The importance of internal and external R&D network linkages for R&D organisations: evidence from Singapore

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This paper examines the importance of internal and external R&D networks for R&D organisations of multinational firms (MNCs) in Singapore and investigates corresponding R&D management requirements in this context, namely a late-industrialising country in Asia. A unique feature of Singapore is its ability to attract 'high quality' foreign direct investment, involving activities of higher value added and more complex technology without having developed full-fledged R&D activities among its business organisations, thus creating a challenging situation for subsidiary R&D managers, both in the internal R&D organisation as well as in the external research environment. This paper analyses these issues.

Based on in-depth interviews with 53 R&D subsidiaries of MNCs operating in Singapore, this paper identifies internal and external R&D management needs. Through our analysis of data gleaned from these interviews, we found that subsidiary R&D managers need to increase and/or maintain the strategic importance of their R&D site internally within their global corporate R&D organisation. This requires constant upgrading of the technological level at the R&D subsidiary and intense communication with headquarters as well as other R&D subsidiaries. Furthermore, our findings indicate that in the external research environment, subsidiary R&D managers need to create an efficient local network of external players. If these internal and external issues are properly addressed, the R&D subsidiary can effectively contribute to the corporate R&D organisation and be a critical partner in the local research network. Lessons learned from the Singapore experience include the need to develop sufficient local expertise as well as to change the mindset of managers to focus on creativity rather than precise execution.

1. Introduction

R&D investment outside the traditional triad regions is a relatively recent, but increasingly important phenomenon (Amsden and Tschang, 2003; Reddy, 1997). This R&D investment raises issues about its implications both for corporate as well as national competitiveness. More specifically, how R&D subsidiary managers need to address both internal as well as external R&D management needs in a latecomer country such as Singapore has not yet been investigated. These R&D management needs are examined from a network perspective in this paper. It is the goal of this paper to contribute to a more differentiated view on these internal and external R&D management needs.

Most research has adopted the viewpoint of firms and as such R&D organisations as autonomous entities (Barney, 1991; Porter, 1980; Wernerfelt, 1984). However, firms and as such R&D
organisations are embedded in networks encompassing a firm’s relationships with other organisations both internally and externally (Gulati et al., 2000). Such networks are increasingly important providing an R&D organisation, for instance, with vital information on new technologies (Gulati, 1999). It is understood that synergies for innovation has been understood to have been derived from such global R&D linkages (Bartlett and Ghoshal, 1998). Previous studies have also indicated the importance of ‘informal’ communication networks in information flows across nations (Cooney and Allen, 1974). Despite the importance of networks for the R&D organisation, only a scant literature examines the importance of internal and external networks for corporate R&D and its implications for inter-R&D profitability (Andersson et al., 2002; Gulati, 1999; Gulati et al., 2000). Moreover, the literature has focused on external networks and has not considered the interaction between internal and external networks. Such internal as well as external R&D network configurations, however, can constitute a competitive advantage for the R&D subsidiary and for the R&D organisation as a whole if the thus resulting R&D management needs are addressed accordingly. Furthermore, the interaction between the two is viewed as important multinational advantage (Andersson et al., 2002).

In this paper, R&D networks refer to both internal (within the corporate R&D organisation) as well as external (with the host environment) R&D network configurations. More specifically, internal R&D networks refer to the R&D site’s relationships with other internal R&D sites as well as headquarters. External R&D networks refer to the R&D site’s relationships with external parties in the local context, namely research institutions, other firms (local and multinational), and the government (for more definitions of networks see Blankenburg Holm et al. 1999; Gulati, 1998; Gulati et al., 2000).

In the internal R&D network three types of relationships (tie modality) have been distinguished (Vereecke et al., 2002). First, relationships of human resources refer to the human resources flow between the different R&D sites and with headquarters. More specifically, the human resources flow refers to the development of critical R&D personnel in the internal R&D organisation.

Second, relationships of innovation are examined. This relationship configuration investigates in how far the locus of innovation is at the R&D subsidiary, at headquarters or at other R&D sites, namely whether R&D sources are at the subsidiary R&D site or whether core technologies are transferred for further development to the respective R&D subsidiary.

Third, relationships of information are subject to investigation. This type of tie modality examines the degree of freedom the R&D subsidiary enjoys, if for instance the R&D subsidiary has to closely follow the R&D program determined by headquarters, if it can show own R&D initiatives and/or if it has a say in the R&D program.

Furthermore, it is examined if these tie modalities occur between R&D subsidiaries and/or between the respective R&D subsidiary and headquarters. The resulting membership structure is then subject to discussion.

The same distinction applies to the external R&D network. Both the tie modality along the dimensions of human resources, innovation and information as well as the membership are examined. This is in accordance with the literature, which distinguishes between relational and structural external network linkage (Andersson et al., 2002). While these concepts have been used in a general context, they have not been applied to R&D subsidiaries. By examining both the tie modality as well as the membership of the external network, we attempt to adequately reflect the external network linkage for R&D subsidiaries.

After analysing the internal as well as external R&D network, its interaction is examined. While internal and external network linkages are important for the R&D subsidiary, its interaction is critical as well. Based on the internal and external R&D network linkage, the R&D subsidiaries under investigation are classified according to four different types of R&D subsidiaries (see Figure 1), namely as loosely linked R&D subsidiary, semi-linked, internally oriented R&D subsidiary, semi-linked, externally oriented R&D subsidiary and fully linked R&D subsidiary.
subsidiary, semi-linked, externally oriented R&D subsidiary, semi-linked, internally oriented R&D subsidiary and fully linked R&D subsidiary.

