities and public labs (e.g. Fritsch and Lukas 2001; Miotti and Sachwald 2003; Belderbos

[1] As illustrated by D'Este et al. (2008), there are several reasons why the use of such a definition is appropriate. First, it helps towards separating invention from innovation by requiring new products and processes to be of economic value, as shown by the commercialisation requirement (i.e. introduction to market). Second, it is consistent with the standard definition of innovation provided by the Oslo Manual (OECD 2005). Finally, it helps separating the firm's efforts in innovative activities (as measured, for instance, by its investment in R&D-related activities) from the outputs of those activities (as reflected by the market introduction of new products): thus, it is congruent with the distinction between competences and capabilities adopted here.

[2] Strictly speaking and as already implied, the product or process innovation thus detected does not amount to the relevant capability – it is the accumulated ability to 'know' (learn) how to effect such an innovation that is the 'capability' in the proper sense. For obvious reasons we do not impose this distinction here. As stated above, the observed product/process innovations are direct indexes of these capabilities.

[3] Question 13 in the UK CIS questionnaire asked whether, in the reference period, the firm engaged in any of the following seven innovation activities: (1) intramural R&D; (2) acquisition of R&D; (3) acquisition of machinery, equipment and software to produce new or significantly improved products; (4) acquisition of external knowledge (e.g. licensing of patents); (5) training of personnel for the development or introduction of innovations; (6) expenditure on design functions for the development of new or improved products or processes; and (7) expenditures on activities for the market preparation and introduction of new or significantly improved products (including market research and launch advertising).

Table 1 Regional distribution of the categorical dependent variable on firms' technological status – number of firms and relative percentages (in brackets)

	UK	Northern England	Midlands	Eastern England	London	Southern England	Wales	Scotland	Northern Ireland
Technologically inactive firm	5,308	1,214	891	461	540	910	348	425	519
(*value 0*)	(35.03)	(34.82)	(34.67)	(35.60)	(36.58)	(32.32)	(34.39)	(36.51)	(38.87)
Firm with technological competences	4,105	983	675	326	357	796	293	335	340
(*value 1*)	(27.09)	(28.20)	(26.26)	(25.17)	(24.19)	(28.28)	(28.95)	(28.78)	(25.47)
Firm with technological capabilities	5,740	1,289	1,004	508	579	1,109	371	404	476
(*value 2*)	(37.88)	(36.98)	(39.07)	(39.23)	(39.23)	(39.40)	(36.66)	(34.71)	(35.66)
Total	**15,153**	**3,486**	**2,570**	**1,295**	**1,476**	**2,815**	**1,012**	**1,164**	**1,335**
	(100)	**(100)**	**(100)**	**(100)**	**(100)**	**(100)**	**(100)**	**(100)**	**(100)**

et al. 2004b; Piga and Vivarelli 2004; Laursen and Salter 2006). Seven types of partner are listed in the CIS questionnaire: (A) other enterprises within the firm's group; (B) suppliers of equipment, materials, services or software; (C) clients or customers; (D) competitors or other enterprises in the firm's industry; (E) consultants, commercial labs, or private R&D institutes; (F) universities or other higher education institutions; (G) government or public research institutes.[4]

Dummies were created for each of the *cooperation partners* reported in question 18, aggregating universities/other higher education institutions and government/public research institutes into one category. Two location levels for each of the six partners were taken into account: local/regional, that is within approximately 100 miles of the surveyed enterprise (as defined in the CIS questionnaire); extra-regional (i.e. national/international). The total number of collaboration dummies is thus 12.

In order to have reasonably homogeneous macro-regions, the eight UK *regions* considered are defined following partial aggregations of NUTS 1 regions: Northern England (North East, North West, Yorkshire and the Humber), Midlands (East Midlands, West Midlands), Eastern England, London, Southern England (South East, South West), Wales, Scotland, and Northern Ireland. The size of our final sample is 15,153 firms, owing to the presence of missing values in the patterns of collaboration. We controlled for the geographical representativeness of our final sample, which turned out to be not statistically different from that of the original sample.

