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PATTERNS OF COLLABORATION FOR INNOVATION AMONGST INNOVATING FIRMS IN TASMANIA

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Patterns of Collaboration for Innovation Amongst Innovating Firms in Tasmania

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EXECUTIVE SUMMARY

In Tasmania, innovation plays a role as a key source of multifactor productivity growth and ultimately economic growth. An increasing complexity of innovation often means that many innovations tend commonly to take place in conjunction with collaboration. This report examines the response to the first Tasmanian Innovation Census to investigate the patterns of collaboration between innovating firms and their partners across all sectors in the Tasmanian economy. Using descriptive and multivariate regression analyses, it aims at investigating what factors are associated with the propensity to collaborate for innovation and how collaboration influences firms' innovation outcomes.

This report provides several key findings. First, the relationship between innovation and collaboration in Tasmania is not so straightforward in the sense that most innovating firms still 'go it alone' for innovation; that is, they develop their innovations without any collaboration. Second, factors related to the engagement in collaboration include firm size, sector, belonging to a firm group, receipt of public innovation funding, conduct of R&D, the share of skilled employees and various types of innovation expenditure intensity; however, their impact on collaboration varies depending on the types of partners. Third, only collaboration with customers is associated with the novelty of the firm's innovation, whilst no association between collaboration and the firm's innovation sales share is found. Finally, the innovation novelty is likely to be influenced by conduct of internal R&D and the design and market cost intensity, whereas the innovation sales share is affected by receipt of R&D tax credit and the high training and market cost intensity.

These findings contribute to a more comprehensive understanding of the patterns of collaboration amongst innovating firms in Tasmania. They show that in Tasmania collaboration is not a main mechanism for an improvement in firms' innovative performance. This may, perhaps, reflect the fact that there are significant costs in implementing collaboration, and if costs are greater than returns obtained, then firms in Tasmania (mostly characterized by small size and low capitalization) are unlikely to collaborate or obtain better innovative performance from their collaboration strategizing efforts. However, these constraints could be compensated to some degree by the provision of public financial assistance in the form of innovation funding or tax incentives that is specifically designed to support collaboration. The findings also pinpoint the importance of customers when entering into collaboration with the intent of creating something radically innovative, as well as, the importance of continuous learning and development of human capitals and the market introduction of innovation as effective ways of improving the share of innovation sales.

INTRODUCTION

In recent years, there has been a growing interest in the role of collaboration in the creation and diffusion of innovation. The increased attention given to collaboration is partly due to a shift away from a linear to an interactive model of innovation and to the recognition of the importance of tacit knowledge to innovation and technology transfer (Arundel & Bordoy, 2006). Innovation, as an interactive process, involves the sharing and exchange of different forms of knowledge, resources and skills between actors. The range of skills and knowledge required to successfully carry out innovation often means that an innovating firm is forced to seek complementary skills to those already held in-house. Collaboration is one mechanism for obtaining necessary skills.

Since innovation is by far more than a stand-alone activity, improved understanding of the patterns of collaboration for innovation in Tasmania is needed to better inform policies to promote the transition of Tasmania towards a knowledge-networked economy with enhanced innovation performance, competitiveness and economic prosperity.

This report seeks to empirically examine the patterns of collaboration for innovation amongst the innovating firms in Tasmania that responded to the Tasmanian Innovation Census (TIC). The TIC was the first wide-scale survey of innovation covering all private sector firms in Tasmania with five or more employees. We use the results from this survey to explore two research issues. First, what factors are associated with the propensity of firms to collaborate for innovation? Second, is there a positive association between collaboration and innovation outcomes proxied by a measure of the novelty of the firm's innovation and the firm's innovation sales share? In this report, we are concerned with mapping the presence or absence of collaboration for innovation in general and with different types of partners in particular. Unfortunately, data restrictions mean that we are not able to directly assess how important this collaboration is to the firms' innovation activities, nor how intense or successful the collaboration is. On the positive side, however, we are able to extend the analysis beyond manufacturing to include all sectors of the Tasmanian economy.

This report is structured as follows. After an introduction to the data and methodology used, a preliminary analysis of distribution of collaboration patterns is presented. This is followed by a discussion of descriptive results including: the range of factors available from the TIC that appear to influence firms' engagement in collaboration, and the influence of collaboration on firms' innovation outcomes. A multivariate analysis of the data is then provided. Finally, conclusions are given in the last section.

DATA AND METHODOLOGY

The data used in this report are taken from the first Tasmanian Innovation Census (TIC). This census was implemented in 2007 by the Australian Innovation Research Centre (AIRC) and is based on guidelines set out in the third version of the OECD's Oslo Manual[1]. The main reference period for the census is the three-year calendar period 2004-2006. The census follows the subject-oriented approach by asking individual firms directly about innovative activities, collaboration and innovation outcomes (e.g. novel

[1] The OECD Oslo Manual, 3rd edition 2005.

innovations and sales of innovative products) via computer-assisted telephone interviews. As the TIC covers all firms with five or more employees across all industry sectors, it is unique and provides an opportunity to empirically investigate patterns of collaboration for innovation in the entire Tasmanian region.

The target population for the TIC consisted of 2,807 eligible firms drawn from six size classes (5-9 employees, 10-19 employees, 20-49 employees, 50-99 employees, 100-249 employees and 250 or more employees) in all sectors of the Tasmanian economy. Of these, 1,591 firms responded to the census, yielding a response rate of 56.7 per cent. A non-response analysis did not detect any bias between innovators and non-innovators in their response to the census.

As in all advanced economies, the population is skewed towards small firms, with 87.2 per cent of responding firms having less than 50 employees. More than two-third (68.2 per cent) of responding firms are single independent entities, while the remainder are part of an enterprise group. The results are given for seven sectors (natural resources; infrastructure; manufacturing; retail, wholesale, accommodation and food services; knowledge intensive business services; health, education, public administration and safety; and other services). These seven sectors are given in Table 1.

Table 1: Industry sectors and corresponding ANZSIC 2006 divisions

Industry sector	ANZSIC 2006 divisions
Natural resources	A. Agriculture, forestry and fishing B. Mining
Manufacturing	C. Manufacturing
Infrastructure	D. Electricity, gas, water and waste Services E. Construction, I. Transport, postal and warehousing
Retail, wholesale, accommodation and food services	F. Wholesale trade G. Retail trade H. Accommodation and food services
Knowledge intensive business services	J. Information media and telecommunications K. Financial and insurance services L. Rental, hiring and real estate services M. Professional, scientific and technical services N. Administrative and support services
Health, education, public administration and safety	O. Public administration and safety P. Education and training Q. Health care and social assistance
Other services	R. Arts and recreation services S. Other services

Note: All respondent firms were coded to the Australian and New Zealand Standard Industrial Classification (ANZIC) 2006.

Of these 1,591 respondents, 1,115 (70.1 per cent) explicitly claimed to have introduced new or significantly improved products [2] (goods or services) or processes (for production or supply of products), and were therefore identified as innovators. For this report, we restrict our analysis to the sample of 1,115 firms that directly identified themselves as innovators and which provided details on whether or not they engaged in collaboration for innovation. The analysis is restricted to innovators rather than all of the responding firms, because collaboration is limited to *'active participation with other enterprises or non-commercial institutions aimed at developing new goods, services or processes'*[3]. It was therefore not possible to include non-innovating firms in the analysis of collaboration.

For those answering 'yes' to this question, the survey then asked about the types of partners which the firm collaborated with and the location of those partners (that is, whether they were located in Tasmania, mainland Australia or outside of Australia). Unfortunately, the TIC did not ask about the number of these linkages, how successful the collaboration had been, or about the motivations for establishing these linkages. Consequently, the possible analysis is restricted, and therefore we are essentially concerned in this report with assessing the presence or absence of collaboration (in general and with different types of partners[4]) across a broad range of firms by size, sector and other characteristics (e.g. ownership, receipt of public innovation funding, conduct of R&D activities and innovation expenditure intensity), and with investigating the effect of collaboration on firms' innovation outcomes.

It is also worth noting that measuring the outcomes of collaboration is not without problems. In this report, the outcomes of collaboration are proxied by a measure of the novelty of innovation and the innovation sales share. In the former measure, firms in the TIC were asked whether they had introduced any products (or processes) on to their market (or industry) before their competitors. In the latter measure, firms were asked to estimate the percentage of their sales that were generated from new or significantly improved products. However, as outcomes can be affected not only by collaboration but also by changes in firms' environments (e.g. the competition firms are facing, the regulatory framework, or what funding for R&D activities is available to firms) and we have no data to control for this effect, our findings are limited. Coupled with the use of cross-sectional data which could limit the opportunity for collaboration to have an effect on innovation output measures, the direction of causality is admittedly questionable and therefore the interpretation of the relationships analysed in this report needs to be done with caution.

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[2] A product is defined as 'significantly improved' in terms of quality, functions or intended uses; or significantly improved through changes in materials, components, design, or other characteristics that enhance performance. For example, new packaging that improves shelf-life or reduces costs would be included, but superficial changes (e.g. new colours or patterns on a label) would be excluded.

[3] This is consistent with definitions in the OECD Oslo Manual, 3rd 2005.

[4] Types of collaboration partners asked in the TIC questionnaire include: other enterprises within enterprise group; suppliers of equipment, materials, services or software; clients or customers; competitors or other enterprises within industry; consultants, commercial labs or private R&D institutes; universities or other higher education institutions; and public research institutes or CRCs (cooperative research centres). Of interest, the aggregations of these partner types including supply-chain partners (suppliers or customers), knowledge-intensive partners (consultants, universities or public research institutes) and public knowledge-intensive partners (universities or public research institutes), are also considered in this report.

Preliminary Analysis of Collaboration Patterns

Table 2 shows the distribution of collaboration for innovation by type and location of partner. Of the 1,115 firms identified as innovators, 482 (43.2 per cent) reported some form of collaboration for innovation. 'Suppliers of equipment, materials, services or software' and 'clients or customers' were the most widely engaged types of collaboration partners. Nearly a third of the innovating firms collaborated with suppliers (32.3 per cent), and a similar proportion collaborated with customers (31.7 per cent). This suggests that supply-chain collaboration for innovation is common amongst innovating firms, though not the dominant form.

Equally relevant is the role played by 'competitors or other enterprises within industry' and 'consultants, commercial labs or private R&D institutes' in the process of innovation collaboration. Approximately 23 per cent of innovating firms had a collaborative link with competitors and around 20 per cent with consultants. Collaboration with 'other enterprises within an enterprise group', however, is of minor significance (13.8 per cent). This corresponds to the fact that Tasmania is dominated (around 60 per cent) by independent small sized enterprises (less than 50 employees) that are not being part of an enterprise group.

While 'universities or other higher education institutions' and 'public research institutes or CRCS' are generally considered to be an important source of knowledge transfer for the firms' innovation activities, collaboration with these partners is less frequent. Only 7.7 per cent of innovating firms collaborated with public research institutes, while 14.7 percent of them collaborated with universities. Taking together, public knowledge-intensive collaboration was reported by 17.1 per cent of innovating firms (see Table 2). This result may be explained by the fact that public knowledge institutions emphasizes more on upstream research and exploration activities which many represent only a small part of overall innovation.

These patterns of collaboration in Tasmania show similarity to those found in the entire Australia and other developed economies. Results from the Australian Business Characteristics Survey (2006-2007) show that around 17 per cent of innovating firms in Australia had collaboration for the purposes of innovation (ABS, 2010). Customers (7.4 per cent) and suppliers (6.1 per cent) were the two most sought-after innovation partners, whilst collaboration with universities (0.3 per cent) and public research institutes (1.2 per cent) were far less likely to be reported by Australian innovators[5]. However, it should be noted that these results cannot be comparable to the TIC's results, because the Australian Business Characteristics Survey uses a one-year reference period compared to the three year reference period used in the TIC (2004-2006). This difference will indeed increase collaboration rates in Tasmania compared to Australia.

