THE ROLE AND DETERMINANTS OF PARTICIPATION IN INDUSTRY-SCIENCE LINKS IN AN OIL-BASED ECONOMY: THE CASE OF OMAN

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Abstract:

The main aim of this research is to explore the determinants of successful industry-science links (ISL), involving cooperation between firms and universities, in order to assist the development of a diversified knowledge-based economy in Oman. The researcher used the development of these links in the advanced countries for the necessary benchmarking. Interactions between industry and science institutions aim at the exchange of knowledge and technology and, when successful, promote the enhanced innovativeness and competitiveness of the ISL partners. At present, not much universities and colleges in Oman sees the importance of establishing links between them and the industries and so based in this premise, the researcher will look into the benefits of ISL and how this can possibly lead to establishing a knowledge-based economy in Oman. Further, the researcher will explain the components that relates to ISL and why it is necessary for Higher Education Institutions in Oman to venture into such collaborative efforts.

Keywords: industry science links, knowledge based economy, higher education, higher education institutions

A. Introduction:

Since dependence on oil cannot be sustainable in the long run for Oman, a shift towards a knowledge economy becomes critical in order to develop a structure of production with which it can become globally competitive over time. In this, the determinants of a supportive technological infrastructure assume criticality. Improvements in technological infrastructure can lead to knowledge related changes in the structure of production. Auburt and Reiffers (2003), Goldstein (2005), Krell and Wiseman (2004), Quevedo (2002) and World Bank (2008a) find a direct relationship between the degree of development of technological structure (especially ICT) and knowledge development. Edquist (1997) and Romero (2000) examine different industries and find that the creation of ‘science and technology infrastructure’ enabled transformation and exploitation of information and knowledge. It may be mentioned that during 2000 Lisbon summit, the European Union set the goal of becoming the most dynamic and competitive knowledge-based economy by 2010, adopting a new focus on innovation and employment and on supporting knowledge and innovation (Haskel, 2007).

The knowledge-based economy or new “e-economy” (Baily and Lawrence, 2001) is based upon an abundant resource endowment of knowledge with a highly educated and mobile labour force without bureaucratic or geographical constraints. The increased importance of knowledge generation in all sectors of the economy causes R&D and technological complexity, besides innovativeness and learning, to be the key determinants of sustainable competitiveness (Asheim et al., 2007). Lundvall and Borras (1998) have pointed out that the process of knowledge generation and exploitation requires a dynamic interplay and transformation of tacit and codified forms of knowledge and interaction of people within organisations and among them. This knowledge creation process becomes increasingly inserted into various forms of networks at regional, national and international levels.

Quah (2002) points out that the impact of ICT on knowledge development has predominantly been not on supply-side improvements or productivity growth but rather on consumption and demand-side changes in the
knowledge economies. In contrast to the traditional viewpoint of the production function as constituted by labour and capital, knowledge has, it is argued, become the leading factor of production. Not only does it impact on other factors, but by itself can contribute directly to economic growth. Solow (1960) originally pointed out the importance of knowledge in the production function, wherein after accounting for physical capital and labour, the remaining contribution to productivity will be through knowledge or what he calls technological change or the residual. Empirical studies on the Solow model (Kevin et al., 1997; Mankiw et al., 1992; McQuinn and Whelan, 2007) document the contribution of accumulated human (indicating knowledge development) and physical capital especially in the poor countries and some suggest that this factor has contributed to a slow convergence in standards of living between the rich and the poor over the very long-run.

However, incentives are required to encourage knowledge creation and restrictions such as the protection of intellectual property rights that may lead to monopoly situations (Maskus, 2000). It is like the situation in the UK during the 18th century when the local craftsmen were prohibited from visiting the continent to spread their knowledge, so that UK manufacturing would dominate given the appropriation of knowledge within her boundaries. Such restrictive practices have their own limitations and even where protection is required, conflicts in the ownership of innovations, pirating and copying will dilute the process of innovation based on patenting, especially when the information flow is asymmetric. It has been argued by Maskus (2000) that with strict IPR regulation, there may be displacement of a significant amount of labour employed in copying unauthorised products. Where universities are involved in the innovation process rather than the multinational enterprises, the IPR regime may be a beneficial factor in the long run (Maskus, 2000). Hence, the shift towards the knowledge economy will frequently require cooperation between higher educational institutions and industries, wherein the effects of IPR regulation can be beneficial for all (Boldrin and Levine, 2002; Mansfield, 1998; Romer, 1990).

The main aim of this research is to explore the determinants of successful industry-science links (ISL), involving cooperation between firms and universities, in order to assist the development of a diversified knowledge-based economy in Oman. The researcher used the development of these links in the advanced countries for the necessary benchmarking. Interactions between industry and science institutions aim at the exchange of knowledge and technology and, when successful, promote the enhanced innovativeness and competitiveness of the ISL partners.

The objectives of this study are to examine the relevance of ISL for conditions obtainable in Oman and to examine whether the different stages and determinants of ISL can be empirically validated as to their interdependence and effectiveness in the case of the Sultan Qaboos University and local firms. This study investigates not only the nature of the interaction between the University and firms, but also how that interaction has developed over different stages and over time. Further, the research seeks to ascertain whether the different motivation of firms and university faculty reinforce each other, so as to generate knowledge development, and how increased university-industry interaction may complement the national innovation strategy. The analysis will also enable to identify best interaction practices to be followed by both industry and university in respect of knowledge and technology transfer activities.

The relevance and efficacy of this development strategy will be assessed through answering the following questions: does Oman require a transformation process and if so, what should be the nature of interaction between the university and the industry? What are the determinants of this interaction process and what will be the likely impact of this interaction on the absorptive capacity of the ISL partners? If ISL expansion, with greater emphasis on technology transfer activities and extension to various sectors and regions, is to be accomplished, what pre-conditions are required, and can they be generalised for further replication? Based upon previous empirical research, we expect to find that participation in ISL is positively influenced by firm size, prior knowledge base, motivation, market adaptation,
R&D capability and IPRs. However, whether participation in ISL in Oman is indeed determined by similar forces to those found in previous research in more advanced economies remains an important element of this research programme. Whilst comparisons with the US are made in the opening and reference throughout is made to the research on ISL which is taking place in the US, it is not an assumption of this research that Oman can emulate American experience. Given that the US is the global leader in ISL, what is intended from these comparisons is to show what Oman can potentially learn from American experience and the results of relevant American research.

There have been very few studies on Oman dealing with technological or institutional nexus aspects, such as industry-science links and none of these studies concentrate on the alternative strategies to be undertaken by the government to catch-up with other knowledge-based economies. Our study fills a gap in understanding the development process in Oman. Further, the study conceptualises the ISL mechanism as an interactive process by suggesting best practices to be adopted to achieve improved innovativeness.

B. Review of empirical studies on ISL

This part reviews evidence on the different types of ISL, the success factors and the barriers experienced by many countries. Since universities are presumed to be power-houses of knowledge generation (Mansfield and Lee, 1996) and provide the necessary research support to the corporation’s (Philbin, 2008) it may be argued that the firms cooperating with them may realise a competitive advantage through the possibility of sharing the technology developed in universities (Wright et al., 2008). This hypothesis may find application not only in advanced but also in those developing countries like Oman that aspire to focus on knowledge-based economic development. Rosenberg and Nelson (1994) and Hounshell (1996) provided historical evidence of such linkages between universities and firms in effecting technological advances in the US, culminating in developments like Stanford University’s Centre for Integrated Systems and the creation of neighbouring clusters of firms to exploit that University’s research. The US Council of Competitiveness (1998) found that the presence of universities in a consortium not only increased the probability of the success of collaborative research, but also created greater research intensity between the partners in developing exportable US technology. Close ties between universities and industry have been integral to the success of ISL ventures like Silicon Valley and the Route 128 of Massachusetts (SBA, 2000). ISL has been a major strategy for the very survival of the firms according to Carayannis and Alexander (1999). As pointed out by Loof and Brostrom (2008), ISL improves both transfer intensity and the absorptive capacity, whilst firms participating in ISL have a greater propensity for innovation, besides having greater incentives to invest in R&D. This alludes to the observation that high-tech firms and organisational structures that encourage innovativeness are able to experience a favourable impact of ISL.

Though universities and industry have different objectives, they have been interacting within a common platform of knowledge sharing and as such, ISL has assumed a critical role in technology transfer (Cosh et al., 2005). Studies have showcased the long-term sustainability of ISL especially in major US universities and how those in Europe, Japan and elsewhere are fast catching-up with the US in respect of obtaining patents and establishing new start-ups (Kodama et al., 2007). For example, in respect of R&D expenditure, the European Union and Japan had lower R&D intensity than the US in 1990 but by 2005, Japan had a higher intensity than the US and the EU closely matched that of the US1. As pointed out by Abramo et al. (2009), EU wants to assign not less than 3 percent of its GDP to research by 2010 in order to become most competitive in the world.

At the university level, the development of an institutional framework to facilitate technology transfer has resulted in the creation of specialised institutions like technology licensing or transfer offices (TLOs/TTOs), as reflected in a more decentralised organisational structure

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1 In 2005 R&D expenditure as a proportion of GDP has been 2.02 percent in the Euro region, 2.68 percent in the US and 3.18 percent in Japan (World Bank, 2008b)
(Siegel et al., 2004). Studies by D’Este et al. (2005) and Yusuf and Nabeshima (2007) point out TTOs can make the alliance between universities and commercial organisations more highly integrated and long-term oriented through mutual knowledge-sharing mechanisms. We find in Oman examples of some such facets, though the advanced stage of establishing high-tech research centres by the university is yet to be realised, partly owing to the absence of TTOs.

This partis divided into five sub-sections. First, on different types of ISL extends the theoretical argument of Turpin et al. (1996) in the formulation of long-term orientation of the interaction process and how ISL has been interpreted in its various forms. The experience of ISL in different countries is analysed in number 2. In number 3, the principles of ISL interaction are reviewed, followed by an examination of R&D’s role in the interaction process. In number 4, the determinants for successful ISL are assessed, while number 5 examines some of the barriers encountered in the process. Examining the different types of ISL provides an insight into considering which type may be appropriate to the conditions persisting in Oman and the factors responsible for its success.