While the relationship between the different forms of cooperation and the technological status of the firm is at the core of our investigation, other firm-level factors must be considered. In particular, our control variables are the following:

- *Size:* firm size in terms of employment (continuous variable).
  The Schumpeterian notion that large firms are more likely both to undertake and to succeed in innovative activities has constituted a constant theme in the literature (Schumpeter 1943). Such a notion has been initially challenged from a theoretical point of view (Arrow 1962), and then proposed again in terms of scale and scope economies in R&D investments (Cohen and Klepper 1996). In the last few decades mixed empirical evidence has been found to support the Schumpeterian hypothesis (e.g. Cohen and Levin 1989; Kleinknecht and Reijnen 1991; Audretsch 1995; Breschi et al. 2000).
- *Group:* whether the firm is part of an enterprise group (dummy).
  Various studies have recognised that the group form of organisation tends to play an important role in promoting and supporting innovation (see, for instance, Filatotchev et al. 2003; Piga and Vivarelli 2004).

[4] It is important to stress that, from a theoretical perspective, our focus is on the influence of cooperation on the firm technological status, i.e. technological capabilities versus competences versus inactivity, and not on cooperation as a determinant of innovation. Moreover, as from the CIS questionnaire, the cooperation is in fact intended to be "cooperation for innovation activities" on the basis of the 'conceptualization' of the CIS and the Oslo Manual that look at innovation as an interactive process.

- *Internationalisation:* the extent of internationalisation of the markets served by the firm, in terms of whether the firm sells products/services outside the national market (dummy).
  This is based on the premise that global competition can spur innovation, competences and capabilities, while technologically inactive firms are doomed to be excluded from the international arena (e.g. Archibugi and Iammarino 1999; Narula and Zanfei 2003).
- *Start-up:* whether the firm was established after 1st January 2000 (dummy).
  The debate on the so-called New Technology Based Firms (NTBFs) points out how – at least in some sectors – young companies may be at the core of the innovation process (see, for instance, Storey and Tether 1998; Colombo et al. 2004; Colombo and Grilli 2005).
- *Human capital:* firm-specific skills in terms of proportion of employees educated to degree level or above (continuous variable).
  Human capital is seen as complementary to innovation, constituting per se a competence of the firm, and generating a super-additive effect in terms of both innovative and economic performance (e.g. Acemoglu 1998; Machin and van Reenen 1998; Piva and Vivarelli 2004; Piva et al. 2005).

The analysis also includes regional dummies in the aggregated model, and sectoral dummies in all specifications.[5] The list of all variables used in the analysis and some descriptive statistics are reported in Appendix 1.

In accordance with the nature of the dependent variables, ordered logistic regressions were run.[6] The following specification has been tested for the country as a whole:

$$\begin{aligned} \textit{Technological status} = {} & \alpha + \beta_1 \log(\textit{employment}) + \beta_2(\textit{group}) \\ & + \beta_3(\textit{internationalisation}) + \beta_4(\textit{start} - \textit{up}) \\ & + \beta_5(\textit{human\_capital}) + \beta_6(\textit{cooperation\_dummies}) \\ & + \beta_7(\textit{sectoral\_dummies}) + \beta_8(\textit{regional\_dummies}) + \varepsilon \end{aligned}$$

[5] We followed the clustering criteria used by the (then) Department for Innovation, University and Skills (DIUS), now Department for Business, Innovation, and Skills (BIS): Primary sector; Engineering-based manufacturing; Other manufacturing; Construction; Retail & distribution; Knowledge-intensive services; Other services.

[6] As the dependent variable is an ordered one, we opted for the ordered logistic model. However, multinomial logistic regressions were also run with the category of technologically inactive firms as the reference (category 0). The results from the multinomial, and the estimated predicted probabilities of both the multinomial and the ordered logistic models, supported our choice of the latter, as the probability distribution between the two estimation methods is not substantially different. Furthermore, a Brant test to verify the parallel regression assumption (also called the proportional odds assumption) was performed after the ordered model and – where feasible in the regional models – it provided evidence that the parallel regression assumption has not been violated.

To explore whether and to what extent the relationship between technological competences and capabilities and different cooperation patterns is region-specific, the same model was also estimated for each of the eight UK regions.

4 Competence, Capabilities and Cooperation for Innovation: Results

This section reports the results on the differences across firms and regions in terms of competences and capabilities for innovation, once we explicitly consider a number of factors, and particularly collaborative linkages, which may influence the dependent variable.

