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Resource and Capability Constraints to Innovation in Small and Large Plants

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ABSTRACT. In an attempt to enhance firm's competitiveness, policy initiatives have sought to encourage more firms to innovate, with a particular focus on small firms. The success of such initiatives, however, depends on a clear understanding of the factors that are constraining innovation activity, and whether these differ for firms of different sizes. This paper examines those resources and capabilities that firms identify as constraining their innovation activity, the difference in these for small and larger plants and the actual impact of these perceived constraints on the probability of innovating and the degree of innovation success. Drawing on longitudinal data the paper demonstrates that innovation is an evolutionary process with the constraints to innovation being different for small and larger plants. From a policy perspective, initiatives to overcome constraints to innovation in small plants should extend beyond those of finance to include greater networking opportunities, cost reduction programmes and marketing strategies to increase the profit margin on new products, human resource management practices on implementing change and easier access to information about new technologies. In contrast policies to promote innovation in larger plants should focus on minimising the risk of development and enhancing access to specialist expertise.

1. Introduction

Successful innovation in new products and processes is increasingly being regarded as the central issue in economic development (Porter, 1998). Indeed, empirical studies have demonstrated that innovating firms grow faster, have higher productivity and are more profitable than their less innovative counterparts (Geroski et al., 1993; Roper and Hewitt-Dundas, 1998). This raises the following questions: why do some firms innovate while others do not? Do innovators and non-innovators face different resource constraints? What effect do resource constraints have on firm's innovation success?

Much has been written on the determinants of innovation activity and in particular the effect of firm size on innovation activity (c.f. e.g. Acs and Audretsch 1988, 1991; Cohen, 1995). Traditional Schumpeterian theory argued that small firms encompass a dynamic creativity and are the driving force of innovation through the introduction of radical new products and industry structures (Schumpeter, 1934). Where monopoly power is achieved, this is only temporary as 'the relevant knowledge base is easily available, [and] new innovators systematically substitute for incumbents' (Cefis, 2003, p. 490). Later Schumpeterian thought moved away from the notion of creative destruction and towards creative accumulation (Schumpeter, 1942). In this context, firm-specific tacit technical knowledge accumulates over time as new knowledge is added to existing knowledge. This results in high barriers to entry for other firms and a market dominated by a few large firms.[1]

Recent empirical studies have provided support for latter Schumpeterian thinking with evidence that small firms are significantly less likely to be innovating than large firms (ESRC CBR, 1996, 1998; Roper, 2001; Roper and Hewitt-Dundas, 1998). For example, in Ireland between 1999 and 2002, 48.6% of manufacturing plants with between 10 and 19 employees were innovators compared to 87.6% of plants with over 100 employees (Roper et al. 2004). This is particularly

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marked in the chemicals and pharmaceuticals industry and the electrical and electronic equipment industry where average plant size is significantly higher than in other industries and the development of radical new products is dominated by large, and typically, multinational enterprises (ibid. 2004).

In the UK and US, policy initiatives to promote innovation have focused on the small firm sector as a source of job creation and radical innovation. With small firms (less than 50 employees) accounting for approximately 95.5% of all enterprises in the EU-15 in 2000 (EC, 2003) it follows that if the proportion of small firms that are innovating can be increased, then this will have significant benefits in terms of increasing the number of near-to-market innovations (Rothwell, 1987), the development of new industrial sectors (Acs and Audretsch, 1988) and wealth (Oakey, 1997). Yet, as Hoffman et al (1998, p. 39) observe, 'despite this strong commitment to supporting innovation within SMEs at both regional and local level, the actual processes whereby small firms undertake innovative activity remain unclear'. It follows that policy initiatives to promote innovation activity and success in small firms can only be effective when they are targeted to address those factors that are stimulating or constraining innovation in small firms.

Although considerable research effort has focused on identifying those conditions and factors that are conducive to innovation in small firms[2] less effort has been directed at examining resource and capability shortages. In other words, do specific resources and capabilities prevent firms from innovating, or constrain their innovation success and are these resource and capability constraints different for large and small firms? By using longitudinal data the effect of inherited resource and capability constraints on current innovation activity is estimated along with the ability of firms to overcome constraints through the reconfiguration of resources and capabilities over time. The remainder of the paper is organised as follows. Section 2 provides a conceptual framework and typology for studying the resource and capability constraints to innovation. The data sources and methodology used in the empirical analysis is described in Section 3. The empirical results are presented in Section 4 with the concluding remarks summarised in Section 5.

2. Contextual framework

Differences in innovation activity and growth rates between firms have frequently been examined from a resource-based view of the firm (RBV) (c.f. e.g. Hadjimanolis, 1999). Although theoretical and empirical contributions to the RBV since the early 1990s have led to modifications in the perspective, (c.f. e.g. Barney, 1996; Dierickx and Cool, 1989; Rumelt, 1984) the central tenets remain unchanged. That is, firms' competitive advantage is comprised of heterogeneous bundles of tangible and intangible assets that are valuable, rare, imperfectly imitable and not substitutable in the implementation of value creating strategies (Barney, 1991; Conner, 1991; Conner and Prahalad, 1996; Grant, 1991; Peteraf, 1993; Wright et al., 2001). More recent resource-based writings have emphasised that irrespective of the uniqueness of firm's resources and capabilities these cannot *sustain* a competitive advantage. 'Both the skills/resources and the way organisations use them must constantly change, leading to the creation of continuously changing temporary advantages' (Fiol, 2001, p. 692).

The ability to continuously reconfigure resources, capabilities and competencies is defined as 'dynamic capabilities' (Teece et al., 1997) or 'combinative capabilities' (Zogut and Zander, 1992).[3] At the centre of this reconfiguration of resources and capabilities is the ability to innovate (Rumelt, 1987). While firms may derive direct benefits from innovating such as cost savings and increased market share, they may also derive indirect benefits in becoming 'more perceptive, flexible and adaptable' to various types of cost and demand shocks (Geroski, 1994, p. 153; Geroski and Machin, 1993). In other words, creative accumulation will occur as the firm-specific, tacit and cumulative nature of the knowledge base builds-up over time (Malerba et al., 1997). At the same time, this also implies that the level of accumulated competencies (resources and capabilities), will significantly affect the future technological performance of the firm (ibid.).

This RBV of the firm echoes latter Schumpeterian thought on creative accumulation whereby cumulative learning creates high barriers to entry for other firms and the opportunities for new innovators becomes limited with a few, typically large, firms dominating the market (Schumpeter, 1942). For the small firm this suggests that they are inherently disadvantaged not only in terms of their inherited resources, capabilities and competencies but also in their ability to develop these resources through learning economies of scale. Research suggests however that small firms do have advantages over large firms in undertaking innovation. Although large firms may have technological and learning economies of scale, these may be outweighed by organisational diseconomies of scale (Zenger, 1994). Indeed, Rothwell (1985 as quoted in Vossen, 1998, p. 90) concludes that 'the relative strengths of large business are predominantly material (economies of scale and scope, financial and technological resources etc.), while those of small firms are mostly behavioural (entrepreneurial dynamism, flexibility, efficiency, proximity to the market, motivation)'.

