UNIVERSITY-INDUSTRY R&D COLLABORATION IN THE AUTOMOTIVE, BIOTECHNOLOGY AND ELECTRONICS FIRMS IN MALAYSIA

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Abstract This paper seeks to examine the drivers of R&D collaboration between firms and universities and research institutes using a sample of automotive, biotechnology and electronics firms from Malaysia. The Probit regression results indicate that R&D intensity, openness to R&D as measured by partner diversity, access to wider range of channels of information, and size matter for university-industry collaboration in the overall sample. Size was inversely correlated with the probability of R&D collaboration between firms, and universities and research institutes in all the industry samples. At the industry-level R&D intensity and importance of university as a source of knowledge were important in automotive firms, R&D intensity, channels of R&D information and partner diversity were important in biotechnology and the channels of R&D information and R&D partner diversity were important in electronics.

Keywords: University-industry collaboration, R&D, automotives, biotechnology, electronics, Malaysia

1. INTRODUCTION

Whatever the entry point of analysis there is consensus that institutions and public goods organizations have an important role to play in firm-level R&D activities.[2] Universities are considered important silos of R&D activities whose knowledge embodied in graduates produced, R&D labs or simply interaction have often been tapped by firms to generate new products and services. The prime difference lies in new institutional economists who believe that markets enjoy the superior defining role (Coase, 1991; North, 1992; Williamson, 1985) and the evolutionary economists who believe in non-market institutions to have equally important influences (Rosenberg, 1976, 1982; Nelson and Winter, 1982; Nelson, 2008; Lall, 1994; Katz, 2005). Acworth (2008) produced evidence of the knowledge integration community (KIC) model by the Massachusetts Institute of Technology (MIT) created to strengthen knowledge flows and cooperation between industry and university.

Recognizing that R&D activities carried out in universities play an important role in driving firm-level innovations, the Malaysian government implemented explicit policies since the early 1990s to stimulate university-industry R&D linkages. Following the Action Plan for Industrial Technology Development (APITD) of 1990 the government launched the Malaysian Technology Development Corporation (MTDC), Malaysia Industry, Government High Technology (MIGHT), the Intensification of Research in Priority Areas (IRPA) grant and a number of other broader organizations to *inter alia* support university-industry R&D linkages. As part of the plan to innovate and commercialize research findings, the government increased strongly the allocation for R&D and commercialization of technology to RM1.6 billion under the 8th Malaysia Plan over the period 2001-2005 compared with RM 1 billion under the Seventh Malaysian Plan over the period 1996-2000 (Malaysia, 1996, 2001). The government also launched the Second Science and Technology Basic Plan strongly advocates national innovation system reform toward a network based system by active interactions between innovation actors over the period 2001-2006 (Malaysia, 2003). The government also added the science fund under the Ministry of Science Technology and Innovation (MOSTI) to *inter alia*,

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[2] Since the neoclassical school believes in spontaneous responses of economic agents through relative price relationships, public goods such as knowledge are little examined and hence are excluded from this paper.

support R&D in universities with preference given to applications that show links with firms. Despite massive government focus, the Federation of Malaysian Manufacturers officials' reported little university-government relationships established in the manufacturing sector in Malaysia.[3]

Hence, it will be worth examining one, the state of university-industry collaborative relationships and two, the drivers of it in Malaysia. The rest of the paper is organized as follows. The next section discusses of the relevant literature to serve as the theoretical guide. Section three presents the methodology and data. Section four analyses the results. Section five provides the conclusions and implications.

2. Theoretical Considerations

There is extensive evolutionary work recognizing the role played by university-industry linkages in stimulating R&D activities in firms.[4] Mazzoleni and Nelson (forthcoming) provided a rich account of industry-university linkages – both jointly and through networks – that was critical in the transfer knowhow in agricultural production and industry.[5] However, the role of particular variables in driving R&D related collaboration between universities and firms is scant. Evidence from evolutionary economists find such relationships stronger in developed countries where the embedding high tech environment (including universities) strong (see Rasiah, 2004; Acworth, 2008). While it is obvious that firms tend to carry out more R&D activities the stronger the supporting knowledge infrastructure there is also evidence that little R&D collaboration exists in locations where the high tech infrastructure is weak. However, little is known over what matters in driving university-industry R&D collaboration activities in developing countries other than the widely researched newly industrialized economies of Korea, Taiwan and Singapore, and anecdotal evidence from others such as Brazil and India.

Evidence on what matters for collaboration are numerous (e.g Ahn, 1995; Chen, 1994; Mansfield, 1991,1996; Bayona *et al*, 2001; Cassier, 1999). These studies have identified various reasons explaining the establishment of cooperative relationship between research organization and industry. This section, thus, focuses on the drivers of industry-university R&D collaboration.

2.1 R&D Intensity

The stock of *ex ante* knowledge to seek, engage as well as absorb effectively R&D spillovers from other economic agents is an important determinant for collaborative research. Using R&D as a proxy of absorptive capacity, Cohen & Levinthal (1990) and Kamien & Zang (2000) argued that it will be positively correlated with collaborative activities. Similarly, Leiponen, (2001), Adams, Chiang & Jensen (2000), Roller *et al* (1997), Kleinknecht & Van Reijnen (1992), Colombo & Gerrone (1996), Dutta & Weiss (1997), Hagedoorn, Link & Vonortas (2000) showed evidence of R&D intensity determining cooperative R&D outside of the firm.