First of all, it is important to note that our results are especially driven by the category of firms with technological capabilities. In fact, the cut-off as between technologically inactive firms and those with competences (enhanced inputs but lacking technological outputs) is generally not statistically significant in the ordered logistic regressions for the country as a whole and for any region in the regional estimations.[7] On the other hand, the few peculiar features that characterise the group of firms with technological competences with respect to the other two firm groups support the conjecture that these firms represent somehow an intermediate innovative behaviour (see also D'Este et al. 2008). This sits comfortably with our choice of distinguishing the three categories of firms according to their technological status.

Table 2 shows the results for the aggregate model – i.e. for the UK as a whole. In line with the theoretical expectations discussed above, all the variables related to firm characteristics are highly significant at 1 % level (with the exception of start-up, with a level of significance of 5 %), indicating a positive impact on the likelihood of firms to be classified as firms with technological capabilities.[8] As far as the independent variables concerning cooperation partners are concerned, linkages with other enterprises within the group, suppliers, clients, and public research and higher education institutions are all positive and highly significant at both local and extra-regional level.

Consistently with the previous literature, both the dummy for belonging to a group and the two dummies indicating cooperation with firms within the same corporate group turn out to be statistically significant at 1 % level, pointing to the strategic role of corporate relationships in enhancing the technological status of the

[7] Equivalent results hold in the unreported multinomial logit regressions, where the coefficients for firms with technological competences (category 1) are in general smaller and/or with lower significance levels than those for firms with technological capabilities (category 2).

[8] In order to verify the relevance of the human capital regressor in the ordered logit estimate, we run the model also excluding the variable: the results are confirmed, indicating that endogeneity issues with respect to this variable are not serious.

Table 2 Determinants of firms' technological status, UK with regional dummies. Ordered logistic regression. Categorical ordered dependent variable: 0 = technologically inactive firm; 1 = firm with technological competences; 2 = firm with technological capabilities

(1)		(2)	
Ln(Employment)	0.12***	*Sectoral dummies*	Yes***
	(9.60)		
Group	0.23***	Primary sector	−1.06***
	(6.27)		(7.67)
Internationalisation	0.56***	Engineering-based manuf	–
	(14.59)		
Start-up	0.10**	Other manufacturing	−0.01
	(2.26)		(0.20)
Human capital	1.41***	Construction	−0.97***
	(16.99)		(13.87)
		Retail and distribution	−0.82***
			(13.54)
C **Cooperation partners for innovation**		Know.-intensive services	−0.28***
			(4.37)
A: other enterp. within group LOCAL	0.40***	Other services	−0.72***
	(2.90)		(12.66)
A: other enterp. within group NON LOCAL	0.32***		
	(2.62)		
B: suppliers LOCAL	0.44***	*Regional dummies*	Yes***
	(3.43)		
B: suppliers NON LOCAL	1.16***	North England	0.11
	(10.81)		(1.63)
C: clients LOCAL	0.44***	Midlands	0.14*
	(3.38)		(1.95)
C: clients NON LOCAL	0.69***	Eastern England	0.09
	(6.16)		(1.12)
D: competitors LOCAL	−0.27*	London	−0.16**
	(1.69)		(2.11)
D: competitors NON LOCAL	0.05	South England	0.20***
	(0.38)		(2.88)
E: consultants LOCAL	0.14	Wales	0.13
	(0.92)		(1.54)
E: consultants NON LOCAL	−0.02	Scotland	–
	(0.12)		
F + G: universities&pub.res. LOCAL	0.46***	Northern Ireland	0.14*
	(3.47)		(1.80)
F + G: universities&pub.res. NON LOCAL	0.34**		
	(2.43)		

(continued)

Table 2 (continued)

(1)	(2)
LR χ^2(d.f.)	χ^2(30) 3,854***
Pseudo R^2	0.12
Observations	15,153

Notes
In brackets: z- statistics; * = 10 % significant; ** = 5 % significant; *** = 1 % significant
In column (1) the control and the cooperation regressors are reported; in column (2) the seven sectoral dummies (DIUS sectoral classification – Engineering-based manufacturing is the reference case) as well as the eight regional dummies (NUTS1 regional aggregations – Scotland is the reference case) are reported. See Appendix 1 for definitions of variables
Yes*** for sectoral and regional dummies reporting that they are, respectively, jointly significant at 1 % level

individual firms involved. Interestingly enough, the enforcement role of cooperation appears more obvious for firms in the same corporate group and also located at a short distance.

