Innovation, innovation strategy and survival

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ERC Research Paper No.17

February 2014

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This paper is published by the independent Enterprise Research Centre. The Enterprise Research Centre is a partnership between Warwick Business School, Aston Business School, Imperial College Business School, Strathclyde Business School, Birmingham Business School and De Montfort University. ERC is funded by the Economic and Social Research Council (ESRC); the Department for Business, Innovation & Skills (BIS); the Technology Strategy Board (TSB); and, through the British Bankers Association (BBA), by the Royal Bank of Scotland PLC; Bank of Scotland; HSBC Bank PLC; Barclays Bank PLC and Lloyds TSB Bank PLC. The support of the funders is acknowledged. The views expressed are those of the authors and do not necessarily represent the views of the funders.

ABSTRACT

Innovation has a recognised effect on survival. Undertaking more risky innovation, for example, may increase the risk of business failure, while more incremental innovation may reduce failure risk. Here, we investigate how firms' innovation strategy choices – which may reduce the riskiness or costs of innovation and/or increase the innovation rewards – moderate the innovation-survival relationship. Our analysis is based on UK Community Innovation Survey data matched with survival data from firms' published accounts. We are able to match nearly 80 per cent of UK CIS respondents. Contrary to expectations we find that innovation partnering and intellectual property protection have little or no moderating effect on the innovation-survival relationship. However, receiving public support for innovation has significant positive moderating effects. This suggests the notion of "survival additionality", i.e. firms receiving public support derive more persistent benefits from innovation than firms which did not receive public support. Specifically, firms which receive public support for innovation are 2.7 per cent more likely to survive for eight years than firms which innovate but without public support. This result is strongest for product and service rather than process change, with implications for innovation policy design and evaluation.

Keywords: Innovation, survival, strategy, public support, additionality, UK

CONTENTS

1. INTRODUCTION

Evidence on the relationship between innovation and business growth, profitability and exporting has become more common in recent years (Love and Roper, 2013). As Cefis and Marsili (2006, p. 795) remark, however, 'staying in the market is a basic requisite for firm success'. At the level of the individual firm this is, of course, true. At the level of the wider industry or economy, however, a certain level of business failure may be desirable, allowing resources to be reallocated towards more productive enterprises. Innovation, along with other influences, can play a key role in driving this process of creative destruction, increasing the competitiveness of some firms and raising the competitive pressure on others (Carree et al., 2011; Schumpeter, 1912). Previous studies suggest, however, that the intensity and speed of creative destruction processes – and therefore the probability of survival or exit in any given period - differs sharply between industries (Dunne et al., 1988) and locations (Colombo and Delmastro, 2001). In addition to the role of competition in driving survival or exit, business strategy may also shape the probability of survival either as part of an entrepreneurial process of rent-seeking (Cefis and Marsili, 2011), or the reallocation of productive resources across multi-plant groups. Alongside the impact of competitive pressures this also suggests the potential influence of firms' organisational context on the probability of survival (Colombo and Delmastro, 2001; Lieberman, 1990; Mata et al., 1995).

The relationship between innovation and survival has been considered by a number of recent studies with contrasting results. Cefis and Marsili (2012), for example, examine the relationship between innovation and alternative forms of exit (closure, merger, acquisition) among Dutch manufacturing firms, and find that product and process innovations have mutually reinforcing negative effects on the probability of exit. Ortega-Argiles and Moreno (2007) using data on Spanish firms also find that both product and process innovation lead to a reduction in failure rates for smaller firms, although only process innovation is significant for larger firms. Other recent evidence for a very large panel of Australian firms, however, suggests that failures in more radical innovation projects may actually increase the probability of exit (Buddelmeyer et al., 2010).

Innovation of any given type – product or process, radical or incremental – can, however, be undertaken in very different ways with implications for the quality of innovation outputs, the riskiness of the activity, and the potential for organisational learning and strategy reformulation (Astebro and Michela, 2005). This suggests the possibility that survival and exit may be contingent not only on the type of innovation which firms are undertaking but also on *how* firms are undertaking that innovation, i.e. the nature of firms' innovation strategies. More specifically, we consider here three elements of firms' innovation strategies which may cetirus paribus moderate the relationship between any given type of innovation and survival. First, we examine whether having external linkages as part of firms' innovation strategy influences the innovation-survival relationship. Partnering strategies, for example, may allow firms to share risk in the innovation process, accelerate or upgrade the quality of the innovations made (Powell, 1998), better appropriate the returns from innovation (Gemser and Wijnberg, 1995), or exploit potential complementarities between internal and external knowledge resources (Roper et al., 2008). Partnering in innovation may also generate learning effects which influence future innovation outcomes (Love et al., 2011). Second, we consider whether the receipt of public support for innovation moderates the innovation-survival relationship. Receiving public support for innovation may help firms to de-risk or enhance their innovation activity with potential implications for survival (Ebersberger, 2011). Finally, we consider whether the use of intellectual property (IP) protection – which may enhance the anticipated and actual returns from innovation - influences the impact of innovation on survival.

Our empirical analysis is based on data from the Third UK Community Innovation Survey, which relates to firms' innovation activity over the 1998 to 2000 period, matched with longitudinal company registry data on survival. We use Cox proportional hazard models and related probit models to explore the relationship between firms' innovation strategy choices and survival (Cader and Leatherman, 2011). Following Buddelmeyer et al. (2010) our data enables us to explore the impact of innovation strategy choice on survival for a large representative group of firms rather than adopting either an industry-specific (Bayus and Agarwal, 2007; Christensen et al., 1998; Colombo and Delmastro, 2001), or cohort approach from which it may be more difficult to generalise (Bayus and Agarwal, 2007).

Our analysis makes three main contributions. First, we extend existing empirical analyses of the innovation-survival relationship to consider the effects of firms' innovation strategy choices on survival. This integrates currently disparate literatures on public support for innovation, partner-based innovation strategies and intellectual property within a common empirical framework. Second, our analysis extends the existing literature on innovation partnering beyond its direct implications for short-term innovation outputs to consider its impact on longer-term business outcomes. Finally, our analysis suggests the importance of survival additionality – the effect of public subsidies for innovation on survival - with implications for innovation policy formulation and evaluation.

The rest of paper is organised as follows. Section 2 reviews previous studies of the innovation-survival relationship and Section 3 develops a number of related hypotheses. Section 4 provides an overview or our data and empirical approach. Section 5 describes the key results. Section 6 briefly reports robustness tests and Section 7 discusses the main strategic and policy implications of our results.