The implication of this is that small firms will be more likely to face material resource and capability constraints to innovation than larger firms, while larger firms will be more likely to experience behavioural constraints to innovation. In terms of firm's ability to overcome constraints in one period through the reconfiguration of resources, it would be expected that small firms would be better positioned to achieve this as a result of their greater organisational flexibility.

2.1. *Resource and capability constraints – a typology*

Resources and capabilities have been defined in a number of ways. Generic definitions (Learned et al., 1969) have defined resources and capabilities as 'strengths conceived by the firm' while in recent years more specific definitions have arisen classifying resources as tangible or intangible (c.f. e.g. Chatterjee and Wernerfelt, 1991; Coyne, 1986; Hall, 1992, 1993). The classification of firm-specific heterogeneous resources and capabilities used in this paper builds on that proposed by Barney (1991) and later developed by Pride et al (1993), Dollinger (1995) and Greene (1995). This typology comprises financial, human and organisational resources and capabilities.

Financial capital resources are the funds required by a firm to start, operate or grow the business (Bygrave, 1992). Empirical evidence suggests that small plants find it more difficult to access finance than larger plants (Binks and Ennew, 1996; Deakins and Hussain, 1991). This is exacerbated by the fact that small firms are less likely to undertake formal technical, commercial and financial appraisals than larger firms (Hewitt-Dundas and Roper, 2002) and therefore will have less accurate predictions about the potential rate of return from innovations, which is often a prerequisite for acquiring finance. 'Information asymmetries and the scope for moral hazard [will result in] general credit rationing or market failure in the provision of finance to small firms' (Freel, 2000, p. 61). Although business angels or venture capitalists may be an important source of finance for small firms, even business angels may prefer to invest in larger firms with more developed managerial competencies (Landström, 1990). This leads to *ex ante* predictions that financial constraints will curtail innovation activity and success to a greater extent in small firms than in larger firms.

Human resources and capabilities refer to the ability of firms to renew, augment and adapt their competencies over time and are closely linked to the skills embodied in the firm (Wright et al., 2001).[4] The resource-based view of the firm stresses that it is not HR practices in a firm *per se* that provides a competitive advantage, given that these can be copied by competitors. Instead, competitive advantage is more likely to be derived from the human capital pool, in terms of the skills or expertise of the workforce and their willingness to work (Wright and McMahan, 1992; Wright et al., 1994).

Research to support this view has identified weak management skills as a major factor inhibiting innovation (Clancy, 2001) by reducing firms' commitment to the development and implementation of new products and processes (Roper and Hofmann, 1993). Yet, this relationship is not straight-forward with conflicting evidence in terms of small and large firms capability to attract and use skilled labour. For example Vossen (1998) posits that while large firms are more capable of attracting highly skilled specialists (Rothwell and Dodgson, 1994) small firms may be more efficient at retaining these specialists through performance-contingent contracts (Zenger, 1994). Smaller firms may face greater problems in the recruitment of skilled staff (Barber et al., 1989) and will tend to under-invest in continual employee training (Brown, et al., 1990) relative to larger firms. The expectation therefore is that small firms would be more likely to identify employee skills as a constraint to innovation activity and success than larger firms, with this being more difficult for small firms to overcome. In contrast however, following-on from Vossen's observation (1998) that small firms' advantage over larger firms is behavioural, it would be expected that the more positive attitude to change of employees in small firms would positively impact on the probability of innovation and the level of innovation success.

In recent years the RBV of the firm has focused more on entrepreneurial characteristics as part of the human resource base.[5] In effect, 'an entrepreneur's expanding knowledge base and absorptive capacity becomes an entrepreneurial firm's competitive advantage' (Alvarez and Buzenitz, 2001, p. 766). With increasing emphasis on the role of the entrepreneur in deriving a competitive advantage human capability constraints related to 'entrepreneurial recognition' (Alvarez and Buzenitz, 2001) are also included in the typology. These include recognition of new market opportunities for innovation, the ability to discover and coordinate knowledge concerning the availability of new technologies, and the entrepreneur's attitude to innovation as measured by the perception of innovation risk. *Ex ante* it is predicted that resource limitations and less sophisticated management structures in small plants (SBRC, 1992) means that the recognition of market opportunities, the identification of new technologies and an aversion to risk will have a greater negative impact on innovation and innovation success in small plants.

Finally, organisational resources and capabilities refer to the ability of a firm to repeatedly integrate specialist knowledge to perform a discrete productive task (Grant, 1991). Specialist knowledge to promote innovation may come from inside or outside the firm. Externally sourced knowledge may take the form of partnerships with other organisations, such as other plants within a group, suppliers, customers, private research labs and government labs etc. with this knowledge enhancing firm's own resource capabilities. For some plants, innovation partners may be preferable where there is a high level of uncertainty and risk associated with innovation (Hitt, 1998; Kogut, 1991; Rothwell, 1991; Von Hippel, 1988). Ultimately external innovation links augment the pool of new information, ideas and possibilities as well as facilitating 'inter-organisational interactions of exchange, concerted action and joint production' (Robertson, et al., 1996, p. 335). As small plants have potentially more to gain from innovative partnerships than larger plants, in terms of accessing specialist expertise, knowledge and technologies etc. (Robertson, et al., 1996), the lack of such partnerships would be expected to have a greater negative impact on the likelihood of innovation or the degree of innovation success in small plants.

Specialist knowledge inside the plant may be measured through the pool of employee skills. Yet, it is the combination and application of these skills that determine the effectiveness with which organisations innovate. One measure of internal specialist skills is the ability of firms to meet legislative or regulatory requirements as part of their innovation activity. For small plants in particular, the bureaucratic burden placed on small firms by government policies may act as a significant barrier to innovation and growth (Henrekson and Jahansson, 1998; Storey, 1994). Where firms are unable to comply with legislative and regulatory requirements this will indicate weaknesses in the internal resources and capabilities of the organisation which will negatively impact on innovation activity and success.

In addressing the key questions of this paper, the financial-human-organisational typology provides a framework for determining those resources and capabilities that are constraining innovation activity and success, the dynamics of resource and capability constraints over time and the extent to which differences exist in the way constraints affect innovation in small and larger plants.

