Towards a Dynamic National System of Innovation in Malaysia: Enhancing the Management of R&D in Public Research Institutions and Universities

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Summary

This article examines the issue of utilization of research findings from public funded research institutions (PRIs) and universities in Malaysia from the perspective of knowledge flows. Such a perspective is adapted from the literature on innovation and knowledge systems. This representation of innovation in terms of knowledge flows helps us to focus on the managerial dimensions involved in the organization of activities such as research and development (R&D). The paper reveals that there is a dismal rate of adoption of research findings generated from PRIs and universities in Malaysia. It is argued that this poor performance is a consequence of weak research management practices. A framework on the key elements of sound research management is described. The article concludes with a discussion on managerial and policy issues arising from these deficiencies and some suggestions for addressing them.

Key words : research findings, management, innovation, knowledge flows, Malaysia

1. Introduction

In recent years, the concept of a National System of Innovation has assumed increasing importance and acceptance in both developed and developing countries. The effectiveness of linkages among the various actors of the system is critical towards ensuring its smooth functioning. Partnerships

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among the various actors of the system that formerly used to operate at arm's length are becoming common. Such partnerships, however, have not characterised the national innovation system of Malaysia. This deficiency is particularly worrying as the Government is keen to demonstrate returns from its substantial investments in research and development (R&D).

Measuring the benefits of R&D is not easy. This is because the benefits of public funding on R&D are less obvious than say health or education. Much has been discussed in the literature on the benefits of undertaking research and will not be discussed here.[1] Instead, the object of this article is to examine the various issues pertaining to the utilization of research findings generated from public research institutions and universities from the perspective of knowledge flows. Managing R&D can be conceived in terms of knowledge flows. Such a conception provides rich insights towards understanding the various interactions and transformations that underpin the research process from the stage of idea generation to final adoption by the end-user.

This paper is in five parts. The first part sketches the interactive nature of the innovation process as well as the translation of research findings into innovations. These transformations are also described in terms of knowledge flows while the R&D organization is conceptualized as a knowledge system. The next part examines the nature of R&D and the various practices that contribute towards effective research management. The third part provides a brief review of R&D in Malaysia while the fourth part examines the findings of studies on research utilization and commercialisation undertaken in Malaysia. The final section identifies the main lessons from these findings and the managerial and policy implications. Some recommendations towards enhanced research utilisation are discussed.

2. R&D, Knowledge Flows and Knowledge Production

The utilization of R&D findings and their conversion to innovations are critical to ensure that the economic benefits from scientific research are realized. But the conversion of research to innovation is not unidirectional as portrayed in the linear model of innovation. Instead, the innovation process is highly interactive with numerous feedbacks taking place.[2] A successful innovation requires the coupling of both the technical and the economic, rather than being solely a matter of 'technology push' or 'market pull' (Walsh, 1984). Such coupling, according to Mowery

1) For an excellent elaboration on the benefits of basic research, please see Salter and Martin (2001, pp. 509-532)
2) See Kline and Rosenberg (1986)

and Rosenberg (1989, p.8) implies close cooperation among many activities in the marketing, R&D and production functions. This nexus among the various activities has important implications for the way in which R&D institutions and their activities are managed.

The importance of managing the innovation process becomes all the more evident since, according to Macdonald (1986, p. 273) the innovation process is essentially an information process and successful innovation is the product of a total information package to which R&D makes only a contribution. Information contributions from other participants in the innovation process are just as vital. This diversity of information inputs from various sources suggests that the engine of innovative activities does not all lie within the formal R&D laboratories alone but can also be located in the firm's larger internal and external environment, in its own production and marketing system and in its relations with its suppliers, distributors and customers.[3] Case studies on partnerships in the agricultural sector (Hall, et al., 2001) remind us that successful technological development is a very complex process and is often a product from the interplay of personal, professional and institutional relationships which change and evolve rapidly over time.

The importance of such relationships and the process by which research gets converted into commercial innovation can also be represented in terms of knowledge flows. Innovation can be considered as a transformation process in which knowledge flows from various activities, including R&D, suppliers and customers are translated into a new or modified product or process. The transformation process is not automatic. Nor does it occur, as Spangenberg, et al. (1990, p. 241) argue, in a standard way. They submit that factors such as organisational freedom in budgeting and resource allocation, communication and environment for the implementation of strategic decisions are critical to the transformation process. Thus, how well these knowledge flows are organised and exploited and, ultimately, contribute value for the customer will determine the performance of the innovative or research activity.

The characterisation of the innovation process in terms of knowledge flows has important implications for the way activities such as R&D are organised as well as determining its potential impact and degree of utilisation of its findings. This perspective helps us to focus on the importance of adopting management practices that enhance the transformation of these knowledge flows from the stage of idea generation to adoption by the end-user. Also, by regarding the research-performing organisation as a knowledge system, we are able to put a spotlight on the

3) Von Hippel (1976, 1988) and several others (for example, Gamser, 1988) have demonstrated the importance of user interactions in the innovation process.

pivotal role of management in the research utilisation process.[4] A stylised representation of the key elements of the research utilisation process in terms of knowledge management is given below.

