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The nature of SME co-operation and innovation: a multi-scalar and multi-dimensional analysis

Revised August 2012

Abstract

Recent work on SMEs and networks has emphasised the importance of external co-operative ties in enhancing firms' innovative performance. These external ties provide resource constrained SMEs with access to a wider set of technological opportunities through information sharing and resource pooling. Previous studies of the SME innovation-cooperation relationship have used categorical measures to capture tie existence which, while providing some useful insights, largely fail to capture the strength of co-operative relationships and/or the variety of relational directions in which co-operation occurs. This study aims to address this measurement deficiency and explore the SME innovation-cooperation relationship by designing and utilising measures that capture both the multi-scalar (strength) and multi-dimensional (variety) nature of co-operation and innovation. We then apply these measures to a survey of UK manufacturing SMEs. Data is obtained for 371 SMEs, and we then assess the innovation-co-operation relationship within a multivariate regression framework. We find that the strength of cooperative ties across a range of productive activities within the value chain are important facilitators for SME innovative capability; this is true for both product and process innovation. However, we find that SME co-operation with rivals (co-opetition) has no significant impact upon innovation. Our results have significant implications for both supply chain managers and policy-makers interested in enhancing innovation among SMEs. In particular, we argue that SME innovative activity benefits from good, close dyadic relations within the supply chain, while more generally policy should be geared towards nurturing and sustaining SME innovation networks.

Keywords: SMEs, Innovation Networks, Co-operation, Strong ties and Manufacturing

JEL Codes: L14, L17, L60, O31

1.0 Introduction

There is now an extensive literature on the role of inter-firm networks and their impact upon firm performance (for a review, see Hoang and Antoncic, 2003) and especially an interest in the links between network ties and innovative performance, particularly among small and medium sized firms (SMEs)[1]. Network ties offer internally resource constrained SMEs access to a wider set of technological opportunities (Chesbrough, 2003, 2007)[2]. By establishing networks, SMEs can overcome their internal resource constraints and obtain the advantages often associated with larger size (Nooteboom 1994). Indeed, a plethora of earlier studies highlighted that SMEs were as innovative as larger firms despite employing less internal resources (see Rothwell and Zegveld, 1982; Pavitt *et al.* 1987; Oakley *et al.* 1988; Acs and Audrescht 1990) and, in this regard, both Lipparini and Sobrero (1994) and De Propris (2002) have postulated this relatively superior performance might reflect the greater capacity of SMEs to (better) exploit their network relationships through information sharing and resource pooling. Additionally, Fountain (1998) has also noted an increasing tendency for large firms to subcontract innovation processes out to their (largely SME) supply chains, which often benefitted from good links with regulators and state funded bodies.

Over the last two decades, policy has followed these developments with numerous initiatives promoting greater inter-firm networking and collaboration being pursued. For instance, in the OECD, innovation policy has shifted from predominantly direct subsidies to individual firms towards funding projects that promote collaborative ties between firms (Bougrain and Huadeville, 2002). In the UK, such an approach continues to influence innovation policy, as

[1] In defining innovation, we closely adhere to the Oslo Manual (OECD, 2005; 46) definition: '*Innovation is the implementation of any new or significantly improved product (goods or services), operational processes (methods of production and service delivery), any new marketing methods (packaging, sales and distribution methods) or new organisational or managerial methods or processes in business practices, workplace organisation or external relations'*.

[2] More generally, SMEs have been seen to benefit from various synergies arising through (developing) their business networks (see for instance, Cooke and Wills, 1999; Cooke et al. 2005).

evident in recent government directives concerned with the leadership, strategy and delivery of innovation (see DIUS, 2008). Innovation networking and collaboration, particularly among SMEs and along supply chains, are thus salient issues for both managers and policy-makers.

A key feature of networks is the degree of co-operation between partner firms and, in particular, the strength of such ties (Uzzi, 1996). Indeed, this is particularly the case in supply chain management (Bessant, et al. (2003). Unfortunately, as we shall highlight, many previous empirical studies exploring innovation-co-operation relationships among SMEs do not explicitly measure the strength of co-operative ties and/or capture the range of relational directions over which co-operation occurs. Rather they tend to capture the existence of such ties through the use of categorical variables. While undoubtedly providing useful insights, such studies may thus omit important information.

The aim of this study is two-fold. First, we aim to overcome some of the measurement deficiencies in previous studies by utilising unique survey data of UK based SME's in manufacturing to explore the relationships between innovation (both product and process) and types of co-operation along the vertical supply chain and horizontally with competitor firms. In doing so, our approach seeks to capture both the scale and the various dimensions of collaboration between firms by using multivariate regression to assess whether the strength of co-operative ties, across a range of productive activities, furthers innovative capability among SMEs. Secondly, our analysis seeks to add to the literature on SMEs and innovation networks and draw conclusions for both practitioners and policy-makers.

The remainder of this paper is set out as follows. Section (2) provides a comprehensive review of the previous literature on SME networks, co-operation and innovation. The section ends with the formulation of three testable hypotheses. In Section (3), we carefully outline our methodological approach and provide details of the data used. Section (4) introduces the model specification, the estimation procedure and presents the main results. In Section (5), we consider the implications of our results for managers and policy-makers, while also deliberating on some wider issues relating to networks. Finally, Section (6) concludes with some caveats to our approach and suggestions for future research.

2.0 Network ties, Co-operation and Innovation

2.1. Networks and Open Innovation

It is now widely acknowledged that a firm's critical resources may extend beyond its traditional boundaries and will draw upon the resources and expertise of others. These external resources are typically accessed through a firm's business network, namely its suppliers, its main consumers and retail outlets and in some cases, collaborations with competitors (known as co-opetition (Brandenburger and Nalebuff, 1996)). In turn, it has been suggested that such resources may enhance a firm's innovative capability (Lundvall, 1992; Chesbrough, 2003, 2007).