3. Data source

Analysis of the impact of resource and capability constraints on innovation activity and innovation success is based on plant-level data from a longitudinal study of innovation in Ireland. More specifically the data used in this paper is drawn from two postal surveys, the 1997 and the 2000 Product and Process Development Surveys (PPDS and PPDS3). For both of these surveys the target population was manufacturing plants with 10 or more employees. Surveys were plant- rather than company-based and structured samples in each region were stratified by industrial sector and plant size-band. The surveys were based on a core postal questionnaire used previously in Northern Ireland and the Republic of Ireland (see Roper, et al., 1995). Response rates were 32.9% and 40.9% for the PPDS and PPDS3 respectively. Non-response checking conducted for both surveys suggested little non-response bias in either region (see Roper and Anderson, 2000, pp. 49–50; Roper and Hewitt-Dundas, 1998, pp. 64–65). In total 348 plants responded to both the PPDS and the PPDS3 surveys and are the bases of the empirical analysis in this paper. The main advantage of using a longitudinal data set is that it enables innovation capability, activity and success to be traced from 1994 to 2000 alongside firm's perceived resource and capability constraints to innovation.[6]

The survey examined innovation as a 'business' rather than a 'technological' process, reflecting the view that the majority of commercially significant innovations are modest improvements or updates of existing products (Audretsch, 1995). Innovation measures used in the analysis were based on the Oslo Manual's (OECD, 1997) definition of 'technological product innovation', as either new or improved products, whose characteristics differ significantly from previous products.

Innovation activity is examined as a binary measure of whether or not new or modified products were introduced in the 3 years prior to the survey. *Innovation success* is defined as the proportion of current sales form products either newly introduced or modified in the preceding 3 years by the plant. For both of these variables a lag dependent variable was generated relating to the first (1997 PPDS) survey. Measures of plant's financial, human and organisational resource and capability constraints were measured on a 5 point likert scale ranging from not significant '1' to very significant '5'. Financial constraints included a lack of finance for innovation and a projected low rate of return from innovative activities. Human resources included internal expertise, both in terms of technical and managerial skills, employees' attitudes to innovation, perceived risk of innovation, a lack of market opportunities for innovation and a lack of information about new technology. Organisational constraints included a lack of external partners with which to innovate and the role of legislative and regulatory requirements as a constraint to innovation.

3.1. *Model specification*

Two models are developed to examine the effect of plant specific factors on (i) the probability of plants innovating and (ii) the success of innovation activity, as measured by the sale of new or modified products. The primary concern is to determine how financial, human and organisational resources and capability constraints impact on the likelihood of innovating as well as innovation success. In other words we are concerned with the innovation production function (Geroski, 1990; Harris and Trainor, 1995; Love and Roper, 1997) where 'innovation output depends on the presence and volume of innovation resources and the utilisation of these internal and external resources in the innovation process' (Oerlemans et al., 2001, p. 9). A general form of innovation production function is therefore adopted (Geroski, 1990; Harris and Trainor, 1995):

$$I_i = \phi_o + \phi_1 S_i + \phi_2 A_i + \phi_3 R_i + \phi_4 F_i + \phi_5 H_i + \phi_6 O_i + \mu_I,$$

where: I_i is an innovation activity indicator; S_i is a set of plant profile indicators including age, location, industrial sector etc.; A_i is a set of plant performance and activity indicators, including lag dependent variables; R_i is a set of indicators on internal characteristics such as education of workforce etc.; F_i is a set of financial resource and capability constraints to innovation; H_i is a set of human resource and capability constraints to innovation; O_i is a set of organisational resource and capability constraints to innovation. A central test of the hypothesis that resource and capability constraints have an impact on the likelihood of plant's innovating will be determined by the empirical significance and sign of the φ_4, φ_5, and φ_6, parameters.

Problems arise in estimating innovation success due to selectivity in the sample of plants. For example, if the sample has a large number of observations in its lower limit, i.e. no sales from new or improved products among non-innovating plants then an OLS will downward bias the estimates for the dependent variable. To overcome these problems a censored Tobit model is used and therefore only product innovators are examined in the innovation success equation.

4. Data analysis

4.1. *Innovation constraints*

A number of dimensions arise in examining the relationship between resource and capability constraints and plants' innovation activity. First, are constraints to innovation independent or inter-related? For example, if a plant experiences financial resource constraints to innovation then is it also likely to experience human resource constraints, or are resources autonomous? Second, and following-on from the first dimension, if inter-dependencies exist between resource constraints, then are these relationships fixed or do these inter-dependencies change as 'resources bundles' are reconfigured over time to overcome prior constraints. Third, are small plants more likely to experience resource and capability constraints than larger plants?

4.1.1. *Relationship between resources*

Data on the inter-relatedness of financial, human and organisational resource and capability constraints to innovation (Table I) suggests three key relationships:

(a) Significant and positive relationships exist between a lack of (internal) expertise and each of the other constraints to innovation (with the exception of a low rate of return and legislative and regulatory requirements as constraints).

(b) Where plant's innovation activity was constrained by a lack of external innovation partners, a lack of finance, the high risk of development and lack of information about new technologies were also identified as significant constraints. This emphasises the importance of external innovation partnerships as a means of acquiring finance or reducing the total cost of innovation, of speeding up innovation and providing access to expertise and resources (Hitt et al., 1998; Inkpen, 2001; Kogut, 1991; Madhok and Tallman, 1998; Rothwell, 1991; Von Hippel, 1988). It is possible that where external partners are found then this will also diminish other constraints, such as a lack of finance, risk etc.

(c) A strong relationship is found between a lack of finance to innovation and the risk attached to innovation, with the risk of innovating also being strongly correlated with the rate of return from innovation.[7]

4.1.2. *Persistence of resource constraints*

Although strong inter-relationships are evident between the resource and capability constraints, given the recent emphasis in the resource-based literature on renewable competitive advantage (Fiol, 2001), it is important to determine the persistence of resource and capability constraints to innovation. Where persistence is found this may indicate that plants are unable to reconfigure their resources over time so that 'inherited position' dominates future innovation activity and success. Correlation coefficients were computed for each of the resource and capability constraints in the 1993–1996 period compared to that the 1996–1999 period (Table II).

Persistence can occur in two ways, first, in terms of the persistence of individual constraints over time and second, in terms of the relationships between the constraints. Looking first at individual constraints, the size and sign of the coefficients suggest that resource constraints do

TABLE I
Correlation coefficients for resource and capability constraints to innovation, 1993–1996

	Lack of finance	low rate of return	Risk	Employee attitudes	Lack of Market Opportunity	Information new technology	Lack of internal expertise	Legislatitive requirements	Lack of external partners
Financial constraints									
Cash barrier	1								
Low rate return	0.93*	1							
Human constraints									
Risk barrier	0.220***	0.298***	1						
Attitudes	0.039	0.010	0.086	1					
Market of opportunity	−0.032	0.243***	0.162***	0.041	1				
Information new technology	0.025	0.021	0.041	0.162***	0.089*	1			
Expertise	0.100*	0.030	0.126**	0.128**	0.093*	0.309***	1		
Organisational constraints									
Legislation	0.082	0.125**	0.042	0.095*	0.179***	0.115**	0.051	1	
Partners	0.108**	0.83	0.107**	−0.006	0.003	0.234***	−0.007	0.180***	1

Notes: ** Denotes correlation is significant at the 0.01 level (2 tailed); * at the 0.05 level (2-tailed).