Hagedoorn, (1995), Koza & Lewin, (1998), Powell et al., (1996) and Beise and Sathl, (1999) reported a strong relationship between firm-level technological capabilities and the number of alliances with universities. Beise and Sathl (1999) argue that a firm's in-house R&D activity shows its ability to absorb the public research results from the university-industry collaboration efforts. In-house R&D capacity, thus, is considered important for firms to be able to benefit from collaboration activities with universities.

[3] Authors' interview conducted in Kuala Lumpur on February 23 2008.
[4] Universities have a wider role to play in the transfer of knowledge to firms than R&D activities (see Bramwell and Wolfe, 2008).
[5] See also Hayami and Ruttan (1985), Dahlman and Frischtak (1993) and Hashimoto (1999) .

Welsh, Glena and Biscotti (2008) produced evidence from 84 interviews to show that industry-university collaboration linkages are important in increasing contact with university scientists but also tend to increase their capitalistic tendencies.

2.2 R&D Partner Diversity

Partner diversity offers the openness necessary for firms to collaborate and appropriate R&D synergies. Partner diversity also means openness and readiness of firms to collaborate for R&D activities. The more diverse the partners are or the source of information obtained from other partners, the more likely that the firms will consider universities as potential R&D partners. Fontana, Geuna and Matt (2006) found that openness of firms to significantly affect collaboration with public research organizations. Similarly, Laursen & Salter, 2003 found that firms searching strategies and number of external channels of information used to innovate to have higher probability of considering university knowledge.

Because proprietary and non-proprietary knowledge is involved, some studies argue that trust and sharing of results are important in driving industry-university collaboration. Relying on a multiple case study approach, Numprasertchai and Barbara's (2004) findings suggest that trust and balanced mutual benefits are the main factors explaining successful research collaboration. Indeed this study recommended universities in developing countries to extend more collaborative efforts with variety of partners to be successful. The theoretical logic here is that diversity provides a wide range of options for knowledge synergies to be appropriated. Sanchez and Tejedor's (1995) study showed that informal establishments enjoying no assistance from the liaison office and large firms tend to collaborate more with universities (Sanchez & Tejedor, 1995).

2.3 Perceived Importance of R&D activities in Universities and Public Research Institutes

It is unlikely that firms would collaborate with universities and public research institutes to undertake R&D activities without understanding the benefits they can appropriate from it. Some studies indicate that the key for collaborative motives are learning by interacting, development of well planned strategies focusing on interaction with industry and identifying the proper channels of communication (Hameri , 1996). Drejer Ina & Jorgensen (2005) found that the lower frequency of public-private research collaboration is the result of a lack of proper mechanisms, such as simple information channels, to ensure that firms know the benefit of collaboration, guidelines for organizing collaborative projects, public co-funding, and conflicts between public and private.

Firms in particularly underdeveloped and emerging economies perceive that universities and public research institutes lack the transparency and openness to support their activities because the bureaucratic nature their organization sets impediments for collaborative activities. Based on interviews with 51 Spanish companies, Baranano (1995) found that a large number of R&D projects are reaching the highest level of innovation success but most of them complain of severe bureaucratic problems, including difficulty in coordination actions, ways of working, culture associated with collaboration process. Therefore, firms' perception, whether real or otherwise, are important in explaining the incidence and intensity of industry-university collaboration.

2.4 Channels of Information

Assess to more channels of R&D information of universities and research institutions for firms are likely to enhance the collaboration. A study by Fontana, Geuna and Matt (2006), suggest that firm's access to knowledge through publications and participation in public policies will have an effect on the levels of collaboration with universities and public research institutes. The wide range of participatory activities is argued to offer the platform necessary to raise the potential for forge collaboration activities.

However, mere engagement in advisory roles and accessing publications may not provide the requisite commercialization synergies. McKelvey's (2008) showed that Swedish universities enjoyed stronger R&D linkages with firms and much of the knowledge created is commercialized compared to American universities though the number of patents and publications generated in the United States is higher. This counter argument could be a consequence of the lack of mechanisms to capture knowledge flows from universities to industry. Where the links are formal the filing of patents as well as the commercialization of the results is visible for researchers to measure.

2.5 Firm Strategy

Firm strategy is an important determinant of industry-university R&D collaboration as well as the mode of the collaboration – i.e. to outsource completely R&D activities to universities, coordinate through public research labs basic R&D undertaken in universities, formal cooperation through joint-ventures, *ad hoc* linkages with particular researchers or simply to undertake such activities in-house. Taiwanese firms tend to access university-based R&D output through public labs – industrial technical institutes (ITRI) (see Lin, 2003).

Firms may also opt between centralizing and decentralizing their R&D activities. Best (2001) and Audrestch (2002) provided evidence from the United States that diversity and decentralization were important drivers of R&D activities of firms. Therefore, firms' R&D strategy may influence the nature, intensity and outcome of collaboration activities. Fontana et al. (2004) found that firms that outsource R&D expenditure and seek patent protection show higher levels of collaboration.