[5] See ABS (Australian Bureau of Statistics). *Innovation in Australian Business, 2006-2007.* ABS cat 8158.0, August 2010. Collection of data included in this release was undertaken based on a random sample of approximately 9,700 businesses in Australia. Of these, 37 per cent were identified as innovators, and 17 per cent of these innovators had collaboration for innovation. Of these collaborating firms, 42.6 per cent collaborated with customers; 36 per cent collaborated with suppliers; 1.9 per cent collaborated with universities and 7.2 per cent collaborated with public research institutes.

Data from the European Community Innovation Survey (CIS 2006) and other national innovation surveys [6] reveal that the share of innovative firms that engage in collaboration, during 2004-2006, ranges from 57 per cent in Finland to 12 per cent in Italy (OECD 2010: 27). Suppliers and customers are the most frequently mentioned as innovation partners, whilst universities and public research institutes represent only a small share of collaborations on innovation. Firms in Finland, for example, reported the largest share of collaboration with universities or public research institutes (15 per cent), compared to only 2.4 per cent in Japan (OECD, 2009: 57). However, these results only indicate the existence of some sort of collaboration, not its frequency or intensity. Nevertheless, they are noteworthy because most innovation is incremental and involves small-scale change which would not necessarily require collaboration with these public knowledge-intensive partners.

Table 2: Collaboration for innovation by type and location of partner

Type of partner	N	% of innovating firms	Location of partner (% of collaborating firms)			***Only*** **TAS partner (% of collaborating firms)**
			TAS	ML	OS	
Any collaboration partner	482	43.2	87.1	75.5	29.9	20.1
Other enterprises within an enterprise group	154	13.8	67.5	66.2	20.1	29.2
Suppliers of equipment, materials, services or software	360	32.3	58.1	68.1	23.3	25.6
Clients or customers	354	31.7	83.9	48.9	20.9	46.6
Competitors or other enterprises within industry	253	22.7	78.3	49.4	12.3	45.5
Consultants, commercial labs or private R&D institutes	216	19.4	75.9	53.7	11.1	44.4
Universities or other higher education institutions	164	14.7	81.1	33.5	9.1	63.4
Public research institutes or CRCs	86	7.7	64.0	58.1	7.0	40.7
Supply-chain partners[1]	430	38.6	79.8	70.2	29.1	24.7
Knowledge-intensive partners[2]	287	25.7	83.3	52.3	11.8	45.6
Public knowledge-intensive partners[3]	191	17.1	80.1	43.5	9.9	53.4

Note: TAS = Tasmania, ML = Mainland Australia and OS = Outside of Australia.
Multiple answers were possible; therefore, the sum of percentages is not equal to 100%.
[1]*Supply-chain partners = suppliers of equipment, materials, services or software or clients or customers.*
[2]*Knowledge-intensive partners = consultants, commercial labs or private R&D institutes or universities or other higher education institutions or public research institutes or CRCs.*
[3]*Public knowledge-intensive partners = universities or other higher education institutions or public research institutes or CRCs.*

Geographical proximity seems to facilitate the collaboration between firms and their innovation partners. A review of the literature suggests that geographical distance affects the ability to receive and transfer knowledge, especially tacit knowledge, and therefore firms' innovations are presumed to be more dependent on local than on distant linkages (see Audretsch, 1998; Cappelo, 1999; Oerlemans, Meeus & Boekema, 2001). As can be seen in Table 2, the location of collaboration partners is mostly concentrated in Tasmania, followed by in the mainland and rarely outside of Australia. Nearly 90 per cent of any collaboration partner were located in Australia (85.5 per cent in Tasmania and 75.5 per cent in the mainland), while only 30 per cent were distributed for overseas

[6] Certain differences may affect comparisons between CIS and non-CIS countries, such as sectoral coverage, size thresholds and sampling methods and the unit of analysis.

partners. This pattern was consistent across all types of partners, except for suppliers where their proportion based in the mainland (68.1 per cent) was relatively higher than in Tasmania (58.1 per cent).

Notably, the importance of collaboration with regional knowledge-intensive partners among responding firms in Tasmania is remarkable. Around half of innovating firms that reported collaboration indicated that they only collaborated with knowledge-intensive partners located within Tasmania, with 63.4 per cent of them forming a partnership with only the University of Tasmania or other local higher education institutions (see Table 2). Some of the reasons for this may be having knowledge-intensive partners in the same geographical area causes fewer confidentiality problems and lower management costs.

DESCRIPTIVE ANALYSIS

Since the mid-1980s, considerable attention has been paid to different ways of achieving innovation, including establishment of strategic technology alliances (Doz & Hamel, 1997), formation of innovation networks (Freeman, 1991), and collaboration for innovation (Brockhoff , Gupta & Rotering, 1991; Fusfeld & Haklisch, 1985; Mora-Valentin, Montoro-Sanchez & Guerras-Martin, 2004). The growing number of these collaborations and alliances, as argued by Teece (1992), means that the standard relationships between market structure and innovation are becoming outmoded, as the boundaries of the firm are becoming increasingly 'fuzzy'.

A variety of reasons are given in the literature for the apparent growth in innovation collaboration, but at a basic level, firms enter into collaboration because internally they lack some or all of the necessary resources and knowledge, and/or because they wish to reduce risks associated with innovation. Not only both of these motives may be present at once, but they may also be inter-related (Tether, 2002).

Studies that analyse why and what kinds of firms establish joint innovation activities are typically based on transaction cost and resource-based view theoretical backgrounds (Tyler & Steensma, 1995). The transaction cost approach describes collaboration as a hybrid form of organisation combining the aspects of hierarchical transactions within the firm and arm-length transactions in the marketplace. Some researchers argue that collaboration for innovation allows every partner to minimize development costs as well as to exploit the available specific know-how (e.g. Das & Teng, 2000; Pisano, 1990). The resource-based view of the firm suggests that the rationale for partnerships is the value-creation potential of pooling firms' resources (Tyler & Steensma, 1995). Collaboration is thus viewed as a mechanism to maximise firm value through effectively combining the resources of the partners by exploiting complementarities (Hagedoorn, Link & Vonortas, 2000).

Nevertheless, collaboration is not without disadvantages. Studies suggesting a negative effect of collaboration mainly explain the disadvantages using the concepts from organisational behaviour perspective such as partners' uncertain behaviours, instability of relationship, the difficulties in executing organisational interaction, leakage of a firm's skills and knowledge, and concerns about revealing information to partners (Geroski, 1995; Lhuilery & Pfister, 2009; Mora-Valentin *et al.*, 2004; Okamuro, 2007).

These disadvantages could partly explain why the majority of innovating firms that responded to the TIC (56.8 per cent) do not develop their innovations via collaboration. However, as suggested in the literature (e.g. Antonelli, 1999; Arundel & Bordoy, 2006), if the benefits of collaboration outweigh its disadvantages, we should expect collaboration to positively influence innovation outcomes in terms of either more novel product or process innovations or more innovation sales share, and thus lead to economic success of firms.

Having briefly sketched some notes from the collaboration literature, we now assess through cross-tabulations and compare means[7]: (i) what factors are associated with the propensity of firms to engage in collaboration in general and with different types of partners for the development of product or process innovations; and (ii) how collaboration appears to influence innovation outcomes. Recognizing that each type of partner possesses different resources and capabilities and exhibits a different behaviour in collaborative relationship, we expect that the effect of collaboration on innovation outcomes may vary depending on the partner type. Results from this descriptive analysis could inform our decisions on which variables to include in the later multivariate regression analysis.

Factors Influencing Collaboration

Firm Size

Firm size is a classic variable of innovation studies, which has been found to have an influence on the nature and pattern of innovation activities and collaborative relationships (Cohen, 1995). Overall, simple cross-tabulations, which do not control for any other factors, reveal a positive size effect on collaboration with only public knowledge-intensive partners[8]. The share of large firms with 250 or more employees that collaborated with universities or public research institutes was three times higher than the share of small firms with 5 to 9 employees (see Table 3). This result may reflect the fact that firm size proxies for financial and human resources. As collaboration with this type of partner demands much of these resources (which are often lacking in smaller firms) to process the generated knowledge, it is more likely to be an activity in which larger firms are involved.

The size of the firm also matters for collaboration with suppliers, other enterprises within an enterprise group, and consultants, even though an inverted U-shaped relationship was observed. Specifically, collaboration with suppliers increased up to the firm size of 20-49 employees, whilst collaboration with group firms and consultants increased up to the firm size of 50-99 and 100-249 employees respectively. Beyond these points, an increase of firm size resulted in a decreasing likelihood of collaboration. The differences by firm size were not statistically significant for the share of firms collaborating with customers and competitors; however, we should bear in mind that this pattern may change when other factors are controlled for.

[7] We used compare means to assess the relationship between collaboration and the innovation sales share only.
[8] though the share of firms with 100-249 employees was slightly lower than those with 50-99 employees

Industry Sector
Collaboration with innovation partners may be different depending on the industry sector to which the firm belongs. As shown in Table 3, without controlling for any other characteristics of the firms, we find that sector does have a significant influence only on the horizontal and knowledge-intensive collaborations. No significant sector effect is found on supply-chain and group collaborations. For horizontal collaboration, the other services firms were found to be the most likely to collaborate with competitors (32.8 per cent), whilst the manufacturing and infrastructure firms were, on the other hand, less likely to collaborate with this type of partner (around 19 per cent).

At the aggregate level, collaboration with knowledge-intensive partners was most frequent amongst the natural resources firms (35.6 per cent). Disaggregating these partners into individual types, however, the pattern was different. Specifically, firms in the health, education, public administration and safety sector were the most likely to have collaboration for innovation with universities (23.9 per cent), whilst those in the natural resources sector exhibited the highest proportion of collaboration with public research institutes (16.7 per cent). There was, however, no significant difference by sector in the percentage of firms collaborating with consultants.

Surprisingly, collaboration with public knowledge-intensive partners was rare among firms in the infrastructure sector: only 7.2 per cent and 4.3 per cent of them set up relations for innovation with universities and public research institutes respectively. This result may be explained by the small local markets in Tasmania which could cause innovative pressure driven by technological dynamics to be less likely to have an impact on the likelihood of firms in the infrastructure sector to engage in public knowledge collaboration.

Ownership
Ownership may also matter for collaborative relationships. The initial (bivarate) results depicted in Table 3 indicate that ownership proves to be a significant factor for determining horizontal collaboration. Firms that are part of an enterprise group, compared to independent firms, developed a lower percentage of their innovation through collaboration with competitors (18.9 per cent versus 24.7 per cent, $p < 0.05$). This may be explained by the fact that firms belonging to an enterprise group are able to draw on resources from within their group and might therefore not need to seek these resources externally from competitors. The transaction costs, particularly those associated with fixation of transfer prices of intangible goods (such as information and know-how), may also represent a reason for their less collaboration with competitors.

The membership of the firm in a group, however, plays no role in the determination of collaboration with the remaining types of partners. A plausible explanation may be that while group firms may be well-resourced, they too can have trouble collaborating for innovation due to structural inertia. As such, the availability of resources may not provide group firms with any advantage, over independent firms, for collaborating with other partner types.