TABLE II
Persistence of resource and capability constraints to innovation between 1993–1996 and 1996–1999

	Resource and capability constraints, 1996–1999									
	Lack of finance	low rate of return	Risk of innovation	Employee attitudes	Lack of market opportunity	Lack of Information about new technology	Lack of technical expertise	Lack of Managerial expertise	Legislatitive requirements	Lack of external partners
Financial Constraints										
Lack of finance	0.401***	0.043	0.066	−0.047	−0.010	0.073	0.064	0.097	0.025	0.133**
Low rate return	0.039	0.190***	0.017	−0.015	0.089	0.064	−0.023	0.062	0.068	0.117*
Human constraints										
Risk of innovation	0.150**	0.174***	0.257***	0.041	0.119*	0.101	0.083	0.239***	0.52	0.055
Employee attitudes	0.052	−0.053	0.032	0.076	−0.020	−0.072	−0.009	−0.024	0.042	−0.057
Lack of market opportunity	0.012	0.226***	0.160**	0.030	0.164***	0.026	0.160**	0.098	0.057	−0.029
Lack information new technology	0.103*	0.003	0.125*	0.051	−0.051	0.063	0.190***	0.142**	−0.021	0.115*
Expertise	0.177***	0.071	0.160**	0.119*	−0.044	0.081	0.247***	0.212***	0.085	0.096
Organisational constraints										
Legislation	0.086	0.130**	0.100	−0.005	0.079	0.095	−0.022	−0.029	0.137**	−0.010
Partners	0.039	0.022	0.100	0.025	0.057	0.113*	0.111*	0.039	0.103	0.246***

Notes: *** Denotes significance at the 0.01 level (2-tailed); ** at the 0.05 level (2-tailed); * at the 0.01 level (2-tailed).

persist over time. In other words, if innovation activity in a plant was constrained by a particular resource or capability between 1993 and 1996, then it was likely that the plant would still experience this constraint to innovation between 1996 and 1999.[8]

The inter-relationships between resource and capability constraints (Table II) are less robust over time. For example, the strong relationship between a lack of expertise and the other resource and capability constraints in the 1993–1996 period is not sustained in the 1996–1999 period. This suggests that plants are reconfiguring their resources over time to gain 'temporary competitive advantages' (Fiol, 2001, p. 692), or more accurately to minimise temporary competitive disadvantages.

Weak persistence between constraints to innovation may be explained in two ways, first, by plant's own pro-active response to innovation constraints as they reconfigure their resources. For example, where plant's lack of in-house expertise is constraining their knowledge of new technologies they may try to overcome this by developing external partnerships to gain access to specialist technological knowledge and capability. In such cases the relationship between constraints will weaken over time.

Second, from an evolutionary perspective it is possible that the combination of resource and capability constraints in one period will shape the type and scale of innovation activity that plants undertake with this leading to different resource and capability constraints in subsequent periods. For example, plants in 1993–1996 identifying a low rate of return as a constraint to innovation were also likely to perceive few market opportunities for innovation. By the 1996–1999 period however, while these plants still perceived a low rate of return from innovation, they no longer perceived a lack of market opportunities as a deterrent to innovation. It is possible that low margins and limited opportunities for product development stimulated a pro-active market identification strategy thereby increasing the potential for product development. In the 1996–1999 period therefore, while low profit margins to innovation persisted, plants were now more likely to identify a lack of partners as a significant innovation constraint.

4.1.3. *Resource constraints in large and small plants*

Literature from a resource-based view of the firm has demonstrated how firm's resource profile is intricately linked to business failure, survival and growth (Cooper et al., 1991). In this survey, as with others (Roper and Anderson, 2001; Freel, 2000), small plants were significantly less likely to undertake innovation than larger plants for both periods. The expectation is that this lower level of engagement in innovation activity by small plants is explained by them facing higher resource and capability constraints to innovation.[9]

During both periods, for approximately 70% of the resource and capability constraints to innovation, small plants were no more likely to identify these constraints than larger plants (Table III). However, small plants were significantly more likely to identify a lack of finance, the lack of market opportunities for innovation and legislation and regulatory requirements as significant constraints to innovation activity in the 1996–1999 period. In contrast, a perceived low rate of return from innovation (both periods) and the risk of development (first period) were significantly more important as constraints to innovation for large plants.

Overall, these results do not support *a priori* expectations that each of the resource and capability constraints to innovation would be greater for smaller plants and therefore do not help to explain lower levels of innovation activity between small and larger plants.

4.2. *Impact of constraints on innovation activity*

The data analysis so far has demonstrated that resource and capability constraints to innovation exist. In other words, plants are identifying resources and capabilities that they perceive to be constraining their innovation activities. This raises the question, are these *perceived* constraints *actually* constraining innovation activity and success and to what extent does this differ for small and larger plants?

TABLE III
Resource and capability constraints to innovation 1993–1996 and 1996–1999, by plant size-band

Percentage of plants	1993–1996					1996–1999				
	Plant size (Number of Employee)					Plant size (Number of Employee)				
	< 20	20–49	50–99	100 +		< 20	20–49	50–99	100 +	
Financial constraints										
Lack of finance	39.2	29.8	40.0	32.5		38.7	26.0	26.7	26.5	**
Low rate of return	17.6	25.0	25.7	41.8	***	33.3	38.9	30.5	49.5	**
Human constraints										
Risk of development	17.6	14.4	271	28.2	**	40.0	14.1	18.6	28.6	
Employee attitudes	3.9	4.8	7.1	6.0		19.2	7.4	5.2	14.1	
Lack of market opportunities	21.6	21.2	14.3	20.5		51.7	18.1	21.7	40.8	***
Lack of information about new technologies	13.7	10.6	12.9	7.7		22.2	14.3	8.3	13.2	
Lack of expertise (technical)	11.8	21.2	25.7	20.5		26.9	20.5	24.2	22.9	
Lack of expertise (managerial)						23.1	16.2	17.5	14.4	
Organisational Constraints										
Legislatory requirements	11.8	17.3	5.7	13.7		26.9	15.7	6.5	13.3	**
Lack of partners	3.9	4.8	7.1	6.0		8.0	9.9	6.9	11.8	

Notes: Chi Square tests *** denotes samples are significantly different at the 0.01 level; ** at the 0.05 level; * at the 0.1 level

TABLE IV
Probit equations on innovation activity for all plants (Equation 1), small plants (Equation 2) and medium and large plants (Equation 3)