2.6 Size

Past research indicates that size plays an important role (Arundel & Geuna 2004; Mohnen & Hoareau 2003; Cohen et al 2002; Laursen and Salter, 2003). The conventional wisdom is that larger firms tend to collaborate more than the small firms since a minimum amount of resources are considered critical before firms manage to participate in R&D activities. However, the relationship between size and collaboration is not obvious at all since new start ups, and especially incubated firms are increasingly turning this logic untenable. Small firms with highly R&D-intensive activities have been important in birth of high tech entrepreneurs in the Silicon Valley and Route 128 in the United States, and Taiwan (see Best, 2001).

Traditionally small and medium size firms in a number of locations are also more likely to access R&D-type knowledge from universities and public labs rather than introducing them in-house. For instance, owing to lack of resources, and with less capability to undertake R&D, small firms may source for alternative source of partners to innovate. Motohashi (2004) has identified that in Japan, university-industry collaboration has spread over to the small and young firms in the recent years. Owing to the insufficient R&D resources, small firms find university collaboration as an alternative source to engage in R&D activities.

2.7 Industry Specificity

Evolutionary economists argue that industrial specificity is important in explaining variances in the intensity, nature and drivers of innovation activity (Freeman, 1995; Nelson, 2008;Mazzoleni and Nelson, forthcoming).

The ecology of actors the incidence and intensity of industry-university R&D collaboration varies with industries. Biotechnology firms tend to show strong reliance on new discoveries and adaptations made in specialized labs and hence are likely to show high industry-university collaboration. The dynamics and specificity of knowledge and its manifestation in humans, labour process, goods and services that demonstration the relevance of industry is articulated succinctly by Rosenberg (1976, 1982). Within biotechnology, Rosenberg (2009) showed that medical innovations have relied extensively on breakthroughs made possible by interdisciplinary flows of knowledge with life and physical sciences playing key roles. Automotives rely on interactive R&D collaboration as in Sweden (see McKelvy, 2008) but in less developed and emerging economies tend to specialize on assembly activities with the most R&D participation in domestic design models and contract R&D-based component adaptations to supply domestic markets (see Quardros, 2003).

Specialization in particular segments of value chains (see Best, 2001; Gereffi, Humphrey and Sturgeon, 2005; Lall, 2003) and the distance of the firm from the technology frontier – which is often defined by sectoral innovation systems - will also have a bearing on the incidence and intensity of industry-university R&D collaboration. Where firms are engaged in standardized product assembly for both exports and sales in domestic markets firms' seldom generate the demand for industry-university R&D collaboration – egs include electronics in Malaysia, Philippines and Thailand (Hobday, 1995). Hence, multinational subsidiaries in Southeast Asia are engaged much more on in-house innovation activities whereas local firms in Taiwan are strongly engaged in industry-university R&D collaboration activities. ITRI in particular has become a major source of R&D inputs for firms in Taiwan since its launching in 1980 (Mathews and Cho, 2000; Amsden and Chu, 2003).

This section identified the key drivers and other explanatory variables that are important determinants of industry-university R&D collaboration, viz. firm-level R&D intensity, R&D partner diversity, perceived importance of universities and researched institutes, channels of information, firm strategy, size and industry specificity. The next section presents the methodology and data for testing these relationships.

3. Methodology

Given the qualitative and subjective nature of the university-industry collaboration variable the choice of a suitable model for identifying the key drivers is important. Hence, this paper uses descriptive statistics to examine the state of collaboration, R&D intensity and other related variables, and a Probit model to examine the drivers of university-industry collaboration with R&D intensity being the key explanatory variable. A Probit model was preferred over a Ordered Logit model because of the normalization undertaken to combine firms' responses to two R&D related variables.

3.1 Data

Primary data collected from firms using a professional body that was funded by the International Development Research Centre (IDRC) is used in the paper.[6] The professional body, i.e. Pemm Consult, used a structured sampling frame using size and ownership as the only criteria to select the firms. A total of 150 firms were chosen from the industries of automotives, biotechnology and electronics. The response rate is shown in the Table below.

Table 1: Sampled data, Malaysia, 2006

	Automotives	**Biotechnology**	**Electronics**
Questionnaires sent	150	150	150

[6] This standard four-page questionnaire was also used in China, India and Korea .

Responses	84	127	150
Response rate	56.0	84.7	100.0

Source: IDRC Survey (2007)

3.2 Variable specification

This section specifies the dependent and independent variables for analysis. Although the questionnaire used was more extensive only questions that related to R&D collaboration were drawn for evaluation.

University-Industry R&D Collaboration

In assessing the degree of collaboration, the firms were asked to assign a value of 1 to 4 (not important to very important) on the reasons for collaboration with universities and public research institutes. The reasons for collaboration includes transfer of technology, technological/consulting advice, absorb technological information, obtain information on engineers, scientist and trends in R&D, contract research to complement firm R&D, contract research that the firm cannot perform, graduate recruitment for supporting R&D activities, use of other university resources, perform product/process testing and improve quality control. The mean values of the importance of all the 10 reasons give an indication of the extent of R&D collaboration between firm and public research institutes. Consequently, using the mean value of the total sample as the threshold value, two dichotomous variables to gauge the different categories of collaborators was created; (1) low collaborator (zero as the value) and (2) high collaborator (one as the value). Therefore, the dependent variable was measured as:

$$COLL = 1 \text{ if high collaboration (1) and 0, otherwise}$$

Explanatory Variables

All R&D and related variables, including R&D strategy and nature of R&D links, were classified as explanatory variables in this paper.

