Forsaking innovation: addressing failure and innovation behaviour variety

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Abstract

This paper analyses how innovation active firms respond when innovation projects fail or are abandoned. We regard innovation as a process where firms engage in a variety of behaviours combining internal and external characteristics including their propensity to cooperate, to compete, to engage in research and development activities as well as on the composition of their knowledge base. We compare how their aggregate innovation behaviour responds when failure is experienced. Using data from the UK innovation survey, our results first highlight that failure has an effect only on specific innovation strategies, and second, when failure occurs, it can either reinforce existing behaviours or reverse them.

Keywords: Innovation failure; innovation behaviour; innovation sources; UK Innovation Survey

Word count: 6933

1. Introduction

In developing innovations, firms can commit considerable resources with no guarantee that outcomes will be commercially viable (Freeman et al., 1972). Although disputed (Castellion and Markham, 2013), rates of failure associated with innovation projects are thought to be high, with estimates ranging from 25 to 80 percent (Cozijnsen et al., 2000; Cierpicki et al. 2000; Radas and Bozic, 2012). Failure is thus a substantial part of the innovation process in firms although much of the literature has neglected its study and investigated instead the relative contribution of different sources of innovation success (Cohen, 2010). Consequently, failure remains an omitted variable in understanding the pathways to innovation.

In the broader management literature, the analysis of failure has been approached from different angles. From the organisational viewpoint, there is extensive discussion on pervasive failures that threaten organisational survival (Masden and Desai, 2010). Other studies looked instead at individual failure from an entrepreneurial perspective and the impact of this on the subsequent likelihood to succeed (Cope 2011). In line with these literatures, we look at the impact of failure on organisational processes underpinning the innovation activity and identify (small) innovation failure as an outcome that contributes to the decision making process. In this sense, failure is the latent symmetrical element complementing the process of innovation discovery (Scotchmer 2004). Accordingly, we look at how experiencing (small project) failure affects future knowledge sourcing strategies.

The aim of this paper is to understand how differently failure impacts on the external and internal activities that contribute to the innovation process. While some studies have looked at the determinants of innovation failure (Mohnen et al. 2008; Lhuillery and Pfister 2009; Radas and Bozic 2012; Hyll and Pippel 2014), few attempts have been made to systematically consider failure as an organic component of the innovation process and at how its occurrence subsequently impacts on innovation strategies (van der Panne et al., 2003; Elmquist and Le Masson 2009). This work aims to fill this gap and reintroduce failure as an active component in the pursuit of innovation, rather than consider it exclusively a negative final outcome. Starting from the assumption that innovation behaviour is heterogeneous, we consider external and internal knowledge sources that affect innovation strategy at the firm level (Rothaermel and Deeds, 2004, Lavie et al. 2010) and then analyse the impact of a small project failure on them. Our research question is therefore twofold: how does innovation failure affect the innovation trajectories of firms? Further, given that firms shape their innovation pathways according to different knowledge sourcing strategies, what is the impact of failure on those different strategies?

2. Literature Review

2.1 *Sources of Innovation Behaviour*

Innovation involves a quest for new opportunities and engagement in practices of knowledge creation, development and absorption (Dosi 1988) combined with a steady flow of internal and external information to nurture its growth (Feldman 1994). In this sense, innovation is not an outcome but rather a dynamic process where the (re)combination of a variety of activities underpins the development of commercially valuable propositions new to the company or to the world (Freeman 1982, Schumpeter 1942).

As innovation involves combining several kinds of knowledge from both internal and external sources, getting the balance right is challenging and could affect both process (the way innovation is achieved) and outcome (whether firms succeed). When this balance is wrong, it can ultimately lead to lock-ins that endanger firms' adaptability (Levinthal 1992; Danneels, 2007) and generate core rigidities (Leonard-Barton 1992).

The context under which innovation develops is important. Firms innovate for many reasons (Allman et. al 2011) and in this process they engage in multiple learning opportunities from a variety of knowledge sources.

Innovation can result from the development of capabilities, that is, from the capacity to develop internal abilities to recognise, reconfigure and assimilate knowledge (Cohen and Levinthal 1990; Cohen 2010). This involves strategies of expansion and accumulation that rest on the company's knowledge base and the related investments in R&D and human capital. The ability to innovate also depends on the capacity to invest resources in R&D and develop a portfolio of inter-related activities. This is far from a linear process (Godin 2006; Santamaria, Nieto and Barge-Gil 2009) and is much aligned with the capacity of firms to nurture internal competences via training or skills acquisition (Leiponen 2005; Caloghirou et al. 2017). In particular, skills contribute to innovation by generating variety in the knowledge base available in the firm (Asheim and Coenen 2005; Asheim et. al 2011).

