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Dynamic capabilities and economic crises: Has openness enhanced a firm's performance in an economic downturn?

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Dynamic capabilities and economic crises: Has openness enhanced a firm's performance in an economic downturn?

Abstract

Many studies have attempted to investigate the potential benefits of open innovation. However, the long term effects of openness have yet to be demonstrated, even if few researchers hypothesised that high openness could increase firms' dynamic capabilities and hence their resilience in the face of adversities, such economic downturns. Hence, this paper attempts to investigate this dynamic relationship between openness and firm performance with particular considerations addressing the recent financial crisis in 2008. Based upon the UK Community Innovation Survey (CIS) panel data collected between 2006 and 2012, this study finds evidence that supports the positive influence of openness on long-term firm performance. The results show that (1) increasing a firm's openness is an effective way of enhancing its dynamic capability and hence its resilience, and (2) of all the various configurations of openness, the collaboration with partners outside the firm's value chain and international partners have the highest impact on turnover recovery, as they will increase the chances of acquiring newer knowledge, which in turn will help firms to identify new opportunities to achieve sustainable growth. The findings of this paper have some practical implications for managers and policy makers.

Keywords: Open Innovation, Economic Crisis, Dynamic Capability, UK

JEL codes: C23•O25•O32

1. Introduction

In recent years, a substantial number of firms, from large to small, have been attracted to the application of open innovation (OI) (Van de Vrande et al., 2009, Chesbrough and Brunswicker, 2013, Spithoven et al., 2013). Since Chesbrough first defined the paradigm in 2003, OI has, as a result, become an important research topic in the field of innovation management (Dahlander and Gann, 2010, West et al., 2014). The majority of early OI studies have focused on illustrative examples of OI adoption and implementation, whilst recently the focus has been on understanding OI benefits and characteristics by analysing large scale data sets (Schroll and Mild, 2012, Podmetina et al., 2014). Researchers have followed the phenomenon closely (Dahlander and Gann, 2010) and started to evaluate the impact of OI expanding the level of analysis, from that of the firm to that of R&D projects (Du et al., 2014) and public sector level (Lee et al., 2012).

Through exploring and exploiting external knowledge and collaborating with various innovation partners, a firm embracing OI may enjoy many benefits, such as the access to necessary complementary assets, the maximisation of the return of investment from intellectual property (IP), the acceleration of innovation processes, the attraction of new customers, and establishment of new technology standards (West and Gallagher, 2006, Dahlander and Gann, 2010, Savitskaya et al., 2010), and these benefits are not confined to a firm level. As noted by Roper et al. (2013), the level of openness in the firm's industry can even stimulate the firm's openness, which suggests the positive externality of an open approach in innovation. Recognising these virtues, it is highly probable that firms actively adopt open strategy to leverage external knowledge sources or internalise the externality in a benign environment and in periods of available slack (O'Brien, 2003). However, it is difficult to predict whether firms are still willing to pursue open strategy during an economic downturn. On the one hand, due to resource constraints and high uncertainty, it is not easy for firms to strongly engage in various innovations in a turbulent environment, but on the other hand, it is also true that OI enables firms to adapt to a dynamic environment (Du et al., 2014) and to achieve a sustainable growth

(Chesbrough, 2003). In fact, open strategy can be the source of firms dynamic capabilities (Teece, 2007), which may be even more important when turbulent environments require substantial changes to organisational routines. The recent global financial crisis, generated by the failure of the US sub-prime market, is an example of a turbulent context that would require firms to reconfigure their innovation strategies for their survival. The adoption of an open approach has been suggested as a way of coping with such a strong external perturbation. The case studies of Chesbrough and Garman (2009) and Di Minin et al. (2010) illustrated how firms can seize future opportunities for revitalising innovation capabilities by releasing non-core knowledge and establishing new partnerships, and a longitudinal analysis are needed to reinforce and further investigate their initial observations.

To meet this need, this study aims to explore the longitudinal impact of openness, its linkage to dynamic capability and innovation resilience of firms using data from the three waves of the UK Community Innovation Survey (CIS) encompassing the period of the recent economic downturn. This paper focuses on manufacturing firms, as it is assumed that innovation patterns may be different for service firms. Manufacturing firms have been prioritised as the impact of OI should be more evident as these firms typically benefit from external information sources, whilst service firms are less likely to engage in formal R&D activities and hence depend upon a more limited range of innovation sources (Mol and Birkinshaw, 2009).

The remainder of this paper comprises five sections. The first describes the theoretical background and develops hypotheses focused on the relationship between openness proxies and firm performance. The data and method are then described in section 3 and the results and discussion follow thereafter. The paper concludes with the implications and limitations.

2. Theoretical background and hypotheses

2.1 Openness, changing routines and dynamic capabilities

Dynamic capability refers to the firm's capacity to reconfigure resources in response to changes in the environment (Teece and Pisano, 1994, Teece et al., 1997). Incremental innovation occurs at all times and firms might need dynamic capabilities even in a buoyant period to accelerate innovation and adapt to small changes in the environment. However, qualified posture may be more favoured in a prosperous environment. As noted by Teece (2007), a firm's success will contribute to the creation of an organisational routine. A routine can be defined as a smooth sequence of coordinated behaviour (Nelson and Winter, 1982), grammars of action (Pentland and Rueter, 1994) or a patterned sequence of learned behaviour (Cohen and Bacdayan, 1994), and a well-established routine enables firms to avoid risks by following these verified procedures (Cyert and March, 1963, Argote and Greve, 2007). Firms can reduce the number of further deliberate choices by confining their organisational behaviour to well-developed channels (Nelson and Winter, 1982). Thus, by following the verified routine firms can stably enjoy the outcome of innovation while minimising uncertainties, which can be considered as an effective strategic posture in a benign environment.