Geographical distance instead does not seem to play a dominant role in the vertical cooperative links, where actually the coefficients related to non local suppliers and customers give a result that is higher in magnitude than those related to local partners. However, the vertical relationships themselves come out as highly significant in all four cases.

By contrast, horizontal cooperative links with competitors and consultants do not bear a significant impact on enhancing the probability that a firm achieves either technological competences or capabilities. In other words, while innovation seems to be reinforced by collaborations along the value or supply chains, once we turn our attention to the horizontal dimension rivalry seems to dominate. It is interesting to note, though, that cooperation with extra-regional consultants turns out to have a much stronger effect in increasing the likelihood of being a firm with technological competences. This can be explained as that firms at the stage of investing in innovation inputs tend to rely much more on the advice provided by external consultants in order to achieve commercial success.

Cooperation with universities and public research institutes turns out to be significant and positively affected by the close proximity of the involved partners. This is not surprising, due to the localised nature of labour markets and the fact that university-industry innovative linkages often occurs through the hiring of graduates by local firms.

In line with expectations, the high significance of the sectoral dummies indicates that the industrial structure matters in affecting the technological status of the firm: not surprisingly, the impact is greatest in engineering-based manufacturing, which is the chosen reference category. The regional dummies in the aggregate regression are also jointly significant at 1 % level, but with rather pronounced variations in terms of sign, magnitude and significance of the coefficients. This result provides

Table 3 Determinants of firms' technological status, regions of UK. Ordered logistic regression: regional analysis. Categorical ordered dependent variable: 0 = technologically inactive firm; 1 = firm with technological competences; 2 = firm with technological capabilities

	(1) Northern England	(2) Midlands	(3) Eastern England	(4) London	(5) Southern England	(6) Wales	(7) Scotland	(8) Northern Ireland
Ln(Employment)	0.12***	0.15***	0.16***	0.10***	0.11***	0.08	0.07	0.14**
	(4.62)	(4.82)	(3.55)	(2.98)	(4.27)	(1.34)	(1.48)	(2.53)
Group	0.22***	0.20**	0.26**	0.45***	0.13	0.21	0.27**	0.21
	(2.01)	(1.56)	(2.79)	(2.18)	(1.99)	(4.05)	(1.52)	(1.37)
Internationalisation	0.61***	0.56***	0.66***	0.32**	0.61***	0.88***	0.75***	0.39***
	(7.34)	(5.84)	(4.90)	(2.77)	(6.61)	(5.43)	(5.35)	(3.23)
Start-up	0.26***	0.04	0.08	0.26*	−0.07	0.03	0.17	0.07
	(2.88)	(0.39)	(0.49)	(1.73)	(0.62)	(0.16)	(1.00)	(0.44)
Human capital	1.89***	1.58***	1.76***	1.06***	1.41***	0.82**	0.93***	1.80***
	(9.26)	(7.02)	(5.62)	(5.79)	(7.26)	(2.36)	(3.26)	(5.44)
Cooperation partners for innovation								
A: other enterp. LOCAL	0.22	0.13	0.43	0.32	0.30	0.89*	1.35***	1.03
	(0.73)	(0.39)	(0.87)	(0.75)	(0.89)	(1.73)	(2.92)	(1.60)
A: other enterp. NON LOCAL	0.41*	0.55	−0.20	0.03	1.11***	−0.15	−0.24	0.82
	(1.67)	(1.47)	(0.46)	(0.11)	(3.61)	(0.28)	(0.49)	(0.88)
B: suppliers LOCAL	0.67**	0.63*	0.65	0.78**	−0.44	0.91*	0.66	0.31
	(2.45)	(1.77)	(1.51)	(2.05)	(1.47)	(1.68)	(1.53)	(0.62)
B: suppliers NON LOCAL	0.83***	1.51***	1.52***	1.40***	1.23***	1.01**	0.79**	1.71***
	(3.76)	(4.36)	(3.91)	(4.59)	(5.19)	(2.25)	(1.99)	(3.27)
C: clients LOCAL	−0.10	1.00***	0.99**	0.09	0.82***	0.37	0.10	0.90*
	(0.36)	(2.93)	(2.14)	(0.21)	(2.58)	(0.73)	(0.22)	(1.72)
C: clients NON LOCAL	0.56**	1.37***	0.81**	0.44	0.27	0.16	0.96**	2.24***
	(2.49)	(4.36)	(2.07)	(1.36)	(1.00)	(0.33)	(2.41)	(2.96)
D: competitors LOCAL	−0.02	−0.39	−0.16	−0.39	−0.60	−0.58	−0.40	−0.70
	(0.07)	(0.98)	(0.26)	(0.83)	(1.36)	(1.01)	(0.75)	(0.11)
D: competitors NON LOCAL	0.20	−0.99***	−0.71	0.70*	1.03***	0.48	−0.56	−0.69
	(0.76)	(2.88)	(1.60)	(1.69)	(3.30)	(0.99)	(1.16)	(0.96)