However, invention, adaptation and learning abilities ultimately do not depend on internal R&D and capabilities alone (Metcalfe 1988) and even large firms integrate their competences with external knowledge flows in their innovation value chain (Roper and Love, 2018). Thus, to adapt their abilities to innovate companies source knowledge from the external environment (Lundvall 2007). This search may be conditioned by a variety of institutional factors including available financial resources and inter-firms IP arrangements (Arora et al., 2001; Gassmann, 2006) and involves a process of continuous learning (Bessant et al, 1990).

In sourcing new knowledge firms also draw on specialist consultants, outsource R&D to universities or specialized firms, or develop co-operative agreements with suppliers, customers and competitors (Veugelers and Cassiman 1999). Absorbing new elements and establishing new links and arrangements depend on prior accumulated knowledge (Arthur 2007; Savino et al. 2017). Thus, combining internal and external sources (Rigby and Zook 2002) can increase innovation productivity (Cassiman and Veugelers 2006) provided internal absorptive capacity is sufficiently well developed to recognize, value and assimilate external knowledge (Zahra and George 2002).

2.2 Failure and the Innovation Process

In the pursuit of innovation, firms may encounter various barriers that hamper their capacity to innovate (D'Este et al. 2012; Coad et al. 2016) and lead to them abandoning innovation projects.

The innovation management literature, with few exceptions (Leoncini 2016; D'Este et al. 2018), has not considered (small) failure as a systematic component of the quest for innovation success. In particular, previous works tend to focus on the contribution of different innovation sources to failure, or on the drastic effects that catastrophic failure entails for an organisation (Mellahi and Wilkinson 2010). In both those instances, failure is treated as an omitted variable rather than an active element that firms experience in their quest for innovation success with a consequent risk of biasing the understanding of the role of failure in entrepreneurship (Denrell 2005).

Recent studies examine the attributes that lead to the breakdown of innovation projects (Radas and Bozic, 2012) with some focusing on the financial constraints slowing down and stopping them (Mohnen et al. 2008). Galia and Legros (2004) identify a combination of financial, organisational and market related barriers to innovation while D'Este et al. (2012) show that implicit barriers also act as deterrent to innovation. Lhuillery and Pfister (2009) and Guzzini et al. (2017) consider the role of cooperation with competitors and public research organisations and their impact on innovation failure, while Hyll and Pippel (2015) discuss the likelihood of failure when cooperating to pursue process or product innovation.

Narrowly constructed, failure can be viewed as a misallocation of resources or inefficient management practices. Other perspectives however focus on learning. Studies on catastrophic or major operational disasters (Wilkinson and Mellahi, 2005) aim to understand how to minimise future problems (Baum and Dahlin, 2007, Madsen and Desai, 2010). In similar vein, 'small' and frequent failures characteristic of innovation exploration have important learning effects. They are intelligent (Edmondson, 2011; Sitkin 1996) as they provide firms with valuable opportunities to gain new knowledge and have a positive outcome on innovation (Khanna et al 2013). Moreover, in the context of R&D, early failures provide better learning opportunities to spur innovative behaviour within firms and offer the chance to revise operating routines in radical ways (Leoncini, 2014). In this sense learning, as well as other spillover effects, may be associated with failure (Garcia-Vega and Lopez, 2010) particularly where past exploration and R&D efforts are persistent (D'Este et al. 2018).

An overarching question still relatively underexplored is how firms react to innovation failure. More specifically, do they change their approach to innovation by reconfiguring their combination of internal and external resources? Failure can also be built into firms' strategic thinking. Thus, when it happens, subsequent innovation behaviours are unlikely to be affected (Edmondson, 2011; Leonard-Barton, 1995). Indeed, some firms may start projects where the intent is to learn about competitors' technologies or market potential knowing that some of those will be eventually abandoned (Criscuolo et al. 2017). However, if firms are assumed to learn from their previous experiences, negative outcomes such as innovation failures are likely to elicit change (Cyert and March, 1963). Conversely, firms may not always respond to innovation failure by changing direction and may persist along suboptimal technological trajectories particularly if they have accumulated knowledge and experience (Maslach, 2016).