Yet, it is hard to deny that dynamic capabilities will play a more vital role in a turbulent environment (Teece et al., 1997). In a turbulent and uncertain environment firms will be at risk of suffering, if they stick only to a tested and tried routine. A closed system may enable firms to harness the existing routine intensively, but they will lose their capability to engage in a new routine (Teece and Pisano, 1994, Teece et al., 1997). Hence, firms occasionally have to set up a new routine to adapt themselves to a changing environment, and increasing openness can be a good way of establishing dynamic capability. In fact, OI cannot be separated from firm strategy (Chesbrough and Appleyard, 2007), in that firms adopt OI to achieve corporate renewal and gain competitive edge (Vanhaverbeke and Cloodt, 2014). Searching and integrating both external and internal knowledge is one of the fundamental ways to harness and develop dynamic capabilities (Nonaka and Takeuchi, 1995, Teece, 2007). Because interaction with external knowledge and partners across firm boundaries triggers resource allocation and the reconfiguration of strategic posture, increasing openness provides a variety of new innovation

routes to a firm (Ahn et al., 2015). In this regard, increasing or establishing an open strategy for innovation is an organisational routine change that should lead to the enhancement of a firm's dynamic capability that innately assumes a certain level of change and strategic adaptation (Teece, 1996).

2.2. Increasing openness in a downturn

Firms often change their strategic directions to adapt to a changing environment (Lawrence and Lorsch, 1967), and this can be more critical in particularly dramatic and uncertain circumstances, such as an economic downturn. The literature has showed that increasing openness is associated with the development of dynamic capabilities. For example, Almirall and Casadesus-Masanell (2010) suggested that a high level of openness can lead to better performance in a dynamic environment. Cruz-Gonzalez et al. (2015) found that the effect of search depth – i.e. the extent to which firms draw intensively from different search channels or sources of innovative ideas (Laursen and Salter, 2006) - is positively significant in more dynamic and turbulent contexts. However, these fragmented findings may not be sufficient to answer whether the benefit of openness could be particularly valuable in to respond to exogenous economic shocks. An economic downturn, such as a recent global financial crisis, is an immense, uncontrollable external change, and given the situation, firms needed to display strong adaptive behaviour to insure their survival. From the perspective of dynamic capability, a sustainable growth can be achieved by firms that will effectively and adequately steer their strategic directions. As shown in Figure 1, organisational routine change can be interpreted as a process of finding a new optimal equilibrium. In a downturn, firms can increase openness to cope with external challenges, strengthen in-house R&D, or simply cut employee and innovation investment under an austerity plan. These three scenarios are examples of a firm's routine change for its organisational adaptation.

----- Insert Figure 1 around here -----

Cutting the innovation budget may be one of the easiest ways of coping with an economic crisis, and in fact, during the recent economic recession, many firms severely reduced their investment in innovation (OECD, 2009, Filippetti and Archibugi, 2011, Paunov, 2012). However, firms are able to better cope with an economic downturn by rather expanding innovation activities instead (Archibugi et al., 2013). Archibugi et al. (2013) showed that most firms reduced innovation input, but highly innovative incumbents and fast growing new entrants instead increased their innovation investment during the recent crisis, which eventually helped them to overcome the challenges of operating in a slow economy. Their results also suggested that both a strong internal R&D and the search into new market are significant predictors of an increase of innovation investment during the downturn (Archibugi et al., 2013).

As noted by Chesbrough and Garman (2009), increasing openness can also be an effective approach for coping with an economic crisis. During the crisis, firms actively engaged in collaboration with new external partners displayed an increased organisational flexibility while preserving innovation capabilities for future growth (Chesbrough and Garman, 2009). For example, Fiat's core R&D organisation, Centro Ricerche Fiat (CRF), did not simply reduce its internal R&D costs during an economic downturn (1993-2003) (Di Minin et al., 2010). Rather, CRF selected what knowledge to keep private and what to expose and then shared non-core technologies with external partners to generate additional income. CRF also established long-term strategic partnerships with customers and new partners to diversify the exploitation of their complementary assets (Di Minin et al., 2010). Such open approaches helped Fiat to avoid substantial reduction of R&D and innovation capability that would have impacted negatively the firm in a long term (Di Minin et al., 2010).

As an open approach increases organisational flexibility by adding new innovation routes (Mortara et al., 2011, Vanhaverbeke and Cloodt, 2014, Vanhaverbeke and Roijakkers, 2014, Ahn et al., 2015), firms can move onto a new equilibrium point that is more robust against external turbulence. Moreover, as openness enables firms to keep necessary innovation resources at arm’s length (Lichtenthaler and Lichtenthaler, 2009), this knowledge retention will

prevent firms from losing innovation capability and better recover once an economic downturn finally ends (Chesbrough and Garman, 2009, Di Minin et al., 2010). However, while the various benefits of open approaches for innovation (e.g., accessing complementary assets) have been identified and proposed as enhancers of firms' resilience, the linkage between open strategy and resilience is still substantially unproven.

2.4. Heterogeneity of openness

As noted by Cruz-González et al. (2015), this paper assumes that openness in innovation might encompass very diverse approaches (i.e. it is heterogeneous). This suggests that Laursen and Salter's (2006) openness proxies, the breadth of the external search, the depth of the external search, and innovation collaboration may have different characteristics (Cruz-González et al., 2015). According to the definition of Laursen and Salter (2006), 'search breadth' indicates the number of different external information sources, whilst 'search depth' refers to the number of different external information sources upon which firms intensively depend. These definitions suggest that a key factor distinguishing these two concepts is intensity (Cruz-González et al., 2015). As absorptive capacity is required to understand and digest new external knowledge (Cohen and Levinthal, 1990, Spithoven et al., 2011, West and Bogers, 2014), access to various external information sources cannot simply be equated to the intensive utilisation of external knowledge. The understanding of newly imported knowledge will demand substantial efforts for internalisation in addition to search activity. Further, since a firm's existing knowledge is a basic reference point for understanding new external knowledge, the boundary of search will have a certain limit. The expansion of the search reaches a peak with an optimal 'cognitive distance' and then inevitably decreases (Wuyts et al., 2005, Cruz-González et al., 2015). Firms might navigate far from their current knowledge domain, but this alone cannot enable firms to effectively leverage external knowledge. Intensive focusing and repetitive access would be necessary to introduce newness for an organisational routine change, but the concept of search breadth does not reflect this aspect. Consequently, high search breadth is apt to be a shallow search, which fits with superficial knowledge exploitation (Cruz-González et al., 2015). By

contrast, search depth indicates intensive (i.e., repetitive) access to particular external information sources, thus it implies a substantial accumulation of specific knowledge (Cruz-González et al., 2015). The repetitive access enhances the understanding of a knowledge acquiring firm, who thereby might learn from even more cognitively distant knowledge that could not be obtained from a shallow search (Hsieh and Tidd, 2012). Therefore, search depth relates to the exploration leading to in-depth knowledge of new and distant information (Cruz-González et al., 2015).