1. **Types of ISL**

   Based on the nature of its commercialisation impact, ISL may involve different types of partnership between universities and the firms. The partnership, when long-term oriented, may generate a continuous process as in the Hewlett-Packard (HP) partnership continuum model or may lead to capacity building as in the case of University of Salford or serve as a benchmark (Allen and Williams, 2005). The HP model builds upon the commercialisation aspect and has developed many new technologies especially in the computing field. This partnership has been accomplished in five stages of awareness, involvement by giving grants, support in the form of consultancy and workshops, sponsorship and strategic partnership involving business development (Allen and Williams, 2005).

   Next, ISL in the form of a capability maturity model distinguishes between organisations that have well-established business processes and those where the processes are immature, to indicate any shift from lower to higher levels. The original model was developed for the US Department of Defence by the Software Engineering Institute at Carnegie Mellon University in 1991 to evaluate software suppliers. The model measures the maturity of a process or activity and a framework for achieving step-by-step improvement. This idea has inherent flexibility and has been adopted for other activities, with a one-to-five year timescale, as in the HP partnership continuum model. This model provides an opportunity to identify where an organisation or an activity is today and what would be required to move it to a higher level (Allen and Williams, 2005).

   Lastly, the University Partnership to Benchmark Enterprise Activities and Technologies Programme measures ISL using a matrix that focuses on successful enterprise ventures (Allen and Williams, 2005). Business development, individual performance, social networking and academic enrichment are potential determinants of the success of these ventures. These have to be related to qualitative aspects like awareness and recognition, competence, development of professional capability, mastery in learning, innovative and integrative skills and sustainable global excellence. This model focuses on formal contacts and strategic partnerships implemented in different stages.

   Since there may be different levels of relationship, activities currently underway can be evaluated and located within a structured framework so that specific actions can move from one stage to the next. The idea that activity tends to be driven by some form of performance driver and the outcome of the activity can be measured qualitatively, suggests that the ISL process is not a one-off process and may be nurtured over a period of time in different stages (Kleyn et al.,
2007). Universities provide new technologies and in turn get benefits like support for strengthening their research infrastructure from industry over a period of time. This enables ISL to be viewed as a long-term oriented partnership, focusing on R&D investment and incentives to scientists for promotional activities. Examples abound in programmes like ‘land of ideas’ as in Germany and ‘technology for life’ initiatives in Spain (Guimon, 2003). In Oman, an initial step toward such a development has been in the shape of ‘origin Oman’. The involvement of university faculty and students in emulating this idea is evidenced locally and is reminiscent of the HP method. When firms with low capacity to absorb technology partner with universities, they may improve their business standards depending on the specific situation and the objectives of knowledge development, ISL can be framed into a specific experience such as HP’s or a new model incorporating the salient features of different models. The present study conceptualises ISL model in four different stages incorporating the salient features of HP and other models. The approach assumes a preliminary stage as pertaining to awareness and the later stages to implementation of advanced interaction activities. The next part examines the process of ISL in the US, European Union and Japan and shows how their experience may yield insights relevant to the present study.

2. The process of ISL

The first-mover advantage which the US enjoyed in ISL when compared to Europe, in part due to the Bayh-Dole Act, enabled widespread commercialisation of university research and the creation of industrial clusters and development of small innovative firms in that country. Increased industry funding of university research and the safeguards of Bayh-Dole Act have positively impacted on the university patenting system. When compared to 1953, the proportion of university funding by US federal government had declined in 2000 (from 69.3 to 64.6 percent) while that of industry has increased from 5.2 to 6.2 percent, that of self-funding increasing from 9.2 to 16.6 percent (Hall, 2004). In a survey of 62 research universities in the US, Siegel et al. (2007) observe that all the patentable inventions are owned by the universities and inventors have more than 40 percent control of the licence income. The creation of TTOs has further strengthened this position.

Creation of spin-offs and new laboratories was the least frequent activity according to a UK study conducted during 1995-2003 involving 4337 university faculty members (D’Este et al., 2005). Whilst according to Crespo and Dridi (2006), researcher’s strategic positioning, the set-up of networks and the costs related to the production of the transferred knowledge and transactions explain why university’s collaboration in Canada is yet to match that of the US. It can be concluded from these surveys that research funding, proximity to university, robustness of research, high degree of risk-taking culture and strong publications are some of the factors that positively impact on collaboration (Belkhodja and Landry, 2007).

As noted, technology transfer from universities was facilitated at an earlier stage in the US when compared to Europe or Japan. In a study of ISL in the US, Chakrabarti and Lester (2002) observe the significant role played by universities in local and regional economic development through collaborative and sponsored research in many states. Veugelers and Cassiman (2005) in their study of Belgian manufacturing document the low levels of ISL in Europe due to lack of demand from the business sector, even though scientific advancement by universities was at a high level (reminiscent of the European paradox). When advanced technology transfer activities are accounted for, spin-offs are a major offshoot of ISL, but their incidence was found to be lower in Europe when compared to that of the US. The intensity of technology-based start-ups in the universities has been more than three per 1000 R&D personnel in the US, but less than two in Europe (OECD, 2002).
It was only after the mid-eighties that the European universities began to pay attention to commercialisation of knowledge and links with industry (Howells and McKinlay, 1999). It may be argued that the role of European universities has been one of facilitating firms in exploitation of their research, rather than exploiting their own research unlike in the US (Decter et al., 2007). Not only the level of ISL intensity but also the number of IPR disclosures has been relatively low in Europe. Further, most of the spin-offs have been informal since the universities had generally no ownership and legal ties (Siegel et al., 2007).

Even in Japan its high R&D expenditure (when compared to Europe or the US) has not resulted in a high rate of university-held patents and spin-offs (Pechter, 2002). In that country, university researchers in 1994 comprised 36 percent of all researchers but contributed only 0.04 percent of all Japan’s patents. According to Pechter (2002), a reason for poor ISL performance in Japan has been its focus on social welfare rather than private interests (in contrast to the more market-oriented framework practiced in the US), which reduces the incentives of firms to participate in areas in which they are not directly interested, notwithstanding their socially desirability. Over a period of time, this tendency has reduced the intensity of the interaction process between Japanese firms and their universities. Nakamura and Ueda (2006) and Kitagawa (2009) corroborate the limited role of ISL in Japan, though it has stimulated some firms to increase their patents, though of moderate quality, wherever adopted. Until recently, Japanese researchers were not allowed to directly share in the commercial returns of ISL. There are exceptions, as pointed out by Jiang et al. (2007) who trace the transformation of Tohoku University (one of the benchmark universities of the present study) into an entrepreneurial university, creating many spin-offs. It can be concluded that the focus on royalty income has resulted in the drive toward technology commercialisation, which tendency has become universal according to Falvey et al. (2006). To imbibe the favourable factors in ISL, Oman has to look toward the success stories of these universities.

The ISL process prevalent during the 1990s in the US, Europe and Japan can be examined to draw some useful lessons for the present study, especially from the policy implications angle. According to the OECD (2002), the US has fared better than other countries in almost all the ISL activities (Table 4.1). However, collaborative research has been a major ISL activity, measured by the relatively high proportion of university R&D being financed by industry in Belgium, Germany, Ireland and the UK. The proportion of university faculty consulting in R&D activities with industry is relatively high in Austria, Sweden, Germany, the UK, the US and Japan.
Table. 1 ISL intensity in Europe, USA and Japan in the 1990s

<table>
<thead>
<tr>
<th>ISL activity</th>
<th>Indicator</th>
<th>Austria</th>
<th>Belgium</th>
<th>Germany</th>
<th>Ireland</th>
<th>Italy</th>
<th>Sweden</th>
<th>UK</th>
<th>US</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaborative research</td>
<td>R&amp;D financing by industry (%)</td>
<td>2.0</td>
<td>10.6</td>
<td>9.7</td>
<td>6.4</td>
<td>3.8</td>
<td>4.5</td>
<td>7.2</td>
<td>6.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Consultancy</td>
<td>R&amp;D consulting</td>
<td>high</td>
<td>low</td>
<td>high</td>
<td>low</td>
<td>Low</td>
<td>High</td>
<td>hig h</td>
<td>hig h</td>
<td>high</td>
</tr>
<tr>
<td>Innovation projects</td>
<td>Innovative firms (%)</td>
<td>12.6</td>
<td>13.4</td>
<td>10.4</td>
<td>13.8</td>
<td>2.5</td>
<td>26.1</td>
<td>11.3</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Mobility</td>
<td>Researchers moving to industry</td>
<td>medium</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>Low</td>
<td>hig h</td>
<td>hig h</td>
<td>low</td>
<td>低</td>
</tr>
<tr>
<td>Training</td>
<td>Income from training</td>
<td>low</td>
<td>high</td>
<td>low</td>
<td>medium</td>
<td>low</td>
<td>Medium</td>
<td>hig h</td>
<td>hig h</td>
<td>low</td>
</tr>
<tr>
<td>Patent application</td>
<td>per 1000 researchers</td>
<td>high</td>
<td>high</td>
<td>low</td>
<td>low</td>
<td>High</td>
<td>hig h</td>
<td>hig h</td>
<td>high</td>
<td></td>
</tr>
<tr>
<td>Royalty</td>
<td>as % to R&amp;D</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>Low</td>
<td>low</td>
<td>hig h</td>
<td>low</td>
<td>高</td>
</tr>
<tr>
<td>Spin-offs</td>
<td>per 1000 researchers</td>
<td>low</td>
<td>low</td>
<td>high</td>
<td>medium</td>
<td>low</td>
<td>hig h</td>
<td>hig h</td>
<td>hig h</td>
<td>high</td>
</tr>
<tr>
<td>Contacts/networks</td>
<td>Networks</td>
<td>medium</td>
<td>low</td>
<td>high</td>
<td>low</td>
<td>High</td>
<td>hig h</td>
<td>hig h</td>
<td>hig h</td>
<td>high</td>
</tr>
</tbody>
</table>

Source: summarised from Table 3, p.40, OECD, 2002

According to the data underpinning Table 1, creation of infrastructure facilities, joint research agreements, consultancy, training of employees in the firms, participation in workshops and conferences, sponsorship of meetings and creation of electronic networks have been the major ISL types. Collaboration was characterised by moderate R&D funding by industry, low participation of innovative firms in the ISL process, low share of royalty income and moderate level of networking between the partners (OECD, 2002). The predominance of the US in ISL, as indicated in the table, has been confirmed more recently by Decter et al. (2007).