2. REVIEW OF RELATED LITERATURE

Four main conceptual perspectives underlie studies of the links between innovation and survival. The first, relates to the efficiency effects of innovation. Here, the line of argument, which either implicitly or explicitly reflects the notion of entrepreneurial learning (Jovanic, 1982), runs that as firms become more mature, innovation may lead to efficiency improvements and higher productivity which then reduces the probability of failure: 'Firms that obtain innovations improve their efficiency, which makes them fitter to survive' (Esteve-Perez and Manez-Castillejo, 2008, p. 234). Consistent with the liability of newness (Stinchcombe, 1965), there is some evidence to support the efficiency-effect model (Colombo and Delmastro, 2001; Doms et al., 1995; Ortega-Argiles and Moreno, 2007) although some studies find no firm age effect on failure probability (Banbury and Mitchell, 1995).

The second conceptual approach to the innovation-survival relationship, derives from the resource-based view and argues that innovation is the route by which firms create inimitable assets, and so achieve sustainable competitive advantage (Esteve-Perez and Manez-Castillejo, 2008)[1]. This focuses attention on the nature of the innovation activity which firms are undertaking, and the accumulation of innovative resources as firms become more mature. Ortega-Argiles and Moreno (2007), for example, focus on the content of firms' innovation activity differentiating between the survival effects of product innovation, which involves new materials, components or design elements, and process changes which involve new machinery or improve flexibility[2]. Alternatively, in their analysis of Australian firms, Buddelmeyer et al. (2010) distinguish between the survival impacts of radical (patent applications) and incremental (trade mark, design applications) innovation activity, finding that radical innovation activity increases the probability of failure while incremental innovation activity is associated with lower failure probability. Banbury and Mitchell (1995), however, find no direct effect on failure probability from incremental innovation in the cardiac pacemaker industry in the US.

A third, and related, perspective derives from contingency theory, and argues that appropriate strategy decisions depend strongly on the market

[1] Ortega-Argiles and Moreno (2007).
[2] In their empirical analysis product innovation incorporating new design elements and process change involving new machinery prove most powerful in promoting firm survival
(Ortega-Argiles and Moreno, 2007, Table 3).

environment in which a firm operates (Scott, 1982)[3]. Typically adopted in studies of survival in individual sectors (Bayus and Agarwal, 2007; Christensen et al., 1998; Colombo and Delmastro, 2001)[4], this approach focuses on firms' strategic decisions such as the relative timing of technological developments, and the technological complexity of new product offerings. Bayus and Agarwal (2007), for example, consider the role of firms' technology strategies on survival in the personal computer industry from 1974 to 1995. Christensen et al. (1998) in their study of the US disk drive industry over the period 1975 to 1990 also consider external factors such as development of a dominant design alongside resource and technology indicators internal to the firm. Industry structure indicators have also been considered with some evidence of an inverted U-shape relationship between market density and failure (Banbury and Mitchell, 1995; Bayus and Agarwal, 2007), and evidence that higher concentration – as measured by the Herfindahl index – is associated with increased failure rates (Colombo and Delmastro, 2001). Both market growth and market size, however, seem to have little significant effect on failure (Banbury and Mitchell, 1995) with one study saying the 'conclusion that emerges most powerfully from this study is that variables related to managerial choice, rather than factors in the outside environment that are beyond the control of managers, were the primary factors driving firm survival' (Christensen et al., 1998, p. S208).

Innovation is, of course, not the only factor which contributes to survival. Firm size, for example, has been used extensively as an indicator of firms' resources, reflecting economies of scale, diversification, managerial capabilities and/or greater access to external resources such as finance or labour (Esteve-Perez and Manez-Castillejo, 2008). The evidence suggests that ceteris paribus larger plants, with greater internal resources than their smaller counterparts are less likely to fail (Bayus and Agarwal, 2007;

[3] Christensen et al. (1998) describe this as an 'integrative perspective'.
[4] Locational factors have also been considered in some studies. A rural location is found to reduce failure rates in Germany by Bruderl and Schussler (1990), while Colombo and Delmastro (2001) find significantly higher failure rates in less developed Southern regions of Italy.

Colombo and Delmastro, 2001; Doms et al., 1995; Esteve-Perez and Manez-Castillejo, 2008; Ortega-Argiles and Moreno, 2007). Investment may also be positively related to survival due either to flexibility or efficiency effects. Doms et al. (1995), for example, explore the impact of capital investment on survival and firms' intensity of use of advanced manufacturing process technologies (e.g. robotics, automated materials handling systems, flexible manufacturing systems). Both prove positively related to productivity and negatively related to failure (see also Colombo and Delmastro, 2001; Esteve-Perez and Manez-Castillejo, 2008). Other studies have also suggested that survival may be positively linked to exporting as exporters have relatively high productivity (Esteve-Perez and Manez-Castillejo, 2008; Melitz, 2003)[5].

All three perspectives considered so far emphasise survival as the continuation of the firm, and failure as dissolution. A fourth, organisational, perspective emphasises, however, that the closure of a business unit may not necessarily reflect any lack of profitability or sustainability in a business unit's activities but may instead reflect broader organisational changes. Merger or acquisition, for example, may lead to the effective closure of some business units (Cefis and Marsili, 2012). Similarly, within a business group, closure of a business unit may be the result of a re-organisation of productive activity. If, as we might anticipate, the costs of closure of group-owned plants are reduced due to the greater efficiency of transfer of intellectual and capital assets within the group rather than disposal this would ceteris paribus increase the probability of closure of group-owned plants. Evidence from a number of studies suggests that this is indeed the case (Colombo and Delmastro, 2001; Lieberman, 1990; Mata et al., 1995) with foreign ownership also linked to higher failure rates (Ortega-Argiles and Moreno, 2007).

[5] Banbury and Mitchell (1995) argue rather differently focussing not on productivity but instead that innovation may lead to survival primarily through its impact on market share. Others have suggested the liability of senescence as maturity leads firms to get locked into particular technological trajectories (Hannan, 1998).

3. HYPOTHESES

Firms' decision to invest in innovation depends on expected post-innovation returns, which will themselves depend both on firm capabilities and the market environment (Du et al., 2007). Firms which do decide to innovate in any given period then need to make choices about the nature of the innovation in which they are going to invest: product, process or both; radical, incremental or a combination. The type of innovation will determine the riskiness of the activity, reflecting the technological complexity of the project as well as commercial concerns about sales, profitability and potential competition (Cabrales et al., 2008; Keizer and Halman, 2007). Technological innovation risks are associated primarily with the potential failure of development projects to achieve the desired technological or performance outcomes, an inability to develop a solution which is cost-effective to manufacture/deliver (Astebro and Michela, 2005), or issues around project development time (Menon et al., 2002, p. 308-309)[6]. Market-related innovation risks have a commercial dimension linked directly to the demand for the innovation but may also involve issues around rivalry or appropriability conditions[7]. Market rivalry and competitors' responses may also play a critical role in shaping market-related innovation risks. Rivals' new product announcements may reduce returns (Fosfuri and Giarratana, 2009), for example, while appropriability conditions may shape firms' ability to benefit from new innovations and therefore their appropriate market strategy (Leiponen and Byma, 2009)[8]. The technological and market-related elements of innovation risk are not independent, however,

[6] In terms of development time, for example, it has been suggested that compressed development time may necessitate overly rapid decision making, reducing innovation quality (Zhang, et al., 2007), with potentially negative effects on post-innovation returns (Bower and Hout, 1988).