R&D intensity

We use the standard measures of R&D intensity. In the survey the firms were asked to report their average percentage of R&D expenditure over sales in the last three years. Using this information, the ratio of R&D expenditure over sales was measured as:

$$R\&D = \text{(R\&D expenditure/Sales)\%}$$

R&D strategy

Firms in the survey indicated the regularity of R&D activities and how they are organized. The firms indicated whether or not they had regular or occasional R&D activities and whether it is centralized or decentralized. This allows us to construct two dummy variables indicating the nature of firms' R&D strategy. The two different R&D strategies were measured as:

$$RDS1 = 1 \text{ if firms have regular R\&D activities and, 0, otherwise}$$
$$RDS2 = 1 \text{ if firms have centralized R\&D activities and, 0, otherwise}$$

R&D Partner Diversity

The firms in the survey have also indicated on the importance of other channels of information about R&D activities, namely with other firms and organizations. The firms were asked to rate from 1 to 4 (not important to very important) on the importance of these channels of information (11 sources) for their R&D activities. This includes rating the importance of patent, publications and reports, conferences and meeting, informal information exchange, hiring of technical personnel, licensed technology, joint R&D projects, contract research, reverse engineering, trade associations and fairs and expositions. If the mean value of all the sources of information is high, then it indicates that the firms have multiple sources of information from different partners. Therefore, R&D partner diversity (*PD*) was measured as:

$$PD = \sum \text{score of all sources} / 11$$

Perceived Importance of University/Public Research Institutes as a Source of Information

The likert-scale measures (1 to 4; not important to very important) was also used to measure the perceived importance of university/research institute as a source of R&D activities for firms. The firms were requested to rate on why universities/research institutes are not an importance source of firm's R&D activities. This include reasons like firms have enough internal R&D activities, universities have no understanding of firm business, research institute have no understanding of firm business, contract agreements are difficult, lack of trust, low quality of research, geographical distance, difficulties in dialogue, and intellectual property issues. Since the reasons are in negative connotation, the scale was recoded and the average scores of all the reasons were used to measure the importance of university/public research institution as a source of information for the firms R&D activities. The perceived importance of university/public research institute as a source of information for firms was measured as:

$$UNI = \sum \text{score of the importance of university/public institute as a source of innovation} / 10$$

Channels of R&D Information

The channels available for firms to access information on the R&D activities of universities and public research institutes is measured using a likert-scale measurements (1 to 4; not important to very important). Firms were asked to indicate on how each of the universities and research institutes channels of information (15 channels) contributes to the firm's innovative activities. The channels include patents, publications and reports, conferences and meetings, informal information exchange, hiring of post graduates, technology licensing, consulting, contract research, joint or cooperative R&D projects, university networks, temporary personnel exchange, incubators, science and technology parks, spin-offs and university/research institute owned firms. The mean value of the scores is used to represent the channels of information (CI) construct. The channels of information (*CI*) were measured as:

$$CI = \sum \text{score of all channels of information} / 15$$

Size

Size is argued to provide both scale (larger numbers) and scope (smaller numbers) effects. We included size for these reasons. The population distribution of size in Malaysia showed a heavy skew towards firms with employment size less than 150 employees (over 99 percent of firms in 2006), which was used as the basis by the statistics department to classify small and medium size in the country to firms with employment size of 150 and less.[7] Hence, a neutral relationship is assumed. Firms with more than 500 workers are considered as large. It was measured as:

Si=1 when S≥150, and Si=0 otherwise.

Where S refers size of firm i.

Industry

In addition to introducing dummies in the overall sample separate industry-based regressions were run to capture industry effects.

Control Variable

Age was included as a control variable in this paper.

Age

The age of the firm is also important as the older ones may have stabilized to understand the local environment so as to be able to interact with universities. However, new firms may have more drive to seek institutional arrangements to participate in knowledge-intensive activities more than old firms.

Hence, a neutral relationship is assumed. Age was measured as:

Ai= number of years since establishment in Malaysia.

Where A refers to age of firm i.

Analytical model

Since the dependent variable are dichotomous (low and high collaboration), the appropriate estimation models would be logit or probit (Greene, 2003). An ordered logit model was avoided because the responses require adjustment of means, and hence the more straightforward demarcation of high and low categories is more appropriate here. Hence, the Probit model was preferred here, which is specified as:

$prob(Y_i = 1 | X_i) = \int_{-\infty}^{x'\beta} \phi(t)dt = \phi(X'_i\beta)$, where the firm is either high collaborator $(Y_i = 1)$ or a low collaborator $(Y_i = 0)$ and the choice depends on vector *X*. Therefore, this involves fitting a probit model for collaboration (*COLL*) based on the following specification:

[7] see Malaysia (2006).

$$\text{Prob}[COLL=1] = f(R\&D, RDS1, RDS2, UNI, CI, SA, SB, SIZE, AGE)$$

where:
COLL = low or no collaboration (0) and high collaboration (1)
R&D = average ratio of R&D expenditure over sales for the past 3 years
RDS1 = firms with occasional R&D (0) and regular R&D (1)
RDS2 = firms with decentralized R&D (0) and centralized R&D (1)
PD = R&D partner diversity measured by adding existing channels and dividing by the total (10).
UNI = importance of university as a source of R&D
CI = available channels of information on university R&D
Age = years in operation
Size = small and medium size firm (0) and large firm (1)[8]

The same estimation technique is used for the specific industry Probit estimation.