As regards ISL in other countries, it has generally been found that an increased level of ISL results in higher rate of patenting (Moehmen and Hoareau 2002). Garcia-Aracil et al. (2003) find a strong relationship between large and high-tech firms and participation in ISL in the Valencia region of Spain. Wu (1997) traces Taiwan’s technology policy to the early 1980’s wherein engineers from China and other countries were attracted resulting in the growth of high-tech firms. However, ISL in this country has not resulted in a level of technological sophistication comparable with that of the US. Small and medium-sized enterprises have been able to absorb technological innovation from the universities only at a modest rate, wherein internal R&D, presence of foreign companies and research institutes exert a larger influence. In China, the ISL process has enabled many start-ups and spin-offs according to Eun et al. (2006). In that country, there are many university-started firms realising improvement in their absorptive capacity. Sunami (2002) cites the progress of China’s Silicon Valley, home to some 30 universities and more than 200 research institutions which houses many spin-offs from universities and research institutes. Though 90 percent of these
enterprises are owned by the state, universities have substantial freedom over
the management of their affiliated enterprises. About 30 percent of Chinese
universities operate high-tech enterprises which provide up to 75 percent of total
revenues of the universities. In countries like Jordan, efforts are on the way to provide
collaborative environments to bring together firms and universities in the pursuit of
updating the knowledge base of the university with the latest industry
developments and align the skills and knowledge of students to real and immediate
industry needs (Al-Agtash and Al-Fahoum, 2008). The experience of these countries
may guide in the development of the institutional framework for Oman, for
example, the problems identified in Taiwan, noted above, would appear to be even truer
of Oman.

3. The role of R&D in the interaction process

Increasing R&D intensity plays an important role in ISL but it is high rates of
return on R&D investment that characterises the potential outcome of the ISL process
(D’Este and Patel, 2007). Collaborations which yield a high rate of return and related
benefits on university research provide a basis for long-term R&D-oriented
partnerships. Since innovation processes are non-linear and complex, calculating rates of
return for public research has to focus not only on the benefits accruing from such
research but also how these benefits are channelled through specific mechanisms
(Scott et al., 2002). One such mechanism, the Knowledge Partnership Programme in
the UK, was initiated to develop active partnerships between higher education
institutions and industry. Others like Medici Fellowship Scheme (for facilitating
industry-university link), Science and Enterprise Challenge (to develop entrepreneurship education in the
universities), University Challenge Initiative Funds (to encourage innovations and start-
ups) have been started to consolidate the effects of ISL in promoting new start-ups
and entrepreneurship (Martin et al., 2008).

As Rohrbeck and Arnold (2006) point out, motivations for such collaboration depend
on firm size, company culture in research and knowledge absorption capacity and
location. At the university level, the relevant factors include financial resources (Schibany
et al., 2002), political pressure, market entry (Walter, 2005), enhancement of teaching
quality and reputation (Smilor et al., 1993), job offers for graduates and new knowledge
coupled with empirical studies (Chakrabarti and Lester, 2002).

A major factor in the degree of commercialisation of knowledge and
technology and its variability may be attributed to differences in R&D capability.
Mueller (2006) has argued that a low level of R&D intensity results in low absorptive
capacity and lower level of knowledge exploitation, a proposition that may be of
particular relevance to Oman. In this, research publications and their citations are
frequently used indicators of R&D intensity. According to Mueller (2006), research
cooporation intensity (RCI) and corporate citation intensity (CCI) indicators can be
used to evaluate the impact of ISL process in the OECD countries. RCI indicates the
quantity of university-industry co-authored research publications as related to the total
number of research publications produced by a university within the same time
interval, whereas CCI refers to the number of citations within corporate research papers
to a university’s research output relative to total number of citable publications by the
university. The positive association between CCI and RCI indicate the interrelated
characteristics of knowledge creation and spill over in the ISL process. The US,
Switzerland, Japan and Canada have high levels of both CCI and RCI, while the
Mediterranean countries, Australia and many Asian countries, including Oman,
have low values (Mueller, 2006). The advanced countries have been able to build
up their knowledge-based economies relying on R&D-intensive high-tech sectors.
Regions with high R&D intensity and entrepreneurship experience greater
productivity levels (Dooley and Kirk, 2007). The study reported later in this book
includes publications and citations as ingredients of knowledge transfer activities in the ISL process.

Decter et al. (2007) find access to new knowledge, prospects of reduction in R&D costs and market possibility in new technology as other facilitating factors in the process. Valentin and Jensen (2007) find that firms with a significant research capability have a greater tendency to collaborate with universities. In a survey on cross-national networks in R&D in Europe and the US for the period 1988-99, Owen-Smith et al. (2002) found that, unlike in Europe where the proportion of collaborative projects was low, the US biotech firms undertook 55 percent of innovative work of all firms. The authors also found that the diversity of the research system, mobility of research staff and promotion of commercialisation of research were some of the distinguishing factors in successful R&D collaborations. It was found that commercialisation aspects involving start-ups assumed greater importance than other R&D-oriented activities (Owen-Smith et al., 2002). If the rate of return on research demanded is high, collaboration has to be viewed in terms of pure R&D alliances as part of overall ISL process (Sampson, 2004). The relationship must be so designed by the supply and demand factors that the merits and incentives for collaboration become mutual to the participants (Hayashi, 2003). These demand side factors include sales and consumer preference over quality and price, while technology-side factors include cost effect of R&D expenditure and firm-specific technological competence. It is this technological competence resulting from R&D intensity that enables sustained competitiveness in market structure (Lee, 2003).

One proxy for the ability to achieve such competence has been taken to be when the proportion of R&D expenditure allocated to exploratory projects is more than 50 percent (Bercovitz and Feldman, 2007). Also, there may be a positive relationship between the innovation strategy of the firm and its interaction with the university (Segarra-Blasco and Arauzo-Carod, 2008). Firms favour establishing R&D alliances with those institutions which possess relevant complementary knowledge and share it. In such instances alliances have intensified the growth of entrepreneurship (Link et al., 2007) and the creation of entrepreneurial universities (Sherwood and Covin, 2008). It has to be seen whether such a change can be brought about in Oman in the near future.

R&D collaboration at firm level may have different outcomes culminating in what Santoro and Chakrabarti (2001) call aggressive, collegial or targeted players, indicating different levels of collaboration. Aggressive players have a higher level of collaboration and generate a higher level of outcome. Both large and small firms in this group are concentrated in high-tech industries. Hence, advancement of new technologies, both core and non-core through ISL is the main goal of these players. They collaborate in R&D and expect a satisfactory level of return. In contrast to this group, collegial players are large firms that have lower levels of collaboration and resource commitments and generate low tangible outcomes from the ISL process. These players are more interested in relationship-building with the universities rather than advancing new products and processes. They depend on universities for their supply of trained human capital and like to be involved in curriculum development. This group will have a long-term orientation and typically, a low level of ISL intensity. The targeted players are mainly high technology-oriented with the objective of advancing core technologies. They aim at a very high level of ISL process with a high level of outcome. This group will usually have a short-term orientation and higher intensity of ISL.

The actual ISL process may exhibit a mix of all these elements, signifying both short-term and long-term as well as core and non-core developmental aspects depending on factors favourable or unfavourable to R&D augmentation. R&D turns out to be one of the major motivating
factors and may be considered as impacting on the success of the ISL process. In the study reported below, the sample firms in Oman typically resemble the collegial group in having recourse to university’s facilities and aiming at a less intensive, but long-term oriented relationship with the university.

4. Determinants of success of the ISL process

This part provides evidences on some of the factors, which have been hypothesised to determine the degree of participation in and success of the ISL process. According to Salmi and Torkkeli (2009), the ability to transfer knowledge across firms with different organisational structures itself represents a favourable factor in the success of ISL. Turpin et al. (1999) point out that the initiative for ISL frequently starts with a university faculty member interested in applying new ideas to solve industry’s problems. Breschi et al. (2007) find that a relatively small proportion of researchers are responsible for the bulk of important publications and patents, since these high performers have extra resources to access. Motivations relate to gaining reputation and enhanced credibility as applied researchers and innovators, whilst non-involvement is related to a lack of awareness, differences in approaches and the complexity of contracting commercial deals (Schartinger et al., 2001). Schibany et al. (2002) demonstrate that access to better trained workers has been the main facilitating factor in the interaction process, besides increasing mobility of researchers between the university and firms.

University faculty are guided by other motivations like ‘keeping abreast of research in industry’, ‘increasing the applications of university research’, ‘getting access to industry expertise’ and ‘anticipations of breakthroughs in technological frontiers’ (D’Este and Patel, 2007). These in turn determine the pace of successful interactions and outcomes in the shape of up-to-date applied research, familiarity with industry issues and making breakthroughs in the technology frontiers. Commitment and integration have been found to positively influence satisfactory participation in technology transfer activities (Valentin and Jensen, 2003). Bozeman and Guaghan (2007) reveal that those faculty members who received frequent research grants from industry had a higher level of industry interaction. Of the other university-industry relationships, joint research has been the most important in terms of the level of participation of university faculty (Van Horne et al., 2008). At the macro level, expanding post-graduate education (Business-Higher Education Forum, 2001), increased awareness of industrial concerns and improved cost effectiveness in doing research (OECD, 2002) and increased business opportunities (Khamseh and Jolly, 2006) have been identified as some of the facilitators of ISL. Proximity to the university enables firms to create new physical facilities and joint research ventures, consultancies and participation in new research areas and e-training (Bjerregaard, 2009).