[7] Astebro and Michela (2005), for example, emphasize demand instability as one of three main factors linked to reduced innovation survival in their analysis of 37 innovations supported by the Canadian Inventors Assistance Programme. The other predictors of innovation survival identified by Astebro and Michela (2005) are 'technical product maturity' and 'entry cost and price'.

[8] Esteve-Perez and Manez-Castillejo (2008) suggest that firms operating in more innovative industries are more likely to fail, and there is some evidence that industry concentration may also increase failure rates (Colombo and Delmastro, 2001).

as Keizer and Holman (2007, p. 30) suggest: 'Radical innovation life cycles are longer, more unpredictable, have more stops and starts, are more context-dependent in that strategic considerations can accelerate, retard or terminate progress, and more often include cross-functional and or cross-unit teamwork. Incremental projects are more linear and predictable, with fewer resource uncertainties, including simpler collaboration relationships'[9]. Iyer et al. (2006) also stress the impact of market context, arguing that in some situations, such as that in developing countries, incremental innovation might represent a more appropriate strategy than radical innovation (Hang et al., 2010).

Once a decision is made on the type of innovation to undertake firms also need to decide how they are going to undertake their innovation project. Here, we focus on three aspects of this innovation strategy decision: whether the firm choses to partner with other organisations as part of its innovation activity; whether the firm obtains public support for its innovation; and, whether it uses IP protection strategies as a means of maximising the returns from its innovation investments. These are clearly not the only dimensions of innovation strategy but are all important from a public policy perspective.

Adopting an innovation strategy involving partnering may help a firm mitigate the risks associated with any given profile of innovation and allow cost sharing. For example, Powell (1998) stresses the potential value of openness in stimulating creativity, reducing risk in the innovation process, accelerating or upgrading the quality of the innovations made, and signalling the quality of firms' innovation activities. Innovation partnerships may also increase firms' access to technology developed elsewhere (Niosi, 2003), and their ability to appropriate the returns from innovation (Gemser and Wijnberg, 1995). Moreover, having more extensive networks of partners is likely to increase the probability of obtaining useful knowledge from outside the firm (Leiponen and Helfat, 2010). For example, by adopting a partner-based innovation strategy, small start-up firms can

[9] See also Leifer et al. (2000).

overcome the liabilities of age and size by tapping into partners' resource networks, distribution channels and customer bases. In return, large incumbent firms can access small start-ups' technology and make use of external knowledge and expertise (Powell and Brantley, 1992; Gassmann and Keupp., 2007).

Empirical evidence also points to the conclusion that knowledge gained from alternative sources tends to be complementary and also complementary to firms' internal knowledge (Roper et al., 2008)[10]. Having more partners may therefore both increase the probability of obtaining valuable knowledge and maximise potential knowledge complementarities. Innovation partnering also has some potential disadvantages. For example, there may be difficulties with managing and protecting intellectual property rights in relationships with partners. Having a larger number of innovation partners may also lead to problems with the management and monitoring of these relationships (Simon, 1947, Audretsch and Stephan, 1996; Sieg et al. 2010), and the simultaneous absorption of knowledge from a number of different sources. These disadvantages are likely to increase as firms' number of partners increases with the potential for the firm to reach a 'saturation level' where the innovation benefits of external linkages are maximised. Beyond that level, the addition of another innovation partner will result in diminishing the innovation performance of the firm as the attention of managers is diluted between large numbers of different knowledge sources. Koput (1997) and Laursen and Salter (2006) reflect this in their notion of 'over-searching'.

Importantly, partnering in firms' innovation strategies has also been shown to affect innovation performance (Hoang and Rothaermel, 2005; 2010; Rothaermel and Deeds, 2006), with potential implications for growth and survival outcomes (Laursen and Salter, 2006; Lichtenthaler and Ernst, 2009). Standardising for any given level of innovation activity, the

[10] Research and development (R&D) can be seen also as a proxy of absorptive capacity of firms (Cohen and Levinthal, 1989). For example, in Rosenberg's (1990) view firms' own research capability is seen as indispensable for monitoring and evaluating research that is performed elsewhere.

implication is that adopting a partnering approach may positively moderate the performance benefits of that innovation activity. This suggests:

Hypothesis 1. Partnering in innovation strategy

Adopting a partnership-based innovation strategy will *ceteris paribus* positively moderate (i.e. enhance) the effect of any given profile of innovation outputs on survival.

Innovating firms also need to decide whether or not to seek public support for their innovation activity, with considerable evidence that such support can have positive effects on new product quality and the speed of innovation processes (Hsu et al., 2009; Licht, 2003; Luukkonen, 2000). For example, Alecke et al. (2012) suggest that among firms receiving research and development (R&D) subsidies in East Germany the probability of making related patent applications – an indication of innovation quality – rises from 20 to 40 per cent. Public support may also generate input additionality, increasing the amount of resources a firm is able to devote to an innovation project (Hsu et al., 2009). Among East German firms, for example, Czarnitzki and Licht (2006) find that R&D subsidies raised R&D intensity (i.e. R&D spend per unit of sales) from 2.3 per cent to 6.4 per cent with potentially significant strategic effect. Standardising for a given profile of innovation activity, both results suggest that the resource augmenting impact of public innovation support may positively moderate the performance benefits of that innovation, suggesting:

Hypothesis 2. Public innovation support

Ceteris paribus receiving public support as part of an innovation strategy will positively moderate (i.e. enhance) the effect of any given profile of innovation outputs on survival.

The firm-level benefits of innovation will also depend on appropriation. Intellectual property (IP) protection may help firms to maximise rents from innovation both by preventing imitation (Gans and Stern, 2003;

Venkataraman, 1997), and creating opportunities for firms to profit from their innovation through licensing (Grindley and Teece, 1997), strategic partnerships or alliances (Cohen et al., 2000). Ownership of intellectual property may be helpful in attracting potential partners, and makes it easier for IP holders to enter into strategic partnerships on favourable terms (Cohen et al., 2000; Hagedoorn et al., 2005). Patents may also play an important role in facilitating small start-up firms' access to providers of early stage capital, including business angels, venture capitalists, financial institutions (Shepherd et al., 2000; Zacharakis and Shepherd, 2005; Franke et al., 2006; Khanin et al., 2009). Other forms of IP protection aside from patents also remain important. The use of trademarks and industrial designs, for example, enable customers to identify a product/service of a particular company. Trade secrets and confidentiality agreements may also supplement a patent when inventors believe that patent protection is too costly relative to the value of their invention (Hanel, 2006; Hanel, 2008). Again, standardising for any given profile of innovation activity, the potential is therefore that firms' IP protection strategies may positively moderate the performance benefits of that innovation activity, i.e.:

Hypothesis 3. Intellectual property strategy

Ceteris paribus actively protecting intellectual property as part of an innovation strategy will positively moderate (i.e. enhance) the effect of any given profile of innovation outputs on survival.