Table 3: Collaboration for innovation by firm-size, industry sector and ownership

	N	% Any Partner	% Other enterprises within an enterprise group	% Suppliers of equipment, materials, services or software	% Clients or customers	% Competitors or other enterprises within industry	% Consultants, commercial labs or private R&D institutes	% Universities or other higher education institutions	% Public research institutes or CRCs	% Supply-chain partners	% Knowledge-intensive partners	% Public knowledge-intensive partners
Total	1,115	43.2	13.8	32.3	31.7	22.7	19.4	14.7	7.7	38.6	25.7	17.1
Firm-Size												
5-9 employees	392	40.6	9.9	27.8	28.3	24.2	15.6	9.4	5.4	34.4	19.9	11.2
10-19 employees	315	40.6	12.7	30.2	29.8	17.8	15.9	13.3	7.0	35.6	22.9	16.2
20-49 employees	239	47.7	15.9	40.2	37.7	26.4	25.1	18.0	8.8	46.0	32.2	20.5
50-99 employees	86	48.8	23.3	36.0	34.9	24.4	27.9	25.6	12.8	44.2	38.4	27.9
100-249 employees	53	47.2	22.6	34.0	39.6	26.4	28.3	20.8	11.3	43.4	32.1	24.5
250 or more employees	30	46.7	16.7	36.7	26.7	13.3	20.0	30.0	16.7	40.0	33.3	33.3
Chi-square (5 *df*)		5.5	16.2**	11.9*	8.8	8.8	17.9**	26.4***	11.1*	11.3*	22.8***	26.4***
Industry Sector												
Natural resources	90	50.0	12.2	33.3	32.2	22.2	24.4	23.3	16.7	43.3	35.6	26.7
Manufacturing	254	38.2	10.6	29.5	31.5	18.5	18.1	11.8	6.3	35.8	21.7	14.6
Infrastructure	138	37.7	12.3	29.7	28.3	18.8	21.0	7.2	4.3	35.5	21.7	8.7
Retail, wholesale, accommodation and food services	257	41.6	15.6	34.6	30.4	20.6	16.7	10.9	7.4	38.1	22.6	14.8
Knowledge intensive business services	251	49.0	15.1	33.1	35.5	28.7	21.5	19.1	8.8	42.6	29.9	20.3
Health, education, public administration and safety	67	41.8	17.9	31.3	28.4	23.9	16.4	23.9	4.5	34.3	29.9	25.4
Other services	58	51.7	15.5	36.2	34.5	32.8	19.0	19.0	8.6	39.7	29.3	20.7
Chi-square (6 *df*)		11.5	4.7	2.5	3.2	12.9*	4.2	25.4***	14.5*	4.5	25.7*	20.4***
Ownership												
Independent firms	724	41.7	-	31.4	30.4	24.7	17.8	13.8	7.3	37.2	25.1	16.2
Group firms	391	42.5[1]	30.4	34.0	34.3	18.9	22.3	16.4	8.4	41.2	26.9	18.9
Chi-square (1 *df*)		0.1	n/a	0.8	1.8	4.9*	3.2	1.3	0.4	1.7	4.5	1.4

*Note: *p < 0.05, **p < 0.01, ***p < 0.001*

[1]Other enterprises within an enterprise group were not counted as any partner.

Multiple answers were possible; therefore, the sum of percentages is not equal to 100.

Public Innovation Funding

Public innovation funding has recently attracted the interest of researchers as a determinant factor in shaping the system of innovation and collaboration (e.g. Cassiman & Veuhelers, 2002; Kaiser, 2002). Outcomes of innovation activities can be, and often are, risky and uncertain. If the risks are too high and expected returns of investments are too low, an individual firm will make a rational decision not to innovate and collaborate. This decision indeed can negatively affect the benefits of the innovation on the level of the society as a whole. To stimulate firms to engage in collaboration, public innovation funding[9] may play an important role (Busom & Fernandez-Ribas, 2008).

In the TIC questionnaire, we asked firms to indicate whether they received any financial support for new good, service, or process development activities from either state or federal governments during the three calendar years 2004-2006. Simple cross-tabulations (before controlling for any other factors) shown in Table 4 indicate that firms that received public innovation funding are significantly more likely to collaborate for innovation than those that did not receive them (see Table 4). In Tasmania, about one-fifth of innovating firms received public financial support for innovation, and around 65 per cent of them reported at least one type of collaboration. This pattern holds significantly across all types of collaboration partners, in particular for universities where the share of firms receiving public innovation funding (30.3 per cent) was three times higher than those without being funded (11.1 per cent).

Tax incentives for R&D can also be regarded as an indirect form of R&D promotion and thus may influence collaboration for innovation of firms. One way in which the Australian taxation system may influence firms' innovation activities is through R&D tax credits. In the TIC, 211 firms that received public innovation funding[10] were asked whether they claimed a tax credit for R&D performed. The bivariate results, depicted in Table 4, show a significant difference between publicly funded firms that claimed a R&D tax credit and those that did not claim such credit in terms of the presence of collaboration with supply-chain and public knowledge-intensive partners: the former was more likely to collaborate with these partner types than the latter. No significant effect of a R&D tax credit, however, was found on collaboration with consultants, competitors and group firms.

Conduct of R&D Activities

Another determining factor in the decision to engage in collaboration is the conduct of R&D activities. In theory, firms that lack their own R&D activities may seek to substitute for this by engaging in collaboration. Meanwhile, firms that carry out R&D, especially novel innovators, might not have the same need to collaborate, and may thus seek to avoid collaboration for fear of losing valuable knowledge through spillovers (Tether, 2002). However, this idea has been argued by a number of empirical studies which report a positive relationship between the conduct of R&D and the propensity of firms to collaborate for innovation (e.g. Becker & Dietz, 2004; Cassiman & Veugelers, 2002; Colombo & Gerrone, 1996; Veugelers, 1997). As argued by Cohen and Levinthal

[9] Public funding for innovation can occur in different ways. The most direct way is public grants to enterprise for covering parts or all costs of innovation. The other ways of financing innovation by the government are to commission the development of innovative products and to purchase innovation, as well as, to guarantee and refinance loans of private banks offered for innovation projects in enterprises.

[10] There were 70 firms receiving public innovation funding from the state government; 94 from the federal government and 47 from both the state and federal governments.

(1990), firms conduct R&D internally in order to raise their ability to learn effectively from their environment and from the work of others; and if this argument is valid, we should expect the conduct of R&D [11] by firms to influence their engagement in collaboration for innovation.

An initial analysis of the data (before controlling for any other characteristics of the firms) reveals that firms that conducted internal R&D are more likely to collaborate for innovation than those that did not have their own R&D (see Table 4). This pattern was observed across all types of collaboration, in particular for public-knowledge intensive collaboration where the share of R&D collaborating firms (22.6 per cent) was almost four times higher than that of non-R&D collaborating firms (6.5 per cent).

Beyond this, we also examine whether the share of skilled employees with science or engineering degrees in the total employment can have an impact on the probability of collaboration. With one exception (group collaboration), the chi-square results revealed a significant difference between innovating firms that had skilled employees in sciences or engineering and those with none (see Table 4). However, a positive relationship between the share of skilled employees and collaboration was not observed for every type of partner: only collaboration in general and with supply-chain and public-knowledge intensive partners was likely to be increased by increasing share of these employees.

Innovation Expenditure Intensity

The intensity of the amount a firm spends on innovation (as a percentage of turnover) can also have an impact on its decision to establish collaboration for innovation. In the TIC questionnaire, we asked whether firms undertook particular types of innovative activity and for expenditure figures on the particular activity, as well as the total turnover[12] from their Tasmanian operations in the most recent financial year (2005-2006). As the majority of firms were able to provide good estimates, it is possible to analyse patterns of collaboration among different types and levels of innovation expenditure intensity.

As shown in Table 5, the initial bivariate analysis, before controlling for any other factors, reveals a significant positive relationship between the total innovation expenditure intensity and collaboration with knowledge-intensive and supply-chain partners (though at the individual level no significant relationship was detected for collaboration with suppliers). There was no significant difference by the level of total innovation expenditure intensity found for collaboration with group firms. Interestingly, this intensity, however, seemed to slightly exert an inverted U-shaped influence on collaboration with competitors. A plausible explanation may be that competitors can exert market dominance, and therefore the greater the effort a firm puts into innovation through collaboration with this type of partner, the more wary it may become of losing valuable knowledge through spillovers. In this case, a very high innovation cost

[11] The TIC question asked: did your enterprise engage in in-house R&D for new products or processes, that is, creative work undertaken within your enterprise on an occasional or regular basis to increase the stock of knowledge and its use to devise new and improved goods, services and processes.

[12] In the TIC questionnaire, turnover is defined as the market sales of goods and services based on the amount earned; include exports and taxes, but exclude GST.

intensity could possibly lead to dissipation in innovation rents and thus reduce incentives to establish collaboration with competitors.

Breaking down the total innovation expenditure by type of innovative activity, it could be seen that collaboration with all types of partners was significantly increased by the intensity of expenditure on in-house R&D (except for group firms) and on acquisition of R&D from other organisations (except for suppliers). A clear positive influence of the intensity of expenditure on acquisition of external knowledge on collaboration was also observed, though surprisingly no relationship emerged for collaboration with public research institutes.

Of note, a positive relationship found between internal R&D cost intensity and collaboration is unexpected, as firms often make a considerable investment in R&D in order to achieve radical innovation (Laursen & Salter, 2006), and the fear of losing competency-enhancing knowledge through a joint-investment may lead these novel firms not to collaborate. Because of this, we expect that this positive relationship may not be observed when other influencing factors are controlled for.

Amongst different types of innovative activities, the most common reported activities were in acquisition of advanced machinery, equipment, computer hardware or software, followed by a considerable investment in internal or external training. Although collaboration is seen as an integral part of successful innovation activities, the intensity of the amount a firm spends on machinery and equipment acquisition did not influence its propensity to collaborate significantly. Concerning the training expenditure intensity, a pattern was different. Supply-chain, horizontal and knowledge-intensive collaborations seemed to be determined by the intensity of training costs. Disaggregating knowledge-intensive partners into universities and public research institutes, however, no significant relationship was detected.

The intensity of expenditure on design and market preparation activities appeared to have a statistically significant effect on collaboration across all types of partners, though a positive relationship was not always the case. Notably, an inverted U-shaped curve was found between the design cost intensity and collaboration with suppliers, and between the market cost intensity and collaboration with other enterprises within a group (see Table 5).

Table 4: Collaboration for innovation by public innovation funding and conduct of R&D activities

	N	% Any Partner	% Other enterprises within an enterprise group	% Suppliers of equipment, materials, services or software	% Clients or customers	% Competitors or other enterprises within industry	% Consultants, commercial labs or private R&D institutes	% Universities or other higher education institutions	% Public research institutes or CRCs	% Supply-chain partners	% Knowledge-intensive partners	% Public knowledge-intensive partners
Total	1,115	43.2	13.8	32.3	31.7	22.7	19.4	14.7	7.7	38.6	25.7	17.1
Public Innovation Funding from State or Federal Governments												
Public Innovation Funding												
-Received funding	211	64.5	21.3	44.5	48.8	32.7	32.7	30.3	14.7	57.8	44.5	33.2
-None	904	38.3	12.1	29.4	27.8	20.4	16.3	11.1	6.1	34.1	21.3	13.4
Chi-square (1 *df*)		47.8***	12.3***	17.9***	35.0***	14.9***	29.6***	50.6***	17.8***	40.7***	48.2***	47.2***
R&D Tax Credit[1]												
-Received a tax credit	81	71.6	24.7	53.1	59.3	33.3	39.5	39.5	24.7	69.1	51.9	43.2
-None	130	60.0	19.2	39.2	42.3	32.3	28.5	24.6	8.5	50.8	40.0	26.9
Chi-square (1 *df*)		0.1	0.9	3.9*	5.7*	0.0	2.8	5.2*	10.5**	6.9**	2.8	6.0*
Conduct of R&D Activities												
Conduct of Internal R&D												
-Had internal R&D	733	50.1	15.6	37.8	38.1	26.1	24.6	19.4	10.6	45.6	32.7	22.6
-None	382	30.1	10.5	21.7	19.6	16.2	9.4	5.8	2.1	25.1	12.3	6.5
Chi-square (1 df)		40.8***	5.4*	29.6***	39.4***	13.8***	36.8***	37.1***	25.8***	44.3***	54.9***	45.9***
Share of Skilled Employees with Science or Engineering Degrees[1] *(as a percentage of total employment*[2]*)*												
-None	710	37.7	12.1	27.5	26.8	21.4	14.9	8.6	4.4	33.1	19.4	11.0
-Up to 25%	252	49.6	16.7	39.3	38.5	21.0	28.2	23.4	13.1	46.4	34.5	25.4
-Over 25% to 50%	68	54.4	10.3	41.2	45.6	32.4	29.4	26.5	17.6	48.5	41.2	29.4
-Over 50% to 75%	34	61.8	17.6	44.1	49.1	38.2	20.6	35.3	8.8	50.0	38.2	35.3
-Over 75%	29	75.9	24.1	55.2	48.3	31.0	24.1	34.5	13.8	69.0	48.3	37.9
Chi-square (4 *df*)		33.7***	7.2	27.8***	26.7***	10.5*	26.4***	64.7***	32.9***	32.0***	44.0***	55.5***