Since the ISL process differs considerably among different institutions, IPRs have been considered as effective tools of commercialisation of university research (Mwamadzingo, 1995). It is the drive to develop patentable and non-patentable inventions and realise monetary and non-monetary returns that motivates the faculty to actively participate in the collaborative projects. Summarising this evidence, and following Dyer et al. (2006) and Arvanitis et al. (2008), the firm-specific factors identified as key determinants of ISL have been: existing knowledge base, in-house R&D, proximity to the university, employment of university graduates, high mobility of researchers and IPR protection at the university level which does not threaten the firm’s revenue. The identified university-specific factors have been: familiarity with industry’s needs, the extent of employment of graduates by industry, incentives available for faculty undertaking industry projects and supportive government policy on university research. The factors found to be common to both firms and universities are: prior collaboration, interest in the interaction process, possibility of high
returns from commercialisation of technology and supportive government policy on ISL (Dyer et al., 2006). When both partners possess relevant complementary knowledge and effectively share it, R&D collaboration turns out to be an important aspect of ISL as already pointed out (Welsh et al., 2008). This is supported by D’Este et al. (2005) who show that awareness of industrial applications and additional research income has been the major motivator for ISL.

5. Barriers to a successful participation in ISL

Factors like IPRs, information asymmetry, faculty immobility and lack of research funding were listed as some of the barriers to successful implementation of ISL. This part presents some empirical evidence on the importance of these barriers. According to Mowery (2007), though Bayh-Dole has impacted on the increase of university patenting through simplified licensing procedures (Massachusetts Institute of Technology, Stanford University and University of California, Berkeley already having a developed system), the Act had resulted in disclosures generating fewer patent applications owing to problems with the protection of the university patents. Ineffective disclosures worked as barriers in successful IPR dissemination and commercialisation of technology. D’Este et al. (2005) find that unfavourable career prospects and conflicts on IPRs and publications have been the major barriers in the interaction process. Restrictions on publications in order to protect IPRs of the universities had limited the diffusion of research results. TTOs which are supposed to facilitate the flow of innovation, have sometimes become gatekeepers and in many cases constrain the flow of inventions and frustrate faculty, entrepreneurs and industry (Litan et al., 2007). As Dyer et al. (2006) point out failure rates in 142 advanced technology programme alliances in the 1990s have been around 50 percent owing to problems in TTO governance and uncertainty of innovations. When these barriers are not tackled, either due to laxity on the part of the industry or the university, ISL becomes even more limited.

Hertzfeld et al. (2006), based on their survey of 250 firms on IPR protection in research joint ventures in North Carolina, point to the following factors as slowing down the ISL process:

1. universities not understanding industry’s problems and business techniques
2. universities wanting to own all IPRs since they are significant sources of income
3. TTOs in the universities being inexperienced and understaffed and not knowing how to complete deals
4. frequent turnover of technology transfer office staff and the office having little authority to commit the university and
5. Contrasting cultural backgrounds of those in industry and universities, resulting in different approaches to project management.

Lhuillery and Pfister (2009) report of the cooperation failures occur, especially in small firms, owing to unsupportive collaboration ties between the ISL partners. D’Este et al. (2005), in their UK study point out unsuitable partnerships as a major barrier in the process (being the most important in all disciplines with a score of 2.81 in a 5-point scale), followed by the absence of institutional support (with a score of 2.38), unsuitable research areas (with a score of 2.25), inappropriate regulations and unfavourable career prospects (with a score of 2.11) and conflicts on IPRs and publications (with a score of 2.12) as inhibiting smooth interaction between universities and industry.

The contention of Howells et al. (1998) that differences in objectives and difficulties in contracting firms hinder ISL also has some relevance. Romero (2007) points out that within the university system, faculty and administrators may compete to control resources but the relationships generated by the interaction process may be strained, since their perspectives on the
outcome may be different in different situations. This suggests the possibility of administrators exercising control over participation of faculty and the potential conflicts that may arise in the interaction process. In such agency problem instances, the attitude of the university administration in tending to reduce the participation of faculty and the attitude of faculty in not disclosing inventions would hamper the prospects of the interaction (Levy et al., 2007).

Large companies in the US have sometimes been reluctant to participate in ISL that involved their core technology, since their aim was overall commercialisation rather than mere partnership. Public agencies also have sometimes been reluctant to participate in projects that benefit only specific firms. In such cases, the nature of ISL was affected by the university’s reputation and the immediate needs of the firms (Romanainen, 1999). On the other hand, innovative small and medium enterprises on the whole have shown a greater inclination to collaborate with universities. Another barrier is the low rate of geographical mobility of researchers, as particularly found in the European Union (OECD, 2002).

Regarding IPRs, the university system in Europe during 1990s established comparative advantage in respect of obtaining R&D funds and their responsiveness to the needs of the industry when compared to research institutes. However, this shift in R&D funding in universities did not result in any major benefits to ISL partners, except in the case of few decentralised universities that have been characterised by greater freedom in research policy and relations with industry (Yeoh, 2009). This shows that rigid organisational structure may be an obstacle in the ISL process.

From the above review, it may be concluded that for collaboration between the universities and industry to succeed many factors have to be present. Prior involvement of the faculty in industry affairs, favourable IPR entitlement and protection, frequent meetings between the personnel of firms and university and employment of a higher proportion of S&T staff facilitate the interaction process effectively. The factors specific to firms include in-house R&D, prior knowledge base and focus on regional development through industrial clustering (Davies, 2008) and networking. The findings of different studies point to the critical role of financial and non-financial motives, additional income and access to appropriate facilities in the start-up process. However barriers like, excessive IPR protection and curbs on publications and unsuitable partnerships besides conflicting ideologies of the firms and the universities and among the university faculty and administration, has slowed down the ISL process. Recently industrialised countries in adopting the ISL strategy have been able to improve their knowledge development and even outperform the US. The nature of constraints on the ISL process in Oman has now to be identified, together with the success factors that enable growth in innovativeness. We find that most of the above key success factors and barriers evidenced in the recent literature seem to be relevant to the case of Oman.

C. Research methodology

This part presents the research methodology adopted to develop the institutional framework of ISL for Oman. The methodology envelops the development of the framework based upon the above empirical review of studies and its assessment is accomplished through a survey of firms and university faculty. The discussion of types and stages of ISL and its development in many countries provides the base for conceptualising the process in Oman with reference to the application of ISL stages and the potential success factors and barriers as identified above. A hypothetical ISL framework is developed as shown in Figure 1 with industry and university structures at the two sides and the ISL process in the centre. The four stages of ISL and the corresponding potential determinants of each are listed. The first is a near threshold stage indicating the basics for ISL awareness and collaboration. In this awareness stage, a tendency
to participate in ISL becomes noticeable, but without any dramatic change in ISL perception. Participation in all or any one of the activities like visits, informal contacts, attending workshops, membership in university bodies, sponsoring student projects and employment of university graduates and providing funding for these activities indicate that a firm is opening the door to partnership with the university. The second threshold stage indicates active or prospective collaboration and sponsorship, facilitating faculty mobility and joint research leading to some perceptible changes toward long-term relationship. The third post-threshold stage involves knowledge sharing and transfer, indicating a further improvement in ISL. The fourth, advanced, stage culminates in commercialisation of technology in different forms like start-ups and spin-offs. A firm or university faculty may be participating in one or more of these stages at the same time and as the stages progress participation becomes more long-term oriented and sustainable.

Figure 1. The Industry-Science Link (ISL) Framework
When both firms and university demonstrate their capacity to acquire adequate R&D intensity (Mueller, 2006), intensive employment of S&T staff formalises the interaction process (Schibany et al., 2002). Larger size of the firms and their proximity to the university (Santoro and Chakrabarti, 2002) may facilitate better knowledge-sharing and faculty motivation than small and far-away firms. With freedom and transparency in the organisational structure, faculty members are more likely to pursue research involving commercial applications. A more flexible organisational structure in the firm or university level also has been found to facilitate the acquisition of new know-how (Scott et al., 2002). When such a process leads to commercialisation, the expectation of adequate financial and non-financial returns from that process dominate for the decisions of firms in contrast to the university’s concern of realising adequate returns from the increasing level of R&D intensity (Decter et al., 2007). Under this circumstance, the firms as well the university faculty may be motivated to achieve higher productivity growth and sustain knowledge development (Kitagawa, 2009). In Figure 1, we have shown motivation as influencing and being influenced by the organisational structure of firms and the university.

When technology importation is cheaper than indigenous development and when the local university research is purely basic or less science-oriented, the barriers affect not only the organisational structure but also R&D capability. When the proportion of S&T personnel is very low with rigid labour market conditions, research capability would be impaired. A weak R&D structure and conflicts of interest within the university system may affect its capacity in not only developing new technology but also in absorbing industry R&D spillovers.

The technological infrastructure and regulatory framework factors may be specific to the particular industry or university. The existing ICT structure, external R&D spillovers and the technology vintage which is being adopted by firms determine the pace at which the industry’s technological infrastructure may facilitate R&D cooperation and the start-up of business incubators. The available technological facilities in the university may encourage R&D growth so that the developed technologies (both patented and non-patented) may be commercialised and licensed.

The degree of commercialisation of the knowledge developed by the university, given its R&D strength and IPR protection regime, may determine how far the university can become an R&D-oriented enterprise. When the university attains that position, the technology transfer or licensing offices may utilise the opportunity to license and sell the technology developed with the objective of establishing a competitive advantage over other research institutions in developing new technologies and having a larger number of industry collaborations. A lack of competitive advantage as a result of cheap technology importation may be a major hindrance not only to the development of ISL but also in its integration in the industrialisation process.

Once awareness of the ISL process and its benefits are discerned, its development will depend upon the zest with which the ISL partners carry on with the process. ISL effectiveness means how rapidly and to what extent the process and outcomes are able to realise the set goals (Fontana et al., 2006). Time and finance may be constraints in this process and hence the ISL strategies have to be selected such that both are appropriate to yield the desired goals. In other words, ISL effectiveness indicates timely completion of its different stages, with the least cost combination of inputs, and with a continuing relationship between the partners based upon achieving the desired goals. When participation in ISL leads to further collaboration, it may materialise into long-term strategic alliances. A shift in the culture at both university and firm levels may open up new opportunities in the shape of increased mobility of faculty, faster accumulation of human capital, new employment opportunities and increased starting-up of new firms. ISL may be effective when these outcomes are realised within the cost and timeframes, the knowledge endowment of the partners undergoing value addition.