The view that external resources play a role in the innovation process accrues from various angles. From a pure 'market failure' perspective, it is often purported that where firms make investments in specific technologies and/or assets whose value in alterative use is low, or where investments are under monopolistic ownership and for which there is heavy reliance (perhaps along the value chain), there lies a risk of opportunistic behaviour which can undermine innovative endeavour (Williamson, 1985). In this regard, strong and close co-operative ties act as a governance mechanism (between partner firms), which can negate such behaviour. This is usually achieved through partner firms promoting social norms and legitimacy for (implicit) codes of conduct, which reduces inter-firm monitoring costs. In addition, the possibility of collective sanctions guards against opportunism, but reliability and good behaviour are rewarded through enhancing a partner's credibility and reputation amongst the network (see Granovetter, 1992; Parkhe, 1993; Aldrich and Fiol, 1994; Uzzi, 1996; Jessop, 1998; Dyer and Singh, 1998). Similarly, in supply chains where there are risks of knowledge diffusion and free riding in technological development, dulled incentives arise as firms are unwilling to invest due to their inability to appropriate the full return on their own innovative activities (Klein *et al.*, 1978; Katz, 1986). However, where strong and close co-operative ties exist, firms are more likely to engage in resource pooling and joint action on technological development, thus collectively improving the appropriability of innovations along the supply chain (Harabi, 1998, Negassi, 2004).

Beyond correcting for 'market failures' there is also wide recognition that strong collaborative network ties between firms are an important source of innovative activity both through direct and indirect means. In the open innovation systems paradigm associated with Chesbrough (2003, 2007), network ties are a direct source of innovative activity because firms can purposively use inflows of knowledge from others to accelerate their own internal innovation and its subsequent market exploitation; similarly outflows of knowledge from a firm may be used by others in the network to do likewise. Chesbrough's work gained significant attention among scholars and practitioners, largely because it identified a significant aspect of the innovation process (namely the role of innovation networks) and provided it with a distinguishable label; open innovation (Huizingh, 2011)[3,4]. Many of the

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[3] According to Huizingh (2001, 2), the extent of Chesbrough's influence among scholars is demonstrated by the fact that '*his 2003 book gathered over 1800 citations in just seven years*'.

[4] Open innovation is clearly distinguished from 'closed innovation', where firms generate and develop new products and processes almost entirely internally (Chesbrough, 2003). Open innovation comprises both inbound innovation, defined as the internal use of external knowledge and outbound innovation - the external exploitation of a firm's internal knowledge (through the market). Given the pre-dominance of the former among

ideas that Chesbrough espoused had their origins in the earlier 'network competency' frameworks of Richardson (1972), Von Hippel (1976, 1988) and Hakansson (1987). These authors emphasised technical advance was very much a product of network ties, particularly within vertical production chains where close relations and shared competences between client and supplier firms may exist. Kogut and Zander (1992) also argued that a firm's capacity to innovate was very much associated with their ability to combine and exchange knowledge resources through inter-firm networks[5]. Brusoni et.al (2001) found that firms invest in the creation of knowledge not only for their own direct use, but so that they may also more easily engage with others to create network ties. Indeed, collaborative ties between firms can lead to mutual or shared learning and the development of new or enhanced internal capabilities leading to technological growth, diversification and hence further innovative opportunities (Duanmu and Fai, 2007).

For innovation, network ties provide firms with opportunities for knowledge transfer and, in particular, the exchange of technical information between producers and users, thus allowing for adjustments to final products and processes (see Tether, 2002). They can also aid standard setting and improve the adoption rate of new technologies through demonstration effects (particularly where the reputation of the user is widely recognised). For instance, Bessant et al. (2003) demonstrated that supply chain learning - through a sharing of common experiences - facilitates the transfer of 'appropriate practice'. Similarly, in studies of both the US and Japanese automotive supply chains, Kotabe et al. (2003) found that knowledge transfer through network ties provided organisational benefits, though interestingly, the impact of high level technology transfer was positively associated with relationship duration.

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firms, in this paper, we follow Lasagni (2012) in focusing upon inbound innovation. Finally, a comprehensive review of the literature and recent developments on open innovation systems is provided by Huizingh (2011).

[5] This 'network view' formed much of Lundvall's (1992) national innovation systems approach, which was highly influential in European innovation policy during the late 1990s and early 2000s (see, for instance DIUS, 2008).

This latter insight again reflects the importance of repeated interaction and enduring relations in promoting strong ties and facilitating fruitful information exchange (see Poldolney and Page, 1998).

2.2 Small firms, Co-operative Ties and Innovation

For small and medium sized firms (SMEs), business networks are particularly important for enhancing innovative capability. This is because SMEs are typically not endowed with significant internal resources for innovation (or its market exploitation) and so, in such cases, external guidance and assistance is often crucial to aid their competitive edge (De Propris, 2002, Rogers, 2004). Networks are significant conduits for exposing SMEs to novel sources of ideas, improving their access to inputs and enhancing the transfer of knowledge and technological opportunity (Nieto and Santamaria, 2007, Zeng et.al 2010). Indeed, by collaborating with other (possibly larger) firms which own relevant assets and sharing those existing assets, SMEs can gain access to (intrinsic) assets that create value and which are often not available for purchase in factor markets, thus overcoming their resource deficiency (Ahuja, 2008).

In recent years, there have been a number of studies exploring the link between co-operative (network) ties and innovation among SMEs. Much of this research has focused upon vertical supply chain networks; these being the closest (and friendliest) set of networks SMEs are engaged in (Huizingh, 2011). It has also tended to utilise survey data, largely to capture different measures of innovation and the nature and extent of network ties. Examples of such studies include De Propris's (2002) study of 435 SMEs in the West Midlands region of the UK. Using binary variables (1/0) to capture co-operative ties, she found a positive relationship between firms engaging in co-operation with both client firms and suppliers over product innovation, while in process innovation, only supplier co-operation was significant. Freel and Harrison's (2006) larger regional survey of over 1300 small and medium sized manufacturing and service sector firms in Northern England and Scotland, which again used a binary approach to measure co-operation, uncovered similar patterns. More recently, Nieto & Santamaria's (2010) study of 1300 Spanish SMEs (using data from the Spanish Business Strategies Survey) found that vertical technological collaboration was the most important factor in improving firms' innovativeness, allowing them to close the innovation gap with their larger rivals. Finally, Lasagni (2012) uses data from a survey of 500 SMEs across six European countries (Austria, Germany, Italy, Hungary, Poland, Slovenia) and finds co-operation over design with both buyers and suppliers being (positively) significant in aiding innovation[6].