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$; *Multiple answers were possible; therefore, the sum of percentages is not equal to 100.*
[1]*R&D tax credit was considered among 211 firms that received public innovation funding.*
[2]*Data are missing for 22 cases.*

Table 5: Collaboration for innovation by innovation expenditure intensity

	N	% Any Partner	% Other enterprises within an enterprise group	% Suppliers of equipment, materials, services or software	% Clients or customers	% Competitors or other enterprises within industry	% Consultants, commercial labs or private R&D institutes	% Universities or other higher education institutions	% Public research institutes or CRCs	% Supply-chain partners	% Knowledge-intensive partners	% Public knowledge-intensive partners
Total with innovation intensity data[1]	961	44.1	13.2	33.5	32.6	23.4	19.5	14.2	7.3	39.9	25.9	16.6
Intensity of Innovation Expenditures (as a percentage of turnover)												
Total Innovation Expenditure												
-Up to 1%	221	37.1	11.8	29.0	25.3	19.0	11.3	7.7	5.0	35.3	16.3	9.5
-Over 1% to 5%	349	42.1	12.6	31.8	29.2	20.3	18.1	12.6	5.4	36.7	24.1	14.6
-Over 5% to 20%	261	49.0	14.2	38.7	37.9	28.7	23.8	17.6	10.0	44.4	31.0	21.8
-Over 20%	130	51.5	15.4	35.4	43.1	28.5	28.5	22.3	10.8	46.9	36.9	23.8
Chi-square (3 *df*)		10.4*	1.3	5.9	17.0**	10.2*	19.6***	18.0***	8.6*	8.4*	23.1***	19.1***
Expenditure on In-house R&D												
-None	385	36.4	12.5	27.5	23.1	18.7	13.8	7.3	4.9	31.7	16.6	9.4
-Up to 1%	287	46.7	10.8	36.2	35.5	25.8	20.2	15.3	8.0	43.6	30.7	19.2
-Over 1%	289	51.9	16.6	38.8	42.2	27.3	26.3	22.1	9.7	47.1	33.6	23.9
Chi-square (2 *df*)		17.3***	4.5	10.7**	29.1***	8.1*	16.7***	30.5***	5.9*	18.6***	29.5***	27.0***
Expenditure on Acquisition of R&D from Other Organisations												
-None	792	41.0	11.7	32.1	30.1	21.6	15.8	12.5	5.7	37.4	21.7	14.3
-Up to 1%	109	55.0	15.6	38.5	40.4	26.6	32.1	17.4	13.8	48.6	42.2	25.7
-Over 1%	60	65.0	28.3	43.3	51.7	41.7	45.0	30.0	16.7	56.7	51.7	31.7
Chi-square (2 *df*)		19.0***	14.0**	4.6	15.3***	13.2**	43.0***	15.1**	17.6***	12.6**	43.1***	19.4***
Expenditure on Acquisition of Advanced Machinery, Equipment, Computer Hardware or Software												
-None	254	40.2	12.2	29.1	30.3	19.7	16.1	13.4	7.9	37.0	23.2	16.5
-Up to 1%	246	48.0	14.6	38.2	33.3	24.8	19.1	13.4	4.1	43.5	25.6	14.6
-Over 1%	461	44.3	13.0	33.4	33.4	24.7	21.5	15.0	8.7	39.5	27.5	17.8
Chi-square (2 *df*)		3.1	0.7	4.6	0.8	2.7	3.0	0.5	5.2	2.2	1.7	1.2

Table 5: Collaboration for innovation by innovation expenditure intensity (continued)

	N	% Any Partner	% Other enterprises within an enterprise group	% Suppliers of equipment, materials, services or software	% Clients or customers	% Competitors or other enterprises within industry	% Consultants, commercial labs or private R&D institutes	% Universities or other higher education institutions	% Public research institutes or CRCs	% Supply-chain partners	% Knowledge-intensive partners	% Public knowledge-intensive partners
Expenditure on Acquisition of External Knowledge												
-None	782	42.5	12.1	31.8	29.7	21.6	16.6	12.5	6.8	38.0	23.1	15.0
-Up to 1%	119	47.1	14.3	38.7	42.0	26.9	26.9	16.0	8.4	45.4	31.9	18.5
-Over 1%	60	60.0	25.0	45.0	51.7	40.0	41.7	31.7	11.7	53.3	50.0	35.0
Chi-square (2 *df*)		7.4*	8.2*	5.9*	17.8***	11.4**	27.1***	17.2***	2.2	7.2*	23.5***	16.5***
Expenditure on Internal or External Training												
-None	313	38.0	11.8	27.5	25.9	17.6	14.4	11.8	7.3	34.2	21.1	14.7
-Up to 1%	492	46.3	-13.8	36.6	34.8	24.8	21.1	14.4	7.1	42.1	27.0	16.9
-Over 1%	156	49.4	14.1	35.9	39.1	30.8	24.4	17.9	7.7	44.2	32.1	19.9
Chi-square (2 *df*)		7.5*	0.8	7.6*	10.5**	11.2**	8.4*	3.3	0.1	6.5*	7.2*	2.0
Expenditure on Design Activities												
-None	747	39.2	11.8	28.9	26.8	21.6	16.1	11.4	6.0	34.8	21.6	13.3
-Up to 1%	128	63.3	15.6	53.9	52.3	28.1	29.7	21.1	10.2	59.4	39.1	25.8
-Over 1%	86	58.1	22.1	43.0	53.5	32.6	33.7	27.9	14.0	54.7	44.2	32.6
Chi-square (2 *df*)		34.2***	8.0*	35.5***	51.4***	7.1*	25.2***	23.2***	9.0*	36.1***	33.9***	30.0***
Expenditure on Activities for the Market Preparation and Introduction of New or Improved Products												
-None	586	37.4	9.7	28.2	25.3	18.8	14.3	10.4	5.1	32.6	20.3	12.3
-Up to 1%	256	53.5	19.5	41.4	41.4	29.7	27.0	19.5	8.6	50.0	34.4	21.9
-Over 1%	119	57.1	16.8	42.9	49.6	32.8	28.6	21.0	15.1	53.8	35.3	26.9
Chi-square (2 *df*)		28.2***	16.5***	19.4***	39.1***	18.5***	25.3***	17.5***	15.6***	33.5***	24.6***	22.1***

Note: $*p < 0.05$, $**p < 0.01$, $***p < 0.001$

[1]*Data are missing for 154 cases*

Multiple answers were possible; therefore, the sum of percentages is not equal to 100.

Innovation Outcomes of Collaboration

Novelty of Innovation

The introduction of new-to-market products[13] or new-to-industry processes[14] could be a sign of a strategic intent for firms to innovate at a higher level, as this kind of innovation requires firms to invest in greater input novelty and involve greater market or industry uncertainty (Hamel & Prahalad, 1989). Tether (2002) argues that as innovation for the market or the industry has greater novelty, it generally requires major information exchange that would be obtained in conditions perhaps more favorable with collaborative arrangements. This argument is supported by a number of empirical studies that find that the novelty of innovations increases with the use of a larger variety of sources of information and collaborative agreements with external partners (Landry & Amara, 2003; Laursen & Salter, 2006; Therrien & Chang, 2003).

As shown in Table 6, simple cross-tabulations, which do not control for any other factors, reveal a significant association between every type of collaboration and more novel innovations. For instance, firms that collaborated with supply-chain partners (64.9 per cent) were more likely to introduce new-to-market products or new-to-industry processes than those that did not collaborate (50.8 per cent). The development of novel innovations was also more common among firms that collaborated with public knowledge-intensive partners (66 per cent), compared to non- collaborating firms (54.2 per cent).

Following the work of Laursen and Salter (2006) who argue that the number of external sources or search channels that firms rely upon in their innovative activities (breadth of collaboration) is a critical component of innovation outcomes, we also test whether responding firms that invested in broader search have a greater ability to innovate. The chi-square results, depicted in Table 6, reveal a positive association between a number of types of collaboration partners and better innovation. Firms that searched broadly or had more than four types of collaboration partners (69 per cent) were significantly more likely to develop novel innovations than those that reported a lower number of partner types (62.2 per cent) or had no partner (50.6 per cent).

Innovation Sales Share

Although much of the literature suggests that firms that access valuable information from external sources should be more successful innovators than firms that do not (Antonelli, 1999), the results of survey research on the contribution of collaboration to the proportion of sales from new or significantly improved products (innovation sales share) have been inconclusive. Some studies show a positive relationship between collaboration and innovation sales share (e.g. Aschhoff & Schmidt, 2008; Mohnen & Therrien, 2003), whilst some show a negative relationship (e.g. Arundel & Bordoy, 2006; Vonortas, 1997). These mixed findings may be explained in part by the difficulty of demonstrating empirically a clear direct causal effect of collaboration and innovative

[13] The TIC question asked about the introduction of a good or service that is new or significantly improved during the past three calendar years 2004 to 2006. This could mean that the good or service is completely new and different to goods and services previously produced by the enterprise. That could also mean that the good or service is significantly improved in terms of quality, functions or intended uses; or significantly improved through changes in materials, components, design, or other characteristics that enhance performance.

[14] The TIC question asked about the use of new or significantly improved methods for the production or supply of goods and services. Purely organizational or managerial changes should not be included.

performance particularly when the innovation success measure is not specifically designed to address the effect of collaboration. Furthermore, as collaboration for innovation require a significant investment in resources, innovation returns often only become realized in the long-term, rather than becoming immediately apparent through obvious changes in short-term innovative performance, particularly in the light of possibility market dynamism, uncertainty and fluctuating risk levels in the general business environment. Indeed, these issues also pose limitations to our study.

According to the TIC data, on average, 27.4 per cent of sales in the most recent fiscal year were from products (goods or services) that were 'significantly improved or new to the firm' within the three year period (2004-2006). Table 6 gives the mean innovation sales share by type and breadth of collaboration. The independent sample-test results reveal a statistically significant difference in the mean scores between collaborating and non-collaborating firms in relation to public knowledge-intensive collaboration. Specifically, firms that collaborated with universities were more likely to have the higher innovation sales share (M = 32.3, SD = 29.9) than non-collaborating firms (M = 26.4, SD = 26.3). Similarly, the innovation sales share was found to be higher in firms that collaborated with public research institutes (M = 34.4, SD = 29.8), as compared to those that did not collaborate (M = 26.8, SD = 26.7). There was no significant difference between collaborating and non-collaborating firms found for the other types of collaboration. A one-way analysis of variance (ANOVA) was also performed to compare mean scores on the innovation sales share between the three groups of collaboration breadth (no partner, 1-4 partners and 5-7 partners), and no statistically significant difference was detected between these groups.