1. Objectives and hypotheses

The research framework developed above is tested through appropriate hypotheses testing. The advantages of developing ISL in Oman establishes, not only for knowledge development to catch-up with that in advanced countries, but also to assist the achievement of sustainable long-term growth through economic diversification away from oil and gas. Based
on the analysis and previous empirical studies which led to the conceptualisation of the four stages of ISL (research support, collaborative research, knowledge transfer and technology transfer), our own empirical research tests the following hypotheses for Oman:

Objective 1. To examine the relevance of ISL to conditions in Oman; i.e. to find out to what extent ISL is being practised by the firms and Sultan Qaboos University (SQU) and if applicable, what is the current nature of this process.

Hypothesis 1. The hypothesis to be tested in respect of this objective is that ISL exists in Oman and the awareness of ISL differs according to various firm sizes and faculty groups.

O2. To examine the nature of different stages of ISL and determinants of both firms and university faculty participation in these stages.

H2. ISL stages are sequential (participation in the third or fourth stages has to be preceded by experience of the first two stages).

H3. The timeframe of ISL activities varies between each stage of ISL.

H4. ISL participation by large firms is more pronounced than in the case of small firms. Likewise, senior faculty are more ISL-oriented than the junior faculty.

H5. Proximity to the University and ISL participation are positively related.

H6. The level of participation depends on the nature and extent of monetary returns expected from the ISL activities.

H7. Firms’ and faculty’s R&D capability and participation in ISL are positively related.

O3. To assess the process of ISL in the near-threshold, threshold, post-threshold and advanced stages

H8. ISL intensity will be a function of the prior knowledge base in the case of firms and familiarity with industry in the case of faculty.

H9. Employee productivity is positively related to ISL participation.

O4. To identify the factors determining the ISL process.

H10. ISL participation depends on the nature of prior knowledge base and market Adaptation of the firm and publications and consultancy activities of the faculty.

H11. The larger the proportion of S&T personnel and university graduates employed by the firms, other things being equal, the higher would be their level of participation in ISL.

H12. The higher the level of incentives and benefits (other than monetary returns) from IPRs, student employment and projects, ceteris paribus, the higher would be the level and intensity of ISL participation.

H13. The higher the level of disclosures of inventions, ceteris paribus, the higher would be the level and intensity of ISL participation.

2. Sample Design

Data collection techniques employed in research studies include telephonic or mail surveys, questionnaires, personal observations and interviews. Interviewing is a technique that is used to gain an understanding of the underlying reasons and motivations for people’s attitudes, preferences or behaviour. Interviews can be undertaken on a personal one-to-one basis or in a group. In-depth information may be obtained by this method. An alternative form of interview to the personal, face-to-face interview is either telephonic or mail surveys. A questionnaire is a data-gathering device that obtains answers from a respondent firm or university faculty to pre-arranged questions presented in a specific order (Malhotra,
2004). Often it is the only feasible way to reach a large number of respondents to allow analysis which can yield statistically significant results. It gathers information on the overall performance of the system and also information on its specific components. Questionnaires are flexible and adaptable to a variety of research designs, populations and purposes (Punch, 2000). The usefulness of questionnaire surveys depend on the frankness and accuracy of the respondent’s responses and need to be designed and carried out carefully so that they provide a genuine reflection of the behaviour of the respondents. The questionnaire method facilitates the collection of relevant information more objectively without the interviewer bias and more reliably than other methods such as interviews or personal observation (Trochim, 2001). Also, the response rate is higher in this method when compared to mail surveys and in telephonic surveys, the required information may not be obtained easily and consistently as in the questionnaire method. Hence, this method has been used in this study and it has been the main means of collecting quantitative primary data and has enabled that to be collected in a standardised way so that the data are internally consistent and coherent.

A questionnaire with a rating scale has been instrumental in obtaining relevant information from both firms and the university faculty regarding their participation in the various ISL activities, which could not have been obtained otherwise in such a short time through interviews or observation. Apart from these advantages, both open and closed type questions were used, providing balance between depth and authenticity.

Secondary data pertaining to innovation and ISL policy in Oman and the regulatory framework in that country are very sparse, though some of the information on this is available in the CRAI report (2007) on research strategy in Oman. Regarding primary data, selection has to be made of the different industry groups and the universities which practice ISL in such a way that, the sample selected throws light on the behavioural patterns of the University and Omani firms.

In an emerging economy where the ISL process is a relatively recent phenomenon, randomly coming across a significant number of ISL participants is unlikely. However, the sample representing of firms and faculty group was chosen to be selectively representative by inclusion of both high-tech and low-tech firms on the one hand and active researchers among the university faculty.

The reference period selected was 2006, with information obtained for the period 2004–06, though the secondary analysis covered the period since 1996. As explained previously, industrial policy in Oman became explicit only after the country entered the World Trade Organisation in 2000 with an emphasis on research starting with the Sixth Five Year Development Plan and IT policy being initiated in the year 2003. While 3-years of data were collected from firms and the university faculty members, emphasis was placed on gaining accurate data for 2006. From firms, information was collected on investment, turnover, S&T employment, R&D expenditure and collaboration with SQU. From the SQU faculty data relating to university research capability, department R&D activities and particulars about innovations were collected. The university faculty and firms also provided information on their knowledge endowment, participation in ISL and their perception about the linkages.

3. Sample structure

Industry groups have been classified as high-tech, medium high-tech, medium low-tech and low-tech according to the International Standard Industrial Classification (ISIC). The various firms in the region have been selected so as to represent not only these industry groups but also different product groups and different sizes based on the quantum of investment and employment. In Oman the number of registered enterprises by the end of 2005
amounted to 24,575 of which the Muscat region accounts for about 36 percent. The average capital per enterprise was $33,982 (MONE, 2008). The number of large and medium manufacturing firms employing more than 10 workers amounted to just 446. Of these 446 medium and large firms in the country, Muscat and part of the neighbouring regions (Sohar) accounted for about 258. Very few firms responded to a query as to participation in ISL in the Muscat region and hence personal visits were undertaken with a pilot questionnaire and 193 firms were selected on the basis of their positive response to cooperate in the survey. Of these firms contacted, the response rate has been 58 percent but their final selection was restricted to 100 after taking into consideration of a few drop-out cases owing to lack of any ISL activities (not even informal contacts). Hence, the sample is only representative of firms who are more likely to participate in some ISL activity, not of the total population of registered enterprises. The sample selection pertains to 94 firms in Muscat and 6 in the Sohar region covering the four major industry groups as detailed in Table 2.

Table 2 Industry sample size

<table>
<thead>
<tr>
<th>High-tech</th>
<th>Medium high-tech</th>
<th>Medium low-tech</th>
<th>Low-tech</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office accounting (OA)</td>
<td>Chemicals (C)</td>
<td>Refined petroleum &amp; gas (RPG)</td>
<td>Food products (FP)</td>
<td>39</td>
</tr>
<tr>
<td>(1)</td>
<td>(15)</td>
<td>(5)</td>
<td>(18)</td>
<td></td>
</tr>
<tr>
<td>Computer machinery (CM)</td>
<td>Electrical machinery (EM)</td>
<td>Basic metals (BM)</td>
<td>Furniture (F)</td>
<td>12</td>
</tr>
<tr>
<td>(1)</td>
<td>(4)</td>
<td>(4)</td>
<td>(3)</td>
<td></td>
</tr>
<tr>
<td>Pharmaceuticals (P)</td>
<td>Motor vehicles (MV)</td>
<td>Non metallic (NM)</td>
<td>Paper &amp; printing</td>
<td>19</td>
</tr>
<tr>
<td>(2)</td>
<td>(2)</td>
<td>(10)</td>
<td>(PP)</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Crude petroleum and gas (CPG)</td>
<td>Fabricated metal products (FMP)</td>
<td>Other Manufacturing</td>
<td>04</td>
</tr>
<tr>
<td>04</td>
<td>29</td>
<td>(10)</td>
<td>&amp; services (OMS)</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(10)</td>
<td>100</td>
</tr>
</tbody>
</table>

Note: The number of firms interviewed is indicated in brackets under each category

Of the total 483 faculty members in the SQU and around 200 in Sohar University, a random sample of 285 faculty in SQU and 100 in Sohar was chosen. Since participation in ISL was observed only in the case of SQU faculty and none in Sohar, only SQU faculty were actually included for the survey. Of the total SQU faculty contacted, 106 members responded, but six members later opted out of the survey and hence the sample size again became 100 and represents not only different faculty groups like professors, associate professors, assistant professors and lecturers but also different departments like engineering, science, commerce, agriculture and fisheries. The sample contains a higher proportion of researchers, indicating a close association between researchers and their participation in ISL; hence the sample was biased in favour of faculty who were more likely to be participating in ISL. The number of firms and University faculty interviewed is shown in Table 3.
Table 3. SQU department, firms and faculty sample size