	Equation 1 all plants		Equation 2 small plants		Equation 3 medium and large plants	
Constant	0.254 (0.218)		0.006 (0.142)		0.0487 (0.0632)	
Plant innovation activity 1993–1996						
Product innovator 1993–1996 (0/1)	0.686 (0.172)	***	0.149 (0.105)		0.2712 (0.0631)	***
Process innovator 1993–1996 (0/1)			0.104 (0.108)			
Plant plant activity 1996–1999						
Organisational change 1996–1999 (0/1)	0.0003 (0.0002)	***	0.0002 (0.0001)	**	0.00005 (0.00006)	
External innovation links (0/1)	0.786 (0.187)	***	0.386 (0.122)	***	0.1785 (0.0628)	***
R&D informal (0/1)			0.0005 (0.0001)	***	0.0002 (0.00006)	***
Plant profile						
Paper and printing sector (0/1)			−0.6091 (0.2852)	**		
SIZEGP1 (< 50 employees (0/1))	−0.424 (0.265)					
SIZEGP2 (50–99 employees (0/1))	−0.423 (0.200)	**				
Plant characteristics						
Employees with degree qualification (%)	0.018 (0.007)	**	0.0068 (0.0042)			
Employees with technician qualification (%)	−0.018 (0.007)	**	−0.684 (0.0042)			
Production - one-offs (0/1)	−0.825 (0.212)	***	−0.622 (0.162)	***	−0.120 (0.0598)	**
Production - small batches (0/1)	0.520 (0.166)	***	0.341 (0.109)	***	0.119 (0.0601)	**
Production - large batches (0/1)	0.303 (0.154)	**	0.279 (0.103)	***		
Barriers to innovation 1993–1996						
Lack of finance (0/1)	0.275 (0.187)		0.220 (0.105)	**		
Lack of partners (0/1)	−0.605 (0.250)	**	−0.410 (0.216)	**		
Risk of development (0/1)	−0.357 (0.211)	*			−0.141 (0.0617)	**
Lack of expertise (0/1)					−0.130 (0.0624)	**
Number of observations	348		163		185	
Log likelihood function	−141.86		−59.81		−73.13	
Significance test	0.000		0.000		0.000	
Pseudo R^2	0.392		0.465		0.295	
Correct predictions (%)	80.2		81.6		80.5	

Note: The figures are coefficients for the marginal values with standard error in square brackets.
The significance of each marginal effect is noted: *** denotes significance at the 99% level, ** at the 95% level and * at the 90% level. Pseudo R^2 is calculated as 1 - (L/Ls) where L is the Log Likelihood Function and Ls is the restricted log likelihood.

The results (Tables IV and V) illustrate that resource and capability constraints provide only part of the explanation for whether or not plants innovate and the level of innovation success. For all plants (Table IV, Equation 1 and Table V, Equation 1), there is evidence of capability building (Geroski, 1994) with plants that were innovating between 1993 and 1996 being significantly more likely to be product innovators in the 1996–1999 period and to have higher sales from new or modified products than non-innovating plants. Such capability building is less evident among small plants with the effect of innovation activity in the first period on activity in the second period being insignificant (albeit positive). Yet, in small plants innovation success was higher in those plants that had undertaken process innovation in the previous (1993–1996) period than non-process innovators (Table V, Equation 2). This provides some support for the notion of dynamic increasing returns with inherited resources and knowledge providing a platform on which subsequent knowledge and resources are shaped and accumulated (Malerba, et al., 1997).

TABLE V
Censored tobit equation for innovation success (% sales from new and modified products 1996–1999)

	All plants	Small plants (< 50 employees)	Medium and large plants (> 50 employees)
Constant	27.616 (4.725) ***	7.668 (7.782)	16.167 (14.297)
Innovation capability & activity (1993–1996)			
Number of new products introduced	0.001 (0.0004) ***		0.0008 (.0005)
Sales to new and modified products (%)			0.262 (0.115) **
R&D spend per employee (£stg)			−0.0254 (0.0085) ***
Innovation capability & activity (1996–1999)			
Process innovator (0/1)	5.819 (4.541)	13.893 (6.422) **	
R&D department in plant (0/1)	15.129 (4.536) ***		13.323 (5.234) **
R&D – informal (0/1)		0.010 (.006) *	
Receipt of Grant assistance for innovation (0/1)	5.368 (4.394)		5.325 (5.219)
Plant characteristics			
Employment (Log)			1.332 (2.869)
Production one-off (0/1)		−18.201 (6.962) ***	
Production small batches (0/1)		18.230 (6.929) ***	
Food, drink & tobacco sector (0/1)	−18.036 (5.364) ***		
Textiles and textile products sector (0/1)	12.681 (6.351) **	15.404 (10.863)	
Chemicals (0/1)	−12.265 (6.511) *		
Electrical & Optical equipment (0/1)		−26.019 (11.980) **	
Barriers to innovation 1993–1996 (0/1)			
Market opportunities	−9.123 (4.670) *		
Perceived low rate of return		23.392 (6.919) ***	
Risk of innovation	5.713 (4.503)	25.483 (8.592) ***	
Employee attitudes to change			17.863 (8.383) **
Information about new technologies	9.304 (5.704) *		16.703 (9.003) *
Internal expertise	−5.901 (5.071)		
Legislation & regulatory requirements		−13.658 (7.805) *	−12.267 (7.347) *
Lack of external partners		−27.287 (13.631) **	−22.547 (9.178) **
Barriers to innovation 1996–1999			
Lack of finance			−0.066 (.034) *
Risk of Innovation			0.056 (0.031) *
Information about new technologies	0.0315 (0.0159) **	0.0248 (0.009) **	
Managerial skills	−0.0338 (0.0164) **		
Lack of external partners			0.0229 (0.010) **
Change in significance of barrier (1993–1996 to 1996–1999)			
Lack of finance		−0.022 (.0107) **	0.0889 (0.0359) **
Employee attitudes			−0.060 (0.017) ***
Lack of market opportunities	−0.007 (0.007)		
Risk of innovation	−0.016 (0.0094) *		−0.055 (0.027) **
Internal expertise	0.0253 (0.0110) **		0.020 (0.0117) *
σ	25.923 (1.417) ***	23.594 (2.284) ***	25.142 (1.679) ***
N	187	72	124
Log Likelihood	−829.93	−278.94	−548.30

Note: The dependent variable is innovation success defined as the percentage of sales in 1999 from product newly introduced or modified by the plant between 1996 and 1999. Estimation is restricted to product innovators only with the dependent variable bounded at 0 and 100. Figures in brackets are standard errors.
*** denotes coefficient significance at 1% level; ** denotes significance at 5% level; * at the 1% level.

Product innovation is more likely to occur where plants are also undertaking organisational innovations, where they have external innovation links with other plants and organisations, and where R&D activity is taking place. The coefficients for the effect of plant profile, performance and internal characteristics on the probability of innovating and the scale of innovation success in small and larger plants are as expected from other empirical studies (see Roper, 2001). The remainder of the discussion therefore focuses on the effect of resource and capability constraints on innovation activity and success.

Drawing on the panel data, dummy variables for each of the financial, human and organisational resource and capability constraints were included in the equations for 1993–1996, 1996–1999 and change in importance of each of the constraints between the two periods. To overcome problems of multi-collinearity and to eliminate those factors that were less important in determining innovation activity, some more insignificant resource and capability constraints were dropped and the models for innovation activity and innovation success were reestimated.