4. DATA AND METHODS

Our analysis is based on data from the Third UK Community Innovation Survey (CIS3), which covers firms' innovation activity for the period 1998-2000, matched with survival information taken from the FAME database for the period 2000 to 2008[11]. The CIS3 is an enterprise-based survey with the

[11] FAME – or Financial Analysis Made Easy – is a commercial database provided by Bureau van Dijk. It provides electronic access to UK company registry data and useful search tools in terms of previous company names etc. See https://fame.bvdinfo.com.

sample drawn from the UK Office for National Statistics Inter-departmental Business Register (IDBR). For smaller firms each enterprise is likely to be a single firm; for larger firms an enterprise may be a business unit although to be included in the CIS3 this required a separate legal identity (Stones, 2001). CIS3 focussed on businesses with 10 or more employees in Sections C-K of the Standard Industrial Classification (1992) which included manufacturing, construction and marketed services across all UK regions[12]. The survey achieved an overall response rate of 42 per cent (8,172 responses) and provides information on enterprises' product and process innovation activities and a range of other information on sources of information and co-operation for innovation, barriers to innovation, protection methods for innovation, public support for innovation as well as data on a number of enterprise characteristics.

Matching information on firms' survival status over the 2000 to 2008 period was gathered from the FAME database during the November 2012 to January 2013 period. CIS3 respondents were matched on the basis of business name and address. Search facilities on FAME allowed us to identify both subsidiary companies and those businesses which had continued but changed their names, addresses or owners. We were ultimately able to match 6,528 businesses, around 79.8 per cent of the original CIS3 respondents. Unmatched companies were typically smaller, private businesses with no Companies House registration – and therefore no company registration data on FAME. Industrial data on the CIS3 suggested that unmatched firms were predominantly in transport, financial services and real estate, with higher proportions of matches in the production industries[13]. Relative to CIS3 our estimation sample is therefore

[12] The survey excluded from these sectors wholesale and retail trades, repair of motor vehicles etc. (SIC 51) and hospitality sectors (Section H) (Stones, 2001).

[13] Unmatched percentages were as follows (overall 20.2 per cent): Mining and quarrying, 14.2 per cent; Food, clothing, wood, paper, publications, 17.8 per cent; Fuels, chemicals, plastics metal, 13.8 per cent; Electrical and optical equipment, 12.5 per cent; Transport equipment, 15.7 per cent; Manufacturing not elsewhere classified, 13.3 per cent; Electricity, gas and water supply, 17.0 per cent; Construction, 23.3 per cent; Wholesale & commission trade 15.4 per cent; Transport, storage and communications, 23.9 per cent; Financial intermediation, 26.4 per cent; Real estate, renting and business activity, 31.2 per cent.

biased towards the production industries, and away from services. It is notable, however, that in CIS3 itself the difference in the proportion of 'innovation active' firms in production and construction (48 per cent) and distribution and other services (45 per cent) is relatively similar (Stones, 2001), suggesting that any overall bias in the results is likely to be limited.

The dependent variable in our analysis is a binary indicator of whether an individual firm was continuing to trade regardless of changes in name, address or ownership (Buddelmeyer et al., 2010). Firms were said to have failed when their status was reported as either 'dissolved' 'dormant', 'in liquidation' or 'in administration' on the FAME database (Smallbone, 1998). Overall 79.5 per cent of firms which were matched in 2000 survived until end-2008. Failure rates among non-innovators were marginally higher than those among innovating firms with 87.9 per cent of innovating firms surviving at end 2008 compared to 78.4 per cent of non-innovators (Figure 1).

We estimate the failure hazard rate using a Cox proportional hazard model (Cox, 1972). This model does not require any restrictive assumptions regarding the baseline hazard, such as a Weibull or lognormal specification. This is appropriate for our purposes, as our main interest is not in the estimation of the baseline hazard function, but in the effect of partnership-based innovation etc. on the innovation-survival relationship. In the Cox model, the failure hazard for firm i at time t, conditional on having survived up to that point, is denoted as $h_i(t|x)$ and can be written as follows:

$$h_i(t|x) = h_0(t)\exp[\beta x_{it}] \quad (1)$$

Where $h_0(t)$ is the baseline hazard function (the parametric form of which is unspecified), β is a vector of the regression parameters, and x_{it} is a vector of covariates for firm i. To verify the suitability of the proportional hazard model we first test the proportional hazard assumption – based on the existence of non-zero slopes in a regression of the Schoenfeld residuals on functions of time (Grambsch and Therneau, 1994). We also check proportionality by including time-dependent covariates in the model. The result shows that all of the time-dependent variables are insignificant either collectively or individually therefore supporting the assumption of proportional hazard.[14]

In our analysis we measure innovation using four different innovation indicators derived from the CIS3 database: a binary indicator of whether or not firms introduced a new or improved product or service during the 1998 to 2000 period; a similar binary indicator relating to process innovation; and, two indicators relating to the percentage of firms' sales of new and new or improved products. To test Hypothesis 1 relating to the moderating effect of innovation partnering we then create a dummy variable p_i which takes value 1 if a firm engaged with partners in its innovation strategy and zero otherwise. If I_i is an innovation indicator we then include in the regressors in the Cox model the terms:

$$\beta_1 I_i p_i + \beta_2 I_i (1 - p_i)$$

where Hypothesis 1 suggests that $\beta_1 > \beta_2$, i.e. that innovation has a larger impact on survival when it involves partnering than otherwise. Essentially similar logic applies to testing subsequent hypotheses. In the case of Hypothesis 2, relating to public support for innovation, CIS3 provides information on whether a firm received innovation support from either local, national or EU sources. We amalgamate these to create a binary indicator of whether or not a firm received any public support for innovation. For Hypothesis 3, relating to IP protection, we construct a binary indicator which takes value 1 where a firm used any type of legal or strategic IP protection strategy and zero otherwise.

We also include in each model a series of control variables relating to business size, age, organisational position and market orientation which have proved significant in other studies of survival (Annex 1). We measure

[14] The proportionality test result for each model is provided upon request.

employee skills by the percentage of employees with a degree in any subject. Firm size is measured by employment in 2000, and firm age is measured by the number of years between incorporation and 2001 (Loderer and Waelchli, 2009).[15] To control for any sectoral effect on firm survival, we also include a set of twelve industry dummy variables.