<table>
<thead>
<tr>
<th>Dept/Centre</th>
<th>Field</th>
<th>ISL firms (sample size)</th>
<th>ISL faculty (sample size)</th>
</tr>
</thead>
<tbody>
<tr>
<td>College of Agricultural and Marine Sciences</td>
<td>Agriculture, fisheries</td>
<td>18 (FP)</td>
<td>15</td>
</tr>
<tr>
<td>College of Commerce and Economics</td>
<td>Business</td>
<td>5 (OMS)</td>
<td>5</td>
</tr>
<tr>
<td>College of Engineering</td>
<td>Construction, roads</td>
<td>4 (EM) 2 (MV)</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 (NM) 7 (C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 (BM) 3 (F)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 (PP) 10 (FMP)</td>
<td></td>
</tr>
<tr>
<td>College of Medical and Health Sciences</td>
<td>Pharmaceuticals</td>
<td>2 (P)</td>
<td>3</td>
</tr>
<tr>
<td>College of Sciences</td>
<td>Biochemistry, computer modelling</td>
<td>1 (CM) 8 (C)</td>
<td>8</td>
</tr>
<tr>
<td>Communication and Information Research Centre</td>
<td>Communication and information</td>
<td>1 (OA) 3 (OMS)</td>
<td>5</td>
</tr>
<tr>
<td>Joint Virtual Reality Centre for Carbonate Studies</td>
<td>Virtual reality facility</td>
<td>3 (CPG)</td>
<td>5</td>
</tr>
<tr>
<td>Oil and Gas Research Centre</td>
<td>Oil &amp; gas</td>
<td>7 (CPG) 5 (RPG)</td>
<td>15</td>
</tr>
<tr>
<td>Water Research Centre</td>
<td>Water</td>
<td>2 (OMS)</td>
<td>2</td>
</tr>
<tr>
<td>Omani Studies Centre</td>
<td>Database</td>
<td>--</td>
<td>2</td>
</tr>
<tr>
<td>Total sample size</td>
<td></td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Note: Acronyms in parentheses indicate the industry groups as in Table 4.2

The field survey questionnaire comprised two elements - SQU faculty and Omani firms. The questionnaire relating to SQU faculty obtained innovation and research sponsorship particulars during 2002-06 and technology commercialisation particulars during 2004-06. Information on IPR status, incentives and the disclosure mechanisms and technology transfer particulars were collected. Their evaluation of participation in ISL stages in respect to the mobility of researchers (from university to the firms for special assignments), joint research, sponsorship and knowledge and technology transmission were obtained from respondents.

Preceding the final survey, a pilot study was undertaken in June-July 2007 in the Rusayl industrial area and the University region and the full survey was undertaken during July-September 2007. A list of selected firms was made and the officers-in-charge of the firms were contacted and the particulars gathered from senior management and workers. In the pilot survey, a dozen firms were contacted and the questionnaire was revised based on their responses on their implementation of the ISL process. The author went to the field expecting a very high level of participation of ISL activities but it was observed that ISL was not practised as anticipated from the literature reviewed above and no university-patented products or processes were perceivable in them. Besides, there was very low awareness about ISL in many cases. Moreover, in some instances, mere awareness of the existence of the University itself was considered as ISL activity. In many cases, a second visit was undertaken to investigate further the nuances of different stages of ISL involvement in each firm and how their practices were changing.

The pilot study as regards the University departments was undertaken in June 2007 and the final survey was undertaken during October-December 2007. From the faculty list, a random selection was made wherein faculty in five departments were contacted and the particulars regarding ISL participation was collected. In the pilot survey, 35 faculty
members were contacted personally with a questionnaire. The survey required respondents to identify the type of ISL process and the extent to which the sample institutions and faculty interact with firms in the region and the effects on knowledge and technology transfer. Given the growth of ICT in the economy and the proximity of SQU to the Rusayl industrial estate, the expectation was of a high level of participation by faculty in ISL activities. However, the pilot questionnaire revealed that ISL was not as prevalent as expected and no patented products or processes were found, with low level of awareness of ISL being displayed in most cases. Moreover, in some instances, mere awareness of the existence of a problem area in local firms, like technology and marketing, was perceived to be tantamount to ISL. The final questionnaire was revised accordingly to incorporate several additional formal and informal interaction activities (like visits, informal contacts, demonstrations and joint publications) so that a more complete picture of ISL could be obtained.

The questionnaire relating to firms elicited particulars on the changing size of the firm during 2004-06 and their type of production activities and extent of competition. Particulars on the interaction with SQU in respect of ISL variables along with their frequencies and benefits were obtained for the same period. In respect of R&D firms, details of R&D expenditure, R&D staff, collaboration with SQU, innovations made, royalties received and problems in the process were collected for these years. There was a separate question to elicit information about the firm’s links with other higher education institutions. Based on the observations in the pilot, particulars about employment of university graduates as an ISL element were added, as were questions related to the mobility of researchers and role of intermediaries in the ISL process.

The questionnaire relating to SQU faculty generated information on the human capital development of the faculty members and their motivation toward participation in research projects during 2004-06. The impact of the research projects in terms of innovations, licences and consultancy were also obtained. Particulars like disclosures, deviations and income from innovations, besides exchange programmes with industry and mobility were collected. After the pilot, questions on motivation, benefits from ISL and the role of intermediaries in the ISL process were added.

4. Data Analysis

The analysis of data collected from the sample firms and the University faculty members has been undertaken in two ways. Participation in ISL process in the four stages was assessed according to the frequency of adoption and the intensity of adoption. For every question put, the respondents had to rate their response on a numerical scale. The respondents were asked to indicate their level of participation or performance in a particular activity. D’Este et al. (2005) used 5-point Likert scale to evaluate the interaction behaviour of the university researchers. We, in this study adopted a similar approach but use a continuous rating (within high, medium or low ranges) in the 3-point scale to indicate the level of intensity of a particular activity’s adoption level.

Next, the significance of various potential determinants like knowledge base, motives, market adaptation, R&D, IPRs and productivity in the case of firms and familiarity, access, joint publications, consultancy, additional income, R&D and benefits from IPRs in the case of University faculty through a logit model, wherein participation in ISL is treated as a dichotomous variable was analyse. To assess the impact of firm size, a logistic regression is run taking four dummies to represent total sales of <3 mil RO, 3-5 mil RO, 5-10 mil RO and >10 mil RO sizes. No firm was found to have larger than 16 mil RO sales and the choice of categories reflects the overall industrial structure of Oman industry. The <3M group was mostly low-tech, whereas >10M group consisted of high-tech and oil and gas companies. In the case of university faculty again four dummies are introduced to represent the four groups of lecturers, assistant professors, associate professors and professors. The sign and significance of the explanatory variables and their marginal effects, besides the odds
ratios were again examined through regression models.

D. Findings and Discussions

The answers to the research questions arising from the research undertaken are presented herewith. The questions relate to the practice of ISL in Oman and its various determinants and the answers developed provide an overview of the study.

a) What is meant by ISL in the context of Oman, and the relevance and extent of ISL in Oman?

Industry-science links characterises the relationship between firms and SQU resulting in exploitation of mutual infrastructural benefits for both, either through a short-term or long-term relationship involving various interactions. ISL exist in Oman, though there is little evidence that they are growing rapidly. Oman’s oil-oriented production structure and its consequent low economic diversification necessitate the emergence of a more diversified economy, as in the UAE or Qatar, and improvement in its knowledge sector if it is to become globally competitive. Long-term partnership between the universities and firms would strengthen Oman’s R&D capability, innovativeness and growth of knowledge. Its national innovation system development has been slow due to limited resources available at its universities and the uncompetitive and small nature of its firms. Improved synergy between the two not only is likely to generate mutual benefits but also bring in new knowledge and technology opportunities as has been experienced in many countries. Instead of depending on technology imports as has been the practice hitherto, Oman has the opportunity to transform itself into a knowledge economy if ISL is propagated extensively.

ISL is being promoted by the government through allocation of strategic research grants to SQU and providing technical and infrastructural facilities to firms in the industrial estates and Knowledge Oasis Muscat. ISL participation by firms has been estimated at 14 percent only, indicating the currently low extent of participation in the sampled firms, a sample which itself was biased in favour of firms more likely to be participating in ISL. The level of participation by SQU faculty was reported to be at 17 percent of total sample, but again the sample was biased in favour of those staff more likely to be participating. The time taken to reach this level has been between 10-20 years. Hence, closer and intensive links are essential if Oman wants to become at the forefront of knowledge development.

b) Whether ISL is characterised by different stages and if so, are they sequential?

The four stages of ISL identified in this research are: research support, collaborative research, knowledge transfer and technology transfer. The support stage is the preliminary stage wherein the links between firms and university are established through support activities. In the next stage, the links are formalised, in the sense of collaborative research. Once collaboration results in knowledge outcomes, knowledge transfer takes place in the next stage, to be followed by technology transfer in the last stage, culminating in commercialisation process. The four stages have been generally found to be sequential, in the sense, that to undertake the knowledge and technology transfer activities, the firm has usually participated in the earlier stages. Though each stage has its own timeframe, there may be overlapping between stages, but commercialisation takes place only when the R&D infrastructure leads to know-how.

c) What are the factors that determine participation in the ISL process?

Participation in and implementation of ISL is usually a long-term process, though there could be short-term projects with limited objectives. At the firm level, the factors identified by this research as affecting participation are the: size of the firm, knowledge base of the firm as determined by its organisational structure, financial and
non-financial motivations behind adoption of ISL activities, adaptation to market requirements, R&D infrastructure, employee productivity and IPRs that define the internal and external absorptive capacity of the firm to absorb new knowledge and technology to be innovative and realise competitive advantage. The results of this current research programme, in general, suggest the relevance of these variables to participation in ISL activities in Oman. Higher the value of these factors, higher would be the ISL participation, though R&D and employee productivity on the whole have negative effect as evidenced by logistic regression analysis.

At the university level, familiarity with problems associated with the firms and easy access to industry facilities encourages university faculty to participate in ISL. The R&D capability of the faculty, the expectation of additional income from undertaking ISL activities, expectation of potential consultancy works, the number of publications and the expected benefits from the IPRs were found to have a positive effect on faculty’s participation in the interaction process.

d) Is participation by the large firms and senior faculty more pronounced?

Yes, participation by large firms and HTs and MHTs has been more pronounced in ISL activities than that other firm group. As regards university faculty, it showed that the senior faculty have a higher level of participation than junior members.

e) What is the timeframe of different ISL activities?

The average time taken to undertake ISL activities increases over the stages from around 11 months in the research support stage to 17 months in the collaborative research stage to 20 months in the knowledge transfer stage and to 26 months in the technology transfer stage.

f) Does proximity contribute to intensive participation?

Over 85 percent of the firms interviewed were close by SQU but other things being equal, distance had a negative and statistically significant effect on the probability of ISL participation. There was little difference between the close-by and far-off firms as regards the participation intensity.

g) What are the key success factors and barriers in the adoption process?