In addition to supply chain networks, there is the potential for horizontal collaboration between SMEs. Known as co-opetition (Brandenburger and Nalebuff, 1996), this is a paradoxical arrangement which encourages collaboration in some stages of the product lifecycle, or in certain technical/production areas but where participants engage in competition in others (Gnyawali and Park, 2009). Of course, SMEs have long used competitors as subcontractors (collaboration) when their own capacity has been reached or to handle large projects/bids (Lechner et.al 2006). Co-opetition however, was popularised through the Italian industrial districts model and its variant; the 'innovative milieu'. Numerous 'Italiannette' case studies thus emphasised the repeated interaction between

[6] Other recent (and non-European) studies include those of Lee et.al (2010), which found that open innovation networks were important in facilitating innovative activity among Korean SMEs. Gronum et.al (2012)'s study of 1435 Australian SMEs (using data from the Australian bureau of Statistics survey), found that the number of network ties and frequency of interaction (a proxy for tie strength) specifically along the supply chain were significant factors in enhancing innovation. Finally, Zeng et.al (2010) small survey of 137 Chinese SMEs found that inter-firm co-operation had a positive impact upon innovation.

horizontal networks of SMEs as part of a process in which mutual interdependence, greater trust and reciprocity were core features; in turn these promoted 'collective learning' aiding innovative performance (Becattini, 1990; Camagni, 1991; Maillat, 1995; Bellandi 2003). More generally, it has become accepted that horizontal collaboration among SMEs can speed up product development, provide economies of scale and mitigate the risk associated with R&D resources and technology, allowing them to compete with larger players (Winch and Bianchi, 2006, Morris et.al, 2007)). However, co-opetition comes at a risk of technology leakage to rivals and a loss of control over the innovative process and must be considered truly worthwhile in order to endure the unique management challenges which often arise (see also Ritala et.al 2012).

From an empirical perspective, some studies have found a positive correlation between co-opetition and innovation. A 5 year panel study of 73 European bio-technology SMEs by Quintana-Garcia and Benavides-Velasco (2004), found that co-opetition had a positive impact upon a firm's innovative capacity. Utilising a path analysis technique, Najib and Kiminami's (2011) study of Indonesian food processing clusters found that a composite measure of inter-firm co-operation (competitor, supplier and buyer) was strongly associated with both product and process innovation. In contrast, both De Propis (2002) and Freel and Harrison (2006) did not find any evidence that horizontal co-operation was significant in explaining innovation among UK SMEs.

2.3 Hypothesis Formulation

The preceding discussion infers that both supply chain collaboration (with both buyers and suppliers) and – perhaps to a lesser extent – co-opetition can have a positive impact upon innovation within SMEs. While this might lead to straightforward hypothesis formulation, it needs to be qualified by also considering the strength of such ties; in short the nature of dyadic relations (see Squire et.al, 2009). Indeed, this is an important adjunct, since the strength of co-operative ties can be an important factor in enhancing innovation (Ahuja, 2000). Strong ties '*enrich relationships through trust and reciprocity'* (Uzzi, 1996, p.677) and facilitate collaboration over a range of activities (Bessant, et al. (2003). This argument has also been made, for instance, in relation to the strength of strategic alliances and it's positive upon impact knowledge transfer (see Autio et al. 2000, Hitt et al., 2000). Inkpen and Tsang (2005) have also noted that strong ties facilitate an environment more conducive for successful knowledge transfer as partner firms are more willing to share knowledge and information. In addition, Kale et al. (2000) found a positive relationship between the strength of ties and the degree of learning within strategic alliances[7].

Unfortunately, the majority of studies – while undoubtedly providing useful insights - have not always captured the nature and intensity of co-operative ties and their impact over innovation. In addition, existing empirical approaches in relation to SMEs have typically not captured the multi-dimensional nature of co-operation (i.e. over a range of activities). For instance, a number of studies have tended to rely upon binary or categorical variables to indicate whether firms co-operate with external partners or not (e.g. De Propis, 2002, Freel and Harrison, 2006). In some cases, tie strength has been measured using proxies such as 'frequency of interaction' (e.g. Gronum et.al, 2012), which may or may not be an accurate reflection of the strength of co-operation. Where a scalar approach (i.e. the use of a Likert scale to indicate the strength of co-operation) has been adopted, this has tended to capture

[7] We are aware that a substantive literature exists – emanating from Granovetter (1973) – on the importance of 'weak ties', which potentially open up new channels of information; it comes with the warning that strong ties may become too closed to new ideas due to over-embeddedness (see also Grabher, 1993). The weak ties argument should not, however, dilute the importance of the quality and strength of co-operative ties (see Tomlinson, 2011).

either a general measure of co-operation or one that covers only a narrow range of activities (e.g. Zeng et.al, 2010, Tiemoury et.al, 2011, Lasagni, 2012).

The main weakness of the aforementioned approaches is they thus omit important information, specifically relating to the scale and various dimensions of co-operative behaviour and innovation. Consequently, such studies are often unable to say much about the nature of the dyad between firms and specifically the degree of inter-firm co-operation required for successful innovation. We seek to address this deficiency, while exploring the links between SMEs, co-operation and innovation.

Based upon the above discussion, we thus suggest the following three hypotheses:

H1: *Stronger co-operative ties with clients over a range of activities enhance SME innovation*

Similarly, in upstream relations

H2: *Stronger co-operative ties with suppliers over a range of activities enhance SME innovation*

And, finally with regards to co-opetition,

H3: *Stronger horizontal co-operative ties (co-opetition) over a range of activities enhance SME innovation*

3.0 Research Methodology

3.1 Sample

During September 2008, a postal questionnaire was mailed specifically to the Managing Directors of 2,480 UK small and medium sized manufacturers across five industrial sectors: aerospace, ceramics, information technology and software, textiles and healthcare (i.e. the manufacture of medical equipment and instruments)[8,9]. These sectors were chosen to provide a generic mix in the sample between old and traditional industries (such as ceramics and textiles) and those sectors perceived as being more modern and (in recent policy terms) strategically important in the UK economy (such as aerospace, information technology and medical equipment). The unit of analysis is the firm and the sampling frame was drawn from the membership directories of the respective main industry trade associations, each of which provided contact and background information on member firms operating at the 4 digit Standard Industrial Classification (SIC) level[10]. A random stratified sampling process was used to select the firms, and a £1 donation was promised to the African Child Trust for each completed and returned questionnaire received in order to facilitate a higher response rate, while reminder letters were sent out at three and then five weeks after the initial mail-out. In total, 371 usable responses (15%) were received, which represented a sampling error of 5.08% at the 95% confidence interval and is within the acceptable limits for survey research (see Oerlemans *et al.*, 2006)[11]. The data was inputted into SPSS (version 19.iso), through which all the statistical analysis was conducted. Tests for non-response bias were conducted by comparing the mean responses of the variables under consideration (innovation, co-

[8] Definitions of small and medium sized (SMEs) firms vary. The EU (2008) guidelines classify SMEs as being those with less than 250 employees, whereas in the US the employment boundary is less than 500 employees (US, SBA, 2010). To facilitate wide international comparison in any future research, we employ the higher US classification (accounting for 6% of firms in the sample; see Table A2). We do, however, control for different stratifications of firm size among SMEs in our empirical analysis.