4. State of University-industry collaboration and other variables

A univariate analysis was conducted on all the key variables used in the paper. Since the data collected followed a strict sampling procedure and the response rate is high with electronics enjoying complete set of responses, the results are expected to be representative of the population of these firms in Malaysia.

The mean age in the sample of all firms, is 17.5 while sectorally, in the electronics, biotechnology and automotive are 19, 13 and 20 years, respectively (see Table 2). Access to universities R&D information (*CI*) on average is 2.02 for the overall sample. Firms in the biotechnology sectors reported to have better access to channel of information with regards to R&D activities of universities. Owing to the basic research nature of R&D work undertaken by biotechnology firms their motivation to access university research information is found to be higher. In fact, many of the biotechnology firms which primary involved in agricultural related research activities have establish linkages with public universities (e.g. UPM and others). This might be the reason why they tend to exhibit a higher mean score compared to other sectors. In terms of R&D activities, the average scores indicate that on average in the past 3 years only 8% of the revenue is invested in R&D related activities in all the firms. Contrasting the score of R&D intensity between sectors indicate that biotechnology, electronics and automotive sectors spends 9 per cent, 7.8 per cent and 7 per cent on research activities, respectively. Firms in the automotive sectors were found to have higher partner diversity (*PD*) (access to R&D information from other firms) compared to that of biotechnology and electronics.

Comparing the firm's perception on the importance and relevance of university as a source for their internal R&D activities (*UNI*), firms in the biotechnology sector recorded a higher score which is higher than the overall mean of the total sample (2.07) and the other two sectors, electronics (2.04) and automotive (1.82).

Table 2: Descriptive Statistics by Sectors, 2006

	All firms (*n*=313)				**Electronics (*n*=122)**				**Biotechnology (*n*=122)**				**Automotive (*n*=69)**			
	Mean	S.D	Min	Max	Mean	S.D	Min	Max	Mean	S.D	Min	Max	Mean	S.D	Min	Max

[8] A dummy was preferred over actual size as it increases the statistical significance of the coefficients. The signs are the same in both sets of regressions.

AGE	17.54	11.06	1.00	63.00	19.68	9.65	3.00	47.00	13.51	11.58	1.00	63.00	20.86	10.40	1.00	40.00
CI	2.02	0.62	1.00	4.00	1.93	0.58	1.00	3.87	2.08	0.66	1.00	4.00	2.04	0.57	1.00	3.40
R&D	0.08	0.05	0.00	0.35	0.078	0.06	0.00	0.35	0.09	0.05	0.00	0.30	0.07	0.04	0.00	0.20
PD	2.14	0.75	1.00	4.00	2.07	0.72	1.00	3.64	2.16	0.76	3.55	1.00	2.21	0.80	1.00	4.00
UNI	2.07	0.95	1.00	4.00	2.04	0.92	1.00	4.00	2.24	0.94	3.40	1.00	1.82	0.97	1.00	4.00
COLL	2.32	0.62	1.10	4.00	2.14	0.65	1.10	4.00	2.47	0.55	1.20	3.70	2.45	0.57	1.30	3.20

Source: IDRC Survey (2007)
Note: The sample size, n<N (survey responses) because of some firms' not filling some questions.
The mean score of *COLL* (collaboration) is the average of the total likert scale scores on 10 reasons indicated for collaborating with universities. These averages were used to categories, two groups of firms, e.g. low and high collaborators. *CI*, *PD*, and *UNI* are average score of the Likert-scale measures, respectively.

Overall, the mean score of collaboration is 2.32 for the overall sample. Firms in the biotechnology sectors on average are found to have higher collaboration mean (2.47) compared to firms in the automotive (2.45) and electronics sectors (2.14). The next section establishes the reasons why this is case, and its relationship with the explanatory variables of R&D intensity, diversity of R&D partners, perceptions of R&D capabilities in universities and public research institutes, channels of information, size and industry type.

5. Drivers of University-industry R&D Collaboration

This section discusses the drivers of industry-university R&D collaboration to examine the importance of the explanatory variables identified by past researchers. The results passed the White test for heteroskedasticity and the chi-square ($\chi 2$) for model fit. As shown in Appendices 1, 2, 3 and 4 the correlation coefficient tests produced strong and significant relationship between a number of and hence six different equations were run for the overall as well as the industry samples. Table 3 presents the overall results while Tables 4, 5 and 6 present the industry-specific results for automotives, biotechnology and electronics respectively.