3. Data

The analysis employs data from the seventh wave of UK Innovation Survey (UKIS). The UKIS is a nationally representative sample of businesses with 10 or more employees covering sectors B to N of the Standard Industrial Classification. The data is a cross-section covering the two-year period between 2009 and 2010 and includes 14,342 companies (UK Office of National Statistics 2012).

From this data, following the standard definition from the Oslo Manual (OECD 2005), we select innovation active firms defined as those either engaged in technological (product or process) or non-technological innovation (implementing changing in corporate strategy, management technique or organisational structure) thereby reducing the number of observations to 9,002.

Failing to innovate is an outcome where the performance of an innovation project is deemed so negative that it has to be terminated (D'Este et al. 2018). Accordingly, among innovation active companies we select those that have abandoned innovation projects (8% of the sample; N=723).

Table 1 and Table 2 present descriptive statistics (total number of answers, mean and standard deviation) respectively for: the full sample of innovation active companies (9,002 observations), those that abandoned (723 observations) and those that did not abandoned innovation (8,279 observations). Eighty percent of companies are small to medium sized with around 32% engaged in product innovation and 20% in process innovation: of those, 69% and 45% respectively abandoned innovation projects. Table 2 presents how companies organise their innovation activities and how they mobilise internal and external resources to carry out innovation projects.

[Insert Table 1 here]

[Insert Table 2 here]

4. Empirical Strategy

4.1 Dependent variable - Innovation Behaviour

Our dependent variable is built by considering how available innovation sources (Table 2) cluster into different patterns of innovation behaviour.

To achieve this, we perform a Principal Component Analysis (PCA) and retain five components with an eigenvalue above one (Hair et al. 2014). The five components explain about 78% of the variance in the sample. We test the robustness of our method in two ways: Squared Multiple Correlation (SMC) and Kaiser-Meyer-Olkin (KMO). SMC identifies the squared multiple correlation between variables that cannot be well explained and therefore need to be excluded from the analysis. Threshold value of 0.5 suggests that all our variables perform well (upper SMC = 0.89; lower SMC = 0.53; average SMC =0.76). The KMO test measures the sampling adequacy. A small KMO value indicates that the correlation across the components is poor. Adequacy is measured from zero to one: our KMO test returns a value of 0.87 thus the PCA has produced distinct and very reliable factors.

[Insert Table 3 here]

Table 4 shows the loading of the five components[1]. The knowledge base for a company is of particular relevance and loads two distinct components: one associated to the full skill variety (PC3) and another to analytical skills (PC5). One component (PC1) identifies an R&D driven behaviour linking sources of the innovation value chain that bundle in-house knowledge creation (R&D, skill base) with external factor (cooperation; inward IP). Context-driven incentives load predominantly in PC2. These relate to the motivations for innovation and describe either internal operational behaviours (such as improvements along quality and production) or external competitive strategies. Finally, sources associated with cooperative behaviour load mostly into PC4 and highlight cooperation along the value chain together with research organisation.

[Insert Table 4 here]

[1] Hair et al. (1998) suggest that a meaningful threshold for components' loadings is linked to the sample size. As a rule of thumb, samples above 350 units can produce reliable components below a threshold of 0.3. Given our sample is over 9,000 observations and that both SMC and KMO tests are robust, we use a threshold of 0.2 to comment on the results.

4.2. *Propensity Score Matching: Model and Robustness checks*

Propensity score matching (PSM) recreates post-experiment conditions from observational studies correcting on selection bias and overcoming the 'naïve' approach when comparing a group subject to a specific treatment (or event) with a group which is not (Rosenbaum and Rubin 1984; Blundell and Costa Dias, 2000). The method looks at the probability of receiving a treatment conditional on the association to a set of covariates, and creates a weighting score to compare the observations (Dehejia and Wahba, 2002). This score collapse such observed covariates into a single indicator expressing the joint association of each observation with the treatment condition.

PSM is extensively used in the evaluation literature (Caliendo and Kopeinig, 2008). However, PSM has also been employed to investigate the impact of different policies, and technological and non-technological features affecting firms' behaviour and performance (Stephan 2014; Guerzoni and Raiteri 2015; Veer et al. 2015).

To create a matched sample, we first estimate a Probit model (expressing the likelihood of experiencing failure in the whole sample) and then select a matching estimator (Kernel) to create the matched samples[2].