[9] Respondents were asked to sign the completed questionnaire and state their (senior) position in the company; anonymity was assured to all respondents. In the few cases where it was unclear whether a Managing Director or Senior Manager had completed the survey or not, a telephone call was made to the firm's senior management to verify the responses.

[10] The respective industry associations were the Ceramics Industry Forum, Society of British Aerospace Companies (SBAC), Intellect, British Apparel and Textile Confederation (BATC) and the Association of British Healthcare Industries (ABHI).

[11] Specifically, there were 97 responses from aerospace, 95 from ceramics, 59 from IT and software, 78 from textiles and 42 from medical equipment.

operation between firms) of the early and late respondents (Armstrong and Overton, 1977); ANOVA analysis revealed no significant differences[12].

Finally, it is important to consider the extent to which the sample is representative of the population of SMEs in UK manufacturing. This was done by comparing the distribution of the employment sized bands (number of employees, 1-10, 10-49, 50-99, 100-250 and 250-499) of the 371 respondent firms with the UK National Office of Statistics (2008) data on the proportion of UK VAT registered units by the employment size. This is documented in Appendix A2, where there is an apparent skew in the sample away from capturing the smallest firms (0-9 employees; sometimes referred to as 'micro' firms). This should be taken into account in considering our empirical analysis, although it can be qualified somewhat in that the official data on VAT registered units does not specifically account for the ownership of such units; where firms own multiple units, the National Statistics population data may overstate the number of smaller firms at the tail end of the distribution. In addition, we note Freel and Harrison's (2006) point that the under-surveying of micro-firms is a familiar problem in firm-level innovation surveys (largely due to concerns over data adequacy, response rates and issue relevance), but that this should not deter researchers since '*custom and practice, and common sense…underwrite the veracity of the analysis*' which is '*not generally compromised' (ibid p.293).*

3.2 Questionnaire and Variable Construction

The questionnaire included questions on the firm's business background, firm size, their R&D and innovation activities, as well as their co-operative and network ties with partner firms. The questions were based upon those used in previous academic research (for details,

[12] Late responses were defined as those received after three weeks from the initial mail-shot. Details of the ANOVA analysis are included in the Appendix A1.

see variable construction below) and covered a range of activities. Responses were measured using a structured set of Likert scales which provided data that was both multi-dimensional and multi-scalar in nature; the data thus contained more information than previous studies into co-operative behaviour and innovation (see Section 2). The questions themselves related to the previous three years of business trading (i.e. 2005/06-2007/08). Details of the questions asked and scales used are provided in Table (1). The primary variables of interest are described as follows:

Innovation: Previous studies, particularly those that rely upon primary data sources, have employed categorical measures of innovation which typically distinguish between 'incremental' and 'novel' innovations, with the distinction often based upon whether innovations are considered to be 'new to the firm' and/or 'new to the industry' (e.g. De Propris, 2002, Freel and Harrison, 2006). Such measures are, however, context dependent and open to possible subjective biases through the various interpretations of both respondents and researchers (Pavitt, 1988)[13]. The measure employed in this study was based upon Tsai and Ghoshal (1998) and Molina-Morales and Martinez-Fernandez (2010) and which also complied with the definition provided in the Oslo Manual (OECD, 2005; see footnote 1). In short, respondents were asked to indicate the number of new innovations the firm had introduced over various activities during the previous three years. This is a frequency based measure and the activities or items included are described in Table (1). For each firm, a composite measure of innovation was constructed, followed by separate measures of product and process innovation. These were done by calculating the mean scores across the items (a-

[13]An alternative measure is patent activity, which has long been a favourite instrument of researchers in capturing innovative activity since such data is readily available in the public domain. This metric though is also not without its problems, with some firms using patents as a defensive strategy rather than a means of recording creative output. Moreover, the propensity of SMEs to patent innovations varies considerably across firms and industries (Pavitt, 1988, Katila, 2002). In the context of this study, patent activity is unlikely to be a reliable measure of innovation.

e) listed in Table (1), with the aggregation being validated by Cronbach's alpha (α). This provided an overall measure of the level of innovation within each firm.

Buyer Co-operation: To capture the degree of downstream co-operation, questions were asked relating to the strength of firms' co-operative ties with their main clients over a range of activities, using items based upon studies into co-operative behaviour between firms by Schmitz (1999, 2000), Knorringa (1999) and Nadvi (1999)[14]. Again, for each firm, buyer co-operation was constructed using the mean score across the items listed in Table (1), with the aggregation being validated by Cronbach's alpha (α).

Supplier Co-operation: The strength of upstream co-operative ties that firms engage in over a range of activities was captured using items based upon Schmitz (1999, 2000), Knorringa (1999) and Nadvi (1999). For each firm, supplier co-operation was constructed using the mean score across the items listed in Table (1), with the aggregation again being validated by Cronbach's alpha (α).

Horizontal Co-operation: Similarly horizontal collaboration, the extent to which firms engage in co-opetition with competitor firms was measured using items based upon Schmitz (1999, 2000), Knorringa (1999) and Nadvi (1999) and listed in Table (1). The mean score across these items was calculated to construct horizontal co-operation, with Cronbach's alpha (α) being used to validate the aggregation process.

[14] These specific studies explored the extent of co-operation and co-operative behaviour between firms in certain clusters in developing countries ((Schmitz, (1999, 2000); Sinos Valley, Brazil), (Knorringa (1999); Agra, India), (Nadvi (1999); Sailkot, Pakistan). They did not consider the impact of co-operation upon innovation. Nevertheless, the measures of co-operation (between firms) employed – utilising Likert scales - are also useful in the context of this paper.