Table 6: Percentage of firms introducing novel product or process innovations and the mean innovation sales share by type and breadth of collaboration

	N	Novelty (%)	Innovation Sales Share[1] Mean	SD
Any Partner				
-None	633	50.2	26.6	26.8
-Collaborated	482	64.1	28.3	27.3
Chi-square (1 *df*) / T-test (794 *df*)		21.4***	-0.89	
Individual Type of Partner				
Other enterprises within an enterprise group				
-None	961	54.6	27.3	26.9
-Collaborated	154	66.2	28.0	27.7
Chi-square (1 *df*) / T-test (794 *df*)		7.3**	-0.25	
Suppliers of equipment, materials, services or software				
-None	755	52.7	27.4	27.4
-Collaborated	360	63.6	27.3	26.3
Chi-square (1 *df*) / T-test (794 *df*)		11.8**	0.07	
Clients or customers				
-None	761	50.9	26.4	26.6
-Collaborated	354	67.8	29.2	27.7
Chi-square (1 *df*) / T-test (794 *df*)		28.2***	-1.43	
Competitors or other enterprises within industry				
-None	862	54.6	27.0	27.0
-Collaborated	253	61.7	28.8	26.9
Chi-square (1 *df*) / T-test (794 *df*)		3.9*	-0.81	
Consultants, commercial labs or private R&D institutes				
-None	899	54.5	27.0	26.6
-Collaborated	216	63.4	29.0	28.3
Chi-square (1 *df*) / T-test (794 *df*)		5.6*	-0.85	
Universities or other higher education institutions				
-None	951	54.2	26.4	26.3
-Collaborated	164	68.3	32.3	29.9
Chi-square (1 *df*) / T-test (794 *df*)		11.4**	-2.27*	
Public research institutes or CRCs				
-None	1,029	55.4	26.8	26.7
-Collaborated	86	66.3	34.4	29.8
Chi-square (1 *df*) / T-test (794 *df*)		3.8*	-2.21*	
Aggregate Type of Partner				
Supply-chain partners				
-None	685	50.8	26.6	26.7
-Collaborated	430	64.9	28.5	27.3
Chi-square (1 *df*) / T-test (794 *df*)		21.3***	-1.00	
Knowledge-intensive partners				
-None	828	53.9	26.4	26.3
-Collaborated	287	63.1	29.8	28.8
Chi-Square (1 *df*) / T-test (794 *df*)		7.3**	-1.58	
Public knowledge-intensive partners				
-None	924	54.2	26.3	26.2
-Collaborated	191	66.0	32.2	29.7
Chi-square (1 *df*) / T-test (794 *df*)		8.9**	-2.43*	
Breadth of Collaboration				
-No partner	640	50.6	26.7	26.8
-1 to 4 partners	362	62.2	26.9	26.2
-5 to 7 partners	113	69.0	32.2	29.9
Chi-square (2 *df*) / ANOVA: F (2, 793)		20.9***	1.66	

$*p < 0.05$, $**p < 0.01$, $***p < 0.001$ (chi-square for 'novelty' and t-test or ANOVA for innovation sales share)
[1]*Data are missing for 319 cases.*

Summary of Descriptive Results

Using simple bivariate and compare mean analyses, we have assessed a various factors that appear to influence the decision of firms to engage in collaboration for innovation (in general and with different types of partners), and the effect of collaboration on innovation outcomes. This sub-section provides a summary of the interim empirical findings.

- Firm size had a positive impact only on certain types of collaboration partners. Only collaboration with public knowledge-intensive partners (either universities or public research institutes) was positively size dependent. An inverse U-shape pattern was observed for collaboration with suppliers, other enterprises within a group and consultants, with the turning size point of 20-49, 50-99 and 100-249 employees respectively. No significant size effect was detected for supply-chain and horizontal collaborations.

- Industry sector was associated with only the engagement in horizontal and knowledge-intensive collaborations. Firms in the other services sector were the most likely, and those in the manufacturing and infrastructure sectors were the least likely, to collaborate with competitors. Natural resources firms exhibited the highest proportion of collaboration with knowledge-intensive partners, whereas the lowest proportion was found in infrastructure firms. There was no significant difference by sector in the share of firms collaborating with supply-chain partners.

- Ownership only related to the incidence of horizontal collaboration for innovation. Firms belonging to a group were less likely to collaborate with competitors than independent firms. Ownership, however, played no role in the determination of collaboration with the remaining types of partners.

- Firms that received public innovation funding were more likely to engage in collaboration across all types of partners, whilst R&D tax credit claimed by these firms tended to be associated with only supply-chain and public knowledge-intensive collaborations.

- The conduct of internal R&D activities seemed to be an important factor in stimulating all types of collaboration. Also, firms that had employees with a university education in science or engineering were more likely to engage in collaboration for innovation than those without these skilled employees. However, only collaboration in general and with supply-chain and public knowledge partners was increased with an increasing share of these skilled employees.

- The greater the total innovation expenditure intensity a firm had, the more likely it was to have at least one collaborative arrangement for innovation, particularly with supply-chain and knowledge-intensive partners. By focusing on each type of innovative activities, it was found that almost all types of collaboration were positively influenced by the intensity of expenditure on internal R&D (except for group firms), external R&D (except for suppliers) and external knowledge acquisition (except for public research institutes). The cost intensity of advanced machinery and equipment acquisition did not significantly influence a firm's propensity to collaborate, whilst the training cost intensity only increased collaboration with competitors, consultants and supply-chain partners. An inverted U-shape relationship was also observed between the design cost intensity and collaboration with suppliers, and between the market cost intensity and collaboration with group firms.

- Collaborating firms were more likely to introduce more novel product or process innovations than non-collaborating firms. Firms that searched broadly (reported many types of partners) tended to be more innovative than those that searched narrowly.

- Innovation sales share tended to be increased with the presence of collaboration with public knowledge-intensive partners (either universities or public research institutes). The breadth of collaboration had no significant impact on the innovation sales share.

MULTIVARIATE ANALYSIS

The above should be regarded as interim findings, as they are based on bivariate and compare mean analyses that did not control for other factors. For example, the natural resources firms may be more likely to engage in collaboration for innovation with public-knowledge-intensive partners, simply because they tend to be larger firms. Also, as larger firms are more likely to develop in-house R&D, it may therefore simply be the development of their own R&D that makes these natural resources firms more likely than other firms to establish such collaboration. In order to analyse the significance or otherwise of these influencing factors in a multivariate framework, we estimate binary logistic and tobit regressions. These regressions aim at evaluating the two main research questions, as outlined in the introduction.

1. What factors are associated with the propensity of firms to collaborate for innovation?
2. Is there a positive association between collaboration and innovation outcomes proxied by a measure of the novelty of the firm's innovations and the firm's innovation sales share?

Both regressions include independent variables for a range of factors that could influence the dependent variables. These include firm size, industry sector (with the retail, wholesale, accommodation and food services sector as the reference category), ownership, receipt of public innovation funding or R&D tax credit, conduct of R&D activities, share of skilled employees, and the intensity of expenditure on different types of innovation activities (with zero expenditure as the reference category). Types of collaboration and the breadth of collaboration (with no partner as the reference category) are also added as independent variables to address the second research question. With two exceptions (firm size and share of skilled employees), all independent variables are dummies, coded as 1 when the characteristic of interest is present and zero otherwise (see Table 7).

In our binary logistic regressions, the dependent variable for collaboration is a dummy variable that indicates whether the firm has collaboration for innovation (value 1) or not (value 0). We are interested in the determinants of collaboration in general and with different types of partners in particular. The analysis is performed at the individual partner type (other enterprises within a group, suppliers, customers, competitors, consultants, universities and public research institutes) and at the aggregate partner type (supply-chain, knowledge-intensive and public knowledge-intensive partners). Similarly, the dependent variable for the novelty of innovation is a dummy which equals 1 when the firm introduced either new-to-market products or new-to-industry processes and zero otherwise.

The binary logistic regression assumes that there is an unobservable variable Y_i^* which is defined by:

$$Y_i^* = \beta X_i + \varepsilon_i, \quad i = 1,\ldots,N$$

$$Y_i = 1 \quad \text{if} \quad Y_i^* > 0$$
$$Y_i = 0 \quad \text{if} \quad Y_i^* = \textit{otherwise},$$

where ε_i has a distribution function derived from the logistic cumulative distribution function:

$$F(X_i) = \frac{1}{1 + \exp(-X_i)}$$

We use this logistic cumulative distribution function to assess the probability of collaboration and of novel innovation on independent variables and to obtain the binary logistic model:

$$Prob(Y_i = 1) = 1 - F(-\beta X_i) = \frac{\exp(\beta X_i)}{1 + \exp(\beta X_i)}$$

where X_i is a vector of the independent variables for the i-th observation and β is the vector of coefficients.

In our tobit regressions, the dependent variable for innovation sales share is censored, ranging from 0 per cent to 100 per cent. We consider using a tobit analysis (see Greene, 2000) because: (i) firms will need to develop a minimum level of internal expertise in order to be able to increase their innovation sales share from zero; and (ii) it is less likely for the innovation sales share to reach 100 per cent due to several constraints such as sales from unchanged products and competition and appropriation effects that prevent firms from dominating the market with their innovative products.

The tobit regressions for the innovation sales share (Y_i) take the following form:

$$Y_i^* = \beta X_i + \varepsilon_i, \quad i = 1,\ldots,N$$

$$Y_i = Y_i^* \quad \text{if} \quad Y_i^* > 0$$
$$Y_i = 0 \quad \text{if} \quad Y_i^* \leq 0$$

Table 7: Independent variables in the logistic and tobit regressions

Variable Name	Description
Dependent Variables for Collaboration, Novelty of Innovation and Innovation Sales Share	
Ln_Employees	Natural logarithm of the firm's employees (Continuous variable)
D_Natural[1]	Dummy identifying firms in the natural resources sector
D_Manuf[1]	Dummy identifying firms in the manufacturing sector
D_infra[1]	Dummy identifying firms in the infrastructure sector
D_Knowledge[1]	Dummy identifying firms in the knowledge intensive business services sector
D_Health[1]	Dummy identifying firms in the health, education, public administration and safety sector
D_OServices[1]	Dummy identifying firms in the other services sector
D_Group	Dummy identifying firms being part of an enterprise group
D_InnFund	Dummy identifying firms receiving public innovation funding from state or federal governments
D_RDTax	Dummy identifying firms claiming a R&D tax credit
D_ConductRD	Dummy identifying firm conducting internal R&D activities
SkillEmploy	Share of skilled employees with science or engineering degrees in total employment (Continuous variable)
D_InRDLow[2]	Dummy identifying firms spending on in-house R&D less than or equal to 1% of turnover
D_InRDHigh[2]	Dummy identifying firms spending on in-house R&D more than 1% of turnover
D_AcqRDLow[2]	Dummy identifying firms spending on acquisition of R&D from other organisations less than or equal to 1% of turnover
D_AcqRDHigh[2]	Dummy identifying firms spending on acquisition of R&D from other organisations more than 1% of turnover
D_AcqKnLow[2]	Dummy identifying firms spending on external knowledge acquisition less than or equal to 1% of turnover
D_AcqKnHigh[2]	Dummy identifying firms spending on external knowledge acquisition more than 1% of turnover
D_TrainLow[2]	Dummy identifying firms spending on internal or external training less than or equal to 1% of turnover
D_TrainHigh[2]	Dummy identifying firms spending on internal or external training more than 1% of turnover
D_DesignLow[2]	Dummy identifying firms spending on design activities less than or equal to 1% of turnover
D_DesignHigh[2]	Dummy identifying firms spending on design activities more than 1% of turnover
D_MkLow[2]	Dummy identifying firms spending on market preparation activities less than or equal to 1% of turnover
D_MkHigh[2]	Dummy identifying firms spending on market preparation activities more than 1% of turnover
Dependent Variables for Novelty of Innovation and Innovation Sales Share	
D_CoAny	Dummy identifying firms having at least one type of collaboration partner
D_CoGroup	Dummy identifying firms collaborating with other enterprises within an enterprise group
D_CoSup	Dummy identifying firms collaborating with suppliers of equipment, materials, services or software
D_CoCus	Dummy identifying firms collaborating with clients or customers
D_CoComp	Dummy identifying firms collaborating with competitors or other enterprises within industry
D_Consult	Dummy identifying firms collaborating with consultants, commercial labs or private R&D institutes
D_CoUni	Dummy identifying firms collaborating with universities or other higher education institutions
D_CoPubRD	Dummy identifying firms collaborating with public research institutes or CRCs
D_CoSupChain	Dummy identifying firms collaborating with supply-chain partners (suppliers or customers)
D_CoKnow[3]	Dummy identifying firms collaborating with knowledge-intensive partners (consultants, universities or public research institutes)
D_BreadthLow[4]	Dummy identifying collaborating firms that reported less than or equal to four types of collaboration partners
D_BreadthHigh[4]	Dummy identifying collaborating firms that reported more than four types of collaboration partners

[1] *The retail, wholesale, accommodation and food services sector is acted as the reference category.*
[2] *Zero expenditure is acted as the reference category. The intensity of expenditure on acquisition of advanced machinery, equipment, computer hardware or software is not included in the multivariate analysis, because the initial bivariate results showed no significant relationship between this type of intensity and all types of collaboration.*
[3] *Public knowledge-intensive collaboration is not included as the independent variable for innovation outcomes, because there is an overlap with D_CoKnow (for universities and public research institutes).*
[4] *Zero partner is acted as the reference category.*

For the multivariate regression analysis in the following sections, we will begin with a model in which all the independent variables are entered. From this 'full model', we will then eliminate the insignificant independent variables (though a few that contribute to the overall strength of the models remain). Both the full and reduced models are presented; however, the reduced models will be the focus of our discussion. Table 8 presents the means and standard deviations for all variables included in the analysis.