- The output of a research activity - undertaken either by industry or a public-funded organisation - is knowledge. This knowledge can be manifested either in a product, a process or a service. The success of the knowledge system, according to Wikstrom and Normann (1994, p. 104), will be decided by the way in which this knowledge is received by the end-users and the value that the knowledge represents for them. Knowledge which makes a big contribution to the customer's own value-creating process will have value for potential customers.

- The alignment of knowledge being developed with that actually demanded by the end-user underscores the need for partnership. And such partnerships can involve, besides the end-user, others such as suppliers, industry associations and other organisations. Such alliances, mean that end-users, as Wikstrom and Normann assert, must be regarded as co-producers in the research organisation's task to create value.[5] This 'value creating philosophy' as well as emphasis towards joint development must underpin research activities of universities and public research institutes. Additionally, partnerships with other organisations will also contribute towards providing resources to exploit ideas. Such co-operation is critical since no one organisation possesses skills across a wide range of disciplines.

- This emphasis on co-operation is particularly relevant since as Gibbons et al (1994) argue a new mode of knowledge production is emerging alongside the traditional familiar one. This new mode of knowledge production - categorised Mode 2 by the authors - is distinguished, among others, by its heterogeneity and organisational diversity. Linking these diverse sources of skills and sites of production would place a premium on developing partnerships and other forms of networking as expounded by Etzkowitz and Leyesdorff (2000) in their triple helix of university-government-industry relations. This new mode of knowledge production would require, according to its proponents, a new style of management where strategies designed to foster inter-linkages among institutions as well as enhancing the permeability

4) The idea for such a conceptualisation was adapted from Wikstrom and Normann's (1994) representation of a company as a knowledge system.

5) Wikstrom and Normann (1994), p. 128.

of institutions, are accorded emphasis. All these strategies and approaches will have to be people-centred since, as Gibbons, et al. (1994, p.164) assert, 'it is people who are the main carriers of competence.'

- People are the fundamental assets of an organisation, more so, in the case of a knowledge generating institution. They are, as Wikstrom and Normann describe, bearers of the knowledge on which the organisation's competence is based, and without competent people able to handle this knowledge, 'even the most advanced artefact will be useless.' Such a perspective underscores the important role of management in the acquisition of staff as well as efforts constantly to enhance the skills of existing staff. Raising expertise assumes importance since, as Cohen and Levinthal (1989, p. 569) remind us, the level of internal absorptive capacity will determine an organisation's capability to identify, assimilate and exploit knowledge from its external environment. These efforts at raising internal absorptive capabilities have characterised the successful technological build-up of Korean firms such as Samsung and Hyundai (Kim, 2002). Acquisition of technological competency is not automatic. It is a product of conscious learning efforts. Such learning efforts, according to Prahalad (1998), take place at various levels including the individual, the group and the organisation as a whole. The challenge for management is to enhance continuous learning at all levels through specific programmes / projects.

- All these relationships with end-users and the workforce mean that the transformation of the various knowledge flows must be viewed in a holistic fashion which has implications for:
  - The way the research activity is organised. For example, all the people and inputs responsible for ensuring the success of the project are assembled at the outset. Such an arrangement would mean that problems are quickly identified and that the output will contribute towards the satisfaction of the end-user;
  - The process by which the project is defined since the customer is regarded as the co-producer in the generation of the output of the project. A pre-feasibility study is often undertaken in order to ensure the viability of the project as well as to ensure that the project's specifications are in conformity with end-user's requirements;
  - The establishment of mechanisms to enhance interactions as well as to integrate the whole research process. Also, systems are in to enhance the knowledge mastery of the organisation;
  - The blurring of divisions within the organisation as well as its relationships with external bodies since interactions and linkages assume primacy.

How well all these knowledge flows and alliances are organised will determine the success or otherwise of the research effort. At the heart of this organisation lies management. And, it is management's task to ensure that the resources available to the organisation in transforming these knowledge flows - people, infrastructure and funding - are welded together through the adoption of proper systems in enhancing, what Nonaka (1992) describes as, the knowledge creation process.

The perspective of an R&D organisation as a knowledge system provides us with new insights on the dynamics of the research utilisation process. Such a portrayal has broad ramifications on the way R&D is conducted as well as on its transfer to the end-user. Above all, it demonstrates that if R&D is to be successfully undertaken and make a significant contribution both at the organisational and national level, it must be steered by sound management practices and not left to serendipity.

3. R&D, Uncertainty and Management

In recent years increasing focus has been given to the management of R&D which has emerged as a separate field of academic enquiry. This attention stems largely from the particular characteristics of R&D as an activity which is distinguished by its high degree of uncertainty, large investments and long gestation period. These characteristics place a premium on the management of R&D which is further compounded by the fact that its success is largely dependent upon the effectiveness of other activities over which it has no control.[6] The other functions that lie outside of R&D, for example marketing, manufacturing and distribution, must be adequately performed to assure the success of the R&D activity. Accordingly, the interface of these diverse functions assumes importance.

The management of uncertainty and the management of interfaces are two important aspects of the management of R&D. Sen (1988, p. 279) submits that the third area of management, vital to R&D, is the management of creativity. R&D is a creative activity and creativity, according to Walters (1965, p. 133), cannot be directed but, instead, must be cultivated. A successful R&D organisation is one that can strike the right balance between flexibility to enhance creativity and control to make the creative ideas compatible with the goals of the organisation. Getting the right balance, however, is not easy. As Twiss (1992, p. 23) emphasises there are no easy

6) See for example, Mansfield, (1982).

answers to this complex activity.