Control Variables: In addition to the aforementioned variables, a number of control variables were also included to account for the differential impacts of firms' internal resources upon the innovation process (Symeonidas, 1996). Measures included Sales Revenue Growth, Firm Size and Research and Development (R&D) expenditure, which were expected to have a positive impact upon innovation (Cohen and Levinthal, 1990)[15]. Further details are provided in Table (1). Sales revenue growth is a binary variable capturing growth over the previous three years, while the other two variables utilise categorical scales; Firm Size is measured in terms of the number of employees and R&D expenditure is expressed as a proportion of sales turnover (De Propris, 2002). Finally, we control for industry differences in innovation levels by including a set of dummy variables, with the medical equipment sector being designated as the base.

INSERT TABLE (1) HERE

3.3 Descriptive Statistics

Table (2) provides details of the descriptive statistics of the aforementioned variables for all 371 SME firms in the sample. The bivariate correlations indicate significant correlation between the co-operation and institution variables. This is perhaps not surprising since firms that are embedded in more co-operative relations, tend to be so in both their upstream and downstream operations, while they are also more likely to engage in horizontal collaboration (co-opetition). Sensitivity between discriminating variables can be problematic in empirical analysis (see Hair *et al.*, 2007), but the size of the correlations and subsequent tests for multi-collinearity (using variance inflation factors) suggests this was not a problem. The co-operation variables are also significantly correlated with innovation.

[15] Although all firms are categorised as being 'small and medium sized', the sample included 'micro' firms (less than 10 employees), small firms and medium sized firms (upto 500 employees); see Section 3.1 and Appendix A2.

For each construct, Cronbach's alpha (α) is also reported, allowing an assessment for *convergent validity,* i.e. whether the items used in specific constructs are related (or share a high proportion of variance in common). In all cases, Cronbach's alpha was greater than the accepted minimum level of 0.70, thus satisfying the criteria for internal consistency and reliability (Hair et al., 2007). Tests for *discriminant validity* were also conducted by comparing the variance-extracted estimates for pairs of constructs with the square of their respective correlation coefficient (see Hair et al, 2007). This captures the extent to which a construct is unique and captures phenomena other measures do not i.e. that it is distinct (Campbell and Fiske, 1959). The test statistics strongly supported the hypothesis that discriminant validity was present[16]. *Face validity* - the theoretical justification for using particular scale items – was satisfied by utilising previously used multi-scale items, as discussed above. Finally, the *validity* of *subjective assessments* of single responses to the survey questions was verified by gathering similar independent data on the key variables from a random selected sample of 50 second participants (these were senior managers) from the surveyed firms (Marsden, 1993, Krackhardt, 1996). These responses were gathered by telephone and this additional control was run for the innovation and co-operation variables, with possible second response bias being tested by a comparison of means; there were no significant differences and so the validity of subjective assessments was considered acceptable (see Appendix, A4).

INSERT TABLE (2) HERE

[16] The exception was in the comparison of the variance extracted (V.E.) estimate for the composite innovation construct and the corresponding inter-squared construct associated with process innovation (0.75 vs 0.81). Given the relative closeness of the statistics under consideration and that both constructs appear in different regression models, this is not a major concern (Hair et.al, 2007). Overall, the tests support the presence of discriminant validity and full details of these tests and calculations are reproduced in Appendix A3.

4. Model Specification, Results and Discussion

4.1 Model Specification

The model employed follows earlier approaches to modelling open innovation (Geroski, 1990, De Propris, 2002, Freel and Harrison, 2006, Oerlemans *et al.*, 2006) and is based upon a standard knowledge production function (namely internal variables), which is supplemented with the independent predictors, the co-operation variables:

$$\text{Innovation} = \beta_0 + \beta_1 \text{ Firm Size} + \beta_2 \text{ R\&D} + \beta_3 \text{ Sales Revenue Growth} + \beta_4 \textit{ Industry Dummy} + \beta_5 \text{ Buyer Co-operation} + B_6 \text{ Supplier Co-operation} + \beta_7 \text{ Competitor Co-operation} + \varepsilon_i \qquad (1)$$

Estimation of Equation (1) took the form of a hierarchical multivariate regression model, where the dependent variable was first regressed on the control variables and then the model was supplemented with the predictor (co-operation) variables. The model was first estimated for the composite measure of innovation, and then subsequently for both the product and process measures; these latter two measures being subsets of the composite model.

4.2 Results

INSERT TABLE (3) HERE

Table (3) presents the results for all three models. While appearing relatively low, the R-squared values are similar to those reported in recent multivariate studies on the determinants of (open) innovation (e.g. De Propris, 2002, Freel and Harrison, 2006 and Molina-Morales &

Martinez-Fernandez, 2006, 2010). At this point we should note the use of perceptional scale-based measures does raise some methodological issues, particularly in relation to the interpretation of the Beta co-efficients in regression models. Such data is however commonly used in research of this kind (Hair et.al, 2007) and has precedent in the innovation literature (Molina-Morales & Martinez-Fernandez, 2006, 2010)[17]. One of the main contributions of the paper is to capture of the scale and multi-dimensional nature of the variables under question (notably the innovation and co-operation constructs). The estimated Beta values thus provide an indication of the magnitude and the relative importance of the explanatory variables in the models while the results themselves are comparable with previous studies, which use more direct measures of co-operation and innovation (see earlier discussion)[18].

In general, the models appear well specified. The internal control variables perform well across all of the models, with Firm Size, Sales Growth and R&D expenditure all being positive and highly significant; thus, as expected, SMEs' internal resources have a positive impact on their innovative capability. The one exception is a surprising, counter-intuitive insignificant Beta coefficient on R&D in the product innovation model. This may reflect the use of a frequency based measure of product innovation, which captures the level(s) of innovation within firms. A drawback of frequency based measures of innovation is their inability to differentiate between high and low value added types of product differentiation and are thus unable to explain variation in innovation strategies (see Griliches, 1990). In contrast, process innovation inherently contains an element of value added in process and organisational changes, especially if they enhance firm efficiency; hence the highly positive and significant result for R&D expenditure in the process innovation model. Finally, the

[17] Molina-Morales & Martinez-Fernandez's (2006, 2010) studies considered the impact of social capital variables – namely measures of 'trust', 'social interaction' and 'shared vision' – upon innovation across five Valencian industrial districts; a positive association was established.

[18] This would suggest the use of the measures and the results in the paper are robust (Hair et.al, 2007).

significance of the industry dummy variables captures the differences in recorded industry innovation levels relative to the medical equipment sector.