Also, it should be noted that the regression analysis assumes a direction of causality which may not be strictly true. For example, by including the conduct of internal R&D and the innovation expenditure intensity, we are assuming these have an influence on whether or not the firms engaged in collaboration for innovation, rather than conversely collaboration being an influence on the conduct of R&D and the innovation expenditure intensity. With these and several of the other variables, the direction of causality cannot be confirmed.

Table 8: Means and standard deviations of all variables

	No. of firms	Mean	SD
InnSalesShare	796	27.38	26.99
D_Novel	1,115	0.56	0.50
D_CoAny	1,115	0.43	0.50
D_CoGroup	1,115	0.14	0.35
D_CoSup	1,115	0.32	0.47
D_CoCus	1,115	0.32	0.47
D_CoComp	1,115	0.23	0.42
D_Consult	1,115	0.19	0.40
D_CoUni	1,115	0.15	0.35
D_CoPubRD	1,115	0.08	0.27
D_CoSupChain	1,115	0.39	0.49
D_CoKnow	1,115	0.26	0.44
D_BreadthLow	1,115	0.32	0.47
D_BreadthHigh	1,115	0.10	0.30
Ln_Employees	1,115	2.85	1.03
D_Natural	1,115	0.08	0.27
D_Manuf	1,115	0.23	0.42
D_Infra	1,115	0.12	0.33
D_Knowledge	1,115	0.23	0.42
D_Health	1,115	0.06	0.24
D_OServices	1,115	0.05	0.22
D_Group	1,115	0.35	0.48
D_InnFund	1,115	0.19	0.39
D_RDTax	1,115	0.07	0.26
D_ConductRD	1,115	0.66	0.48
SkillEmploy	1,093	8.96	19.63
D_InRDLow	961	0.30	0.46
D_InRDHigh	961	0.30	0.46
D_AcqRDLow	961	0.11	0.32
D_AcqRDHigh	961	0.06	0.24
D_AcqKnLow	961	0.12	0.33
D_AcqKnHigh	961	0.06	0.24
D_TrainLow	961	0.51	0.50
D_TrainHigh	961	0.16	0.37
D_DesignLow	961	0.13	0.34
D_DesignHigh	961	0.09	0.29
D_MkLow	961	0.27	0.44
D_MkHigh	961	0.12	0.33

Collaboration in General

Table 9 provides logistic model results for any collaboration as the dependent variable. Firm size, sector and the membership of the firm in a group had no effect in this model. Of note, although we could not detect a significant difference by sector, the positive regression coefficients found in the natural resources, health, education, public administration and safety, and other services sectors could imply that firms in these three sectors were more likely to engage in at least one type of collaboration, compared to the reference category of retail, wholesale, accommodation and food services firms.

As expected, firms that received public funding for innovation were significantly more likely to collaborate with any partner than those that did not receive funding. Also, the possibility of collaboration tended to be increased through the conduct of internal R&D activities and by increasing share of skilled employees with science or engineering degrees. No significant association between a R&D tax credit and the engagement in collaboration was observed in this model.

Three types of innovation expenditure intensity (acquisition of external R&D, design activities and market preparation activities) had a significant effect on the likelihood of developing an innovation via collaboration. Firms that spent large amounts (on a per turnover basis) on externally acquired R&D and market preparation activities were significantly more likely to have collaborative arrangements with one or more types of partners. An inverted U-shaped relationship between the cost intensity of design activities and the propensity to collaborate was detected. Specifically, firms exerted innovation efforts on design activities at all increases their propensity to collaborate with any partner until such efforts reached 1 per cent of their turnover. After this point, no significant relationship was found.

Table 9: Full and reduced logistic regressions for any collaboration

	Any Partner	
	Full Model	**Reduced Model**
Ln_Employees	-0.039	-
D_Natural	0.213	0.175
D_Manuf	-0.361	-0.396
D_Infra	-0.214	-0.229
D_Knowledge	-0.144	-0.136
D_Health	0.194	0.206
D_OServices	0.523	0.516
D_Group	0.059	-
D_InnFund	0.609**	0.678***
D_RDTax	0.217	-
D_ConductRD	0.649*	0.326*
SkillEmploy	0.015***	0.015***
D_InRDLow	-0.418	-
D_InRDHigh	-0.388	-
D_AcqRDLow	0.456*	0.438*
D_AcqRDHigh	0.750*	0.729*
D_AcqKnLow	0.034	-
D_AcqKnHigh	0.257	-
D_TrainLow	0.191	-
D_TrainHigh	0.063	-
D_DesignLow	0.811***	0.799***
D_DesignHigh	0.326	0.288
D_MkLow	0.412*	0.403*
D_MkHigh	0.505	0.528*
Constant	-1.083***	-1.044***
N (Observations)	949	949
Initial -2 Log likelihood	1181.4	1186.5
Model Chi-square*** (*df*)	120.7 (24)	115.6 (15)
Nagelkerke Pseudo R^2	0.160	0.154

*Note: *p < 0.05, **p < 0.01, ***p < 0.001*

Supply-Chain Collaboration

Table 10 provides results of logistic models for supply-chain collaboration as the dependent variable. Firm size, sector and the membership of the firm in a group had no significant effect in any of these models. Of note, despite no significant sector effect observed, the positive coefficients found in the other services sector across all regressions suggest that firms in this sector were more likely (than the retail, wholesale, accommodation and food services firms that acted as the base) to collaborate with supply-chain partners.

The receipt of public innovation funding and the conduct of R&D activities tended to make supply-chain collaboration more probable, although at the individual level no significant relationship was detected between receipt of public funding and collaboration with suppliers and between conduct of R&D and collaboration with customers. The share of skilled employees in total employment also made a statistically significant contribution to the possibility of firms to collaborate for innovation with supply-chain partners. No significant effect of a R&D tax credit was found in all regressions.

The expenditure intensity of market preparation activities positively determined the propensity to engage in supply-chain collaboration, whilst that of external knowledge acquisition was found to be associated with collaboration with customers only.

Table 10: Full and reduced logistic regressions for supply-chain collaboration

	Suppliers		Customers		Suppliers *or* Customers	
	Full	Reduced	Full	Reduced	Full	Reduced
Ln_Employees	0.036	-	-0.058	-	0.008	-
D_Natural	-0.093	-	0.037	-	0.229	-
D_Manuf	-0.423	-	-0.104	-	-0.281	-
D_Infra	-0.306	-	-0.072	-	-0.126	-
D_Knowledge	-0.418	-	-0.280	-	-0.231	-
D_Health	-0.092	-	-0.011	-	-0.042	-
D_OServices	0.108	-	0.261	-	0.147	-
D_Group	0.046	-	0.095	-	0.067	-
D_InnFund	0.213	-	0.460*	0.683***	0.469*	0.647***
D_RDTax	0.293	-	0.445	-	0.515	-
D_ConductRD	0.531*	0.398*	0.375	-	0.720**	0.484**
SkillEmploy	0.013**	0.013***	0.012**	0.012**	0.014**	0.014***
D_InRDLow	-0.232	-	-0.019	-	-0.338	-
D_InRDHigh	-0.184	-	0.172	-	-0.342	-
D_AcqRDLow	0.159	-	0.362	-	0.365	-
D_AcqRDHigh	0.255	-	0.516	-	0.485	-
D_AcqKnLow	0.171	-	0.486*	0.532*	0.197	-
D_AcqKnHigh	0.185	-	0.422	0.563*	0.159	-
D_TrainLow	0.314	-	0.274	-	0.218	-
D_TrainHigh	0.146	-	0.173	-	0.102	-
D_MkLow	0.421*	0.519**	0.489*	0.632**	0.521**	0.571**
D_MkHigh	0.468*	0.498*	0.737*	0.895**	0.682**	0.677***
Constant	-1.449***	-1.315***	-1.691***	-1.408***	-1.387***	-1.264***
N (Observations)	949	949	949	949	949	949
Initial -2 Log likelihood	1150.0	1167.9	1096.5	1118.8	1176.0	1193.9
Model Chi-square***(*df*)	59.1 (22)	41.2 (4)	99.8 (22)	77.4 (6)	99.3 (22)	81.3 (5)
Nagelkerke Pseudo R^2	0.084	0.059	0.139	0.109	0.134	0.111

*Note: *p < 0.05, **p < 0.01, ***p < 0.001*

The intensity of expenditure on design activities (D_DesignLow and D_DesignHigh) was not included in these regressions due to the strong significance of this variable detected in the bivariate supply-chain analyses. This strong result could be due to the fact that firms that need design work often contract it out to design companies and collaborate with the company on the final design. The close link between design and supply-chain collaboration would imply that design measures collaboration itself and thus should be excluded from the analyses.

Knowledge-Intensive Collaboration

Table 11 provides the results of logistic models for knowledge-intensive collaboration as the dependent variable. As expected, the positive size effect was detected only on collaboration with public-knowledge intensive partners. Looking in details at the individual partner type, it was found that the size effect was stronger for collaboration with universities than with public research institutions.

Sectors also mattered in relation to collaboration for innovation with public knowledge-intensive partners. Compared to the reference category of retail, wholesale, accommodation and food services firms, firms in the natural resources sector were significantly more likely to engage in collaboration with public research institutes, whilst those in the health, education, public administration and safety, and other services sectors were significantly more likely to collaborate with universities. The lowest probability to collaborate with either of these partners was, however, found among infrastructure firms.

Firms that received public innovation funding were significantly more likely to collaborate with consultants and universities than those that did not receive funding. The conduct of internal R&D provided a stimulus for collaboration across all types of knowledge-intensive partners. The high share of skilled employees in total employment also made collaboration with these knowledge partners (except for consultants) more probable. There was, however, no significant effect of a R&D tax credit and the membership of the firm found on any regressions.

The intensity of expenditure on internal R&D negatively affected the propensity to collaborate for innovation with consultants and pubic research institutes, whilst that on external R&D had a positive impact on collaboration with every type of knowledge-intensive partners but not significantly so in the case of universities if such activity was spent on less than 1 per cent of the firm's turnover.

Firms that spent large amounts (on a per turnover basis) on external knowledge acquisition or on design activities were more like to collaborate with consultants. A positive association between the expenditure intensity of external knowledge acquisition and collaboration with universities was also observed if such intensity was greater than 1 per cent of the firm's turnover. The high cost intensity of market preparation activities exceeding 1 percent of turnover made a significant contribution to collaboration with public research institutes. This market cost intensity also exerted an inverted U-shaped influence on collaboration with consultants.