5. EMPIRICAL RESULTS

Table 1 presents descriptive statistics and correlations of all variables included in our analysis. Baseline models of the effects of the different innovation indicators on survival over the 2001 to end-2008 period are reported in Table 2. Each of our innovation indictors – relating to both product and process change – is associated with a decrease in the probability of failure. These effects are, however, significant only for process innovation and sales of improved products. Our baseline estimates are consistent with the general result in the innovation-survival literature that innovating firms generally have a higher survival probability than non-innovating firms. More specifically, our results on incremental product or service change reflect those of Buddelmeyer et al. (2010) for Australian firms, while the impact of process changes reflects the Spanish results of Ortega-Argiles and Moreno (2007). Other control variables in the baseline models also have the anticipated effects. Ceteris paribus older and smaller firms in our sample are generally less likely to fail (Bayus and Agarwal, 2007; Colombo and Delmastro, 2001; Doms et al., 1995; Esteve-Perez and Manez-Castillejo, 2008; Ortega-Argiles and Moreno, 2007). However, businesses which are part of larger groups prove less likely to fail in any given period in contrast to some earlier results (Colombo and Delmastro, 2001; Lieberman, 1990; Mata et al., 1995). Firms facing financing constraints are also more likely to fail (Musso and Schiavo, 2008), while we find little evidence that workforce skills, or geographic market orientation have any significant survival effect (Table 2).

[15] Data on incorporation date is taken from FAME rather than CIS3 as no specific data on incorporation is available in CIS3. Business vintage has been found to be an important determinant of innovation activity in other studies.

Hypothesis 1 relates to the impact of partnering as part of firms' innovation strategy and suggests that engaging with external partners may positively moderate (enhance) the survival effects of innovation. As Table 3 suggests, comparing the coefficients with and without partnering, we find no support for this proposition. Instead, in both Model 2, relating to incremental product or service innovation, and Model 4, relating to process change, conducting partner-based innovation *negatively* moderates the survival effect of innovation. These negative moderation effects are relatively weak, however, with Wald tests suggesting no significant differences between coefficients with and without innovation partnering. Nonetheless, this negative result – which means that firms adopting a partnering innovation strategy were more likely to fail than those conducting similar innovation on their own - contrasts strongly with other evidence which suggests that partnership-based innovation can be faster and tends to generate 'better' and more complex innovations than 'closed' innovation (Powell, 1998). Partnership-based innovation may also, however, involve sharing the revenue streams derived from innovations, reducing the survival effect of any given innovation. Or, in longer term, one-time innovation partners may become competitors in the same marketplace influencing survival through a competition effect (Chowdhury and Chowdhury, 2001).

Another element of innovation strategy which previous studies have shown to have positive behavioural and innovation output effects is the receipt of public support for innovation (Afcha Chavez, 2011; Clarysse et al., 2009; Falk, 2004; Hewitt-Dundas and Roper, 2009). Hypothesis 2 therefore suggests that the receipt of public support will positively moderate the survival effects of innovation. Table 4 reports Cox hazard models including the public support effects and comparing the coefficients with and without public support provides some evidence for the proposition: in terms of product innovation (Model 1) and sales of improved products (Model 2) moderating effects are positive and statistically significant. In terms of process innovation (Model 4) there is also evidence of a positive moderating effect from public support although this effect is statistically weaker. These results suggests a 'sustained additionality' effect, with public innovation support having a positive impact on firms' survival over and above any short-term or project specific innovation effects. This is illustrated in Figure 2 which shows the predicted survival curves from Model 1 in Table 4, distinguishing by the receipt of public support for innovation. The predicted survival curves suggest that public support for innovation (over and above the effect of innovation itself without public support) increases the survival rate by 0.5 per cent after 3 years, 1.2 per cent after 5 years and 2.8 per cent after 8 years. In terms of failure rates (again relative to innovation without public support), public support reduces the probability of failure by 19.4 per cent after 3 years, 19.0 per cent after 5 years and 18.4 per cent after 8 years.

Our final hypothesis relates to the possibility that IP protection positively moderates the innovation-survival relationship. We find little support for this hypothesis in Table 5 when we compare the coefficients with and without IP protextion. The negative coefficients in Models 1 (relating to product innovation), 2 (relating to sales of improved products) and 4 (relating to process innovation), suggest an increased probability of survival. As with innovation partnering, however, the positive effect is in statistical terms relatively weak. A possible explanation for this is that it is the efficiency rather than the simple adoption of IP protection in the innovation process that matters to a firm's survivability. Prior studies find that effective use of IP rights in the innovation process enhances a firm's potential for generating future revenue, market control or developing a strong market position (Shane, 2001; Vinig and De Haan, 2002; Nerkar and Shane, 2003).

6. ROBUSTNESS TESTS

For each of our hypotheses we examine the moderating role of firms' innovation strategy choices on the innovation-survival relationship using four different innovation measures. These innovation measures reflect different dimensions of firms' product and process innovation. The rationale here stems from Buddelmeyer et al. (2010) who find that different types of innovative activity have varying implications for survival. Although our baseline models suggest that in our data each type of innovation has a positive effect on survival, the results of Buddelmeyer et al. (2010) do suggest that we might expect different moderating relationships. In fact, for innovation partnering, public support and IP protection we observe moderating effects which are consistent in sign but which do differ in statistical significance.

The negative moderating effects we find from partnership-based innovation on the innovation–survival relationship are unanticipated. We conducted two robustness checks. First, following Laursen and Salter (2006) we examined the moderating effect of innovation partnering using a count variable representing the number of types of innovation partners with which firms were working. This type of variable has been widely used to represent the breadth or diversity of firms' innovation partnering[16]. We included in the Cox models interactions of this count-based measure with each of the innovation variables. The results suggest very similar patterns to that in Table 3, i.e. partnering in innovation has weak negative moderating effects on the innovation-survival relationship. Estimating similar relationships using Probit models for survival over the 2000 to 2008 period also suggests identical results. Using Probit models to measure the moderating effects of public innovation support and IP protection also suggests similar results to the Cox models in Tables 4 and 5.

7. DISCUSSION

Our results emphasise the survival effects of innovation, highlighting in particular the positive effect of incremental product and service change and process change on the survival of UK firms (Table 6). However, we find little support for the hypothesis that either partnering in innovation or

[16] In the CIS3 nine different types of external innovation partners are identified including, for example, customers, suppliers and universities. The count-based measure of the breadth of firms' innovation partnering therefore takes values 0 where firms have no external partners to 9 where firms have links with all nine types of external partner.

engaging in intellectual property protection positively moderates the innovation-survival relationship. Indeed, we find weak negative moderating effects in each case; i.e. innovation in firms engaging in innovation partnering and/or in IPP innovation has a smaller survival effect than otherwise. We find relatively strong support, however, for the proposition that receipt of public support for innovation does positively moderate the innovation-survival relationship (Table 6). Firms receiving public support for their product or service innovation are around 2.7 per cent more likely to survive over eight years than firms which conduct innovation without public support (Table 4).