The success factors include an organisational structure which encourages innovativeness, administrative support, enterprising university faculty, adequate resources for R&D, access to venture capital, long-term links to business and economic activities, proximity between industry and university, tax credits for start-ups and so on. Barriers include risks connected to technological obsolescence and adoption of ICT, increasing costs, organisational rigidity, lack of S&T staff, poor IT infrastructure, government regulation (Oman has a score of 4.9 in 7-point scale in intellectual property protection in 2006 according to Global Competitiveness Report), presence of competitors in ISL and poor customer feedback.

h) What is the contribution of ISL to knowledge development in the region?

ISL activities in Oman are a recent phenomenon and hence its contribution to knowledge development in the region is yet to materialise fully. Its contribution can only become a key factor in driving diversification when a significant number of start-ups, spin-offs and technology parks are established out of the interaction process.

i) When compared to the benchmark indicators, how does ISL in Oman fare?

When compared to the derived benchmark ISL indicators, Oman compares unfavourably suggesting a major effort is necessary if these activities are to make a
significant contribution to its economic development.

j) **Summary of regression results**

The logit regression models used to identify the major determinants of ISL both in firms and university suggest that the independent variables previously identified in research covering other countries can explain some of the variability in ISL participation: the pseudo $R^2$ being relatively high. This suggests that the selection of the determining variables - KBAS (knowledge base), MOT (motivation), MARK (market adaptation), RD (R&D intensity), IPR (invention-oriented intellectual property rights) and PROD (employee productivity), the different firm sizes taken as dummies, in the case of firms and FAM (familiarity), ACS (access to facilities), RD (R&D capability), PUB (publications), CON (consultancy), INC (additional income expectation) and BEN (benefits from inventions), the different faculty groups taken as dummies, were appropriate as was the model chosen to test the hypotheses. Table 4 summarises the major findings regarding the determinants of ISL in respect of firms as well as university faculty.

In respect of firms, KBAS, MOT, MARK and IPR have the expected positive coefficients in all the stages of ISL. RD has a positive coefficient only in knowledge and technology transfer stages, while PROD is positive only in the fourth stage.

### Table 4. Sign and significance of the ISL determinants

<table>
<thead>
<tr>
<th>Firm/Faculty determinant</th>
<th>Research support</th>
<th>Collaborative research</th>
<th>Knowledge transfer</th>
<th>Technology transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COE</td>
<td>SIGN</td>
<td>COE</td>
<td>SIGN</td>
</tr>
<tr>
<td><strong>Firm</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge base</td>
<td>KBAS</td>
<td>+</td>
<td>**</td>
<td>+</td>
</tr>
<tr>
<td>Motivation</td>
<td>MOT</td>
<td>+</td>
<td>*****</td>
<td>+</td>
</tr>
<tr>
<td>Market adaptation</td>
<td>MARK</td>
<td>+</td>
<td>*****</td>
<td>+</td>
</tr>
<tr>
<td>R&amp;D intensity</td>
<td>RD</td>
<td>-</td>
<td>****</td>
<td>-</td>
</tr>
<tr>
<td>Inventions</td>
<td>IPR</td>
<td>+</td>
<td>****</td>
<td>+</td>
</tr>
<tr>
<td>Productivity</td>
<td>PROD</td>
<td>-</td>
<td>**</td>
<td>-</td>
</tr>
<tr>
<td>3-5 mil RO size</td>
<td>3-5M</td>
<td>-</td>
<td>**</td>
<td>+</td>
</tr>
<tr>
<td>5-10 mil RO size</td>
<td>5-10M</td>
<td>+</td>
<td>&lt;</td>
<td>+</td>
</tr>
<tr>
<td>Above 10 mil RO size</td>
<td>&gt;10M</td>
<td>+</td>
<td>****</td>
<td>+</td>
</tr>
<tr>
<td><strong>Faculty</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Familiarity</td>
<td>FAM</td>
<td>+</td>
<td>****</td>
<td>+</td>
</tr>
<tr>
<td>Access</td>
<td>ACS</td>
<td>+</td>
<td>**</td>
<td>+</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>RD</td>
<td>-</td>
<td>&lt;</td>
<td>-</td>
</tr>
<tr>
<td>Publications</td>
<td>PUB</td>
<td>+</td>
<td>**</td>
<td>+</td>
</tr>
<tr>
<td>Consultancy</td>
<td>CON</td>
<td>-</td>
<td>*</td>
<td>-</td>
</tr>
<tr>
<td>Income</td>
<td>INC</td>
<td>+</td>
<td>**</td>
<td>-</td>
</tr>
<tr>
<td>Benefits</td>
<td>BEN</td>
<td>-</td>
<td>**</td>
<td>+</td>
</tr>
<tr>
<td>Asst Professor</td>
<td>ASST</td>
<td>-</td>
<td>&lt;</td>
<td>+</td>
</tr>
<tr>
<td>Associate Professor</td>
<td>ASPRO</td>
<td>+</td>
<td>&lt;</td>
<td>+</td>
</tr>
</tbody>
</table>

[56]
When the <3m size is treated as the base, the 3-5M group has positive coefficient, except in research support stage and is not a significant variable in knowledge transfer stage. The 5-10M group has positive coefficients in all the stages and is significant, except in research support and knowledge transfer stages. The >10m size has positive coefficients and is significant in all the ISL stages. This is in line with the hypothesis that large firms, other things taken as constant, have a higher level of participation in ISL. Any increase in these two variables leads to reduced ISL participation, especially in the earlier stages. This may be suggestive that these firms have not yet reached a sustainable R&D intensity to enable innovativeness. However, most of the explanatory variables are significant at 5 percent level, though. PROD is insignificant in the later three stages and thus higher employee productivity is no guarantee that firms would participate in ISL to a greater extent.

FAM and ACS in the case of university faculty have positive coefficients and are significant at 5 percent or better in all the stages (except ACS in technology transfer stage). PUB has positive values, being insignificant only in the collaborative research stage. CON has negative values and is insignificant in many stages and INC has positive coefficients, except in collaborative research and is significant except in technology transfer stage. On the whole BEN has positive values and is a significant variable in ISL participation. RD has negative impact on ISL participation in all the stages, save in technology transfer, indicating a relationship similar to that of firms. It is significant only in the last stage, indicating its importance in the commercialisation process, however, owing to a small number of observations in this category this result needs to be treated with caution.

When LECT is considered as the base dummy, the senior faculty on the whole exhibit a higher participation level. The faculty dummies are significant, except in research support stage, indicating that participation differences are more pronounced in later stages. This is in line with the findings of D’Este and Patel (2007) who found out that general awareness of industrial application and access to external resources were leading determinants of faculty participation in activities like training and dissemination, development of technical artefacts and commercialisation. Our findings relating to familiarity, access and income support this and also the study on faculty participation in ISL by Perkmann et al. (2009) who reports that senior faculty give more importance to contract research and licensing when compared to junior faculty. Hence, they are able to generate a higher amount of prototypes and realise a higher level of additional income. Further, the faculty have been reported to participate in specialised programmes like local innovation system projects such as in Massachusetts Institute of Technology in internationalising technology transfer activities (Lester, 2005). Studies also suggest that a strong orientation to applied research and less teaching load normally turn out a larger number of licences than others (Arvanitis et al., 2008), which finding most of the SQU faculty subjects would vouchsafe for. Finally, as Abramo et al. (2009) point out, those university researchers who are participating in ISL are able to generate better quality research than their colleagues. We have observed that all those SQU faculty members who have generated licences have invariably participated in the ISL process and are able to realise better research publications and benefits.

k) R&D and innovativeness
The analysis of R&D infrastructure in the firm groups indicates that the high-tech firms have allotted 1.8 percent of their total revenue to R&D efforts. This intensity enables the HTs to achieve a higher degree of innovativeness but the share is lower in other groups. As regards information sources relate to the innovation process, the SQU contribution is the largest at 26 percent (more or less uniform across the different groups and sizes) followed by competitors, customers feedback, other research institutes and business meetings. The major barriers in the innovation process identified are the inability to adapt to customers preferences, followed by regulatory framework, market risks, organisational rigidity and deficiency of research staff. An analysis of the ISL interaction process involved the use of 14 indicators, such as faculty exchange, student projects, SQU facilities, sponsorship and licences, and realisation of benefits has been higher for the large firms. The average time taken in participation in knowledge and technology transfer activities is longer than in the earlier stages, suggesting that the firms have to be attuned to a sustainable and long-term relationship with the universities to fully exploit the benefits of ISL.

1) Faculty invention disclosures

Inventions in SQU have been made in the fields of industrial engineering, oil and gas exploration, agriculture, marine sciences and food processing. Only about half of faculty members filing disclosures feel that disclosure norms relating to either inventions or consultancy are satisfactory. As regards taking decisions related to knowledge or technology transfer, more than half of faculty have reported that the nature of collaboration has to be in their field of interest and not thrust upon. In respect of consultancy, the proportion is higher. Those, who are not satisfied with the university norms of disclosure would not like to disclose to the university, but deal directly to the firms about selling the invention in order to get the maximum benefit for themselves. This may be encouraged by firms since it saves them paying the licence fee to the university; however this robs the University of its Due Rights in intellectual property and share in licence fees and, ultimately, its Incentive to participate in ISL activities. In non-filing cases, deviation has occurred in one case in the shape of hiding necessary invention particulars from the university administration. In another case, SQU has been able to overcome non-compliance by providing additional incentives to the faculty. The percentage of disclosures of inventions deemed by respondents to be satisfactory is higher in the PROF group followed by ASPRO and others. Where monetary incentives have been provided by university administration, the disclosure mechanism has worked well.

There has been less institutional patenting and technology transfer activities. Further, not all disclosures result in patenting. Various incentives provided by the university for those who disclose include a slightly higher share in licences fees or royalty, new contracts, procurement of new instruments for research and deputation to participate in national and international events. Where incentives have been provided, the transfer process has been facilitated smoothly and the satisfaction score of the faculty has been high.