All models improve their explanatory power with the introduction of the predictor variables. As expected, buyer co-operation is positive and significant in the composite model and in the product innovation model. Thus H1 is supported with close co-operation with clients ensuring products are designed to meet specific customer requirements and market demand, while also enabling opportunities for inter-firm learning. It also reduces the potential for problems to emerge ex-post, and serves to reduce demands upon 'post-delivery learning'. The benefits to innovators are realised in terms of freer time and resources for future innovation (see also Freel and Harrison, 2006). H2 is also supported with supplier co-operation being highly significant across all three models. Indeed, the *B* values would also indicate that supplier co-operation is relatively more important than buyer co-operation in the innovation process. With regards to product innovation, users appear to gain much from greater co-operation with suppliers over key inputs and in exchanging information and new ideas. In terms of process innovation, upstream co-operation over delivery times, technological inputs, labour training and production organisation also appear to generate positive feedback effects and synergies along the supply chain, thus supporting innovative process activities. Finally, horizontal co-operation (co-opetition) is not significant and thus H3 is not supported here; there appears no significant horizontal collaboration between firms over innovation across the whole sample. This result thus confirms that of similar studies involving UK SMEs, which also explored the impact of co-opetition upon innovation (De Propris, 2002, Freel and Harrison, 2006).

In short, the results support the contention that vertical co-operation enhances innovative activity among SMEs. As mentioned, the general results are similar to the two aforementioned UK manufacturing studies by De Propris (2002) and Freel and Harrison (2006). While these studies were regional, the current study highlights network effects that extend beyond geographical boundaries. More generally, the results here emphasise the nature of the dyad between firms, by specifically capturing the *range of co-operative activities* which aid innovative capacity and not just the existence of a co-operative tie. In addition, the reported results also emphasise the importance of the *degree of intensity* between co-operating partners for innovation; in short, stronger ties along the supply chain induce greater levels of innovative activity among SMEs.

5.0 Wider Discussion and Policy Issues

The results hold particular resonance among SMES and supply chain managers, who will be particularly interested in co-ordinating ties among partner firms. In the early literature, close co-operation may have been seen as an alternative governance mechanism to counter the appropriability problem and opportunism (Williamson, 1985). Now, however, nurturing closer ties across a range of activities such as joint product design to marketing and distribution, particularly between SMEs in the value chain, facilitates knowledge transfer and organisational learning and aids innovation performance.

This is not easy to achieve, since there are inherent difficulties in nurturing inter-firm relations. For instance, joint commitments are particularly vulnerable to opportunism and may be particularly problematic where synergies are not easily transparent or where firms are sceptical and inert to changing circumstances (Jessop, 1998, Huggins, 2001). Furthermore, SMEs are particularly sceptical about networking and are less likely to participate in innovation networks than larger firms (see also Asheim *et al.*, 2003); it may be the case that many SMEs are not exploiting the opportunities that external collaboration can provide. Indeed, Hanna and Walsh (2002) report that few small firms network with their peers (co-opetition) over R&D largely because of lack of trust or intimidation by a more dominant partner. Moreover, in exploring barriers to co-operation in innovation among Chinese SMEs, Xie et.al's (2010) survey highlighted problems such as a 'lack of technical experts', 'lack of financial capital (in relation to R&D)', 'lack of technical information regarding new technologies' and a 'lack of suitable partners' as being significant. Yet, clearly such barriers are related to SME's inherent internal resource constraints that hinder their ability to build and maintain sustainable networks beyond the Chinese context (Huizingh, 2011).

This may suggest a more significant role for external (state) funding to help to nurture and establish SME innovation networks. To some extent, this has already become a facet of innovation policy within some European quarters (Aranguren et.al, 2010; DIUS, 2008). Moreover, there is evidence that it does have a positive impact. Huggins et.al (2012) for instance, compare the regional impact of network funding in three European regions (UK; northern England; Greece; Thessalonki; Turkey; Istanbul metropolitan) and find that SME innovation performance is significantly and positively related to '*network capital investment in dynamically configured inter-organisational knowledge alliances' (ibid; p. 221).* This is however qualified by the fact that the effectiveness of such funding often differs in national and regional contexts and which in part reflects differential attitudes/cultures to co-operation (see also Dachs et.al, 2008).

At the practitioner level, recent research on the socialisation of the supply chain and in improving the dyad between firms may help to overcome barriers to co-operation.

Suggestions here have ranged from promoting more open communication systems between firms, the facilitation of joint workshops and reciprocal firm visits and discussions over (joint) problems which can help to build relational capital and engineer greater goodwill and understanding between parties, providing the basis for fruitful long term relationships (see Cousins *et al.* 2006). To assist this process, there may be a greater role for trade organisations and associated institutions to act as appropriate conduits for building inter-firm relational capital (Zeng et.al, 2010). In addition, Aranguren *et al.* (2010) have also recently argued for suitable information exchanges – a role which might be performed through existing trade bodies. Lee et. al (2010) suggest such bodies could provide SMEs with lists of appropriate partners, with data on strengths, weaknesses and capabilities on each so as to facilitate network development.

Our final comment relates to absorptive capacity (Cohen and Levinthal, 1990). Although this paper has not specifically considered this issue in the context of innovation (aside from controlling for internal resources in our empirical analysis), it is a relevant point that warrants further consideration. Earlier research has suggested the amount of external knowledge a firm observes is an increasing function of its absorptive capacity (see Brusoni et.al, 2001; Zahra and George, 2002; Negassi, 2004). Barge-Gil (2010), for instance, notes that absorptive capacity reduces the costs of openness by reducing search and assimilation costs and increases profitable innovation by ensuring better application to in-house activities. Moreover, Ritala et.al's (2012) study of Finnish firms found that absorptive capacity and appropriability were particularly important in horizontal networks; where firms were better able to obtain, assimilate, transform and utilize knowledge to innovate (absorptive capacity) and better able to protect their intellectual property (appropriability), they were more able to reap the rewards from co-operation over innovation. Clearly, SMEs endowed with greater absorptive capacity (and appropriability) are more likely to engage in innovation networks.