The crucial step to model the matched sample is the identification of those observed characteristics which contemporarily affect the probability of failure (treatment) and innovation behaviour (potential outcome) excluding those which exert an influence into failure alone. Table 5 shows the results of the PSM implemented via Probit estimation[3]. Following the literature, we use controls for firms' age (less than three years old), size dummies, sector dummies and geographical market and the introduction of innovation new to the market.

The data available for this work are cross sectional, thus there is a risk of using information collected after failure occurred and an associated problem of endogeneity. We argue that it is reasonable to assume that most of those covariates are fixed as they represent either structural characteristics (firm's age) or characteristics unlikely to change in two years (such as sector or size dummy and to a lesser extent product market). Chances of failure can be heightened by introducing innovation new to the market. However, given that it is more likely to abandon innovation only after attempting to pursue

[2] Kernel matching is highly efficient: it uses weighted averages from nearly all observations in the control group to create a sample, providing scores with a lower level of variance. Matches are drawn only from a region of common support between treated and untreated (Caliendo and Kopeinig 2008). To check for the robustness of our results we performed a Nearest Neighbour matching without replacement (1:1).

[3] The Probit estimation identifies all those characteristics which contemporarily affect the probability of failure and innovation behaviour excluding those which exert an influence on failure alone (Caliendo and Kopeining 2008). In PSM, the Probit model is instrumental to calculate the propensity score: accordingly, the discussion about its results has been omitted (Zanutto 2006).

some radical invention (and not vice versa), the risk of endogeneity associated to this variable should not be too severe.

[Insert Table 5 here]

Table 6 presents the balancing of the model (robustness check) by using four methods: the t- test for equality of means[4]; the analysis on the reduction of standardised bias; the analyses on the pseudo R square; and the joint likelihood ratio test. All the results suggest a good level of balancing. Particularly, we can observe a reduction in the overall predictive power of the matched sample (pseudo-R^2), the average bias after the matching is well below the 5% threshold and the likelihood ratio test points to the reliability of the chosen set of covariates for the propensity model.

[Insert Table 6 here]

5. Results

Table 7 presents results of the Average Treatment effect on the Treated analysis (ATT). The ATT describes the average difference in the outcome variable (innovation behaviour) between firms experiencing failure and firms which do not. The table shows two sets of results for each innovation behaviour, respectively for: the unmatched (Unmatched) and matched (ATT) samples[5]. The results support the idea that failure is not significant across all innovation behaviours and that where failure is significant its effect depends on the sources underpinning the innovation strategy.

The effect of failure is statistically significant where innovation behaviour is largely associated with internal knowledge (R&D driven or knowledge base driven), but it does not have an effect on innovation strategies that rely mostly on external knowledge sources (context and cooperation).

When behaviours are associated with R&D (PC1), the effect of failure is positive and significant suggesting that failure does little to modify the firm's approach to innovating. In the unmatched sample, the difference between treated and controls is significant and high (1.023) but if we consider the matched sample, the difference although still significant, decreases (0.601).

Results are more nuanced when we consider failure in relation to strategies or behaviours that are driven by the knowledge base composition (PC 3 and PC5). When the firm's behaviour is driven by

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[4] Due to space limitations, the results for the t-test are available on request.
[5] The literature on PSM is divided in terms of the capacity of standard errors and T statistics to be a reliable measure of significance due to the calibrations necessary to create matched samples (see Caliendo et al. (2008). To produce a more accurate estimation of the effect of the treatment on the treated, we follow Hirano et al. (2003), and assess the significance of the effect of failure by estimating a double robust regression weighted on the propensity score. Thus, we run five regressions where we look at whether Failure is statistically significant and use significance levels obtained from those. The results in terms of significance are reported accordingly in the ATT tables.

its broader knowledge base assets (PC3), differences in both the matched (ATT) and unmatched sample are significant. However, when observing the impact of failure on the latter, its effect is small and positive (0.002). Conversely, on the matched (ATT) sample the impact of failure suggests a negative effect on the knowledge base (-0.042). This finding is confirmed when we consider the knowledge base associated with analytical skills (PC5). Here, both the matched and unmatched samples show a negative and significant association with innovation failure: in the unmatched sample the difference is (-0.093) while in the matched sample is marginally lower (-0.072). This suggests that where the innovation behaviour is predominantly determined by the knowledge base, the effect of abandoning an innovation project results in a decrease of the associated knowledge sources and a retreat from the established innovation strategy.