Innovation activity (1996–1999) was not affected by any of the resource or capability constraints to innovation in that period, nor by the changing importance to plants of individual resource constraints between the two periods. With weak and insignificant coefficients, these variables were excluded from the analysis and the equations re-estimated. The probability of plants innovating was however significantly affected by resource constraints in the previous period. Again this supports later Schumpeterian and recent resource-based writing that accumulated competencies or inherited position, significantly affects future technological performance (Teece and Pisano, 1994).

In terms of innovation success (Table V), again resource constraints in the previous period (1993–1996) affected the level of sales from new and/or modified products in the subsequent (1996–1999) period. In particular, a lack of market opportunities between 1993 and 1996 had a significant negative effect on innovation success between 1996 and 1999. In contrast, plants identifying a lack of information about new technologies as a barrier to innovation (for both the 1993–1996 and 1996–1999 periods) had significantly higher innovation sales. While it would be expected that a lack of technical information would curtail innovation success, the coefficients suggest that this is not the case. Instead, it is possible that those plants claiming that information about new technologies was a significant barrier to innovation were more actively engaged in external knowledge sourcing as part of their product development activities. This supports other research demonstrating the positive relationship between the external sourcing of knowledge and technological developments (Rosenkopf and Nerkar, 2001) and performance (Brierly and Chakrabarti, 1996).

Innovation success was also affected by changes in the strength of specific constraints over the two periods. For example, where the risk of innovation increased in importance over the two periods, this had a significantly negative effect on sales from new and modified products. Plants identifying managerial expertise as an increasing constraint to innovation over the two periods were significantly more likely to have higher innovation sales. At first glance this appears to contradict other research demonstrating a positive association between skills and innovation or business success (c.f. e.g. Beal and Yasai-Ardekani, 2000; Freel, 2003; Thomas and Ramaswamy, 1993). It is likely, however, that the limits of managerial expertise are more apparent where change (as manifest in product innovation activities) is more pervasive. Obviously where this occurs the plant must seek to address the skills shortages if future sales from new or modified products are not to be negatively affected.

4.2.1. *Resource and capability constraints to innovation in small plants*

Only two constraints were significantly related to the likelihood of small plants innovating; a lack of finance between 1993 and 1996 (positive) and a lack of partners between 1993 and 1996 (negative).

Studies of SME growth and innovation consistently stress that a lack of finance is the most important constraint to innovation (Mizgajska, 2000; Vossen, 1998) in curtailing necessary technical and commercial investments. Financial constraints would therefore be expected to negatively affect the probability of innovation in small plants as opposed to the positive relationship found here. A possible explanation for this is that those small plants with financial constraints between 1993 and 1996 were investing heavily in product development, through either formal or informal R&D, and therefore were more conscious of financial constraints to innovation activities. This assertion is supported with positive correlation coefficients between plants undertaking R&D and the importance of a lack of finance between 1993 and 1996.[10] In other words, those small plants engaged in product development activities between 1993 and 1996 may have been more aware of financial constraints in that period. These plants are then benefiting from the investments in development work with new and modified products being brought to the market in the 1996–1999 period.

The second constraint to small plants undertaking innovation related to the lack of external innovation partnerships which, as predicted, had a significant negative effect on the likelihood of plants innovating. The potential advantages from innovation partnerships or strategic alliances are well documented and include such benefits as strategic flexibility, reducing or sharing risk (Hitt et al., 1998), access to complementary assets (Ireland and Hitt, 1999) and resources (Gulati et al., 2000). Such relationships have already been highlighted (Table I) with positive and significant correlation coefficients between a lack of partners and other constraints in the 1993–1996 period, namely lack of finance, risk of development, lack of information about new technologies and lack of specialist expertise. Further, a lack of partners for innovation is a constraint that persists over time and while the strength of the correlations with a lack of finance and the risk of development weaken, a lack of information about technologies and lack of technical expertise still remain important (Table II). Given these findings it is not surprising that a lack of such partnerships has a negative impact on the ability of small plants to undertake innovation.

A lack of external innovation partners did not have a significant effect on the probability of innovating in larger plants. From a resource-based perspective this suggests that the external resources and capabilities that small plants can access through external innovation partnerships may provide small plants with the stimulus, capability or capacity to innovate that they would not otherwise have. In contrast, for larger plants while distinct knowledge benefits may be accrued from strategic alliances these alone will not determine whether or not a plant innovates.

A number of resource and capability constraints were found to significantly impact on innovation success in small plants (Table V). While it is not surprising to find that constraints such as the perceived risk and rate of return arising from innovation significantly affect innovation sales, the sign of the coefficients, in some instances, are counterintuitive. Six resource and capability constraints are found to significantly affect innovation success for small plants, with three of these having a negative effect and three having a positive effect.

Constraints negatively affecting innovation success in small plants include legislative and regulatory requirements (1993–1996), a lack of external partners (1993–1996) and the increasing constraint of a lack of finance over the two periods. Research has demonstrated that the labour and administrative costs of complying with legislative and regulatory requirements are substantial, and felt most acutely by small plants characterised by 'limited economic resources and economic vulnerability' (EIRO, 2003, P. 1, see also Henrekson and Jahansson, 1998; Storey, 1994). In the UK, realisation by government of the legislative burden on small firms has resulted in efforts to reduce 'red tape', most notably in relation to taxation and employment practices. Yet, legislation remains a significant constraint not only to growth and profitability, but as is found here also to innovation success in small (and larger) plants.

The benefits to small plants from external partnerships have already been highlighted, with these including, speeding-up of innovation activity, reducing the risk of innovation as well as providing small plants with access to complementary assets and resources. The coefficients suggest that not only do external partnerships act as an important stimulus to innovation activity, but in addition, where small plants engage in such partnerships, this positively affects innovation success.

The effect of financial constraints on small plant's innovation activity is complicated. The results suggest that small plants were more likely to undertake product innovation in 1996–1999 where financial constraints were experienced in the previous period, 1993–1996. Therefore, while financial constraints may prompt small plants to innovate, where these financial constraints persist over time, this will negatively impact on the scale of innovation success.

Where small plants identified a perceived low rate of return or the high risk of innovation as a barrier to innovation between 1993 and 1996, this also positively related to higher innovation success in the subsequent 1996–1999 period. Further, innovation success was also significantly higher were small plants had a significant lack of information about new technologies between 1996 and 1999 (Table V).