6.0 Conclusion

The results in this study demonstrate that close co-operation along the supply chain plays an important role in the innovation process of SMEs. Through establishing networks, SMEs can overcome their internal resource constraints and obtain the advantages often associated with larger size (Nooteboom 1994). In particular, it is the strength of co-operative ties and across a range of productive activities that is crucial for innovation. Given previous studies in this area, this may not appear an overly surprising result. However, prior studies of SME innovation networks have merely captured the existence of collaboration, but said little about the nature of dyadic relations between firms. In contrast, this study captured these multi-dimensional and multi-scalar characteristics in the data and empirical analysis, thus going beyond previous empirical approaches and facilitating the inclusion of additional information.

The implications of the study suggest that nurturing innovation networks and improving the dyad between partner firms – particularly in relation to facilitating knowledge transfer and organisational learning - is crucial for SME innovative activity along the value chain. However, as we noted this is not always easy to achieve, since there are inherent difficulties in nurturing such relations. It may be that state funding and a larger role for trade associations is required to facilitate network development. A related issue which is not covered here, but is the focus of our future research is whether there is an optimal level of co-operation that firms should strive to achieve to enhance their innovative endeavour. As noted earlier (see footnote 7), firms can become over-embedded in relationships, and invest too much time and resources in specific dyads at the expense of seeking alternative partners (Granovetter, 1973).

Identifying, an ‘appropriate’ level of co-operation for SMEs could improve resource allocation.

Finally, there are some caveats in relation to our approach that should be noted. First, innovative and co-operative firms were identified by self-declaration, which could generate bias among self-confident firms. However, this is a problem familiar to all survey based approaches, where researchers use self-reported data and have to rely upon managers’ judgement regarding responses. Consequently, this should not overly detract from the analysis (Lasagni, 2012). Secondly, the assumption of causation running from co-operation to innovation; in cross-sectoral studies of this type, the reverse may be the case with more innovative firms engaging in co-operation. However, given previous studies have uncovered similar patterns, we hold a strong degree of confidence in our results and their wider interpretation[19]. Future research may however, warrant a more qualitative approach, which may also seek to explore the intrinsic characteristics of dyadic relations in SME innovation networks in more detail.

Thirdly, the time window of the current study was relatively short (3 years). In part, this is the nature of survey work in that it typically captures variables at a specific point in time. By specifying a three year window, we were able to focus respondents upon their recent relations with their partners. However, our empirics are nonetheless, relatively static which may be a reason (though this is not uncommon in studies of this type) for the relatively low R-squared values in our models. It is highly probable that the dynamics of the relationships covered will change over time, particularly as new firms enter/exit industries and external challenges to supply chains emerge. Moreover, managers may change in firms and they will have different

[19] Indeed, while our results relate specifically to UK manufacturing, the recent plethora of other international studies in this area suggests a degree of conformity in the innovation-co-operation relationship.

perceptions on their co-operative relationships. These dynamics might be better captured through periodic follow up surveys to provide longitudinal data that takes account of a longer time window.

7.0 References

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Table (1) Variable Construction: Details of Survey Items used to construct variables

Note: All Co-operation constructs use a 5 point Likert scale, where 1 = no co-operation and

Variables	**Method used to construct the variables**
Product Innovation	*(a). Number of new product lines introduced* *(b). Number of changes/improvements to existing product lines*
Process Innovation	*(c). Number of new equipment/technology introduced in the production process* *(d).New input materials introduced in the production process* *(e). Number of organisational changes/improvements made in the production processes* *(Scale 1-7; where 1 = Zero, 2 = to 1-5, 3 = 6-10, 4 =11-15, 5 = 15-25, 6= 26-50, 7 = greater than 50)* *Based upon Tsai and Ghoshal (1998), Molina-Morales and Martinez-Fernandez (2010)*
Firm Size	Number of employees *(Scale 1-5; where 1 = less than 10, 2 = 10-49, 3 = 50-99, 4 = 100-250, 5 = 250-499)* *Based upon De Propris (2002), Freel and Harrison (2006)*
R&D expenditure	% of turnover spent on R&D *(Scale 1-5; where 1 = 1-5%, 2 = 6-10%, 3 = 11-20%, 4 = 21-30%, 5 = Greater than 30%)* *Based upon De Propris (200), Freel and Harrison(2006)*
Sales Revenue Growth	1/0; 1 *if firm has attained sales revenue growth over the three year period 2005/06-2007/08; 0 otherwise* Based upon De Propris (2002)
Co-operation with Buyers *(Product Innovation)*	*(a). Improving Product quality* *(b). New Product designs* *(c). Exchange of information/experiences*
Co-operation with Buyers *(Process Innovation)*	*(d). Marketing and Distribution of products* *(e). Production organisation* *(f). Technological upgrading* *(g). Exchange of information/experiences* *Based upon Schmitz (1999, 2000), Knorringa (1999) and Nadvi (1999)*
Co-operation with Suppliers *(Product Innovation)*	*(a). Improving quality of inputs* *(b). Exchange of information/experiences*
Co-operation with Suppliers *(Process Innovation)*	*(c). Improving delivery times* *(d). Labour training* *(e). Production organisation* *(f). Technological upgrading* *(g). Exchange of information/experiences* *Based upon Schmitz (1999, 2000), Knorringa (1999) and Nadvi (1999)*
Co-operation with Competitors *(Product Innovation)*	*(a).New Product Designs* *(b).Exchange of information/experiences*
Co-operation with Competitors *(Process Innovation)*	*(c).Marketing and Distribution of products* *(d).Labour training* *(e). Production organisation* *(f). Outsourcing production* *(g). Technological upgrading* *(h). Exchange of information/experiences* *Based upon Schmitz (1999, 2000), Knorringa (1999) and Nadvi (1999)*

5 = Very high level of co-operation

Table (2) Descriptive Statistics and Bivariate correlations (to two decimal places)

N=371	Mean	S.D	α	VIF	1	2	3	4	5	6	7	8	9
1. Innovation (Composite)	2.77	1.08	0.75	N/A	1								
2. Product Innovation	3.27	1.56	0.70	N/A	0.80**	1							
3. Process Innovation	2.42	1.06	0.72	N/A	0.90**	0.46**	1						
4. Firm Size	2.00	1.00	N/A	1.52	0.27**	0.13*	0.30**	1					
5. R&D expenditure	2.05	1.30	N/A	1.19	0.01	-0.05	0.04	-0.14**	1				
6. Sales Growth	0.56	0.50	N/A	1.27	0.23**	0.15**	0.22**	0.17**	0.09	1			
7. Co-operation with Buyers	2.71	0.81	0.80	1.36	0.22**	0.14**	0.30**	0.13**	0.08	0.04	1		
8.Co-operation with Suppliers	2.40	0.92	0.88	1.28	0.25**	0.14**	0.26**	0.18**	0.02	0.01	0.40**	1	
9. Co-operation with Competitors	1.66	0.64	0.86	0.85	-0.14*	-0.12*	-0.10	-0.13*	0.28**	0.04	0.05	0.15**	1

*** Pearson's Correlation is significant at the 0.01 level (2-tailed test)
** Pearson's Correlation is significant at the 0.05 level (2-tailed test)
* Pearson's Correlation is significant at the 0.10 level (2-tailed test)
α – Cronbach's alpha
VIF – Variance Inflation Factor; where VIF > 5, it is likely that multi-collinearity is present (Hair et.al, 2007).