Collaboration constitutes a different openness dimension from search breadth and depth. Laursen and Salter (2006) treated collaboration as an auxiliary variable that confirms the effects of openness on innovation performance, but collaboration is innately different from a knowledge search. External information search (both breadth and depth) is a one-directional knowledge transfer (i.e., outside-in or in-bound). Therefore, it assumes the internal use of external knowledge (i.e., knowledge integration). However, collaboration is a more complicated process involving mutual interactions or even an organisational resource swap. Therefore, it is a coupled process involving a two-directional (i.e., inside-out and outside-in) knowledge transfer (Enkel et al., 2009, Ahn et al., 2013). This ambi-directional interaction distinguishes collaboration from external search activities. A firm can retain required knowledge or skills at an arm's length by establishing a collaborative relationship (Lichtenthaler and Lichtenthaler, 2009). Accordingly, successful collaboration is a complex process requiring an additional capacity (e.g., connective or transformative capacity) on top of absorptive capacity (Zahra and George, 2002, Lichtenthaler and Lichtenthaler, 2009). Recognising these aspects, innovation collaboration can be considered to be a higher degree of openness compared to the one-directional knowledge search. However, as in the case of search breadth and depth, the achievable level of collaboration may not be the same for all the types of collaboration partner. For instance, it may be easier to collaborate with a partner located inside a firm's value chain (e.g., suppliers, customers, enterprise groups), since these actors share innovation processes in the value chain. However, by being bounded to a value chain that

enforces knowledge and goal sharing, a firm might not find it easy to import substantially new knowledge. By contrast, it may be harder to collaborate with a partner located outside a value chain (e.g., universities and private research institutes) or an international partner. It is because of the time- and resource-consuming trust building process (Narula, 2004, Oakey, 2013), or different cultures, regulations, or technology standards (Hottenrott and Lopes-Bento, 2014). However, collaboration with this type of partners can increase the chances of acquiring newer knowledge, in the sense that universities or research institutes usually conduct more scientific or long-term R&D projects and the interaction with partners distributed across the globe enables firm to access location-specific knowledge (Hagedoorn, 2002).

2.4. Research hypotheses

The early case studies and subsequent empirical analyses on OI have revealed the significant impact of this open approach on firms' innovation performance (Dahlander and Gann, 2010, Schroll and Mild, 2012, Podmetina et al., 2014), and we argue that an open strategy can contribute to the enhancement of a firm's financial performance over time even during a downturn. The mechanism behind this reasoning is that an open strategy increases firms' managerial flexibility and provides new innovation opportunities by expanding knowledge stocks and network boundaries (Chesbrough et al., 2006). As such, a high level of openness will enhance a firm's dynamic capability by helping its resource reconfiguration, which consequently enables it to cope with turbulent environment, such as an economic crisis.

To benefit from an open strategy, firms have to increase the degree of openness that will be attained by their innovation activities, such as external searches and collaborations. Firms taking more extrovert approaches can better cope with an economic crisis by successfully establishing dynamic capability necessary for a routine change. As openness offers managerial flexibility (Ahn et al., 2015), firms will be able to diversify their innovation routes without solely depending upon resource-consuming internal knowledge creation. This new routine and knowledge retention achieved by openness will enable firms to save resources on their

innovation while preserving capacity to innovate after a downturn (Chesbrough and Garman, 2009, Archibugi et al., 2013). This resilience power will make firms better cope with a downturn and recover their performance after a downturn. Hence:

(Hypothesis 1) *Increasing openness during the downturn will positively impact a firm's financial performance recovery after the downturn.*

As an important dynamic capability, increasing openness may help firms to adequately reconfigure their strategic posture during and after a downturn. However, the effect of knowledge search breadth, depth and collaboration may not be the same because the degree of newness that each type of openness will bring will be different. Recognising this heterogeneity, we presume the level of openness increases from search breadth to depth, value-chain, and outside value-chain/international collaboration. Search depth may be a higher degree of openness than search breadth because of the repetition of access (Cruz-González et al., 2015), and collaboration may be higher openness than search due to its involvement in ambi-directional interaction. Similarly, collaboration with universities/research institutes (non-value chain partner) or international partners may provide a high level of openness, because universities/research institutes conduct longer-term, science-based R&D and by means of international collaboration firms can realise cross-fertilisation of technology using location specific knowledge. New knowledge imported via higher ranked openness will be used for firms to identify new technological opportunities and achieve new growth momentum. Hence:

(Hypothesis 2) *Higher forms of openness during a downturn will lead to higher financial performance recovery after the downturn.*

3. Data and method

3.1 Data

To see the longitudinal effects of openness, this paper analysed the UK version of CIS data sets[1] that were based on the Organization for Economic Co-operation and Development's

(OECD) Oslo Manual (OECD, 1997). The data sets include CIS 6, 7, and 8 that were collected at three different time points. CIS 6, 7 and 8 have a similar question structure that enables us to stack data. We aggregated the CIS 6, 7 and 8 data and then selected firms that participated in all three CISs using list-wise deletion. Consequently, 1,440 observations of 480 manufacturing firms were selected for the analysis. To see the longitudinal effects of openness, difference terms were made by measuring changes between CIS 8 and 7 or CIS 7 and 6. CIS 6 was collected during the period between 2006 and 2008, i.e., before the crisis. CIS 7 was collected during the financial crisis period between 2008 and 2010, whilst CIS 8 was collected after the crisis between 2010 and 2012. As such, by measuring differences between CIS data (see Figure 2), this paper attempts to investigate *how strategic routine changes during the crisis (compared to before the crisis) affected the power of resilience of firms after the crisis (compared to during the crisis).* As shown in Figure 1, a firm may choose one of the possible routine changes during the crisis, and this study aims to analyse the consequence of its selections: open strategy, closed approach (strengthen internal R&D) or implementing an austerity plan (employment cut).