In models 1 and 2 of the overall sample (see Table 3), the results show that R&D intensity is significant and has strong positive effects on the likelihood of being a collaborator. The relationship between R&D intensity and the likelihood of collaboration is even stronger in the automotive and biotechnology samples (see Tables 4 and 5). It is only in the electronics sample that there was no statistical relationship between the two variables (see Table 6), which could be a consequence of heavy dominance of foreign firms as 80.6 percent of equity in this industry in 2006 was foreign owned (Malaysia, 2007). The evidence generally supports the argument that it is important to have high in-house R&D capability for firms to undertake collaborative R&D activities with universities and public research institutes.

Firm strategy on R&D collaboration was also important as RDS1 in model 4 and RDS2 in models 5 and 6 were statistically significant and their coefficients were positive and strong (see Table 3). Firm strategy was unimportant in automotive firms as the coefficients of both RDS1 and RDS2 were statistically significant (see Table 4). The choice of centralized R&D or ad hoc one-off collaboration strategy was most important in biotechnology firms as RDS1 and RDS2 showed strong and positive coefficients that were statistically significant in models 4 and 6 (see Table 5). Firm strategy was significant in the electronics sample when it came to preferring a centralized over a decentralized R&D framework (see Table 6). Industry-type matters with firm strategy as it was unimportant in automotive firms.

Perceived importance of universities and research institutes as important source of R&D (UNI) was statistically significant and the coefficients positive in all the models in the overall sample (see Table 3). The coefficients were highly significant in models 1, 2, 3 and 5. The relationship between UNI and the likelihood of R&D collaboration were also strong and significant in the automotives sample (see Table 4). UNI was either statistically insignificant or only significant at the 10% level in the biotechnology sample (see Table 5). UNI was statistically significant at the 10% level in models 1, 3, 4 and 5. UNI was statistically insignificant in all the models in the electronics sample. Hence, perception of the importance of universities and research institutes are only important in automotive firms among the three samples when seeking R&D collaboration suggesting that industry-type matters.

Partner diversity (PD) and range of information channels (CI) were highly significant in the overall sample (at 1% level) (see Table 3). Both variables were insignificant in the automotive sample (see Table 4). They were highly significant, and the coefficients positive and strong in biotechnology sample (see Table 5). CI was highly significant but PD was only significant at the 10% level in model 4 in the electronics sample (see Table 6). The strong and positive impact of PD on the likelihood of R&D collaboration with university and research institutes support the findings of Bayona, Marco and Huerta (2001), it is largely influenced by biotechnology firms. These results suggest that industry matters.

Size was statistically significant but the coefficients were negative in all samples and all models (see Tables 3, 4, 5 and 6). The evidence shows that firms with strong R&D intensities need not be large as size is inversely correlated with industry-university R&D collaboration supporting the arguments of Motohashi (2004). Also, the coefficient of correlation between size and R&D intensity was extremely low in the overall, biotechnology and electronics samples (see Appendix 3 and 4). Hence, it will be useful to subject the findings of Arundel & Geuna (2004), Mohnen & Hoareau (2003), Cohen et al (2002) and Laursen & Salter (2003) to greater scrutiny on the effects of size on the intensity of R&D collaboration between firms and universities and research institutes.

The influence of industry has been critical from the evidence above with all the variables as there were consistent relationships only between size and the likelihood of R&D collaboration between firms, and universities and research institutes.

Table 3: Estimated Probit Regression (All firms)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Variable				Coefficient		
C	-2.615(0.479)***	-1.318(0.342)***	-2.601(0.558)***	-1.534(0.444)***	-2.55(0.519)**	-1.521(0.402)
R&D	1.947(0.966)**	1.938(0.878)**	-	-	-	-
RDS1	-	-	0.449(0.344)	0.713(0.345)**	-	-
RDS2	-	-	-	-	0.472(0.215)**	0.699(0.236)***
UNI	0.320(0.094)***	0.246(0.086)***	0.284(0.097)***	0.153(0.090)*	0.283(0.096)***	0.162(0.087)*
CI	0.974(0.173)***	-	1.010(0.174)***	-	0.985(0.174)***	-
PD	-	0.449(0.119)***	-	0.482(0.119)***	-	0.488(0.119)***
AGE	0.007(0.008)	0.009(0.008)	0.009(0.008)	0.008(0.008)	0.0115(0.009)	0.010(0.008)
SIZE	-0.770(0.168)***	-0.749(0.195)***	-0.815(0.204)***	-0.842(0.195)***	-0.817(0.205)***	-0.844(0.196)***
LR (X^2)	152.520***	134.843***	155.979***	130.929***	158.003***	135.579***
Log Likelihood	-148.106	-156.935	-143.947	-156.472	-142.935	-154.148
Pseudo *R*-squared	0.339	0.301	0.351	0.294	0.356	0.305
N	313	313	313	313	313	313

Note: ***<0.01, **<0.05 and *<0.10, respectively. Figures in parenthesis are standard errors. Dummy for sectors included but not reported here.