Table (3) Multivariate Regression Analysis (Dependent Variable: Innovation)

Variable	Innovation (Composite) (1)	Innovation (Composite) (2)	Product Innovation (1)	Product Innovation (2)	Process Innovation (1)	Process Innovation (2)
Constant	-1.391*** (0.193)	-1.312*** (0.210)	-1.292*** 0.230	-1.169*** (0.227)	-1.472*** (0.224)	-1.337*** (0.218)
Firm Size	0.215*** (0.044)	.206*** (0.046)	0.226*** 0.052	0.197*** (0.052)	0.273*** (0.051)	0.236*** (0.049)
R&D expenditure	0.082* (0.033)	0.059* (0.036)	0.073* 0.039	0.062 (0.039)	0.120*** (0.038)	0.109*** (0.037)
Sales Growth	0.318*** (0.081)	0.339*** (0.087)	0.332*** 0.097	0.342*** (0.095)	0.317*** (0.094)	0.332*** (0.091)
Textiles	0.813*** (0.150)	0.725*** (0.165)	0.777*** (0.179)	0.665*** (0.183)	0.852*** (0.174)	0.726*** (0.175)
Ceramics	0.599*** (0.152)	0.727*** (0.164)	0.710*** 0.181	0.762*** (0.178)	0.583*** (0.176)	0.652*** (0.171)
Aerospace	0.395*** (0.150)	0.381** (0.163)	0.438** 0.179	0.385** (0.178)	0.475*** (0.175)	0.420** (0.170)
Information Technology & Software	0.230 (0.158)	0.320* (0.172)	0.173 0.188	0.159 (0.187)	0.218 (0.183)	0.234 (0.180)
Co-operation with Buyers		0.081* (.045)		0.101* (0.055)		0.070 (0.053)
Co-operation with Suppliers		0.166*** (.047)		0.171*** (0.058)		0.253*** (0.056)
Co-operation with Competitors		-0.058 0.046		-0.034 (0.055)		-0.052 (0.053)
Adjusted R^2	0.167	0.223	0.122	0.157	0.165	0.225
F statistic	11.60***	10.216***	8.439***	7.935***	11.473***	11.750***
N = 371						

*** p<0.01; ** p<0.05; * p < 0.10, Non-standardized regression coefficients (errors in brackets)

Appendices

Table A1: Tests for Non-Response Survey Bias

All Firms (n = 371) Variable	Early Respondents (n = 206) Mean	S.D.	Late Respondents (n = 165) Mean	S.D.	F Test Pr(F>3.84)=0.05
Innovation	2.81	0.78	2.72	0.91	1.05
Buyer Co-operation	2.75	0.63	2.66	0.72	1.65
Supplier Co-operation	2.38	0.62	2.42	0.69	2.53
Competitor Co-operation	1.7	0.56	1.64	0.51	2.57

Insignificant F test results (at 5%) indicate no substantive differences between early and late respondents (Armstrong and Overton, 1977).

Table A2: Proportion of Firms by Firm Size

Number of employees	All Firms (Manufacturing)	
	Sample	Population
0-9	42.9%	74%
10-49	31.7%	19%
50-99	12.3%	3%
100-250	7.1	2%
250-499	6%	2%

Sources: UK Office for National Statistics (2008).

Note: The UK Office for National Statistics (2008) data measures the proportion of VAT registered units (based upon 2003 SIC codes). As such, it does not specifically account for the ownership of such units. Since firms may own multiple units, the National Statistics data may overstate the proportion of smaller firms in each stratification of the actual population.

Table A3: Tests for Construct Discriminant Validity

N=371	V.E.	1	2	3	4	5	6
1.Innovation (Composite)	0.75	1	0.64	0.81	0.05	0.06	0.02
2. Product Innovation	0.72	0.80	1	0.21	0.02	0.02	0.01
3. Process Innovation	0.77	0.90	0.46	1	0.09	0.07	0.01
4. Buyer Co-operation	0.89	0.22	0.14	0.30	1	0.16	0.002
5. Supplier Co-operation	0.88	0.25	0.14	0.26	0.40	1	0.02
6. Competitor Co-operation	0.62	-0.14	-0.12	-0.10	0.05	0.15	1

V.E. – Variance Extracted for each factor constructed

Notes:

For discriminant validity, a comparison is made between the variance extracted estimates (V.E.) for each factor with the squared inter-construct correlations associated with that factor (Hair et.al, 2007). According to Hair et.al (2007: 778) 'The variance estimates should be greater than the squared correlation estimate – the logic being that a latent construct should explain its item measures better than it explains another construct. Passing this test provides good evidence of discriminant validity'.

In the Table, the variance-extracted estimates are greater than the corresponding inter-construct squared correlation estimates (which are above the diagonal and are shaded), with the exception of the composite innovation and process constructs. However, given the relative closeness of the statistics (0.75 vs 0.81) under consideration and that both constructs appear in different regression models, this is not a major concern (Hair et.al, 2007). Overall, the tests support the presence of discriminant validity.

Table A4: Tests for Validity of Subjective Assessments

Firms (n=50)	First Respondents		Second Respondents		
Variable	Mean	S.D	Mean	S.D	F Test Pr(F>4.03)=0.05
Innovation	2.75	0.71	2.82	0.64	0.16
Buyer Co-operation	2.65	0.68	2.69	0.62	0.24
Supplier Co-operation	2.45	0.83	2.39	0.78	0.10
Competitor Co-operation	1.64	0.54	1.59	0.61	0.88

Insignificant F Test results (at 5%) indicate no substantive differences between first and second respondents from 50 randomly selected firms, thus indicating validity of measures employed (Marsden, 1993, Krackhardt, 1996).