----- Insert Figure 2 around here -----

3.2 Variables

As shown in Figure 2, the key variables of this paper are openness, closed approach (internal R&D) and employment cut (austerity plan). Detailed measurements of each variable are shown below, and overall illustrative and descriptive statistics are shown in Tables 1 and 2, respectively. A Pearson correlation table is provided in the appendix

----- Insert Table 1 around here -----

----- Insert Table 2 around here -----

3.2.1 Openness: breadth, depth and collaboration

Laursen and Salter's (2006) seminal paper suggested a way of measuring openness by counting the number of information sources (breadth) and the degree of their importance (depth); the

effectiveness of this measure has been verified in many studies (e.g., Schweitzer et al., 2011, Roper et al., 2013). Using and expanding on Laursen and Salter's (2006) concepts, 'search breadth' indicates how widely firms explore external information[2]. All the external information source variables in the raw data were transformed into binary variables (0: not used, 1: used) and then added up to indicate twelve levels (0: none of the information sources used to 11: eleven different information sources used). 'Search depth' refers to how intensively firms use external information sources. The respondents' answers assessing the importance of external information sources were transformed into binary variables (0: not, low or medium-level importance, 1: high importance) and then added up to make a 'depth of search' variable (i.e., 0 to 11 according to the number of information sources significantly used). 'Collaboration' refers to how actively firms cooperate with external partners[3]. This variable refers to the formal engagement of the company with external partners. A firm gets a score of '0' when it does not collaborate at all and '7' when it collaborates with all types of partners. In a similar way, we created a 'value chain collaboration' (with suppliers, customers, and enterprise groups), an 'outside value chain collaboration' (with competitors, R&D institutes, universities, and public institutes) and an 'international collaboration' (partners outside UK). After creating all the openness measures, difference terms were made by subtracting openness in CIS 6 from openness in CIS 7 to identify firms' strategic innovation routine change (see Figure 2 and Table 1).

3.2.2 Closed strategy: internal R&D

To measure the closed approach, we made a variable indicating a change of internal R&D investment and a change in the portion of employees who have a degree or higher qualification (e.g., BA/BSc, MA, PhD, PGCE) in science and technology (S&T). These variables attempt to measure whether a firm increased internal R&D investment during the financial crisis by increasing either internal R&D financing or employees.

3.2.3 Austerity plan[4]: employment cut

To identify an austerity plan, we created a variable indicating a change of employment between CIS 6 and CIS 7. However, as the variable name 'employment cut' indicates, negative coding was adopted by subtracting the employment number of CIS 7 from that of CIS 6 (see Table 1). Thus, a positive value of this variable indicates an employment reduction (job cut) during the crisis, i.e., an austerity plan, whist a negative value indicates an increase in employment.

3.2.4 Dependent variable: turnover change

As for dependent variables, an objective measure of general financial performance, the firm's turnover, was employed. This choice was made, as we think that the dependent variable typically employed in other OI studies (e.g. the innovation performance measured for instance from the launch of new products) is too closely linked with an innovation input (e.g., internal R&D or increasing openness). However, this may be misleading, because it underestimates the financial and cognitive costs involved in an open strategy (Cruz-González et al., 2015) and would neglect its possible delayed effects (Ahn et al., 2013). Yet, in fact, external knowledge is not free (Cruz-González et al., 2015). To benefit from external knowledge, firms have to build substantial absorptive capacity to assimilate it with internal knowledge, thereby making it digestible and understandable (Cohen and Levinthal, 1990, Salter et al., 2014, Cruz-González et al., 2015). In this respect, to ascertain whether openness eventually brings benefits to a firm, it is necessary to investigate a firm's final output variable reflecting costs, organisational efforts and the possible delayed effects of open strategy. Due to their reliability and easy accessibility as publicly announced data, turnover data were obtained from IDBR (the Inter-Departmental Business Register) database using firm reference numbers in the UK CIS data. Turnover change was calculated by subtracting the turnover value for CIS 7 from that of CIS 8 in order to capture a firm's resilience after the downturn.

3.2.5 Controls

Three control variables, technology level, firm size and government support, were adopted to enhance the explanation power of the analysis. Four technology levels, high, medium-high,

medium-low and low, were measured based on OECD classifications. A two-digit Standard Industrial Classification (SIC) was used to classify technology levels. Firm size was also controlled in that it is an important factor affecting the extent of openness (Van de Vrande et al., 2009, Drechsler and Natter, 2012, Spithoven et al., 2013, Vanhaverbeke and Cloodt, 2014). This variable was measured by taking the natural logarithm of total employee[5] numbers of CIS 8 data. Government support was employed because it encourages firms' networking and interactions (Rothwell and Dodgson, 1994, Kang and Park, 2012) even in an economic downturn (Hud and Hussinger, 2015). It was measured as a binary variable using data from the CIS 8 dataset.

3.3 Method

Two statistical methods, cluster analysis and econometric regression, were employed to investigate the long-term impact of openness on firms' financial performance. First, a cluster analysis was conducted to classify firms' strategic routine change. As such, three open strategy variables (search breadth change, search depth change, collaboration breadth change), two closed strategy variable (internal investment change, S&T employee portion change), and one austerity plan variable (employment cut) were used as criteria identifying firm groups that implemented different strategic routine change. Three to four groups were initially suggested by hierarchical clustering analysis (Ward method), and then K-means cluster analysis was applied to group the three identified clusters.