Table 11: Full and reduced logistic regressions for knowledge-intensive collaboration

	Consultants		Universities		Public Research Institutes		Consultants *or* Universities *or* Public Research Institutes		Universities *or* Public Research Institutes	
	Full	Reduced	Full	Reduced	Full	Reduced	Full	Reduced	Full	Reduced
Ln_Employees	0.040	-	0.279**	0.284**	0.189	-	0.132	-	0.259**	0.248**
D_Natural	0.338	-	0.605	0.596	0.985*	1.225**	0.424	-	0.581	0.492
D_Manuf	-0.114	-	-0.306	-0.229	-0.508	-0.312	-0.376	-	-0.341	-0.350
D_Infra	0.276	-	-0.829	-0.868	-1.029	-0.915	-0.178	-	-1.014*	-1.073*
D_Knowledge	-0.065	-	0.109	0.114	-0.522	-0.385	-0.106	-	-0.111	-0.130
D_Health	0.207	-	1.218**	1.135**	-0.658	-0.737	0.579	-	1.026*	1.007*
D_OServices	0.171	-	0.873	0.863*	0.305	0.248	0.439	-	0.625	0.592
D_Group	0.013	-	0.023	-	-0.440	-	-0.101	-	-0.062	-
D_InnFund	0.512*	0.601**	0.838**	0.972***	0.114	-	0.768**	0.794***	0.690**	0.725**
D_RDTax	0.028	-	0.073	-	0.696	-	-0.110	-	0.008	-
D_ConductRD	1.249***	1.182***	0.808	1.060***	2.051***	2.122***	1.171***	0.812***	1.306**	1.041***
SkillEmploy	0.006	-	0.018***	0.019***	0.017**	0.018**	0.014**	0.013**	0.018***	0.018***
D_InRDLow	-0.930**	-0.813**	0.043	-	-1.272**	-1.174**	-0.412	-	-0.391	-
D_InRDHigh	-0.722*	-0.629*	0.182	-	-1.154**	-1.087**	-0.502	-	-0.346	-
D_AcqRDLow	0.810**	0.857***	0.225	0.262	1.106**	1.145**	0.854***	0.910***	0.629*	0.572*
D_AcqRDHigh	1.217***	1.134***	0.707*	0.731*	1.101*	1.001*	1.118***	0.987**	0.718*	0.816*
D_AcqKnLow	0.505*	0.542*	0.167	0.224	0.167	-	0.301	0.428	0.121	-
D_AcqKnHigh	0.811*	1.006**	0.651	0.727*	-0.279	-	0.815*	0.869**	0.583	-
D_TrainLow	0.321	-	-0.072	-	0.012	-	0.100	-	-0.101	-
D_TrainHigh	0.121	-	-0.317	-	-0.477	-	-0.001	-	-0.383	-
D_DesignLow	0.436	0.478*	0.448	-	0.104	-	0.551*	0.495*	0.532*	0.560*
D_DesignHigh	0.624*	0.665*	0.430	-	0.252	-	0.677*	0.608*	0.620*	0.656*
D_MkLow	0.458*	0.447*	0.277	-	0.201	0.363	0.296	-	0.246	-
D_MkHigh	0.435	0.310	0.404	-	1.115**	0.990**	0.246	-	0.549	-
Constant	-3.058***	-2.681***	-4.247***	-4.254***	-4.427***	-4.199***	-2.883***	-2.435***	-3.901***	-3.***
N (Observations)	949	949	949	949	949	949	949	949	949	949
Initial -2 Log likelihood	826.2	843.7	637.3	645.4	410.0	421.1	930.8	952.1	707.1	715.8
Model Chi-square*** (*df*)	107.3 (24)	103.5 (12)	135.4 (24)	127.4 (14)	79.4 (24)	68.4 (14)	153.2 (24)	131.9 (9)	141.0 (24)	132.3 (14)
Nagelkerke Pseudo R^2	0.171	0.163	0.239	0.225	0.199	0.173	0.219	0.191	0.234	0.220

Note: $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Horizontal and Group Collaboration

Table 12 provides logistic model results for horizontal and group collaboration as the dependent variable. As expected, firms being part of a group were less likely than independent firms to develop an innovation via collaboration with competitors. In the light of sector, other services firms were more likely (than the reference category of retail, wholesale, accommodation and food services firms) to collaborate for innovation with competitors. Sector, however, played no role in relation to collaboration with other enterprises within an enterprise group.

Receipt of public innovation funding was positively associated with collaboration with competitors but not with group firms. No significant effect of firm size and R&D tax credit was detected in both regressions. Firms that spent on external R&D acquisition more than 1 per cent of their turnover were significantly more likely to establish collaboration with competitors and group firms. A significant positive relationship was also observed between the expenditure intensity of market preparation activities and horizontal collaboration, and between the expenditure intensity of design activities and group collaboration.

Table 12: Full and reduced logistic regressions for horizontal/group collaboration

	Competitors		Other Enterprises within a Group[1]	
	Full	Reduced	Full	Reduced
Ln_Employees	-0.060	-	-0.073	-
D_Natural	0.141	0.089	0.120	-
D_Manuf	-0.146	-0.210	-0.368	-
D_Infra	-0.111	-0.131	-0.106	-
D_Knowledge	0.240	0.340	-0.015	-
D_Health	0.352	0.417	0.888	-
D_OServices	0.713*	0.714*	0.794	-
D_Group	-0.394*	-0.403*	n/a	n/a
D_InnFund	0.478*	0.464*	0.313	-
D_RDTax	-0.197	-	0.026	-
D_ConductRD	0.486	-	0.097	-
SkillEmploy	0.005	-	0.005	-
D_InRDLow	-0.152	-	-0.723	-
D_InRDHigh	-0.304	-	-0.223	-
D_AcqRDLow	0.212	0.236	0.337	0.137
D_AcqRDHigh	0.645*	0.733*	1.079	1.146*
D_AcqKnLow	0.117	-	0.472	-
D_AcqKnHigh	0.594	-	0.145	-
D_TrainLow	0.344	-	0.140	-
D_TrainHigh	0.342	-	-0.153	-
D_DesignLow	0.155	-	0.952	0.825*
D_DesignHigh	0.212	-	0.762*	1.065**
D_MkLow	0.467*	0.550**	0.458	-
D_MkHigh	0.440	0.648**	0.343	-
Constant	-1.950***	-1.597***	-1.156***	-1.162***
N (Observations)	949	949	311	311
Initial -2 Log likelihood	967.2	995.7	342.5	369.9
Model Chi-square*** (*df*)	65.2 (24)	50.3 (12)	35.2 (23)	17.2 (4)
Nagelkerke Pseudo R^2	0.100	0.077	0.152	0.075

*Note: *p < 0.05, **p < 0.01, ***p < 0.001*

[1] *The analysis was limited to firms that reported being part of a group.*

Collaboration and Novelty of Innovation

Table 13 provides logistic model results for the novelty of the firm's innovation as the dependent variable. Obviously, firms that collaborated with customers were significantly more likely to introduce new-to-market products or new-to-industry processes that those that did not collaborate. No effect of the other types of collaboration was detected, indicating that only collaboration with customers play a key role in innovation novelties. Of note, no significant association between the breadth of collaboration and better innovation was observed in any of these regression models.

Firm size and industry sector had no effect in all regressions. The lacking relationship between sector and novelty indicates that firms have understood the importance of developing all types of innovations, not only for the radical ones. Firms that are part of a group were more likely than independent firms to develop more radical forms of innovation. The conduct of internal R&D activities also made a significant contribution to the possibility of firms to introduce more novel innovations. This finding is hardly surprising, since R&D is normally active in development of new technologies which will add to the novelty of products or processes. Conversely, the share of skilled employees in total employment as well as receipt of public innovation funding and R&D tax credit did not matter for the radicality of innovations.

Among different types of innovative activities, only firms that spent more on design and market activities (on a per turnover basis) were significantly more likely to develop novel innovations than those that had zero expenditure on such activities. No effect of other types of innovation expenditure intensity was detected across all regression models.

Table 13: Full and reduced logistic regressions for novelty of innovation

	NOVELTY OF INNOVATION					
	Any partner		Individual partner type		Aggregate partner type	
	Full	Reduced	Full	Reduced	Full	Reduced
D_CoAny	1.429	1.420	-	-	-	-
D_CoGroup	-	-	-0.211	-0.230	-	-
D_CoSup	-	-	-0.048	-0.089	-	-
D_CoCus	-	-	0.403	0.492*	-	-
D_CoComp	-	-	-0.188	-0.184	-	-
D_Consult	-	-	-0.273	-0.227	-	-
D_CoUni	-	-	0.084	0.139	-	-
D_CoPubRD	-	-	-0.190	-0.223	-	-
D_CoSupChain	-	-	0.244	-	0.148	0.201
D_CoKnow	-	-	0.685	-	-0.288	-0.294
D_BreadthLow	-1.162	-1.146	0.244	0.209	0.254	0.224
D_BreadthHigh	-0.916	-0.936	0.685	0.563	0.622	0.562
Ln_Employees	0.044	-	0.039	-	0.044	-
D_Natural	-0.379	-	-0.359	-	-0.369	-
D_Manuf	0.207	-	0.195	-	0.199	-
D_Infra	0.129	-	0.137	-	0.127	-
D_Knowledge	-0.128	-	-0.110	-	-0.124	-
D_Health	-0.174	-	-0.159	-	-0.129	-
D_OServices	0.281	-	0.319	-	0.313	-
D_Group	0.521**	0.533***	0.543**	0.556***	0.516**	0.523***
D_InnFund	0.180	-	0.180	-	0.204	-
D_RDTax	0.360	-	0.324	-	0.332	-
D_ConductRD	0.649*	0.518**	0.698*	0.508**	0.658*	0.531**
SkillEmploy	0.002	-	0.002	-	0.002	-
D_InRDLow	-0.287	-	-0.356	-	-0.283	-
D_InRDHigh	-0.167	-	-0.229	-	-0.159	-
D_AcqRDLow	0.090	-	-0.062	-	-0.059	-
D_AcqRDHigh	0.191	-	-0.117	-	-0.144	-
D_AcqKnLow	0.325	-	0.298	-	0.321	-
D_AcqKnHigh	-0.060	-	-0.080	-	-0.055	-
D_TrainLow	-0.154	-	-0.149	-	-0.158	-
D_TrainHigh	0.416	-	0.430	-	0.422	-
D_DesignLow	0.470*	0.509*	0.440	0.461*	0.472*	0.508*
D_DesignHigh	0.627*	0.686*	0.600*	0.645*	0.626*	0.693*
D_MkLow	0.381*	0.339*	0.408*	0.356*	0.391*	0.351*
D_MkHigh	0.860**	0.887***	0.849**	0.875***	0.840**	0.875***
Constant	-0.854**	-0.700***	-0.844**	-0.686***	-0.863**	-0.695***
N (Observations)	949	949	949	949	949	949
Initial -2 Log likelihood	1186.4	1223.5	1183.5	1219.0	1186.7	1223.6
Model Chi-square***(*df*)	112.6 (27)	91.4 (9)	115.6 (33)	95.8 (15)	112.4 (28)	91.3 (10)
Nagelkerke Pseudo R^2	0.150	0.122	0.154	0.127	0.150	0.122

Note: $*p < 0.05$, $**p < 0.01$, $***p < 0.001$

Collaboration and Innovation Sales Share

Table 14 provides the tobit model results for the innovation sales share as the dependent variable. Obviously, every type of collaboration and the breadth of collaboration had no effect on the percentage of sales from new or significantly improved products in any of these models. This suggests that openness to external sources through collaboration may not be a critical component of innovative performance.

As shown in Table 14, the firm's sector also has a significant impact on the innovation sales share. Compared to the reference category of the retail, wholesale, accommodation and food services sector, the lowest innovation sales shares were in the other services and manufacturing sectors. The low innovation sales share among infrastructure firms may be explained as a result of small local markets in Tasmania.