It is possible to explain the positive signs for perceived rate of return and risk of innovation (1993–1996) on the level of innovation success (1996–1999) in terms of plant's product development strategy. In other words, it is possible that small plants faced with high risk from innovation in one period, devise a strategy that seeks *not* to avoid risk, but to diagnose and manage risk (c.f e.g. Keizer et al., 2002; Smith, 1999). Similarly, small plants identifying a low rate of return from innovation as an important constraint to their innovation activity are characterised by low market share. Where this occurs, price-taking conditions limit their ability to predict or control the profit from new or improved products. A possible response to high risk and low profit margins from product innovations may be to avoid being too dependent on single products, and instead, diversify the portfolio of new and modified products. This may in turn positively impact on the level of sales from new and modified products. Evidence to support this view is found in the sample with small plants introducing, on average, 0.9 new or improved products per employee between 1996 and 1999 compared to only 0.16 per employee for medium and large plants.[11]

Somewhat counter-intuitively, where small plants lacked information about new technologies this significantly increased innovation success. Cohen and Levinthal (1990) suggest that it is difficult for plants merely to identify and acquire new technologies, but rather, technological acquisition is closely related to existing competencies within the plant. It is possible that this coefficient is therefore identifying the relationship between plant's ability to identify and adopt new technologies and their absorptive capacity. For example, where plants stated that they had a lack of information about new technology this may be indicative of a greater underlying absorptive capacity, or consciousness of technological developments that may be integrated into their production process. In other words, it is those plants with higher skills and those which are more proactively trying to identify technologies as a stimulus to innovation that are more aware of the limitations of their knowledge on new technologies. Support for this proposition is found in the data with those small plants identifying a lack of information about new technologies as a constraint to innovation, having a significantly higher proportion of their workforce with degree level qualifications than those plants that did not perceive this as a barrier ($t = 2.03$, $\rho = 0.047$).

4.2.2. *Resource and capability constraints to innovation in larger plants*

Only two resource and capability constraints had a significant effect on the probability of larger plants innovating between 1996 and 1999, namely (i) the risk of development between 1993 and 1996 (negative and significant) and (ii) a lack of internal expertise between 1993 and 1996 (negative and significant).

Risk aversion is usually examined from a small business perspective, with the entrepreneur's perception of risk and their response to it affecting business growth (Acs and Audretsch, 1991). Yet, the effect of perceived risk of innovation on the probability of small plants innovating was small and insignificant and therefore excluded in the estimation (Table IV). For larger plants however, the risk of innovation is a significant deterrent to subsequent product innovation. Where larger plants have an established market, or their role is tightly defined by corporate or external networks, the introduction of new products may be risky if activity or responsibility is redefined. As for small plants, larger plants will seek to minimise risk taking where there is the possibility of failure and where this cannot be absorbed in the wider activities of the business. Innovation activity in this context will tend to be low risk, immediate reward, incremental projects (Dougherty and Hardy, 1996).

As with studies of risk, academic studies of the impact of managerial skills on plant performance are often in the context of small plants. Indeed, research suggests that larger plants are better at attracting highly skilled specialists (Rothwell and Dodgson, 1994) and have more comprehensive management structures with specialists in areas such as design and engineering, production, sales, marketing, logistics etc. Yet, the coefficients suggest that where deficiencies in internal expertise are experienced this will have a negative impact on innovation activity.

A number of constraints were found to significantly affect innovation success in larger plants. As for small plants, legislative and regulatory requirements and a lack of external partners were significant constraints on innovation success. Again, both of these constraints have typically been considered in terms of their effect on small firms with Robertson et al. (1996) purporsing that small firms have more to gain from external partnerships. Yet, the results suggest that compliance costs may diminish the scale of innovation activity that larger plants undertake and that the potential benefits from collaboration with external partners (Hitt et al., 1998; Kogut, 1991; Rothwell, 1991; Von Hippel, 1998) are equally as important to larger plants as to small plants.

As was also found for small plants, where larger plants identified a lack of information about new technologies as an important constraint to innovation, this had a positive (and significant) effect on innovation success. As previously outlined, this result is counterintuitive, but the explanation for this finding may reflect the relationship between innovation success and the absorptive capability of the plant (Cohen and Levinthal, 1990) in sourcing new technological developments (Brierly and Chakrabarti, 1996; Rosenkopf and Nerkar, 2001) as discussed for small plants.

Financial constraints between 1996 and 1999 had a significantly negative effect on innovation success. Where access to finance had increased as a barrier to innovation between 1993–1996 and 1996–1999, this had a positive effect on innovation success, unlike the negative effect for smaller plants. Based on the available data these findings are difficult to explain, however, it is likely that the small and larger plant coefficients are reflecting different situations. For small plants, where a lack of finance persists over time this directly reduces innovation success. For larger plants however, the increasing importance over time, of financial constraints to innovation may reflect the scale of innovation being undertaken.

Human constraints were found to be more important to innovation success in larger plants than small plants. Innovation success (1996–1999) was higher in plants where employee attitudes to change were identified as a significant constraint in the previous period. It is likely that this attitudinal barrier to change between 1993 and 1996 was the result of changes that were underway in the plant, with these changes then being converted into innovation sales between 1996 and 1999. Of greater interest is the negative coefficient where employee attitudes to change increased as a barrier between 1993–1996 and 1996–1999. This suggests that it is not employee attitudes *per se* that constrain innovation success, but rather it is how these are managed over time. To rephrase, employee resistance to change is not necessarily counterproductive for innovation success, but if these attitudes persist or increase over time, then this will have a significant negative impact on innovation success.

The importance of risk as a constraint to innovation success is another variable where the relationship is not straight-forward. The positive and significant coefficient between high risk of innovation (1996–1999) and innovation success suggests that the higher the risk then the higher the potential reward from innovation. At the same time, the results also illustrate that if risk increases as a barrier to innovation from one period to the next, then this will negatively affect innovation success.

Finally, plants stating that internal expertise had become a greater constraint to innovation over the two periods had significantly higher innovation success. As for small plants, again it is likely that the coefficient is identifying critical points in the growth trajectory of larger plants where following a period of significant change, managerial resource shortages are identified in specialist technical and managerial skills.

5. Conclusions

This paper has drawn upon the resource-based view of the plant to examine the relationship between plant's resources and capabilities and their innovativeness. The approach adopted differs from conventional resource-based writings in examining those resources and capabilities that are absent, or lacking, as opposed to those that exist in the firm. More specifically, this paper has identified some of the resource and capability constraints that plants face in undertaking innovation, the inter-dependencies between different constraints and the dynamics of these constraints over time. The analysis not only identifies those resources and capabilities that plants *perceive* to be constraining their innovation activity but also examines the *actual* effect of these constraints on innovation activity and success and whether this is different for small and larger plants.

A number of key findings emerge from the analysis, as follows:

(i) Small and large plants alike have heterogeneous bundles of tangible and intangible resource constraints, yet associations between resource constraints are evident. For example, where plants have internal skill constraints they are also likely to experience a wide range of other human, financial and organisational constraints. Where plants innovation activities are constrained by a lack of external innovation partners, then other constraints are closely aligned to the missed benefit from these external relationships. Finally, the risk of innovation is strongly associated with the availability of finance as opposed to human or organisational constraints.