Further, to breakdown the longitudinal effects of each variable on financial performance change, a regression analysis was conducted. Before the analysis, all strategic routine variables (open, closed and austerity) were standardised, and VIF values were checked. However, it was indicated that there were no serious multi-collinearity issues, because all the VIF values were between 1.043 and 2.351. For lack of space, VIF values for the model 5 were reported. For heteroscedasticity control purposes, robust standard errors were employed in

evaluating the significance of the variables. To assess the explanation power of regression models, both R^2 and adjusted R^2 were reported[6].

4. Results

4.1 Cluster analysis

Cluster analysis identified three different firm groups. The mean values of all the variables and the number of the firms for each group are reported in Table 3 to show their innovation behaviour pattern during the economic crisis.

----- Insert Table 3 around here -----

As shown in Table 3, the strategic changes of each cluster (i.e. open, closed strategy and austerity plan variable) were different. The firms in cluster 1 did not reduce employees while showing larger openness values. On the basis of this extrovert and out-looking routine change, we labelled them 'Open Innovators'. The firms in cluster 2 conducted an employment cut, but increased internal innovation capacity by increasing internal R&D investment and the number of scientific and technologically knowledgeable employees. Due to this introvert, in-house oriented strategic posture, they were labelled as 'Closed Innovators'. Lastly, the firms in cluster 3 conducted the largest employment cut and reduced all the innovation activities, both open and closed. In this respect, they were labelled as an 'Austerity planners'. To identify any differences in financial performance (i.e., ΔTurnover) among these groups, one-way ANOVA was conducted. As shown in Table 3, the results showed that the turnover change of ‘Open Innovators’ was the largest, and, as expected, that of 'Austerity planners' was the smallest. To examine the group difference of 'ΔTurnover' among 'Open Innovator', 'Closed Innovator', and 'Austerity Planners', a Bonferroni test was conducted. These post-hoc analysis results showed that the 'ΔTurnover' of 'Open Innovators' and 'Closed Innovators' were statistically different from that of 'Austerity Planner' (both p-values for 'Open Innovator - Austerity Planner' and 'Closed Innovator - Austerity Planner' were smaller than 0.05). However, a significant difference between

'Open Innovators' and 'Closed Innovators' was not identified (p-value>0.05).

4.2 Econometric analysis: the dynamic effect of openness

To investigate the impact of each group of variable, a hierarchical linear regression was employed. The results of five different models were reported in Table 4. The model 1 included only control variables, and closed approach and austerity variables were added to the model 2. The model 3 included three openness variables (search breadth, search depth and collaboration) in addition to control variables. The model 4 was basically the same as the model 3, but three specific collaboration variables, collaboration inside value-chain partners, outside value-chain partners, and international partners, were added. However, 'Δcollaboration' was dropped in mode 4 to avoid possible multicollinearity. Finally, the model 5 included all the variables except for 'Δcollaboration'. This selection was made, because 'Δcollaboration' showed no statistical significant impact in model 3 but outside-value chain and international collaboration variables showed their significant influence on performance in model 4. As the results show, employment cut played a negative role in increasing turnover after the crisis, which is in line with the results of cluster analysis. Maintaining internal innovation capacity through an increase in internal R&D investment was important for turnover enhancement, and a high level of openness, such as collaboration with partners outside value chain or international partners, was positively associated with turnover increase after the financial crisis.

----- Insert Table 4 around here -----

5. Discussion

The recent global economic crisis has substantially affected firms' willingness to invest in innovation (Filippetti and Archibugi, 2011, Paunov, 2012). Many firms had to stop or postpone innovation projects, but firms “swimming against the stream” by aggressively investing in

innovation can better cope with an economic crisis (Paunov, 2012: 303). Recent case studies (e.g., Chesbrough and Garman, 2009, Di Minin et al., 2010) showed that increasing openness can also be an effective way of coping with hardship, and the current paper has investigated the generalisability of this finding using the UK CIS panel data. Our results confirmed that increasing openness can be an effective approach to enhancing firm performance over time, in particular in an economic downturn.

As illustrated in Figure 1, firms have to change their routines to adapt themselves to the new environment dictated by the financial crisis. The cluster analysis results supported the idea that pursuing innovation (both open and closed) during the crisis enables firms to have resilience power high enough to achieve a sustainable growth in the long term. The sample firms were grouped into three categories - Closed Innovators who focused on internal R&D, Open Innovators who increased openness, and Austerity Planners who simply reduced employment and all the innovation activities. However, these different strategic choices brought dissimilar consequences to firms; the turnover enhancement of both the Open and Closed Innovators outweighed that of the Austerity Planners, which suggests the importance of resilience power during the crisis. In hard times, an austerity plan could be a tempting offer. Employment cuts and the reduction of internal and external innovation may save resources for the moment, so this retrenchment management style might help firms to endure hardship. However, the main problem of this strategic choice is that it makes firms lose their capability to innovate, thus difficult to adequately recover after the downturn. As noted by Archibugi et al. (2013), firms that maintained innovation investment better coped with the crisis, and our results showed that increasing openness can also be an important dynamic capability for a sustainable growth. Instead of an austerity plan, Open Innovators enhanced their openness via innovation collaboration and even increased their number of employees. Due to this bold approach, they were able to achieve a high turnover increase after the crisis. This is in line with what indicated by the case studies carried out by Chesbrough and Garman (2009) and Di Minin et al. (2010) that showed that open strategy can preserve innovation capability, and our

econometric analysis results also support this interpretation. As shown in Table 4, employment cuts were negatively associated with turnover increase, suggesting that such cuts can harm firms' resilience power. However, strategic changes associated with open strategies, such as innovation collaboration with partners outside value chain and across borders, contributed to the enhancement of turnover when the economic turmoil ends. This is attributed to the virtue of an open strategy enabling firms to access innovation resources at arm's length without internalisation (Chesbrough et al., 2014). Certainly, reducing innovation investment and cutting employment can save resources, but utilising external knowledge can be an effective approach in a downturn when firms seek an alternative way of knowledge creation. By opening innovation process firms are able to broaden the boundary of firms' innovation resources. As external knowledge and networks are newly included to the expanded boundary, partners' complementary assets are retained around the firms. As such, without generating knowledge internally, firms are able to save resources while maintaining the access to the necessary knowledge, which in turn will help firms to preserver the power to innovate continuously.