The complexities surrounding R&D do not suggest that it cannot be managed. On the contrary they reinforce the need for proper management given the inherent unknowns associated with this activity. Successful implementation of R&D, asserts Roussel *et al* (1991, p. 143) is fundamentally an activity aimed at reducing the uncertainties surrounding the outcome. Uncertainties can be reduced when there are systems in place to ensure that projects are properly selected, executed, monitored and modified using optimum resources of the organisation. Without proper systems in place it is argued that organisations may find that strategically correct projects turn into misfits and mishaps.[7)]

These uncertainties in R&D underscore the importance of managerial judgement since as Moss (1985, p. 5) emphasises there is no one management approach which may be appropriate for the entire spectrum of activities involved in innovation. Twiss also expresses a similar view by noting that each stage in the development of a new product or process has different characteristics and calls for a management style and the use of management techniques which may be quite inappropriate at another stage.[8)]

These differences add to the intricacies of managing R&D as mentioned earlier. Unlike a factory producing standard items and whose strict adherence to set routines is fundamental to productivity, R&D is essentially a knowledge creating activity whose outcomes are not repetitious and predictable.[9)] Its productivity is enhanced through the deliberate organisation of the creative and interpretative skills of its researchers as well as that of other external sources of knowledge production. The uncertainties surrounding this knowledge creation process would be reduced if there were systems in place that provided for timely interventions from management. Adoption of systems, besides helping to reduce uncertainties, would also contribute towards aligning the interests of the various parties involved in the research effort. However, R&D should never become so highly structured that the capacity to nurture serendipitious discovery is lost. At the same time, it should not depreciate the value of discipline in creativity. Striking the right balance between these two positions is never easy.

Several studies on innovation and new product development as well as references to the research management literature reveal the presence of certain characteristics or practices that are associated with successful innovations and which are frequently absent in failures.[10)] These

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7) Roussel, et al. (1991), p. 143.

8) See Twiss (1992), p. 14-15.

9) See Spangenberg et al. (1990), p. 24

practices, include among others, the following (not necessarily in order of importance):

- disciplined project management;
- communication and intelligence gathering;
- system focused approach to R&D management;
- building partnerships;
- marketing/transfer;
- leadership and commitment;
- a supportive organisational environment;
- people.

The presence of these factors alone will not guarantee success of the R&D undertaking. There is no magical formula that will ensure that this happens. However, sensitivity to these factors will contribute towards superior returns from R&D investments. Such returns have not been forthcoming from public R&D investments in Malaysia to which we turn next.

4. Overview of S&T in Malaysia

Key features of Malaysia's S&T can be summarised as follows.

i. Institutional development in S&T is of recent origin although some research institutions were established in the early part of the last century.

ii. Scientific activities are undertaken through several ministries although coordination is effected through the Ministry of Science, Technology and the Environment (MOSTE). Coordination of S&T activities of the various agencies is achieved through the National Council on Scientific Research and Development.

iii. National Science Policy was first formulated in 1986. Revisions to the policy were launched recently. New policy aims to achieve the following objectives:
   - R&D expenditure of 1.5% of GDP by 2010 (from present 0.5%);
   - R&D manpower of 60 RSEs per 10,000 labour force by 2010 (from present 15.6).

iv. The number of R&D personnel increased from 7 per 10,000 labour force in 1998 to

10) For an elaboration of these factors and characteristics, see Rothwell (1992), Cooper and Kleinschmidt (1993), and Steele (1989).

15.6 in 2000. Institutions of higher learning have the largest share of total R&D researchers (48.9%) followed by industry (30.9%) and the government research institutes (20.2%).

v. R&D expenditure rose from 0.39% in 1998 to 0.50% in 2000. Industry continues to account for the largest share of R&D expenditure even though its share has declined from 66.2% in 1998 to 57.9% in 2000. GRIs account for 25.0% of R&D expenditure followed by institutes of higher learning (17.1%). Applied research continues to obtain the largest share of R&D expenditure (51%), followed by basic research (27%) and experimental research (22%). The three fields of research with the largest share of total R&D expenditure include applied sciences and technologies (31.6%); information, computer and communications technology (22.9%) and engineering sciences (18%).

vi. The National Innovation Survey 1997-1999 revealed that about 21% of the firms in the manufacturing sector undertook innovation. The incidence of innovative activity differed from one industry to another with greater innovative activity reported among the high and medium-high technology industries. The proportion of innovative firms was highest amongst large firms compared to the small and medium-sized firms.

vii. Malaysia ranks a poor 63rd out of 69 countries in terms of total scientific and technical publications per GDP.

viii. The number of patents filed and granted is extremely low. Additionally, most of the patents files and granted were by non-residents. For example, 6,021 of the 6,227 patent applications in the year 2000 were from non-residents.

ix. National survey on commercialisation undertaken by MOSTE in 2003 revealed, among others, that poor commercialisation performance of public R&D due to weak infrastructure and poor linkages among public research institutions, academia and industry. About 5% of research projects undertaken in Sixth (1991-1996) and Seventh Malaysia Plans (1996-2000) were commercialised. Firm to firm collaboration is more prevalent than collaboration of firms with public research organisations. Industry is of the view that services offered by these institutions are irrelevant to their needs.

x. Many generic and specific incentives introduced to support R&D and technology development activities. However, many firms are not aware of these incentives, and for those that were aware, did not use them due to complicated processes involved in securing the incentives.