Table 4:Estimated Probit Regression (Automotive)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Variable				Coefficient		
C	-4.406(1.332)***	-4.189(1.273)***	-3.662(1.316)***	-3.089(1.226)**	-3.864(1.262)***	-3.598(1.218)***
R&D	6.467(3.295)**	7.028(3.457)**	-	-	-	-
RDS1	-	-	0.129(0.708)	0.084(0.736)	-	-
RDS2	-	-	-	-	0.486(0.668)	0.639(0.660)
UNI	0.842(0.371)**	0.878(0.397)**	0.526(0.240)**	0.483(0.241)**	0.531(0.241)**	0.512(0.244)**
CI	0.138(0.472)	-	0.534(0.367)	-	0.476(0.377)	-
PD	-	0.044(0.364)		0.304(0.295)	-	0.298(0.293)
AGE	0.054(0.025)**	0.055(0.025)**	0.035(0.021)*	0.034(0.020)*	0.037(0.021)*	0.035(0.021)*
SIZE	-1.227(0.587)**	-1.241(0.594)**	-0.898(0.458)**	-0.887(0.456)*	-0.958(0.468)**	-0.988(0.473)**
LR (X^2)	19.284***	19.216***	10.787**	9.789**	11.325**	10.821**
Log Likelihood	-19.066	-19.099	-23.314	-23.813	-23.045	-23.297
Pseudo *R*-squared	0.336	0.335	0.171	0.171	0.197	0.188
N	69	69	69	69	69	69

Note: ***<0.01, **<0.05 and *<0.10, respectively. Figures in parenthesis are the standard error. Dummy for sectors included. Due to high correlation between PD & CI, and RDS1 & R&D, separate restricted models (model 1 -6) were estimated.

Table 5 Estimated Probit Regression (Biotechnology)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Variable			Coefficient			
C	-3.666(1.234)***	-1.828(0.602)***	-3.308(1.277)***	-5.334(1.785)***	-3.232(1.102)***	-2.52(0.859)***
R&D	4.688(2.698)*	4.33(2.405)*	-	-	-	-
RDS1	-	-	0.303(0.977)	4.419(1.837)**	-	-
RDS2	-	-	-	-	0.477(0.594)	1.347(0.664)**
UNI	0.367(0.211)*	0.061(0.239)	0.397(0.229)*	0.870(0.484)*	0.366(0.213)*	0.0832(0.209)
CI	1.654(0.426)***	-	1.535(0.404)***	-	1.471(0.401)***	1.216(0.2833)***
PD	-	1.246(0.292)***	-	1.971(0.524)***	-	-
SIZE	-0.927(0.329)***	-0.963(0.332)***	-0.973(0.327)***	-0.807(0.346)**	-1.009(0.328)***	-1.052(0.339)***
$LR\ (X^2)$	51.159***	46.728***	40.382***	43.431***	40.929***	40.984***
Log Likelihood	-41.599	-43.813	-42.527	-41.002	-42.254	-42.226
Pseudo *R*-squared	0.380	0.347	0.322	0.346	0.326	0.327
N	122	122	122	122	122	122

Note: ***<0.01, **<0.05 and *<0.10, respectively. Figures in parenthesis are the standard error. Dummy for sectors included. Due to high correlation between age and size, separate regression with age and size were estimated, respectively but age was found to be insignificant. Therefore, we exclude age from the regression.

Table 6 Estimated Probit Regression (Electronics)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Variable			Coefficient			
C	-2.282(0.737)***	-0.716(0.504)	-2.605(0.862)***	-0.861(0.606)	-2.694(0.853)***	-0.903(0.580)
R&D	0.488(1.331)	1.635(1.211)	-	-	-	-
RDS1	-	-	0.462(0.483)	0.675(0.472)	-	-
RDS2	-	-	-	-	0.453(0.318)	0.565(0.303)*
UNI	0.154(0.140)	0.121(0.127)	0.122(0.149)	0.0234(0.136)	0.129(0.147)	0.047(0.132)
CI	1.037(0.284)***	-	1.105(0.278)***	-	1.118(0.283)***	-
PD	-	0.239(0.172)	-	0.293(0.170)*	-	0.305(0.012)
AGE	0.018(0.013)	0.018(0.013)	0.016(0.0128)	0.0142(0.0123)	0.019(0.013)	0.018(0.013)
SIZE	-0.723(0.313)**	-0.781(0.288)***	-0.800(0.323)**	-0.951(0.293)***	-0.727(0.321)**	-0.872(0.289)***
LR (X^2)	32.699***	17.855**	35.068***	18.373***	36.203***	19.805***
Log Likelihood	-72.232	-79.654	-71.173	-79.520	-70.605	-78.804
Pseudo *R*-squared	0.184	0.107	0.198	0.103	0.204	0.112
N	122	122	122	122	122	122

Note: ***<0.01, **<0.05 and *<0.10, respectively. Figures in parenthesis are the standard error. Dummy for sectors included. Due to high correlation between CI and PD, separate models (model 1 -6) were estimated.

All in all, the evidence generally replicates the findings of past research. The evolutionary argument about the importance of industrial specificity is also supported. However, the Malaysian experience produced an inverse relationship between size and the likelihood of R&D collaboration and the coefficients are largely strong and highly significant. This important finding suggests that small and medium firms with a certain threshold of R&D capability (as the relationship between R&D intensity and R&D collaboration is generally strong and positive) seek to complement their knowledge requirements through collaboration with universities and research institutes.