[Insert Table 7 here]

6. Discussion and Conclusions

The search for innovation is regarded as a process for the new which requires a balance between knowledge, organization and the environment. Striking such a balance is challenging and in the face of the uncertainty associated with innovation, firms may decide to abandon innovation projects. For instance, while collaborative agreements are thought to be beneficial for innovation development, disagreement among collaborating partners may lead to abandoning projects (Lhuillery & Pfister, 2009; Hyll and Pippel 2016). Firms also strategically abandon projects after initial R&D experimentation if they appear to be technically or economically unfeasible (Khanna et al., 2013). In some cases large firms may start innovation projects intending to abandon them if the intent is to learn about competitors' technologies (Criscuolo et al. 2017). If failure is factored in the firm's strategic thinking, then future innovation behaviours are unlikely to be significantly affected if some projects fail (Edmondson, 2011; Leonard-Barton, 1995). Indeed, firms heavily involved in external and internal R&D sourcing tend not to deviate from their innovation strategy and may instead intensify it (Eggers 2012; Maslach 2016; D'Este et al. 2018).

In this paper we have considered how firms respond when they encounter innovation failure. In doing so, and in contrast to the main innovation literature on the topic, this work does not single out a predominant innovation source. Instead, it compares a wide range of innovation activities and how their aggregate behaviour responds to experiencing failure (van der Panne et al., 2003; Elmquist and Le Masson 2009). Our results support the idea that first, failure has an effect only on specific innovation strategies, and second that when failure occurs it can either reinforce existing behaviours or reverse them. For instance, when companies are embedded into an innovation value chain (Love and Roper 2018) and their innovation process engages internal and external sources (such as commitments in R&D investments, knowledge and IP acquisitions) firms do not deviate from their existing plans regardless of whether they abandon their innovation projects. Also, in line with the literature, we find support for the idea that skill base variety alone can drive knowledge creation (Asheim and Coenen 2005; Asheim et. al 2011). However, in this instance we observe that failure produces a soft shift in the proportions of skills needed where the variety of knowledge base is wide, or a more substantial readjustment of the existing combination of skills where the variety is narrow. In contrast with other literature, we do not find support to the idea that cooperation induces companies experiencing failure to collaborate more (Guzzini et al. 2017). Indeed, failure is not significant in relation to strategies mostly based on collaboration or driven by contextual factors and in the absence of relevant commitment of internal sources.

Conversely from the majority of the literature on failure, this work includes in the sample a large proportion of SMEs. Our results suggests that also SMEs can redesign their strategies in order to cope with failure in similar fashion to larger companies. A potential explanation for this can be that, in the innovation context, all companies to a certain degree move along a learning curve dictated by their internal and external arrangements of knowledge sources. Such learning effect, in combination with commitments to more or less explorative activities involving third parties, would support the idea that once the innovation process starts, companies build mechanisms that absorb small project failure as one of the expected outcomes of the innovation process regardless of their size. This notion links to the idea that failure is not just a negative innovation outcome, but a latent symmetrical element which complements the process of innovation discovery and can help addressing it (Freeman et al.1972, Rothwell et al. 1974).

This analysis has obvious limitations. First, it is based on cross-sectional survey data that carry issues associated to response bias and endogeneity. To overcome these issues we analysed failure in a context where companies were matched according to structural characteristics that would not be affected by project abandonment itself. Nonetheless, an ideal design to adjust for this problem would involve the collection and analysis of longitudinal data.

Moreover, avenues for future research could include more detailed investigations on the stage at which failure occurs. For example, is failure more or less likely in the ideation phase or prototyping? And how are innovation strategies subsequently modified? This would allow the opportunity to shed light into the relationship between failure and learning and assess its capacity to support the discovery process. Further, given the results, it would be interesting to expand the focus on SMEs. In contrast to large firms (Madsen and Desai 2010; Dorfler and Baumann 2014), little is known about the contribution of failure to the learning mechanisms in SMEs. While this work shows that SMEs use failure to manage their external and internal resources and change their innovation strategies, more could be unpacked about the characteristics that support SMEs experimentation and the degree to which failure benefits them, given SMEs tend to be relatively more constrained financially.

Overall, this analysis points to the challenges that firms face in mediating the delicate balance of their strategies as they search for innovation success and the results seem to confirm that the capacity of failure to trigger such changes varies according to the sources of knowledge adopted in the process.

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