The policy literature on public support for innovation focuses attention on 'additionality', i.e. the extent to which firms given public support change their behaviours and/or undertake activities that they would not have taken without support (Buiseret et al., 1995; Georghiou, 2004; Luukkonen, 2000). Typically additionality is evaluated within the timescale of an innovation project, or in relation to a subsequent period over which an innovation is commercialised. Our results suggest, however, that there is also a need to consider the longer term effects of public innovation support on survival, or what we might call survival additionality. Ignoring this longer-term survival additionality effect is likely to lead evaluators to under-estimate the beneficial effects of innovation support. But, how might any survival additionality effect be working? Public support for innovation may, for example, enable firms to introduce new, higher quality, products or accelerate their innovation processes (Luukkonen, 2000). Innovations – enabled by public support – if more novel, more complex or more successful than otherwise - may lead to a quality ladder effect, and more successful innovation in subsequent periods (Grossman and Helpman, 1991)[17]. A second mechanism through which survival additionality may be working is through its effect on the innovation value of firms' in-house knowledge investments. This effect may occur where public support for R&D or innovation has a legacy of cost or quality impacts on the in-house

[17] Such quality ladder effects have been shown to be important in determining the duration of exporting (Chen, 2012).

R&D resources which a firm has available (Hsu et al., 2009; Luukkonen, 2000; Mansfield and Switzer, 1984). A third mechanism through which survival additionality may occur is through its impact on skills. For example, firms undertaking publicly supported innovation activities may develop new or improved skill sets which add value to subsequent innovation projects (Leiponen, 2005; Sakakibara, 1997). It is also possible to envisage mechanisms through which survival additionality may occur even where there is no induced change in innovation behaviour[18]. Here, public support for innovation simply introduces an element of financial slack into the firm, increasing liquidity and reducing leverage with potential implications for survival (Holtzeakin et al., 1994).

The potential for survival additionality has implications for the justification and evaluation of public innovation support. Public intervention to support innovation is often justified in terms of the positive externalities of innovation, and firms' tendency to under-invest in innovation relative to the social optimum. The extent of any positive externalities from innovation will, however, depend on firms' survival. The potential for survival additionality has clear implications for the persistence of externality effects, and suggests that excluding such effects from any evaluation is likely to under-estimate the social value of public innovation support. Less clear from our analysis is the mechanism through which survival additionality occurs, and in particular whether this is through its effect on innovation outcomes or behaviour or through a liquidity effect. Distinguishing between these mechanisms empirically represents an interesting avenue for future research.

Our study is however subject to a number of limitations. First, the use of CIS data limits the dependent and independent variables we can study, though the dataset does give us detailed information relating to the innovation activities of a comprehensive sample of UK businesses. Future research could complement and extend our study by examining samples of

[18] In the policy literature this would be referred to as zero additionality or deadweight.

companies at a more fine-grained level. Second, our use of financial accounts data here focuses on a rather simplistic success-failure distinction. It would also be interesting to explore the implications of firms' innovation strategy choices for other types of corporate changes such as shifts in ownership or governance (Cefis and Marsili, 2012). Third, in this study we look only firms' survivability. However, it would be interesting to study how firms' innovation strategies affect the output of a firm's innovation and other performance indicators, such as sales growth and profitability over time. Fourth, we focus on multiple industries, although we controlled for a number of possible sector effects on firm survival. This leads us to use general measures for innovation partnership and IP protection strategies. As the type and the nature of firms' innovation strategies may vary across industries, however, an interesting line of research would be to explore these cross industry differences using industry-specific measures for firms' innovation strategies. This would also help in terms of controlling for any tendency for firms in some sectors to adopt more innovative strategies (or strategies which have a particular character) because of competition and failure risks within particular sectors. Fifth, we focus here on three dimensions of innovation strategy which are particularly interesting from a public policy standpoint. Other elements of corporate strategy around exporting, training growth orientation may also be worth considering in future studies. Finally, the generalizability of our finding may be limited by the institutional setting of our study, specially its focus on the UK. Future research should verify the generalizability of our findings across institutional environments.

Table 1: Descriptive statistics and variable correlations

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Survival time by month (2000-08)															
2. Product innovation	.03														
3. Process innovation	.035	.38													
4. % of sales of improved products	<-.01	.50	.20												
5. % of new product sales	.03	.54	.25	.13											
6. Public support	.18	.20	.15	.10	.12										
7. Open innovation	.01	.33	.29	.19	.17	.18									
8. IP protection	<.01	.24	.19	.14	.14	.12	.21								
9. Business subsidiary	.02	.11	.07	.03	.02	-.06	.14	.14							
10. Employee skills	-.07	.19	.05	.03	.24	.09	.01	.10	.06						
11. Relative industry sales	-.01	<-.01	-.01	.02	<.01	-.04	.01	.04	.07	.08					
12. Firm age (in 2000)	.04	-.01	.02	-.04	-.09	-.01	.06	.03	.18	-.15	-.06				
13. Firm size	.02	.17	.18	.11	.01	-.02	.16	.13	.27	<.01	.02	.12			
14. International market	<.01	.18	.08	.05	.15	.14	.17	.18	.08	.24	.14	-.04	.06		
15. Organisational rigidity	.05	.03	.01	.01	-.01	.03	.01	.03	.05	-.04	.02	.05	.04	-.02	
16. Lacking in finance	-.04	.05	.02	.03	.06	.02	.03	.11	-.02	<.01	-.02	-.04	-.04	.07	.09
Mean	62.31	0.20	0.14	3.08	4.41	0.03	0.30	0.59	0.49	7.43	89.98	16.24	1.09	0.12	0.31
S.D.	23.71	0.40	0.35	12.35	16.14	0.18	1.11	0.49	0.50	13.39	161.41	18.08	0.28	0.33	0.60

Notes and sources: N=4,354. Correlation coefficients greater than .05 in absolute terms are significant at the 5 per cent level. Sources: UK CIS3 and FAME.

Table 2: Cox proportionate hazard estimates of probability of failure: Baseline models

	Model 1		Model 2		Model 3		Model 4	
	Coef.		Coef.		Coef.		Coef.	
Product innovation	-0.14							
% sales of new/improved products			-0.09	**				
% of new product sales					-0.05			
Process innovation							-0.42	***
Business subsidiary	-0.14	*	-0.12		-0.12		-0.13	*
Employee skills	<0.01		<0.01		<0.01		<0.01	
Relative industry sales	<-0.01		<-0.01		<-0.01		<-0.01	
Firm age (in 2000)	-0.02	***	-0.02	***	-0.02	***	-0.02	***
Small or medium company	-0.62	***	-0.61	***	-0.62	***	-0.57	***
International market	-0.06		-0.06		-0.07		-0.06	
Organisational rigidity	-0.06		-0.07		-0.06		-0.06	
Lacking in finance	0.44	***	0.43	***	0.43	***	0.44	***
Number of observations	4402		4352		4352		4402	
Equation χ^2	262.39		256.08		252.41		278.12	
Pseudo R^2	0.02		0.02		0.02		0.02	
BIC	11765.64		11606.28		11609.95		11749.91	

Notes and sources: Each model includes industry dummy variables – not reported. Observations are weighted to give representative results. * p<.10, ** p<.05, *** p<.01. Variable definitions in Annex 1. Sources: UK CIS3 and FAME.