4.1 Overview of Public Sector R&D Management in Malaysia

Public R&D in Malaysia is funded through the Intensification of Research in Priority Areas mechanism (more commonly referred to as IRPA) which was first established in 1987. The increase in allocation under this programme under the various five-year development plans is as shown in Table 1. With the exception of the Palm Oil Research Institute of Malaysia (PORIM) and the Rubber Research Institute of Malaysia (RRIM) which also receive additional funding through collection of cess, IRPA is the only significant source of funding for R&D in public research institutions and universities. A total of 34 R&D institutions, universities and specialised government agencies are recipients of IRPA grants.

Table 1 : IRPA Allocation from Fifth to Eighth Malaysia Plans

Development Plan	Approved Allocation
Fifth Malaysia Plan (1986-1990)	RM 400 million
Sixth Malaysia Plan (1991-1995)	RM 600 million
Seventh Malaysia Plan (1996-2000)	RM 1,000 million
Eighth Malaysia Plan (2001-2005)	RM 1,363 million

Source : various Malaysia Plan documents

Malaysia's early growth has relied heavily on plantation and agriculture-based industries and public sector R&D has played a significant role in maintaining competitiveness, as well as providing a means of diversification into downstream secondary industries. It is significant that in the case of rubber and palm oil, the R&D effort has been mostly funded and strongly directed by industry. However, this influence has been largely absent in the manufacturing sector where much of the IRPA funded research are not in alignment of actual industry's needs. This disconnection of public R&D in the growth of Malaysian industry todate, has meant that links with R&D have not been well developed.

The weak linkages are just one of several gaps in the IRPA programme. Other major deficiencies include lack of market orientation; lack of priority focus; increasing bottom-up orientation; weak national R&D capacity; poor commercialisation and poor industrial R&D capabilities. Under the Seventh Plan the IRPA programme was revamped to address these weaknesses. Separate funding was made available to support industry R&D efforts but its weaknesses still remained.

In summary, the framework for S&T in Malaysia is sound albeit highly centralized. However, its potential has not been exploited. It is sound because it has structures for defining national

S&T and R&D priorities; it possesses authority to allocate resources towards implementing these policies and plans; and it provides avenues for coordination of S&T policies with those of education, trade and industry and other relevant policies. The failure to realise the potential of this framework lies with the deficiency at the fulcrum of the framework, that is, MOSTE, in not assuming a more dominant role in setting and directing the S&T agenda of the country. This deficiency is a consequence of the limited manpower resources endowed to MOSTE to steer this national agenda. This managerial deficiency at the center is also reflected in the research institutions and universities to which we turn next.

5. Key Findings from Studies on Research Management and Commercialisation in Malaysia

Recent studies on research management practices, commercialisation and industry-public sector linkages undertaken in Malaysia revealed, among others, that successful research does not happen by chance.[11] Instead, attention to a number of key research management practices and issues is critical in ensuring that the research effort is navigated successfully from the stage of idea-generation to adoption by the end-user. The key findings from these studies can be summarized as follows:

5.1 Adoption of Sound Management Practices

- Adoption of sound research management practices is central towards enhancing research utilization. Such practices help to reduce uncertainties surrounding the implementation of a research project. The studies revealed the importance of adhering to a number of management practices such as ensuring focused research; initiating preparatory activities prior to the research proper; provision of adequate funding; provision of demonstration facilities; forging linkages; developing marketing activities; sensitivity to non-technical factors; swiftness to market; research leadership and commitment; and adoption of a holistic approach to research utilization;

- There are wide disparities in the adoption of sound research management practices among PRIs and universities despite being subjected to similar external funding environment and civil service regulations. These disparities are a reflection of varying top management's

11) The material in this section is drawn from studies undertaken by Thiruchelvam (1996), Hii (2003) and Mansur (2003)

commitment to the research effort in these organizations as well as being a consequence of the deficiencies in the national public research funding mechanism;

- Lack of regular research assessment exercise has led to disparities as described above. Such exercises are critical to demonstrate to fund-receiving bodies that the Government is serious about the effectiveness of research spending. Absence of measures such as research audit to keep PRIs and universities on constant alert in terms of adoption of proper management practices would only promote weak research performance;

- The research process in PRIs and the universities, particularly the latter, is characterized by a linear approach whereby research projects are largely initiated by researchers and implemented in a sequential manner without addressing the end-user's requirements until the projects is about to be transferred to the end-user. Industry participation in many of these projects is minimal. Box 1 documents specific case study on the consequence of poor end-user interactions.