No significant effect of firm size, the membership of the firm in a group, the conduct of R&D and the share of skilled employees in total employment, was found in all regressions. The R&D tax credit seemed to play a more significant role, than direct public funding for innovation, in determining the proportion of sales from innovative products. Specifically, we found that firms claiming a R&D tax credit had a higher innovation sales share than those without such credit, whereas no significant association between receipt of public innovation funding and the innovation sales share was detected.

Two types of innovation expenditure intensity had a significant positive effect on the innovation sales share. Firms that spent on training and market preparation activities more than 1 per cent of their turnover were more likely to have a higher share of innovation sales than those that spent less or did not spend on such activities. No significant effect of the other types of innovation expenditure intensity was observed in any regression models.

Table 14: Full and reduced logistic regressions for innovation sales share

	INNOVATION SALES SHARE					
	Any partner		Individual partner type		Aggregate partner type	
	Full	Reduced	Full	Reduced	Full	Reduced
D_CoAny	4.941	10.164	-	-	-	-
D_CoGroup	-	-	-2.414	-1.302	-	-
D_CoSup	-	-	-5.011	-5.262	-	-
D_CoCus	-	-	5.339	5.620	-	-
D_CoComp	-	-	0.600	-0.874	-	-
D_Consult	-	-	-1.234	-2.434	-	-
D_CoUni	-	-	5.415	4.426	-	-
D_CoPubRD	-	-	4.035	3.289	-	-
D_CoSupChain	-	-	-	-	3.139	2.792
D_CoKnow	-	-	-	-	2.839	1.649
D_BreadthLow	-7.473	-12.592	-3.174	-2.350	-6.701	-5.835
D_BreadthHigh	-2.934	-7.664	-2.588	0.434	-3.870	-1.996
Ln_Employees	-1.541	-	-1.668	-	-1.618	-
D_Natural	-2.867	-3.180	-3.769	-4.019	-2.913	-3.208
D_Manuf	-4.223	-3.925	-4.541	-4.221	-4.111	-3.866
D_Infra	-7.262	-8.880*	-7.104	-8.856*	-7.160	-8.867*
D_Knowledge	0.653	1.521	0.709	1.453	0.796	1.703
D_Health	-5.690	-7.145	-6.170	-7.910	-5.751	-7.163
D_OServices	-14.211**	-15.185**	-14.289**	-15.080**	-13.799**	-14.702**
D_Group	1.449	-	2.500	-	1.525	-
D_InnFund	-3.612	-	-4.338	-	-3.925	-
D_RDTax	10.822*	9.646*	10.647*	8.706*	10.931*	9.451*
D_ConductRD	4.239	-	4.159	-	4.050	-
SkillEmploy	0.059	-	0.049	-	0.058	-
D_InRDLow	1.554	-	1.377	-	1.619	-
D_InRDHigh	5.813	-	5.796	-	6.064	-
D_AcqRDLow	-3.513	-	-4.332	-	-3.773	-
D_AcqRDHigh	-2.414	-	-2.744	-	-2.529	-
D_AcqKnLow	-1.587	-	-1.880	-	-1.640	-
D_AcqKnHigh	-7.521	-	-7.501	-	-7.563	-
D_TrainLow	-2.475	-2.125	-2.484	-2.044	-2.443	-2.093
D_TrainHigh	6.150	7.564*	6.160	7.747*	6.079	7.590*
D_DesignLow	0.162	-	0.367	-	0.031	-
D_DesignHigh	3.576	-	3.191	-	3.371	-
D_MkLow	-0.048	-0.089	-0.056	-0.085	-0.051	-0.089
D_MkHigh	8.792*	10.771**	8.126*	10.150**	8.796*	10.741**
Constant	27.894***	27.838***	28.562***	28.136***	28.159***	27.829***
N (Observations)	732	739	732	739	732	739
Log likelihood	-3165.1	-3209.6	-3161.6	-3206.7	-3164.7	-3209.6
LR Chi-square***(*df*)	80.8 (27)	59.4 (14)	87.7 (27)	65.2 (20)	81.5 (28)	59.4 (15)
Pseudo R^2	0.013	0.009	0.014	0.010	0.013	0.009

*Note: *p < 0.05, **p < 0.01, ***p < 0.001*

Summary of Multivariate Regression Results

Based on multivariate regression results, many factors have been found to influence the pattern of collaboration for innovation. Some factors are general to any collaboration, whilst others are peculiar to each type of collaboration partners. These possible factors are summarised as follows:

- Firm size was positively associated with public knowledge-intensive collaboration, dominantly with universities. A significant investment in financial and personnel resources for managing and translating the shared knowledge with this type of collaboration could explain this finding.

- Sector plays a significant role in the determination of certain types of collaboration for innovation. Firms in the natural resources sector were most likely to collaborate with public research institutes. Collaboration with universities was most frequent among firms in the health, education, public administration and safety and other services sectors, while only those in the other services sector engaged predominantly in collaboration with competitors. The lowest proportion of collaboration with public-knowledge intensive partners, however, was found among infrastructure firms.

- Belonging to an enterprise group significantly reduced the propensity to collaborate with competitors. Transaction costs associating with fixation of transfer prices of intangible goods can be an explanation of this finding (Lhuillery & Pfister, 2009).

- The positive association between receipt of public innovation funding and collaboration was notable, although at the individual level such association did not turn out to be significant for collaboration with suppliers, public research institutes and group firms. No effect of an R&D tax credit was observed in all regressions.

- Firms that conducted R&D internally were more likely to engage in at least one type of collaboration (particularly with suppliers, consultants, universities and pubic research institutions) than those that did not have their own R&D. The share of skilled employees with science or engineering degrees in total employment had a positive effect on the propensity to collaborate with supply-chain and public-knowledge intensive partners.

- The magnitude of innovative efforts (measured by the percentage of turnover spent for innovative activities) was associated with the engagement in various types of collaboration. Specifically, collaboration with consultants and public research institutes decreased with the internal R&D cost intensity but increased with the external R&D cost intensity, suggesting that external R&D resources from these partners were used as substitutes for internal R&D resources. A positive influence of the high external R&D cost intensity (over 1 per cent of turnover) was also observed on collaboration with the remaining types of partners, except for suppliers.

- The amount a firm spent (on a turnover basis) on external knowledge acquisition had a significant positive influence on collaboration with consultants over other types of knowledge-intensive partners. This finding could be explained by the fact that collaboration with consultants can be easily and flexibly achieved by firms than with public knowledge counterparts (Ebersberger & Lehtoranta, 2005).

- Firms that spent more on market preparation activities (as percentage of turnover) were more likely to engage in at least one type of collaboration particularly with supply-chain and horizontal partners, whilst those that spent more on design activities were more likely to collaborate with consultants and group firms. Of note, an inverted U-shaped influence of the cost intensity of market preparation activities was also detected on collaboration with consultants.

Among different types of collaboration, only collaboration with customers was found to have a significant positive influence on the novelty of innovation. This finding may reflect the importance of customers in helping firms reduce the risk associated with the market introduction of innovations (Gardiner & Rothwell, 1985; Lassen, Laugen & Middel, 2008; Quinn, 1985). Firms that conducted R&D internally and those that had the higher intensity of expenditure on design and market preparation activities were more likely to develop novel innovations. The findings of a non-significant association between the other types of collaboration (and collaboration breadth) and novelty, and a significant association between belonging to an enterprise group and novelty, also indicate that the loss of direct control held by one firm over the development of radical innovations is a major risk in connection with collaboration.

The results of the tobit regression analyses revealed no association between collaboration and the innovation sales share. Firms in the other services and infrastructure sectors were found to have a relatively lower innovation sales share than the reference category of the retail, wholesale, accommodation and food services firms. We also observed a stronger positive influence of a R&D tax credit over direct public innovation funding on the innovation sales share. A high share of innovation sales were also likely to be common among firms spending on training and market preparation activities more than 1 per cent of their turnover.

CONCLUSIONS

Many authors have argued that innovation is now no longer the province of individual firms but a matter of collective action with firms acting together to form collaborative arrangements for innovation with various types of partners. This report has examined this issue using evidence from the response to the first Tasmanian Innovation Census (TIC). Using descriptive and multivariate regression analyses, we have investigated factors associated with the engagement in collaboration and the contribution of collaboration to innovation outcomes.

Results show that collaboration for innovation in Tasmania is still far from the norm, as the majority of innovating firms (especially infrastructure firms) continue to 'go it alone' for innovation in the sense that they do not have any collaborative arrangement through which they develop their innovation. Various factors (including firm size, sector, belonging to a firm group, receipt of public innovation funding, conduct of R&D, the share of skilled employees, and the intensity of expenditure on internal R&D, external R&D, external knowledge acquisition, design and market preparation activities) are found to influence the propensity to collaborate for innovation; however, their influence vary depending on the type of collaboration partners.

Among different types of collaboration, collaboration with customers has been shown to be of the most importance because of a positive influence on the novelty of innovation. This finding has implications for the extensive focus on user-driven innovation as the impact will be of a more radical nature. The probability of introducing novel products or processes also associates with the conduct of internal R&D and the intensity of expenditure on design and market preparation activities. This suggests that innovations in which the R&D function is involved and the magnitude of design and market efforts is high, have more radical outputs.

Through empirical analysis, this study provides no evidence to support the theoretical concept that collaboration plays a key role in the innovation sales share. Rather, the receipt of R&D tax credit and the high cost intensity of training and market preparation activities are essential. This finding places explicit emphasis on the continuous learning and development of the human capitals and the market introduction of innovation as more effective ways of improving the firm's innovation sales share. However, we note that this does not mean that external knowledge is unimportant, but it implies that collaboration is not a main mechanism for an improvement in the innovation sales share to occur. This result may reflect the fact that innovation collaboration is not costless. It can be time consuming, expensive and laborious which could hinder innovation performance. In Tasmania, the other mechanisms for knowledge flows such as informal contacts and job mobility may play a more centre role than collaboration, although this cannot be confirmed due to the current data restriction.

For policy implications, the findings in this report highlight the need for the provision of financial assistance in the form of public innovation funding and tax incentives to assist innovating firms to be successful in their collaboration strategizing efforts. Although it is unclear what form this government assistance takes (e.g. R&D grants or simply assistance for firms in distress), our results show that firms that received public innovation funding are more likely to collaborate for innovation, and only those that claimed a R&D tax credit have a higher innovation sales share. We argue that the small size of most responding firms and small local markets in Tasmania may inhibit collaboration for innovation and the bringing of innovation to the domestic and international markets in a successful way. These constraints, however, could be compensated to some degree by the provision of public funding and tax credits that are specifically designed to support collaboration for innovation.

Of note, although this report has raised many important and worthwhile issues, it has some limitations as well. As pointed out earlier in this report, our findings are limited by the use of recursive equations and cross-sectional data. The relationship between some factors and collaboration can be non-recursive characterized by a feedback loop; for example, the development of novel innovations by firms may also increase their likelihood of engaging in collaboration for innovation. Without testing this reversed relationship, the direction of causality is questionable. Furthermore, it is reasonable to assume that collaboration does not contribute to innovative performance right away, but rather in subsequent periods. The time lag between collaboration and its effects may also vary with the type of collaboration partners. For example, collaboration for innovation with public-knowledge intensive partners is usually more focused on advance research and technologies; therefore, the results of these activities take longer to be implemented in innovative products or processes than the results of activities undertaken with supply-chain partners. The use of cross sectional data, therefore, prevents us from establishing proof of causality. Also, although our regression models fitted the sampled data well, there may also be other models that fit the data at or near to the same degree. This suggests that a finding of good fit to the models, in fact, should not be taken to imply correctness or truth, but only plausibility. Coupled with the fact that other unknown intervening variables could have lead to an error in the causality analysis, the interpretation and generalizability of the relationships found in this study therefore needs to be done with caution.

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