From the statistical analysis undertaken in this research programme, it can be concluded that many of the previously identified determinants of both firm and university faculty participation in ISL are present in Oman, the exceptions being R&D intensity and productivity (firm). Motivation, market adaptation and IPRs are statistically significant in all the ISL stages in respect of the firms. In the case of faculty, familiarity is significant in all the stages. Since R&D capabilities are generally weak in Oman, innovative and entrepreneurial activities of the firms and the faculty are limited. The disclosure practice suggests that licensing is an important activity only in the case of non-patented activities.

E. Policy implications and recommendations

Any particular type of partnership explores the implications of impact that links the
incidence of ISL in a country like Oman to the economic circumstances the universities and the firms are facing. The ISL framework was presented and the same has been empirically tested as in Figure 4. In this section, the implications of the study and recommendations are examined with respect to the firms, SQU and the government.

a) Firms

The firm organisational culture (indicating how incentives are provided to acquire and develop knowledge) is characterised by a low orientation to R&D, but research suggests that a high R&D intensity is crucial for innovativeness and competitive advantage. The low level of research funding, low share of high-tech manufacturing, low R&D staff ratio and weak research sector contribute to a low internal absorptive capacity. Weak adaptation to cutting-edge technological structure has resulted in low levels of research capability and absence of R&D spill overs, restricting the role of external absorptive capacity also.

Increased R&D orientation leads to more innovations and a transformation toward high-tech diversification. Certain innovative practices like ‘made in Oman’, ‘origin Oman’ etc. have been initiated, but an innovative technological culture which could replace the current technology dependency regime and diversify the economy is yet to be accomplished. No doubt the motives of the firms and the university are not always mutually compatible and there may be at times clashes between them. However, incentives and prospects of additional income from ISL activities would constitute the major motivation behind ISL participation.

Low level of prior knowledge shows ISL is not yet completely incorporated into the industrial system and as indicated in Figure 8.1, ISL process has to be developed with a view to realise the benchmark indicators of knowledge and technology transfer activities. ISL has to be formalised through establishing a consortium amongst different firms in an industry so that economies of scale and scope are realised. Periodic assessment and stock taking have to be formalised with necessary benchmarks so that ISL becomes effective even in the case of small enterprises. Training in technology transfer, conduct of ISL benchmark studies, interaction through employment of graduates and cooperation with student projects, greater involvement of university faculty in solving industry problems and diversifying through various ISL activities can be developed through appropriate policy directions. These involve increased funding and establishment of R&D cells besides appropriation of external R&D spillovers. The resulting new start-ups and spin-offs will be automatic offshoots of such a process, indicating the competitive advantage of the technology system.

Firms in Oman that have technological development capabilities and highly skilled employees have been constrained in respect of time, cost and technical expertise in accessing information on available technologies. Some firms have insufficient information about their own manufacturing processes or are unaware of best practices applied elsewhere. The idea of ISL is just to bridge this infrastructure gap and make available to these firms knowledge about what new technologies are available in the market. ISL also strengthens the business infrastructure when it links the firms through the interaction process in collaborating for competitive advantage. Since the absorptive capacity of the firms involve information, management, training and financing, balancing the micro issues at the firm level with the macro infrastructure becomes essential for benchmarking and adoption of best practices, technical assistance and partnership. For this, they will have to attend workshops and become members of university bodies by focusing on knowledge transfer, institution of sponsorships and research projects and adopting up-to-date technology developments. The important fallout of the study is how the
participating firms render the outcome of participation more effective and how non-participating firms are going to be incentivised in the interaction process. Successful horizontal diversification in Oman has to be driven by an expanding private sector. Rather than crowding out the private sector the government has to provide support and greater incentives for the growth of the indigenous private sector. Hence government policy need to promote both diversification and ISL activities based upon a re-invigorated private sector.

b) Sultan Qaboos University

If SQU wants to play an important role in the national innovation process, it has to make R&D a central part of its mission and play an important role in regional economic development through its teaching and research. The university has to induce into its organisational structure elements of excellence in both teaching and research and become more entrepreneurial in generating a greater number of technology transfer programmes having direct impact on local firms as substantiated by studies like Arvanitis et al (2008). Various structural issues relate to specification of goals and focus of links, the number of firms which can be partnered, the number of faculty and students that can be involved in the process and the nature of funding that is essential for achieving the objectives of partnership programmes. The perception of partnership and its success and achievement of the goals of the particular organisation matter most for the future growth of the partnership programmes.

The benchmark universities interact intensely with firms in knowledge and technology transfers. Likewise, some departments of SQU, like engineering, agriculture and marine sciences (which have already produced or are in the process of producing patentable inventions), have to be made wholly R&D oriented, allowing the scientists to devote more time to applied research. Periodical demonstrations as to the utility of research to the firms and propagation of knowledge programmes would enhance the leadership of these departments in technology advancement. Over a period of time, SQU itself has to be transformed into a research university. Given the strategic importance of food self-sufficiency in the region, the involvement of SQU faculty in these sectors would give them a first-mover advantage. Being the only state university in the country and endowed with special research grants, SQU would have an advantage as regards research in agriculture, fisheries and in manufacturing. While most of the GCC countries depend on imports in respect of food and other products, SQU’s activities in reducing the distance travelled by raw materials to produce final products especially in food (origin Oman) places it in an advantageous position when compared to other institutions in this specific innovative process.

Establishment of a technology transfer office in the university may not only enhance the research capability but also the commercial outcomes emanating from such efforts. This calls for intensification of the technological infrastructure such that it complements SQU’s R&D capability and other core activities. SQU and other university faculty have to address the concerns of local industry and misgivings of the firms, besides removing any financial and human constraints to the partnership process. A department’s research capability should be judged from not only the number of research projects undertaken and scientific publications accomplished, but also by the number of patents and non-patent inventions made by its faculty. Strengthening of conduct of student projects in cutting-edge technologies and providing training to firm personnel in latest technologies become imperative. The university administration has to encourage collaborative behaviour amongst its faculty by providing adequate incentives and long-term contracts. Since ISL can be very generic, collaboration between industry and any university for that matter may be instrumental in developing business parks and new enterprises.

The university administration on its part has to properly assess the value of research and the consequent improvement in the university’s image. They will have to enforce such rules which favour the faculty to do better research through participation in ISL activities. The administration has to clearly distinguish between single and multi-disciplinary research and provide necessary incentives for the same. New
field have to be selected for further explorative studies.

c.) Government

As explained above, the achievement of a knowledge-based economy in Oman depends on growth in knowledge, economic incentives, innovation, and education and ICT infrastructure as pointed out by World Bank (2008). Economic incentives have to ensure the efficient use of resources and fostering of local and global knowledge. The innovation system has to involve cooperation amongst the stakeholders toward an efficient innovation system. Education has to ensure emergence of skilled and flexible manpower to create a band of entrepreneurial and innovative labour force. The ICT infrastructure has to support all sectors toward modernisation. Under economic incentives may be included financial and non-financial motives of firms and additional income and benefits for university faculty. Innovation is conditioned by the R&D intensity in the firms and research capability of the faculty. When education generates a greater proportion of R&D staff, the knowledge base improves. The market adaptation of the firms depends on the existing technological structure. Increased intensity of knowledge base and R&D intensity, coupled with market adaptation as evidenced in this study would lead to such knowledge development and improve Oman’s rankings.

A glance at the knowledge index (Table 1.2) during 2000 and 2007 reveals that to improve the knowledge economy index in Oman, all the five indices especially education and innovation have to be greatly improved. In both the reference country (Denmark, since the US has registered a decline in ranking) and Oman, these indices have increased by more or less the same magnitude, though the rate of growth over the base period is higher in the latter case. For example, in Denmark, the knowledge index increases from 8.5 to 9.6, whereas in Oman, the increase has been from 3.4 to 5.3. The increase in the economic incentive index (tariff and non-tariff and regulatory framework providing incentives for efficient use of existing and new knowledge toward growth of entrepreneurship) is quite substantial in Oman (3.3 to 7.3), but in innovation (intensity of royalty payments, technical journal articles and patents granted) and education (adult literacy rate and gross enrolment in secondary and tertiary education), the increase has been small, indicating slower growth in R&D and innovativeness. Not only when compared to advanced countries, but also when compared to GCC countries, the gap becomes evident as explained in sections 2.5 and 2.6. Again, a comparison of diversification index (based on the share of non-oil sector in GDP, government revenue and total exports) between 1976 and 2007 reveals that the gap between Oman and UAE is widening.

There is an argument on the redirection of government policy towards directly stimulating and supporting the indigenous private sector in Oman. The government should establish a separate ISL cell in the Ministry of Commerce and Industry to oversee the partnership programmes and growth of knowledge development through a spiral pattern of linkage among the university, industry and government as propagated by Leydesdorff and Etzkowitz (1998). By encouraging public-private partnerships between the government, universities and industries, the National Innovation System can be strengthened to achieve technological improvements and greater innovativeness in the economy.

Further development of the National Innovation System calls for increased provision of tax incentives for undertaking R&D works, support to technological fairs, popularisation of research results, innovative technology transfer facilities at the university level, establishment of technology transfer and a country patent offices and encouraging local innovativeness, as in the case of benchmark universities can be strengthened by focusing on research and contracts with firms to employ a greater proportion of researchers. Since the structure of ISL depends on size and orientation of research, incentives and regulatory framework have to strengthen financial flows between public and private research institutions, labour mobility and other knowledge flows like patents and joint publications. The experience of Dubai in starting its Biotechnology and Research Park to develop biotechnology and agricultural research of a global standard is a good example to follow. For
this, the organisation structures of the university and the firms have to be geared into a motivating situation toward technology commercialisation. Hence, ISL-related programmes have to focus on increase in government’s share in R&D. R&D financing by firms, credit and tax allowances for ISL activities and financial incentives for collaborative research, support for joint R&D facilities, establishment of centres of excellence, support for researcher mobility and training, support for IPR activities, promotion of networking initiatives and generation of start-ups and regional approaches to ISL. To conclude, the government has to create a collaborative environment through institutional arrangements of the Research Council wherein both firms and universities would participate in establishing links in several areas, developing the innovation system.

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