5.2 Linkages

- Linkages between industry and PRIs/Academia, although growing in recent years, are still minimal. Less than 15% of total research funding of PRIs and universities are derived from non-IRPA sources.[12] PRIs/Academia are not aggressive in reaching out to industry since funding is relatively easy to obtain from IRPA. Although self-financing targets for PRIs and universities have been identified in the second science and technology policy document, implementation of this measure has not been undertaken due to weak implementation capacity of the policy. As a consequence of this heavy dependence on IRPA funding, there has not been established (except in the agricultural commodity sector) a long standing relationship between industry and these research performing organisations;

- There are no attractive incentives offered for researchers to collaborate with industry. Also, researchers themselves perceive that working with industry is 'second class' compared to academic research;

- Industry has very little confidence in the ability of universities and PRIs to address their problems due to a number of factors including poor adherence to tight timelines by university personnel as well as lack of customer-service mentality among universities and PRIs. Industry expects local research institutions to hand-hold local industry long after the research findings have been transferred (see Box 2);

12) Communication with MOSTE official

- Industry does not require sophisticated technologies but, instead, simple adaptations or improvements to existing processes. PRIs and universities fail to address these needs and are also poor at promoting their research findings in terms that industry best comprehend - that is, cost savings or increased profits/sales.

5.3 Research Management and Funding

- Although separate business units have been established in almost all the universities to support commercialisation efforts, such units have, in most cases, been not effective due to funding difficulties as well as lacking the appropriate skills to perform this function competently. Accordingly, efforts to reach out to industry and other potential clients have not been aggressive;

- While there are sufficient venture capital funds in the system, the bulk of finance is still at the expansion growth and IPO stages. There is still a paucity of seed capital in the financial system (Bank Negara Malaysia, 2003);

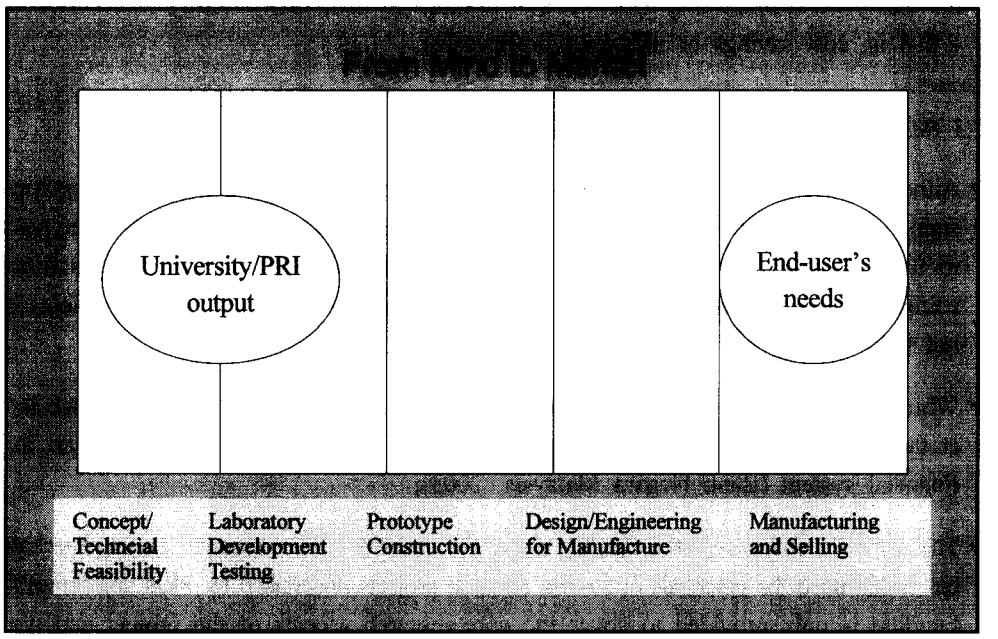
- The narrow focus in research funding under the national public research funding mechanism has undermined the potentials of several research projects undertaken by PRIs and universities. Funding is only provided to cover the core research aspects of the project and not its subsequent related activities that are crucial in transforming it to a form readily adopted by the end-user. Also, funding for pre-technical, prototype construction, design/engineering, technical extension and marketing activities undertaken by PRIs and universities are not provided. This gap in funding has resulted in most of the output especially from the universities to be at a stage where further development work is required before they can be adopted by industry (see Figure 1). Additionally, membership into networks or activities aimed at strengthening networks are not funded. Box 3 depicts case study of a promising research project that failed to realise its potentials due to lack of funds for further development work;

- Seeking research funding or incentives involve transactions with numerous government agencies. Industry has suggested that these incentives be streamlined and easy to access;

- Leadership and commitment from top management are essential in ensuring that systems and structures that are established to enhance the research utilization process are made to work for the organization. Most, if not all, the PRIs and universities under study boast of impressive screening, selection and monitoring systems. However, the implementation of these systems in many PRIs and universities has been unsatisfactory;

- Research projects undertaken by Universities are generally not linked to any strategic agenda. Accordingly, projects that are funded are widely diffused across a broad range of research

areas and do not lead to a consolidation in the development of particular set of capabilities.



Source : Adapted from Invetach (1993)

Fig. 1 : University's Output vs. End-user Requirements - The Transformation Gap

5.4 Governance

- PRIs and universities are constrained by civil service regulations from adopting more effective research management practices to enhance their research efforts. For example, PRIs and universities are not provided with the flexibility and resources to make quick decisions on administrative, financial or personnel matters;
- Senior appointments in Universities do not reflect importance of commercialisation activity. Presently, there is no separate Deputy Vice-Chancellor appointed for commercialisation unlike similar appointments for academic research, student affairs and development. This absence undermines the performance of public universities in developing and sustaining linkages with industry;
- The two public research organizations that have performed well (in terms of transfer of research findings) owe their success largely due to strong industry participation in their operations right from the outset of their establishment. They are essentially industry-specific research organisations;

- There is no clear policy in terms of intellectual property rights (IPR) ownership as well as on spin-outs.