Further, external knowledge can contribute to the development of new innovation routes (Ahn et al., 2015). As shown in Figure 1, increasing openness can be recognised as an effective tool of moving onto a new routine, and in this process newly imported knowledge will play a vital role in helping firms to create innovation and pivot strategic directions. However, opening innovation process does not necessarily introduce a high level of newness to firms. As shown in Table 4, information search and collaboration with value chain partners were not significantly associated with turnover change, which validates our assumption of heterogeneity in openness. This paper distinguished search breadth and depth due to their different intensities, cognitive distances, and degree of introducing new information. Similarly, for innovation collaboration, a distinction was made between partnering within, outside the value chain and international collaborators according to the degree of new ideas these collaborations would introduce. Recognising this heterogeneity, the results showed that the increase of high level openness – collaboration with outside value chain and international partners – was positively

associated with turnover recovery. As noted by Almirall and Casadesus-Masanell (2010), a high level of openness can lead to better performance in a dynamic environment, and our results suggest the importance of a high level of newness as a source of dynamic capability creation. Utilising external knowledge can be an effective approach in a downturn, but this does not necessarily mean that all types of open approaches help firms to establish the dynamic capability for strategic adaptation. Since firms should deviate from the current routines, substantial driving force would be necessary for firms to arrive at a new equilibrium. In this process, newness acquired by fresher and more divergent knowledge will play an important role in establishing the necessary driving force for a routine change. A high level of openness, such as collaborating with a partner who is substantially differently configured, can be an effective way of introducing high newness to firms. Expanded knowledge stock and strong engagement with new partners will trigger internal resource allocation and increase organisational flexibility in firms, which will help them to reconfigure or change their strategic posture. This can be particularly important in a downturn, in the sense that new knowledge and networks imported via higher ranked openness will provide firms with a complementary innovation route that an austerity plan may not offer, which in turn will help firms to identify new opportunities to survive and achieve sustainable growth.

6. Implications and limitations

Recently, more attention has been given to open strategy for innovation, and many studies have revealed various benefits from opening firm boundaries (West et al., 2014). Among these benefits, the fact that an open strategy can be an effective way of coping with an economic downturn is noteworthy. However, to the best of our knowledge, few attempts have been made to examine the longitudinal effects of openness on firm performance during a downturn. The present research recognised the different characteristics in openness dimensions and investigated the impact of strategic change during the recent crisis on financial performance recovery after the downturn. Based on empirical evidence from the UK CIS panel data, the

findings reported in this paper add to our knowledge, showing that open approaches can contribute to the establishment of the necessary dynamic capability for a strategic adaptation in a slow economy.

The results provide some practical implications. Managers in firms should realise that the benefits of open approaches are valid in a longitudinal context. Roper et al. (2013) showed the positive externality of openness, and this paper confirmed that the virtue of increasing openness is still valid even in hard times. When faced with a turbulent external shock, such as economic turmoil, it may be easier for top management to reduce innovation inputs. However, our results suggest that increasing a high level openness can be an effective approach for the adaptation to the turbulent environment and preserving resilience. For sustainable growth, it is important for firms to keep their growth momentum. Establishing relevant dynamic capabilities plays a vital role in achieving a new leap forward. Acknowledging this positive role of openness, policy makers have to develop a policy promoting firms' openness to help those facing difficulties during an economic recession.

Though there are potential benefits offered by this research, it cannot be denied that the paper suffers from research limitations. Despite of the various benefits of out-bound OI, its longitudinal effect could not be explored in this paper. As noted by Chesbrough and Garman (2009), out-bound OI, such as IP licensing-out or spin-offs, may positively affect firm performance in a downturn. However, because some variables associated with out-bound OI did not consistently appear in the CIS data, they could not be included in the analysis. For a similar reason, the boundary of the analysis was limited because the main purpose of the CIS is in investigating general innovation activities. Panel datasets were created by integrating different waves of surveys. However, as there were some changes in questionnaires, only limited variables were employed for the analysis. Future studies and dataset presenting broader variables and more consistent longitudinal data will enable us to obtain more in-depth understanding about OI phenomena.