Table 3: Cox proportionate hazard estimates of probability of failure: Innovation partnering

Independent variable	Model 1		Model 2		Model 3		Model 4	
	Coef.		Coef.		Coef.		Coef.	
Product innovation x partnering	-0.16							
Product innovation x no partnering	-0.13							
Log(% of sales of new/improved products) x partnering			-0.07					
Log(% of sales of new/improved products) x no partnering			-0.09	**				
Log(% of new product sales) x partnering					-0.05			
Log(% of new product sales) x no partnering					-0.04			
Process innovation x partnering							-0.31	*
Process innovation only x no partnering							-0.47	***
Business subsidiary	-0.14	*	-0.12		-0.12		-0.14	*
Employee skills	<0.01		<0.01		<0.01		<0.01	
Relative industry sales	<-0.01		<-0.01		<-0.01		<-0.01	
Small or medium company	-0.62	***	-0.61	***	-0.62	***	-0.58	***
Firm age (in 2000)	-0.02	***	-0.02	***	-0.02	***	-0.02	***
International market	-0.06		-0.06		-0.07		-0.07	
Organisational rigidity	-0.06		-0.07		-0.06		-0.06	
Lacking in finance	0.44	***	0.43	***	0.43	***	0.44	***
Number of observations	4402		4352		4352		4402	
Equation χ^2	262.43		256.18		252.42		278.71	
Pseudo R^2	0.02		0.02		0.02		0.02	
BIC	11773.98		11614.56		11618.32		11757.70	
Wald tests	0.04		0.10		0.02		0.61	

Notes and sources: Each model includes industry dummy variables – not reported. Observations are weighted to give representative results. * p<.10, ** p<.05, *** p<.01. Variable definitions in Annex 1. Sources: UK CIS3 and FAME.

Table 4: Cox proportionate hazard estimates of probability of failure: Public support

Independent variable	Model 1		Model 2		Model 3		Model 4	
	Coef.		Coef.		Coef.		Coef.	
Product innovation x public support	-0.52	**						
Product innovation x no public support	-0.08							
Log(% of sales of new/improved products) x public support			-0.29	**				
Log(% of sales of new/improved products only) x no public support			-0.06					
Log(% of new product sales) x public support					-0.13			
Log(% of new product sales) x no public support					-0.03			
Process innovation x public support							-0.78	***
Process innovation x no public support							-0.36	***
Business subsidiary	-0.14	*	-0.13		-0.13		-0.14	*
Employee skills	<0.01		<0.01		<0.01		<0.01	
Relative industry sales	<-0.01		<-0.01		<-0.01		<-0.01	
Small or medium company	-0.61	***	-0.61	***	-0.62	***	-0.58	***
Firm age (in 2000)	-0.02	***	-0.02	***	-0.02	***	-0.02	***
International market	-0.04		-0.05		-0.06		-0.06	
Organisational rigidity	-0.06		-0.07		-0.06		-0.06	
Lacking in finance	0.44	***	0.43	***	0.43	***	0.44	***
Number of observations	4402		4352		4352		4402	
Equation χ^2	265.84		260.54		253.73		280.32	
Pseudo R^2	0.02		0.02		0.02		0.02	
BIC	11770.57		11610.20		11617.00		11756.10	
Wald tests	3.10	**	3.63	**	1.23		1.98	

Notes and sources: Each model includes industry dummy variables – not reported. Observations are weighted to give representative results. * p<.10, ** p<.05, *** p<.01. Variable definitions in Annex 1. Sources: UK CIS3 and FAME.

Table 5: Cox proportionate hazard estimates of probability of failure: IP protection

Independent variable	Model 1		Model 2		Model 3		Model 4	
	Coef.		Coef.		Coef.		Coef.	
Product innovation x IP protection	-0.17	*						
Product innovation x No IP protection	-0.05							
Log (% of sales of new/improved products) x IP protection			-0.08	**				
Log (% of sales of new/improved products only) x No IP protection			-0.10					
Log (% of new product sales) x IP protection					-0.06			
Log(% of new product sales only) x No IP protection					0.03			
Process innovation x IP protection							-0.39	***
Process innovation only x No IP protection							-0.55	**
Business subsidiary	-0.13	*	-0.12	*	-0.12		-0.14	*
Employee skills	<0.01		<0.01		<0.01		<0.01	
Relative industry sales	<-0.01		<-0.01		<-0.01		<-0.01	
Small or medium company	-0.61	***	-0.61	***	-0.61	***	-0.58	***
Firm age (in 2000)	-0.02	***	-0.02	***	-0.02	***	-0.02	***
International market	-0.05		-0.06		-0.07		-0.07	
Organisational rigidity	-0.06		-0.07		-0.06		-0.06	
Lacking in finance	0.44	***	0.43	***	0.43	***	0.44	***
Number of observations	4402		4352		4352		4402	
Equation χ^2	263.42		256.09		253.56		278.58	
Pseudo R^2	0.02		0.02		0.02		0.02	
BIC	11772.99		11614.65		11617.18		11757.84	
Wald tests	1.09		0.01		1.24		0.45	

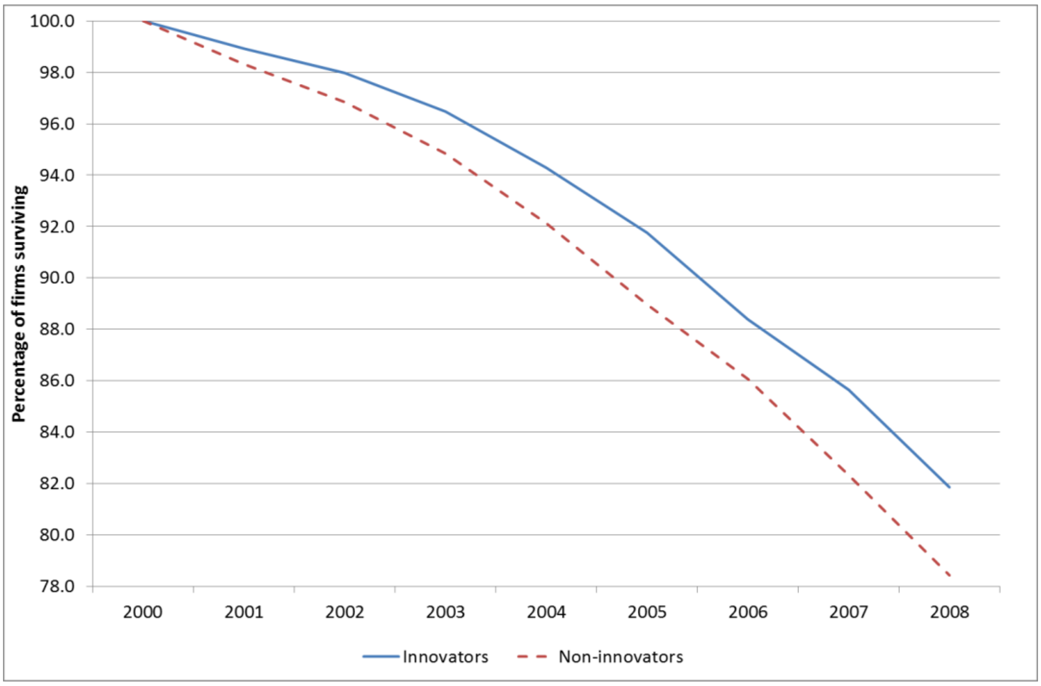
Notes and sources: Each model includes industry dummy variables – not reported. Observations are weighted to give representative results. * p<.10, ** p<.05, *** p<.01. Variable definitions in Annex 1. Sources: UK CIS3 and FAME.