(ii) Constraints to innovation tend to persist from one period to the next. In other words, with the exception of employee attitudes to change and information about new technologies, if a resource or capability was identified as a significant constraint to innovation between 1993 and 1996 then this would still be a significant constraint in 1996–1999. Persistence in the relationship between constraints to innovation were less strong over time, suggesting that plants were re-configuring their bundles of resources and capabilities to overcome competitive weaknesses.

(iii) Resource and capability constraints to innovation are remarkably similar for small and large plants. The only exception to this is a lack of finance, limited market opportunities and legislative or regulatory pressures which were more significant for small plants. This supports other research suggesting that advantages (disadvantages) in large plants are mainly material (behavioural) while the advantages (disadvantages) in small plants are behavioural (material) (Vossen, 1998).

(iv) The probability of plant's undertaking innovation is strongly influenced by their inherited resource and capability constraints. Indeed, inherited constraints have a greater influence on current innovation activity than current perceived constraints.

(v) The resource and capabilities constraints that prevent plants from innovating are different for small and larger plants. For small plants the most important barrier to undertaking product innovation is a lack of external partners. In contrast, for larger plants it is the high risk of development or a lack of internal expertise which present the greatest barrier to product innovation.

(vi) Legislative and regulatory requirements and a lack of external partners as significant constraints to innovation, negatively effect innovation success in both small and larger plants.

(vii) Financial constraint to innovation for both small and larger plants have a counterintuitive effect on innovation success. In some cases financial constraints appear to act as a stimulus to innovation success, either in terms of product development or business strategy. Yet, where financial constraints persist over time, then this can have a detrimental effect on innovation success, particularly in smaller plants.

(viii) The view that small plants will benefit from behavioural advantages (Vossen, 1998) is supported by the findings in relation to innovation success. In particular, employee resistance to change is more significant in larger plants, and where this persists over time in larger plants, can negatively effect innovation success.

These findings raise a number of points of interest in both a conceptual and policy perspective.

In terms of the conceptual debate, the data suggests that innovation is not a purely random process responding to exogenous shocks. Instead plant's innovative activity and success reflect their heterogeneity, whereby dynamic increasing returns are gained through knowledge and/or resource accumulation. Resource and capability constraints act in the same manner as resource endowments. In other words, inherited resources (present or absent) strongly effect plant's subsequent resource accumulation and therefore their innovation activity and success. This applies to both small and larger plants although differences exist, with financial and organisational constraints being particularly difficult for small plants to overcome as compared to human constraints among larger plants.

Where possible, plants will attempt to reconfigure their 'bundles of heterogeneous resources' to derive temporary competitive advantages. In the same way, plants will also reconfigure their resources to minimise temporary competitive disadvantages. Inherited position therefore conditions plant's strategy choices in such as way as to maximise (minimise) temporary advantages (disadvantages).

From a policy perspective, initiatives designed to promote greater innovation in small plants by tackling the 'barriers to innovation' need to distinguish not only between the type of barriers that plants are facing but also the impact of these constraints on innovation. The belief that the greatest constraint to small plants undertaking innovation is a lack of finance needs to be reviewed and support extended to include greater networking opportunities. If small plants are to become more innovation-driven then support should encourage greater external collaboration while seeking to minimise the re-tape of doing business. Other initiatives of particular benefit to small plants include cost reduction programmes to increase the profit margin on new products and initiatives to improve access to information about new technologies.

Support to stimulate innovation activity and increase the level of sales from innovation should distinguish between small and larger plants. While policy initiatives tend to focus on small plants, for larger plants, initiatives to understand and minimise the risk of innovation as well as increase access to specialist expertise (perhaps through cluster initiatives, improved HR planning, training and retention policies) may positively influence the proportion of larger plants that are innovating. Similarly, support for larger plants in identifying new market opportunities, forming external collaborative relationships, dealing with legislation and regulatory requirements and managing change may have a significant effect on the proportion of sales from new or modified products.

It follows therefore that a 'one-size-fits-all' approach to public intervention is inappropriate and instead, initiatives to overcome resource and capability constraints to innovation should take into account plant size, the objective of public sector support i.e. whether support is to encourage innovation activity or to promote innovation success, as well as plant's current and inherited resource and constraints profile.

In conclusion, the analysis in this paper has revisited the notion of barriers to innovation and their relationship to innovation activity and success. In many instances the findings have lent support to other research, for example in terms of the benefits to plants of engaging in external partnerships. In other instances however, the relationship between resources and capabilities and innovation activity and success have been counterintuitive. Further research could examine these anomalies through qualitative analysis and/or by using more objective measures of constraints to innovation rather than the subjective indicators adopted here.

Notes

[1] There is some support for both of these Schumpeterian perspectives in the work of Deakins and Freel (2002) which found that large firms dominated innovation in

mature sectors and small firms dominated innovation in new and emergent sectors, such as bio-technology and E-commerce.

[2] See Hoffman et al. for a discussion of UK literature on SMEs and innovation.

[3] Eisenhardt and Martin (2000, as quoted in Wright et al., 2001, p. 712) describe these dynamic capabilities as 'the organisational and strategic routines by which firms achieve new resource reconfigurations as markets emerge, collide, split, evolve and die'.

[4] The relationship between employee skills, productivity and competitiveness has being documented widely. (c.f. e.g. Office of Science and Technology Assessment 1990 and Prais et al., 1989).

[5] Alvarez and Buzenitz (2001) stress that while early work on the resource-based theory, such as that by Conner (1991) and Rumelt (1987), acknowledged entrepreneurship as an intricate part of the resource-based framework, most entrepreneurial resource-based research has failed to integrate creativity and the entrepreneurial act into the analysis.

[6] Details of the surveys and follow-up methodology are given in Roper and Hewitt-Dundas (1998) and Roper and Anderson (2000) for the Northern Ireland and Republic of Ireland PPDS and PPDS3 surveys, respectively. These documents can be accessed at www.innlab.org

[7] Other research has found that the higher the level of innovation, and potential reward, the greater the risk of innovation. Where innovation accounts for a higher share of business activity, this may increase the importance of having significant profit margins from innovation. In contrast, where innovation represents a smaller proportion of sales, then lower profit margins may be easier to sustain, especially if the innovation contributes to the wider strategic aims of the business.

[8] The only exception to this is the persistence of employee attitudes and information about technologies over the two periods.

[9] It is possible that where small plants are part of a larger corporate structure and have limited responsibility for product development activities, this may explain lower innovation rates, relative to larger plants. In the sample of 162 small plants, 123 were single, independently owned plants, a further five were the parent plant of a wider group of plants and a further 34 plants were subsidiary plants. Analysis of innovation activity and innovation success for each of these plant-types demonstrated that there was no significant difference, either in the proportion of plants undertaking innovation or in the percentage of sales from new or modified products, between the plant-types. Ownership structure therefore has no clear effect on innovation activity or success in small plants.

[10] $\chi^2 = 23.762, \beta = 0.000$.

[11] This result is statistically significant with $\chi^2 = -0.116$ ($\beta = 0.008$).

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