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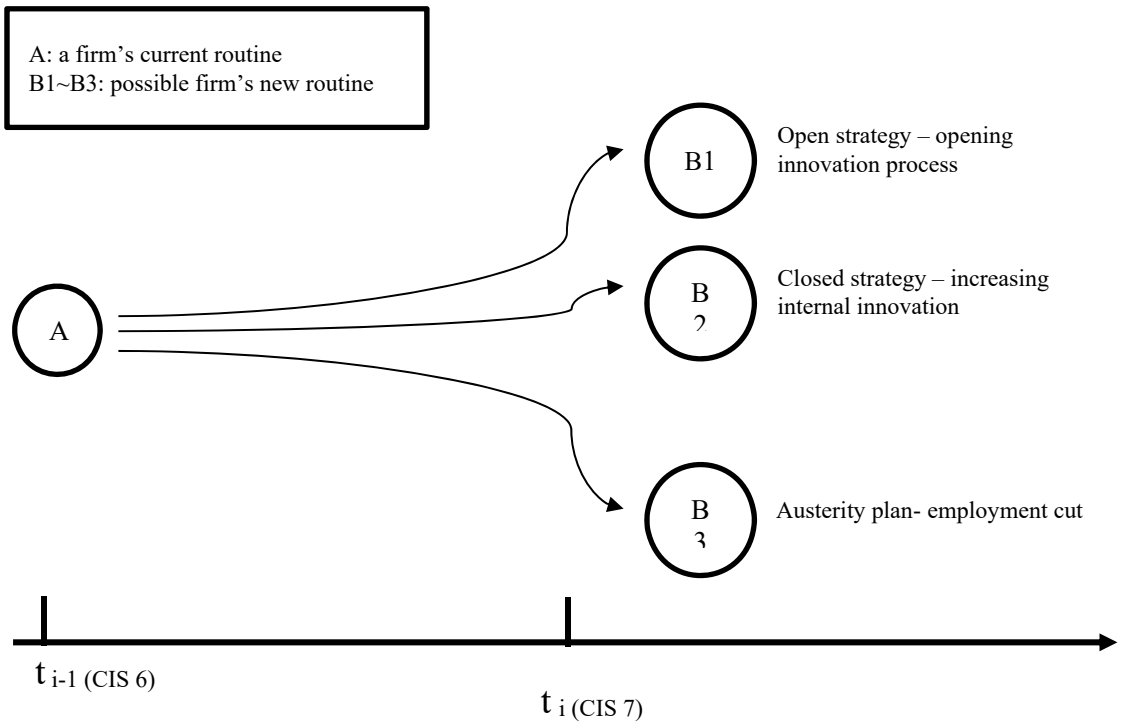

Figure 1 Types of possible routine changes

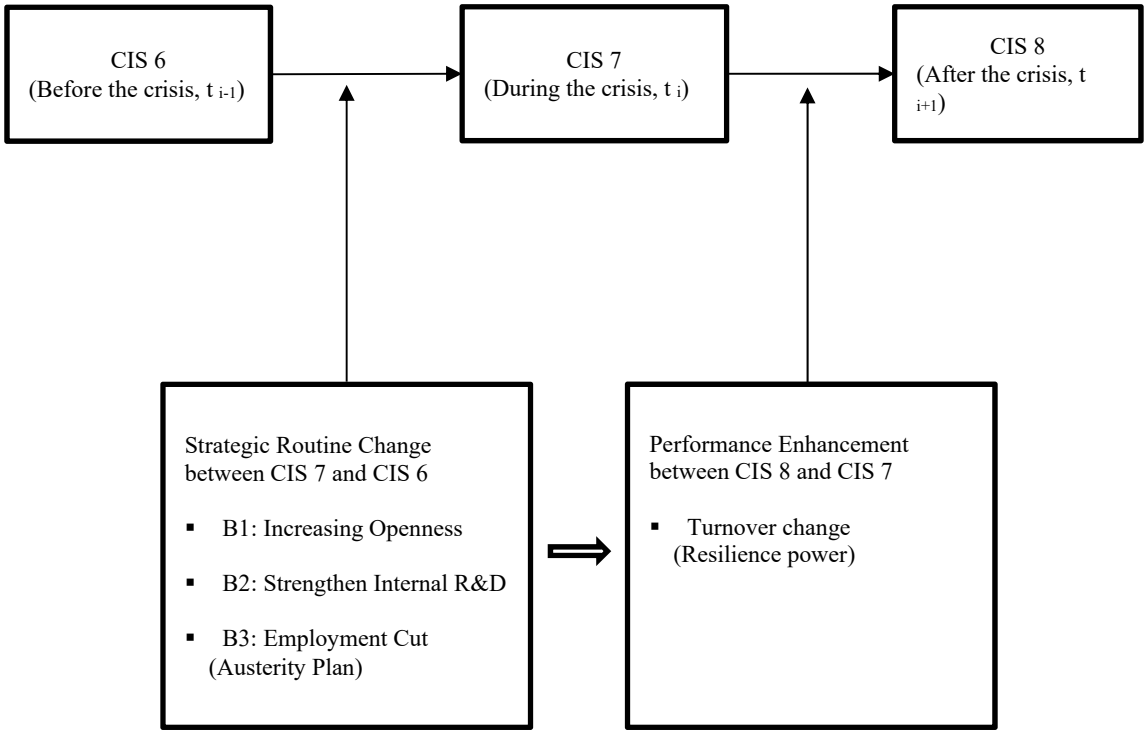

Figure 2 Research Model

Table 1 Variable illustration

Variable name	Meaning	Measurement
Tech level	The level of technology (4 levels) : High, Medium-high, Medium-low and Low	2-digit SIC based on OECD classification
Firm size	The size of the company	Natural logarithm of the employment number in CIS 8
Government	Whether a firm received financial support from the UK or EU government	0: not received, 1: received
ΔInternal R&D	The differences of internal R&D investment between CIS 7 and CIS 6 (unit: thousand GBP)	Internal R&D of CIS 7 – Internal R&D of CIS 6
ΔS&T employee	The differences of S&T employee portion between CIS 7 and CIS 6	The proportion of S&T employees of CIS 7 - The proportion of S&T employees of CIS 6
ΔEmployee cut	The decrease of employment of CIS 7 compared to that of CIS 6	Employment of CIS 6 - Employment of CIS 7 (negative coding)
ΔSearch breadth	The differences of the number of external information source utilisation between CIS 7 and CIS 6	Breadth of information source of CIS 7 - Breadth of information source of CIS 6
ΔSearch depth	The differences of the number of external information source highly used between CIS 7 and CIS 6	Depth of information source of CIS 7 - Depth of information source of CIS 6
ΔCollaboration	The differences of the number of collaboration partners between CIS 7 and CIS 6	Breadth of collaboration of CIS 7 - Breadth of collaboration of CIS 6
Δ Value chain collaboration	The differences of the number of value chain collaboration between CIS 7 and CIS 6	Vertical collaboration of CIS 7 - Vertical collaboration of CIS 6
ΔOutside value chain collaboration	The differences of the number of non-value chain collaboration between CIS 7 and CIS 6	Horizontal collaboration of CIS 7 - Horizontal collaboration of CIS 6
ΔInternational collaboration	The differences of the number of international collaboration between CIS 7 and CIS 6	International collaboration of CIS 7 - International collaboration of CIS 6
ΔTurnover	The differences of turnover between CIS 8 and CIS 7 (unit: thousand GBP)	Turnover of CIS 8 – Turnover of CIS 7