In short, the findings suggest that management play a pivotal role in shaping and steering the national research system through attention to the following elements (not necessarily in order of importance):

Capital - comprehensive funding from pre-technical studies to marketing is crucial in order to enhance the research utilization process. Without such funding, brilliant ideas and promising research findings, will never reach the market place. Also, ease of access to funding as well as rigour in selecting projects are vital.

Connection - transforming knowledge into products or processes required by the end-user places a high premium on an organisation's ability to collaborate not only physically but also intellectually. Connections are needed to be forged not only within an organization but also across institutions, disciplines, sectors and nations.

Commitment - commitment from top management is vital for the success of any research endeavour particularly when its outcome is subject to numerous uncertainties. Systems must be in place to enhance commitment from all members of the organization as well as to reduce uncertainties in the research activity.

Competence - research is done by people and not by machines. The best and brightest minds must be attracted to careers in R&D. Additionally, skills of researchers must be continuously upgraded given the explosive pace in S&T developments.

Competition - a competitive environment for funding is essential to ensure that the best projects are being funded.

Culture - research will flourish in an environment that supports experimentation and is tolerant of failures. Also, culture of organization, particularly that of a PRI or a university, must encourage work with industry.

Customer - end-user's needs are correctly specified and incorporated as early as possible into the project's life-cycle. Correct identification means that the end-user's needs and affordability must be clearly understood.

Control - new institutional arrangements required to encourage greater industry participation and ownership of public research organisations to ensure more focused approach. Also, institutions cannot be organized according to civil service regulations.

Figure 2 depicts the interplay of these elements. Mere adoption of these 8'Cs' alone does not

guarantee success in the research effort. However, sensitivity to these elements is crucial towards enhancing the success of the research activity. These elements of successful research effort do not happen by chance. They must be made to happen. And making them happen and work for the organization is the central task of leadership at the project, institutional and national levels. It is to these managerial and policy issues that we turn to in the concluding section.

6. Conclusions

A number of managerial and policy implications emerge from the above findings as follows:

- Successful research utilisation is essentially a process issue. Disciplined research management and top management commitment are crucial in ensuring that sound research management practices are being effectively implemented in an organisation. Failure to exercise such discipline and commitment would result in the indifferent adoption of these practices as evident in many PRIs and universities;

- Adoption of a holistic approach to research utilisation in PRIs and universities would have implications on the funding of projects since all activities from the stage of preparatory studies to marketing of the research findings as well as provision of technical services should be supported. Also, inputs from all the parties involved in the project including the end-user must be actively sought prior to the implementation of the project;

- The weaknesses in the national public research funding mechanism (or IRPA), for example, the absence on adoption of sound management practices as a condition for funding - have failed to impress upon most of the PRIs and universities on the need to adopt sound research management practices;

- PRIs and universities are unable to adopt more responsive research management practices due to the need to adhere to civil service regulations. Such regulations have impeded their ability to take quick decisions as well as to initiate actions designed to enhance their research efforts. Additionally, public research institutions need to be more industry-specific in their operations in order to foster acceptance by industry of their activities;

- Building relationships and trust is central to any research endeavour particularly in a developing country environment where level of technological competence among firms is low. A more service-oriented approach is needed if PRIs and universities are to reach out to industry in order to build credibility and trust. However, such an approach will be enhanced by personnel, institutional and funding policies that promote such linkages.