Table 6: Symbolic summary of impacts on the probability of failure

Independent variable	Hypothesis and anticipated signs	Probability of Product Innovation	New and improved sales	New product sales	Probability of process innovation
Main effect from baseline model (Table 2) (- denotes decreased failure probability)		(-)	-	(-)	-
Moderating effects (- denotes reduced failure probability)					
Innovation partnering (Table 3)	H1: -	(-)	+	(-)	+
Public support (Table 4)	H2: -	-	-	(-)	-
IP protection (Table 5)	H3: -	-	+	(-)	+

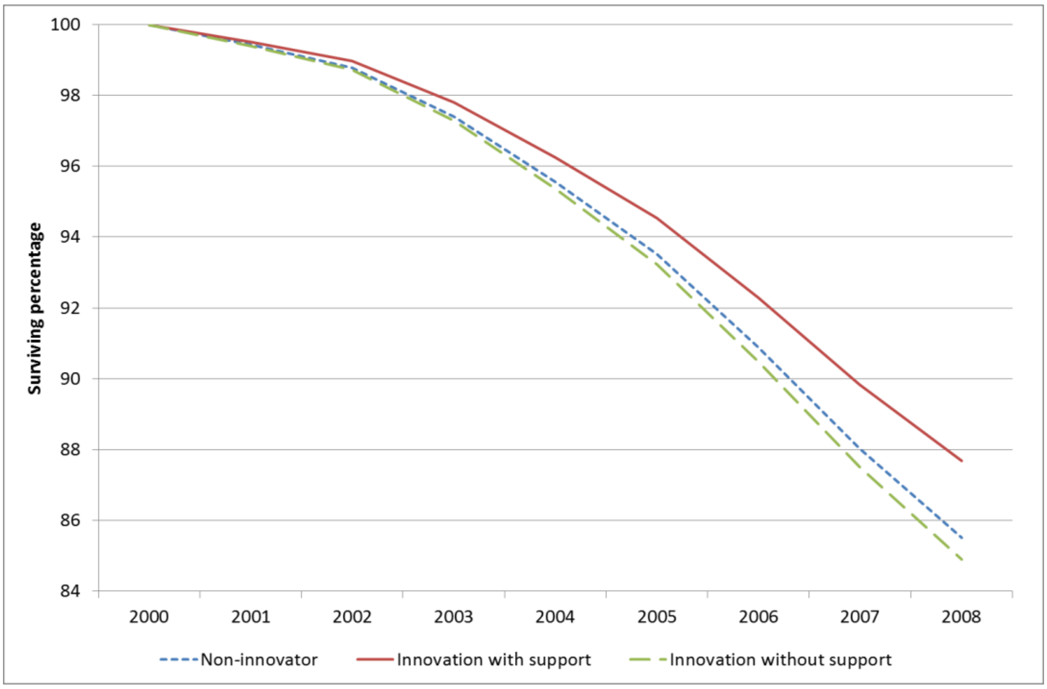
Notes: '-' ('+') denotes a negative (positive) and significant coefficient and or moderating effect; '(+)' or '(-)' denotes an insignificant and positive or negative coefficient or moderating effect respectively.

Figure 1: Proportion of surviving firms: innovators and non-innovators



Notes: Innovating firms are those undertaking either product or process innovation during the 1998 to 2000 period. Sources: Matched data from UK CIS3 and FAME.

Figure 2: Survival additionality - predicted survival rates with and without public innovation support



Notes: Innovating firms are those undertaking either product or process innovation during the 1998 to 2000 period either with or without public support. Predicted values are calculated at the mean value of all other regressors in model 1, Table 4. Source: Matched data from UK CIS3 and FAME.

Annex 1: Variable definitions

Label	Definition	Source
Survival indicator	Dummy variable taking value 1 in months when an enterprise was continuing to trade and 0 where an enterprise has failed	FAME
Innovation indicators		
Product innovation	Dummy variable taking value 1 if the enterprise introduced a new or improved product or service between 1998 and 2000	CIS3
% of sales of new/improved products	Percentage of sales derived from new and improved products, 2000	CIS3
% of new product sales	Percentage of sales derived from new products, 2000	CIS3
Process innovation	Dummy variable taking value 1 if the enterprise introduced a new or improved process between 1998 and 2000	CIS3
Moderators		
Innovation partnering	Dummy variable taking value 1 if the firm was cooperating with any innovation partners and 0 otherwise	CIS3
Public support	Dummy variable taking value 1 if the firm received innovation support from either EU, national or regional sources and 0 otherwise	CIS3
IP protection	Dummy variable taking value 1 if the firm used either strategic or legal methods of IP protection and 0 otherwise	CIS3
Control variables		
Business subsidiary	Dummy variable taking value 1 if the enterprise is part of a larger firm and 0 otherwise	CIS3
Employee skills	Percentage of the workforce with a degree level qualification	CIS3
Relative industry sales	Sales per employee relative to the (2 digit) industry average	CIS3
Small or medium company	Dummy variable taking value 1 if firm employment is less than 250 and 0 otherwise	CIS3
Firm age (in 2000)	Firm age in years measured as the time since incorporation	FAME
Organisational rigidity	Dummy variable taking value 1 if organisational rigidities within the enterprise were of ‘some’ or ‘high’ importance in innovation and 0 otherwise	CIS3
Lacking in finance	Dummy variable taking value 1 if lack of finance within the enterprise were of ‘some’ or ‘high’ importance in innovation and 0 otherwise	CIS3
International market	Dummy variable taking value 1 if enterprise is trading outside the UK and 0 otherwise	CIS3

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The Enterprise Research Centre is an independent research centre funded by the Economic and Social Research Council (ESRC); the Department for Business, Innovation & Skills (BIS); the Technology Strategy Board (TSB); and, through the British Bankers Association (BBA), by the Royal Bank of Scotland PLC; Bank of Scotland PLC; HSBC Bank PLC; Barclays Bank PLC and Lloyds TSB Bank PLC.

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