6. Conclusions

This study sought to identify the important drivers of university-industry R&D collaboration. A Probit model was adopted to examine the influence of R&D intensity, perceived significance of universities and research institutes as source of knowledge, partner diversity, range of information channels, firm strategy on establishing R&D links with universities and research institutes, industry specificity and firm size. Accept for size, the results generally support past findings.

Apart from the electronics sample, all other results support the dominant argument from past research that in-house firm-level R&D capability is important in supporting R&D collaboration with universities and research institutes. Firms' R&D strategies, perceived importance of universities and research institutes as sources of knowledge, partner diversity and range of information channels is also important in the overall samples. The results also show that industry-type matters as the relationship between R&D intensity and the likelihood of R&D collaboration with universities and research institutes is the strongest in automotive firms followed by biotechnology firms. Industry type also mattered in the influence of perceived significance of universities and research institutes as sources of knowledge, partner diversity, range of information channels, and firm strategies on establishing R&D links with universities and research institutes.

Contrary to most past findings, small and medium firms in the Malaysian samples show stronger likelihood of R&D collaboration with universities and research institutes than large firms. Therefore, it can be argued that small and medium firms lacking the requisite human capital and other resources are seeking R&D support from universities and research institutes to complement their own in-house initiatives. It could also be that the R&D capabilities at Malaysian universities are either not sufficiently advanced or not in areas sought by the large firms. Further research is necessary to confirm this.

Taken together, the results offer policy relevant implications for strengthening industry-university (research institutes) R&D collaboration. The significant results demonstrate that universities and research institutes should formulate R&D strategies that take cognizance of firm-level evidence. This paper should be made available for university researchers.

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Appendix 1: Correlation matrix, All firms, 2006

	AGE	CI	PD	RD	UNI	RDS2	RDS1	SIZE	SE	SB
AGE	1.00									
CI	0.067	1.000								
PD	0.151	0.708**	1.000							
R&D	-0.040	0.304**	0.330**	1.000						
UNI	-0.059	0.034	0.094	0.127	1.000					
RDS2	-0.091	0.229	0.106	0.227	0.219	1.000				
RDS1	0.029	0.257	0.273	0.276	0.279	0.365**	1.000			
SIZE	0.288	0.002	-0.027	0.086	0.039	-0.003	0.025	1.000		
SE	0.151	-0.130	-0.070	-0.090	-0.033	-0.134	-0.052	-0.372**	1.000	
SB	-0.285	0.128	0.048	0.172	0.170	0.127	0.099	-0.345**	-0.632**	1.000
SA	0.156	0.001	0.025	-0.095	-0.159	0.007	-0.054	-0.031	-0.428**	-0.428**

Source: IDRC Survey (2007)
Note: ** $p< 0.01$; * $p<0.05$; ;SE, SB and SA represents electronics, biotechnology and automotive sectors, respectively; n=313

Appendix 2: Correlation matrix, Automotives, 2006

	AGE	CI	PD	RD	UNI	RDS2	RDS1
AGE	1.000						
CI	0.221	1.000					
PD	0.229	0.708**	1.000				
RD	0.138	0.102	0.155	1.000			
UNI	-0.168	-0.455**	-0.374**	0.125	1.000		
RDS2	-0.056	0.195	0.042	0.231	-0.061	1.000	
RDS1	0.070	0.040	0.292	0.460**	-0.139	0.270	1.000
SIZE	0.026	-0.042	-0.184	0.415**	0.225	0.226	-0.042

Source: IDRC Survey (2007)
Note: ** $p< 0.01$; * $p<0.05$; $^{+}$ denotes dummy variables; n=69.

Appendix 3: Correlation matrix, Biotechnology, 2006

	AGE	CI	PD	RD	UNI	RDS2	RDS1
AGE	1.00						
CI	0.048	1.000					
PD	0.079	0.654**	1.000				
RD	-0.037	0.191	0.250	1.000			
UNI	0.027	0.289	0.456**	0.270	1.000		
RDS2	-0.029	0.253	0.148	0.131	0.480**	1.000	
RDS1	0.004	0.412**	0.323**	0.397**	0.546**	0.511**	1.000
SIZE	0.518**	0.166	-0.023	0.018	0.067	-0.030	0.056

Source: IDRC Survey, 2007
Note: ** $p< 0.01$; * $p<0.05$; $^{+}$ denotes dummy variables; n=122

Appendix 4: Correlation matrix, Electronics, 2006

	AGE	CI	PD	RD	UNI	RDS2	RDS1
AGE	1.000						
CI	0.110	1.000					
PD	0.241	0.768*	1.000				
R&D	-0.002	0.472**	0.499**	1.000			
UNI	0.057	0.041	0.077	-0.056	1.000		
RDS2	-0.094	0.198	0.097	0.258	0.173	1.000	
RDS1	0.108	0.270*	0.228	0.100	0.349**	0.333**	1.000
SIZE	0.184	0.071	0.115	0.125	0.032	0.022	0.121

Source: IDRC Survey (2007)

Note: ** $p < 0.01$; * $p<0.05$; $^{+}$ denotes dummy variables; , n=122