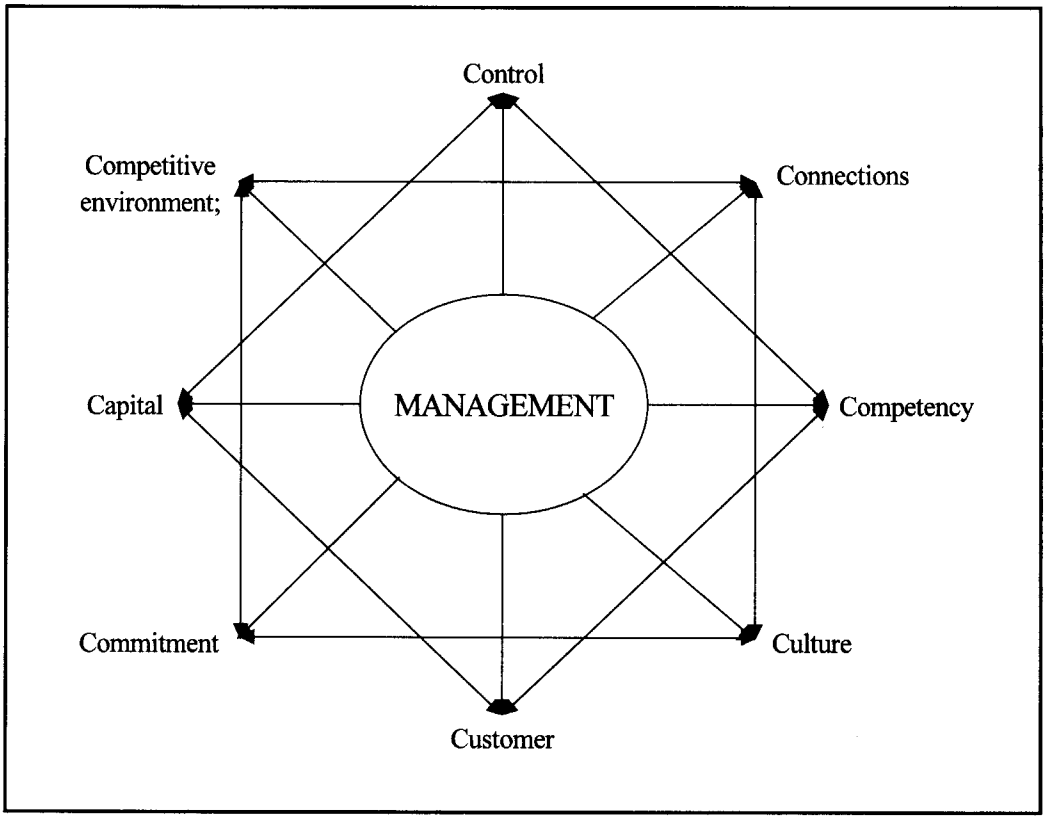


Fig. 2 : Key Elements in Managing Research

The above managerial and policy implications suggest that changes are necessary in the way public R&D is being organised and funded in Malaysia. These changes are essential so that the fruits of public R&D can contribute towards the acquisition and strengthening of the nation's technological capabilities. Such efforts would be aided by a public R&D enterprise that fosters institutional flexibility and creativity besides promoting a culture of sound research management practices underpinned by relevance, quality and partnership. These characteristics are absent in most PRIs and universities. Accordingly, institutional reforms as suggested by Intarakumnerd et al (2002) in the case of Thailand, is in order if Malaysia's National Innovation System is to evolve into a more dynamic and connected system. Such reforms will have to take cognisant of the local 'nuances' among public research institutions, academia and industry as emphasised by Hall et al and need not be mere transplants of what have been developed in other countries.

6.1 Towards Strengthening R&D Management

Enhancing research management demands unflinching commitment and leadership on the part of top management. Such efforts must be sustained and institutionalised lest organisations drift. These efforts would also be aided by an external environment which fosters the adoption of good management practices. This paper submits some suggestions towards strengthening the research management of PRIs and universities as follows:

6.2 Developing a Competitive Environment for Research Funding

The perception that IRPA funding is relatively easy to obtain, if left unchecked, may lead to indifference towards adopting sound research management practices since funding is seen not to be competitive. Accordingly, it is suggested here that the IRPA funding mechanism should be revitalised to ensure a more competitive environment for research funding. This can be achieved through the following measures:

- *Ensuring Research Funding to be More Focused and Stringent*

Given limited financial resources, it is vital that IRPA adopt strict guidelines in funding research projects. In the case of applied projects, only proposals that come with industry participation or are specifically addressed to solve industry problems would be considered for funding. Such a condition would ensure that partnerships with industry are encouraged.[13] Such stringent requirements would ensure that management in PRIs and universities reorientate their research activities as well as adopt tighter project management practices.

- *Instituting Research Management Benchmarking Exercise*

The uneven research management practices among the PRIs and universities, would, if left unchecked, have serious consequences on public sector R&D as a whole. Not only will scarce financial resources be wasted but more promising projects proposed by the better managed organisations may go unsupported. It is suggested here that a research management benchmarking[14] exercise be commissioned to gauge performance of fund recipient organisations according to

13) A recent World Bank funded study on Industrial Technology for Malaysia, concluded among others, that forging R&D-centred links between universities and industry would be enhanced if innovative activities of industrial firms are supported in the first place. (see Bell, et al., 1995, p. 16.)

14) Such an exercise is not new. For example, a benchmarking exercise was undertaken to examine the strategies for best practices in selected research and technology institutes from 8 countries (see Rush, et al., 1995).

standard research management practice. A research management league table can be prepared following this benchmarking exercise and organisations which continue to fare badly will find their funding support levels progressively reduced. Such an exercise would send a powerful message to top management of PRIs and universities to be fully committed to the research effort in their respective organisations lest they risk having funding levels drastically trimmed. Such an exercise will also inform policy-makers on how well investments in research are being expended.

6.3 Expanding the Scope of IRPA Funding

The present narrow scope of activities funded under IRPA, as evident from the case studies, should be expanded to include activities like development, upscaling, engineering and testing of research findings. Such activities are crucial in order to establish the parameters of utilisation by the end-user. Also, preliminary technical activities are vital in reducing uncertainties surrounding a research project and should be supported. Additionally, funding should be provided to assist the marketing activities of the Business Units of universities as well as promoting industrial technical extension activities among the PRIs. IRPA funding should also be expanded to cover partnerships with Malaysian and foreign scientists abroad.

6.4 Separate Funding for Promoting Linkages and Pre-seed Development

There is a pressing need for decentralisation of research funding in order to promote responsiveness among the PRIs and universities. Although PRIs and universities are presently provided with separate allocations for institutional funding, this is not sufficient to enable them to forge linkages with industry or to fund interesting ideas.