Table 2 Descriptive statistics

Variable name	Mean	Min.	Max.	Sample number
Tech level	2.25	1	4	480
Firm size	5.70	2.30	8.70	480
Government	0.18	0	1	397
ΔInternal R&D (thousand GBP)	546.12	-29640.00	119555.00	253
ΔS&T employee	1.2688	-70.00	78.00	398
ΔEmployee cut	24.3167	-1528.00	1449.00	480
ΔSearch breadth	.8116	-10.00	10.00	207
ΔSearch depth	.0188	-7.00	5.00	213
ΔCollaboration	-.0696	-7.00	7.00	345
ΔValue chain collaboration	.0000	-3.00	3.00	317
ΔOutside value chain collaboration	-.0357	-4.00	4.00	308
ΔInternational collaboration	.2742	-7.00	10.00	310
ΔTurnover (thousand GBP)	11502.95	-224505.00	1293123.00	480

Table 3 Mean values of clusters

Mean values	Cluster 1 (N=59) Open Innovator	Cluster 2 (N=46) Closed Innovator	Cluster 3 (N=50) Austerity Planners
Tech level	2.29	2.26	2.54
Firm size	591.63	394.35	564.96
ΔInternal R&D^{+}(thousand GBP)	-0.0706	**0.678**	**-0.1850**
ΔS&T employee^{+}	0.0422	**0.1543**	**-0.2744**
ΔEmployee cut (negative coding)	**-121.01**	74.44	**92.00**
ΔSearch breadth $^{+}$	-0.0411	-0.0177	**-0.2988**
ΔSearch depth^{+}	**0.1223**	-0.2296	**-0.4024**
ΔCollaboration^{+}	**0.1143**	0.0806	**-0.2627**
ΔValue chain collaboration^{+}	-0.0428	0.0893	**-0.1342**
ΔOutside value chain collaboration^{+}	**0.2062**	0.0120	**-0.2567**
ΔInternational collaboration^{+}	**0.0638**	-0.0273	**-0.2184**
ΔTurnover (thousand GBP)	20421.94	18123.39	7491.72
Note: total sample number =155 / + Standardised mean			

Table 4 Econometric analysis results

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	VIF (Model5)
Tech level	0.094*	0.098	0.128*	0.131*	0.101	1.400
Firm size	0.147***	0.158**	0.163**	0.156**	0.220***	1.151
Government	0.063	0.057	0.064	0.047	-0.030	1.217
ΔInternal R&D		0.136**			0.396***	1.164
ΔS&T employee		0.058			0.101	1.387
ΔEmployee cut		-0.185***			-0.206***	1.043
ΔSearch breadth			-0.003	-0.013	-0.042	1.223
ΔSearch depth			-0.042	-0.029	-0.025	1.111
ΔCollaboration			-0.050			
ΔValue chain collaboration				0.020	0.071	1.953
ΔOutside value chain collaboration				0.223***	0.171**	1.880
ΔInternational collaboration				0.207**	0.212**	2.351
R^2	0.035	0.109	0.045	0.094	0.310	
Adjusted R^2	0.028	0.086	0.015	0.054	0.256	
Durbin-Watson's d	2.009	1.964	1.999	2.027	1.985	
N (sample number) List-wise deletion	397	240	195	193	152	
Significance level: * p<0.1, ** p<0.05, *** p<0.01						

Appendix Pearson correlation table (Standardized)

	1	2	3	4	5	6	7	8	9	10	11	12
1. ΔTurnover	1											
2. ΔInternal R&D	0.355***	1										
3. ΔS&T employee	0.151*	0.082	1									
4. ΔEmployee cut	-0.177**	0.143*	0.028	1								
5. ΔSearch breadth	-0.021	-0.001	0.003	0.021	1							
6. ΔSearch depth	0.030	0.038	0.184**	-0.084	0.172**	1						
7. ΔValue chain collaboration	0.103	-0.011	-0.052	-0.020	0.338***	0.061	1					
8. ΔOutside value chain collaboration	0.163**	0.090	-0.026	0.052	-0.251***	-0.225***	-0.256***	1				
9. ΔInternational collaboration	0.219***	-0.018	0.167**	-0.080	0.218**	0.157*	0.445***	-0.470***	1			
10. Tech level	0.118	0.048	0.111	-0.003	-0.112	0.105	0.038	-0.109	.060	1		
11. Government	0.105	0.162**	0.157*	-0.038	0.017	0.111	0.220***	-0.136*	0.183**	.000	1	
12. Firm size	0.201**	-0.131	-0.026	-0.107	0.064	0.026	0.026	-0.099	0.192**	-.057	.090	1
Significance level: * p<0.1, ** p<0.05, *** p<0.01 List-wise N=152												

[1] Department for Business, Innovation and Skills and Office for National Statistics, UK Innovation Survey, 1996-2011: Secure Data Access [computer file], Colchester, Essex; UK Data Archive [distributor], July 2011, SN:6699

[2] Through firms, suppliers, customers, other firms, consultants, universities, public research institutes, conferences, industry association, technical standards, and journals.

[3] With enterprise groups, suppliers, customers, competitors, R&D institutes, universities, and public institutes (governments, etc.).

[4] If a firm reduced its internal R&D investment or S&T employee portion, those variables can also be used to identify the firm's austerity plan.

[5] To increase data quality, the number of employees was also obtained from the IDBR database.

[6] As the regression is not time-series analysis, auto-correlation issues may not occur. However, to detect possible serial correlation of residuals of errors, the Drubin-Watson test was conducted. All the Durbin-Watson's d values were close to "2", indicating no serious autocorrelation issue.