(continued)

Table 3 (continued)

	(1) Northern England	(2) Midlands	(3) Eastern England	(4) London	(5) Southern England	(6) Wales	(7) Scotland	(8) Northern Ireland
E: consultants LOCAL	0.65**	−0.08	−0.45	−0.22	0.73*	0.49	−0.08	−0.92
	(1.97)	(0.20)	(0.77)	(0.52)	(1.78)	(0.76)	(0.17)	(1.38)
E: consultants NON LOCAL	0.61**	−0.75**	0.20	−0.29	−0.24	0.38	0.36	1.02
	(2.04)	(2.06)	(0.39)	(0.68)	(0.74)	(0.70)	(0.66)	(1.04)
F + G: universities&pub.res. LOCAL	0.81***	0.04	0.62	0.10	0.47	−0.03	0.56	0.54
	(3.17)	(0.11)	(1.16)	(0.22)	(1.29)	(0.08)	(1.19)	(1.03)
F + G: universities&pub.res. NON LOCAL	0.08	0.91**	0.47	0.24	0.26	0.66	0.50	−1.65*
	(0.30)	(2.50)	(1.04)	(0.59)	(0.75)	(1.10)	(1.04)	(1.77)
Sectoral dummies	Yes***	Yes***	Yes***	Yes***	Yes***	Yes***	Yes***	Yes***
Primary sector	−1.13***	−0.84**	−0.73	−1.84***	−0.70*	−0.97	−1.23***	−1.29***
	(3.20)	(2.10)	(1.46)	(3.76)	(1.89)	(1.60)	(3.91)	(3.17)
Engineering-based manuf.								
Other manufacturing	1.18	−0.02	0.06	−0.70**	0.08	0.02	−0.22	−0.19
	(1.57)	(0.18)	(0.30)	(2.40)	(0.55)	(0.08)	(0.99)	(0.90)
Construction	−0.66***	−0.98***	−1.16***	−1.60***	−1.06***	−1.33***	−0.87***	−0.97***
	(4.67)	(5.95)	(4.49)	(4.99)	(6.21)	(5.02)	(3.52)	(4.22)
Retail and distribution	−0.65***	−0.82**	−0.71***	−1.40***	−0.73***	−1.02***	−0.74***	−1.07***
	(5.23)	(5.79)	(3.45)	(4.92)	(5.09)	(4.43)	(3.19)	(5.18)
Knowledge-intensive services	−0.19	−0.32**	−0.40*	−1.04***	−0.24*	−0.14	−0.20	0.16
	(1.44)	(2.17)	(1.80)	(3.80)	(1.65)	(0.58)	(0.87)	(0.61)
Other services	−0.48***	−0.81***	−0.89***	−1.32***	−0.71**	−0.80***	−0.74***	−0.74***
	(4.22)	(6.14)	(4.45)	(4.91)	(5.23)	(3.76)	(3.52)	(3.45)
LR χ^2(d.f.)	χ^2(23) 891***	(23) 700***	(23) 418***	(23) 323***	(23) 801***	(23) 298***	(23) 293***	(23) 341***
Pseudo R^2	0.12	0.13	0.15	0.10	0.13	0.14	0.12	0.12
Observations	3,486	2,570	1,295	1,476	2,815	1,012	1,164	1,335

Notes

In brackets: z- statistics; * = 10 % significant; ** = 5 % significant; *** = 1 % significant

Seven sectoral dummies are included (DIUS sectoral classification)

Yes*** for sectoral dummies reporting that they are jointly significant at 1 % level further justification to our choice to investigate the regional location, that may have an important role in moulding technological firms' competences and capabilities.