6.5 Autonomous Operations of PRIs and Universities

Much has been said about the constraints faced by PRIs and universities in adopting more effective management practices due to the rigidities imposed by the need to adhere to civil service regulations. It is imperative that PRIs and universities be granted greater autonomy to set their own administrative, personnel and financial procedures and conditions if they are to succeed in an operating environment where partnerships are crucial. Such autonomy can be achieved, for example, through administrative or statutory means. Whatever the route, such autonomy would ensure that PRIs and universities are able to take decisions quickly; engage in activities designed to enhance the utilisation of their research findings; review their institutional

structure so as to be more focused, less bureaucratic and more client-oriented; and introduce more appropriate remuneration schemes for recruiting as well as rewarding staff.

This paper has consistently argued that adoption of sound research management practices is crucial towards enhancing research utilisation. Adoption of such practices demands commitment and discipline at project, institutional and national levels. Without such commitment, pouring more resources to R&D will be futile.

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Appendix 1. Application of Enzymes for Processing of Clarified Fruit Juices

The process of clarification of fruit juices is well known. However, the application of enzymes in the processing of clarified tropical fruit juices is still new. A team of two researchers from a local university undertook a project to ascertain the feasibility of producing clarified fruit juices using local fruits such as guava, rambutan and pineapple. No soft drink manufacturer was approached at the outset to participate in this project.

After three years of experimentation and sensory testing evaluation, the project team reported technical success in their efforts particularly in the clarification of guava juice. However, no techno-economic studies were undertaken to cost the production of clarified local fruit juices on a commercial scale or how such production could be incorporated into the existing operations of local soft drink manufacturers. In addition, no serious efforts were made by the researchers or the university to market the research findings. This hands-off attitude was partly due to the prevailing culture then where utilisation of research findings was not given due emphasis.

This project reveals that despite promising technical findings, failure to address specific end-user requirements or obtain end-user participation at the outset has resulted in its failure to be utilised (Thiruchelvam, 1996).

Appendix 2. Development of an Automated Sealing and Capping Machine

Care Food Industries Sdn.Bhd.'s sambal (a local fish paste) tastes good but, according to the firm's owner/managing director Mr. Mickey Quah, it had problems selling the product initially because of packaging problems. The firm experimented with various machines and techniques but to no avail. Such a process required machinery which could not be purchased off the shelf as the packaging must be specially designed.

He then contacted SIRIM as it had earlier successfully completed a project for the company. SIRIM developed a five-part automatic sealing and capping machine(ASCM) to trim, seal, cap label and package the food products after almost 18 months of research. Since then the ASCM has improved the consistency and quality of the food pastes, enabling Care Food Industries to make the break into the export market. The machine consists of a receiving station, sealing cum trimming station and capping station linked together by a material handling robot. The whole system is controlled by a programmable logic control.

Basic skills to assemble the machine were available within SIRIM. The project leader visited some local food industry exhibitions to obtain some ideas for the machine. Although the firm lacked technical knowledge they provided valuable inputs to SIRIM on the problems they faced with the previous mechanical machines. The firm cooperated very closely with SIRIM in all phases of the project and this close cooperation contributed towards the success of the project. After the machine was commissioned, SIRIM continued to provide after sales technical service in order to ensure that the machine was running smoothly. Some problems were encountered and were attended to immediately.

Cost of the project was borne by both SIRIM and the company. Presently there is no firm in Malaysia that develops such purpose-built machine. SIRIM has received offers to develop similar machines for others.

Both parties benefited from this joint project. The firm gained through automated packaging of its product whilst SIRIM acquired the expertise in developing a customised equipment for automated vacuum sealed packaging line. Presently, the firm's food pastes are exported to Japan, Canada and Australia. This is a big achievement considering that it is a newcomer to the food processing industry, having just started in the business in late 1989 (Thiruchelvam, 1996).

Appendix 3. Automated Post-Bond Wire Inspection in Integrated Circuit Assembly

Wire bonding is a step in integrated circuit (IC) assembly during which physical connections are made between the integrated circuit ("die") and the package leads using wires. Despite the dramatic improvements which have been made in the design of mechanical bonding machines, a significant number of faults can still occur due to incorrect bonding and breakage in the bonding wire. The situation is exacerbated as the density of integrated circuits increases following an increased number of bonds per chip. To ensure quality and reliability of the manufactured ICs, products of the bonding process must meet specifications established by international standards. Meeting these standards mean that inspection becomes crucial. The current trend towards minitiaurisation and denser packing makes inspection tasks even more difficult.

Given the above problem, a research project was proposed to develop an automatic visual inspection system designed to inspect the quality of wires in the IC assembly process. Such a system has been used in other industrial applications but not in wire inspection. The project was funded under the IRPA mechanism. It also received a grant of RM 30,000 from Intel

Technology Malaysia Pte Ltd. The firm, however, was not involved in the formulation of the project nor did it request any particular task to be addressed in the project. But the firm participated actively in the project through the provision of samples for testing of the system as well as providing inputs to the system developed by the researcher.

The research achieved satisfactory results at the laboratory scale. Despite the promising results and the potential of such applications Intel was not keen to invest in further developing the system. According to one source,[15] their reluctance is because they expect further work to be undertaken to the system which has not been developed to a full working model. Such a full scale working was not developed due to limited funding for the project. The researcher is planning to submit a proposal for funding to cover further development work to this system which has been tested at the laboratory scale.

This project emphasises the need for researchers particularly in developing countries to develop complete systems or working models before they can expect industry to utilise their findings (Thiruchelvam, 1996).

15) View communicated to writer by senior Intel research staff member.