Table 3 provides the estimates for the individual UK regions. As we can see, the cooperation variables show remarkable differences in influencing the technological status of firms, according to the specific regional context.

London for instance, emerges as a peculiar case in terms of the relationship between cooperation for innovation and firms' technological status. The only type of cooperative linkage that turns out to be significant is that with suppliers at both local and, even more, extra-regional level. This would suggest that a firm's location in the metropolitan area does not tend to entail a strong relationship between collaborative linkages and its technological capabilities (see Schienstock 2009, for similar results on firms' capabilities in city-regions). Indeed, the London metropolitan area has to be understood more as an "accumulation node" of global economic and financial transactions, rather than a self-contained regional system. Therefore London's boundaries per se do not set up significant interactions for local firms in terms of either markets or social organisations (Budd 2006), but rather comprise an array of control and management nodes for global transactions and businesses (Newman and Thornley 2005). In this context, London firms' innovative strengths are driven mostly by high levels of variables such as size, corporate group, foreign sales and, especially, human capital.

Considering Southern England, the impact of collaborative relations on firms' capabilities is much more evident than for London, though the strongest of these links are again mostly non local. The only notable exception is intra-regional collaborations with clients, which strongly increase the probability of the firm being classified as having technological capabilities. The peculiar strongly positive effect of horizontal collaboration with extra-regional competitors may perhaps be explained by an 'M4 corridor effect' that could reflect national and international strategic technological alliances among large and/or multinational enterprises whose headquarters are located elsewhere.

In the Eastern England region, the likelihood that firms display technological capabilities is positively influenced by collaborations with extra-regional suppliers and with both local and non-local clients. This latter effect might be justified by the presence of the 'Cambridge cluster', whose successful innovative performance is however counterbalanced by some lagging behind of the rest of the region (Gray et al. 2006).

As far as vertical cooperation is concerned, the results for the Midlands are similar to those for Eastern England, though with more significant linkages with clients and an additional positive impact of local suppliers on firms' technological capabilities (significant at 10 % level). A peculiar feature of the Midlands is the positive effect on firms' capabilities of linkages with universities and public research located outside the region. Indeed, in recent decades the Midlands – characterised until the 1970s and '1980s as the Fordist heartland of the country, particularly for automotive and metal manufacturing, and by coal-based industry – have gone through a period of post-industrial economic restructuring which, more recently, has sparked local innovation potential and connectivity among firms

(AWM 2004; Green and Berkeley 2006; Hardill et al. 2006). This path of evolution of the regional industrial structure may also underlie the negative and significant effect on firms' competences and capabilities of linkages with competitors and consultants external to the region, suggesting that the firms located in the Midlands may be facing difficulties in the international technological race.

Northern England turns out to be the UK region where the association between the different independent variables and firm technological status is the most striking. For example, the start-up variable is strongly significant and positively affecting the probability of firms having technological capabilities, driving the effect at the country level at large. This might be interpreted in terms of a process of gradual replacement of declining and mature industries and shifts of the regional industrial structure towards more advanced manufacturing and service sectors. This seems to be further supported by the positive and significant sign of cooperative linkages with both regional and extra-regional private research and consultants, which again determines the result at the national level. Remarkably, the North is also the only region where the probability of being a firm with technological capabilities is strongly increased by collaborations with local public research institutes and universities, once more driving the result for the UK as a whole. Such a result should be interpreted in the light of the 'Northern Way' strategy implemented for the three Northern English regions (North East, North West and Yorkshire and Humber) since 2000. The 'Northern Way' is mainly aimed at strengthening intra-regional coordination in economic and social development efforts, with a strong emphasis on the local knowledge base, and the local integration of innovation, research and education and training. The remarkable concentration of high-rank universities in the region (among others Manchester, Newcastle, Leeds, Sheffield) has acted as one of the main pillars of this strategy (e.g. Byrne and Benneworth 2006; Wilson and Baker 2006; Gore and Jones 2006).

A remarkable multinational presence and a high degree of openness[9] – as also highlighted by the magnitude of the coefficients of the Internationalisation variable – underlie the patterns of collaboration for innovation in the regions of Wales (Cooke et al. 1994, 1998; Arndt and Sternberg 2000; De Laurentis 2006) and Scotland (Raines et al. 2001; De Laurentis 2006). In Wales, only the cooperation with non-local suppliers influences the likelihood that firms are in the category of those with technological capabilities. Similarly to Wales, Scotland shows a positive impact of cooperation with extra-local suppliers and clients, possibly due to the corporate vertical integration of the multinational enterprises located in the region (Turok 1997; Raines et al. 2001).

A similar pattern to Scotland emerges for Northern Ireland's vertical cooperative linkages, with strongly positive coefficients for collaborations with extra-regional suppliers and clients. This is not surprising, due to the strong economic integration of Northern Ireland with the other UK regions.

[9] Both towards the other UK regions and towards the international markets.

5 Conclusions

The aim of this chapter has been to investigate the relationship between different forms of collaborative linkages for innovation and firms' technological competence and capabilities, considering in particular the role of the environment of the firm in the form of its regional location.

Our findings indicate that highly significant results obtained for the UK as a whole actually mask considerable differences among the regions. In particular, the findings show remarkable regional specificities in terms of the association between collaborative patterns and technological capabilities at the firm level. For instance, UK regions such as the Midlands, and even more Northern England, show the greatest evidence of utilising a richer variety of collaborative linkages at the firm level to restructure their regional systems of innovation and enhance their technological capabilities. On the contrary, the highly globalised metropolitan region of London displays a weak association between cooperative patterns and the technological status of firms located there. By the same token, local networking is also less crucial in less central – but highly open – regions such as Scotland, Wales and Northern Ireland.

The main suggestion for regional analysis is that the scope for interaction varies greatly among regions and in some contexts is potentially huge, provided that private and public resources are devoted to identifying and facilitating the most effective linkages for the observed region. In other words, managing regional interactions and cooperation in order to enhance firms' technological capabilities is not a free lunch.

In particular, regional policy should start from the distinction drawn between technological competences and capabilities, being aware that simply marshalling the resources – i.e. increasing innovation inputs – cannot be enough, and finally recognizing that fuelling the link between cooperative networking and firms' capabilities is a policy target that has to be tailored to the specific features of a given regional economic and innovation system.

On the whole, taking into account the economic and social structures of the different UK regions, policies which prove to be successful in one region may not automatically be effective in other contexts; this calls for a targeted innovation policy, bearing in mind the geographical and sectoral structures which characterise the potential beneficiaries.

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Appendix 1: List of Variables

Name	Nature	Mean	Standard deviation
Dependent variable			
Technological status of the firm	Categorical ordered (N = 15,153)	1.028	0.853
Technologically inactive firm = 0	N = 5,308		
Firm with technological competences = 1	N = 4,105		
Firm with technological capabilities = 2	N = 5,740		
Independent/control variables			
Cooperation partners	Dummies		
A: other enterp. LOCAL		0.036	0.187
A: other enterp. NON-LOCAL		0.059	0.235
B: suppliers LOCAL		0.046	0.209
B: suppliers NON-LOCAL		0.091	0.287
C: clients LOCAL		0.050	0.217
C: clients NON-LOCAL		0.084	0.278
D: competitors LOCAL		0.026	0.160
D: competitors NON-LOCAL		0.051	0.220
E: consultants LOCAL		0.030	0.170
E: consultants NON-LOCAL		0.049	0.216
F + G: universities&pub.res. LOCAL		0.040	0.195
F + G: universities&pub.res. NON-LOCAL		0.047	0.212
Size: Ln(Employment)	Continuous	4.043	1.504
(Number of employees)		(276.192)	(1403.906)
Group	Dummy	0.358	0.479
Internationalisation	Dummy	0.342	0.474
Start-up	Dummy	0.150	0.357
Human capital	Continuous	0.127	0.230
Sectors	Dummies		
Primary sector		0.015	
Engineering-based manuf		0.137	
Other manufacturing		0.175	
Construction		0.093	
Retail and distribution		0.165	
Knowledge-intensive services		0.169	
Other services		0.246	
Regions	Dummies		
North England (North East, North West, Yorkshire and the Humber)		0.230	
Midlands (East Midlands, West Midlands)		0.170	
Eastern England		0.085	
London		0.097	
South England (South East, South West)		0.186	
Wales		0.067	

(continued)

Name	Nature	Mean	Standard deviation
Scotland		0.077	
Northern Ireland		0.088	

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