This paper proceeds as follows. The following section illustrates the context of the R&D investment, namely a late-industrialising country such as Singapore. Third, the conceptual framework is discussed. The fourth section introduces the methodology before the results are discussed. A final section concludes.

2. The context of Singapore: economic development and the fostering of R&D activities

The following outline of the context of Singapore serves as a basis to understand the late-industrialising context in which the R&D investment under discussion takes place. Late-industrialising countries like Taiwan, South Korea and Singapore have much higher US patenting activities compared to other emerging economies of Asia and Latin America (Mahmood and Singh, 2003). These countries have national innovation policies which are believed to have made a significant difference to their economic development and progress (Shyu et al., 2001). The Singapore government has consistently promoted economic development since Singapore’s independence in 1965. Starting with the promotion of labour intensive industrialisation in the 1960s, Singapore progressed to attract capital intensive industries in the 1970s, high-tech and high value added industries in the 1990s and R&D activities in the 2000s. Through these years, Singapore has progressed up the technology ladder with improving infrastructures and changing the incentives and policies environment to attract different types of foreign direct investment (FDI) according to its economic developmental needs.

Singapore’s industrial policy has been focused on manufacturing in the beginning of its industrialisation in the 1960s. Singapore adopted a technology leverage strategy towards MNCs by encouraging FDI through highly favourable conditions and the promotion of own domestic firms’ development as suppliers of goods and services to these MNCs, with the goal of raising overall technological capabilities. This strategy has resulted in sustainable industrial development and was mostly based on manufacturing (Matthews, 1999).

With new economies in Asia gaining importance in manufacturing, such as China, Malaysia, Indonesia and Thailand due to their lower manufacturing costs compared to Singapore, manufacturing activities are increasingly transferred from Singapore and other more developed countries to these neighbouring countries. To maintain themselves, many companies based in Singapore, which include the subsidiaries of MNCs, have also upgraded themselves by leveraging on their knowledge and experiences through R&D activities in the manufacturing process technologies as well as becoming training centres and technology transfer centres for the region. At the same time, the Singapore government intends to upgrade Singapore’s economy further by attracting new types of industries and developing more R&D activities to ensure its future economic development and growth. This has led to Singapore’s recent economic policy which aims at the growth of economic activities beyond manufacturing and thus at the transformation of its economy into a knowledge-based economy. Strong emphasis is now placed on fostering R&D activities. Singapore’s recent science and technology policy is based on building up research activities as they are conducted in the triad nations (US, Europe, and Japan; the internationalisation of R&D is still confined to these triad nations, see Edler et al., 2002). While R&D activities are fostered in all sectors, the most recent efforts focus on the biomedical sciences. The R&D capabilities in this sector comprise the pharmaceuticals, medical devices, biotechnology, and healthcare services sector. As part of this strategy, the Singapore government has decided to build the biomedical sciences industry as the economy’s ‘fourth pillar’, the other three ‘pillars’ being electronics, chemicals, and engineering (Wess, 2002). The two main government institutions, the Economic Development Board (EDB) and the Agency for Science, Technology and Research (A*Star), are responsible for Singapore’s economic policy.

An example of one of the first firms investing in the biomedical sciences is the Swiss pharmaceutical firm Novartis, which has established a Novartis Institute for Tropical Diseases to conduct research on the diseases of dengue fever and tuberculosis. A further example is the investment by the American pharmaceutical firm Eli Lilly in form of Lilly Systems Biology, which was one of the first firms to receive funding from the Singaporean government’s US$600 biomedical sciences fund. The growth target for the biomedical sciences sector is a 10% contribution to Singapore’s total manufacturing output by 2010 (Yong, 2003).
A*Star has identified three key thrusts in its science and technology policy: to strategise public research to integrate with industry clusters; to train human capital for research and industry; and to create, own and exploit (COE) intellectual capital, for instance by offering incentives schemes such as the ‘R&D Assistance Scheme’ or the ‘Cooperative Research Program’. The stimulation and entrenchment of R&D in Singapore-based private sector firms are key goals (Agency for Science, Technology and Research, 2001).

Besides A*Star, the EDB also plans and executes strategies to sustain Singapore’s competitiveness. It enables multinational and Singapore-based companies to enhance and upgrade to higher value-creating operations. Furthermore, the EDB offers various incentives for fostering R&D activities.

This illustration of the context of Singapore attempted to show the specific characteristics of a late-industrialising country. Even though one might argue that Singapore is a rather special case due to its size and specific government regulations, we would still argue that Singapore has certain common characteristics pertaining in general to late-industrialising countries. First, its industrialization efforts only started in the 1960s. Second, as in the case of other late-industrialising countries, technology leverage has been important in creating a certain knowledge and skill base. And third, consistent efforts in promoting the economic development are typical of a late-industrialising country (also see Amsden and Tschang, 2003).

3. Internal and external network linkage: a conceptual framework of its interaction

While previous literature has looked at internal and external R&D networks separately, this paper attempts to analyse its interaction. The internal R&D network is important for the R&D subsidiary in three ways (Vereecke et al., 2002): first, it enables the R&D subsidiary to gain and develop critical human resources, to actively participate in the corporate R&D program and to be internally connected information-wise. These internal ties reflect the extent to which the R&D subsidiary is embedded in the internal R&D organization and refer to relationships with other internal R&D sites as well as headquarters.

External R&D network linkage refers to the R&D site’s relationships with external partners in the local context, namely research institutions, other firms (local and multinational), and the government. Being a critical external partner in the local R&D network allows the R&D subsidiary to tap into critical human resources, to gain new and/or complementary knowledge and to enhance/maintain its competitiveness.

In general, it has been posited that there is a link between internal and external network linkage (Asakawa, 2001). Examples of such a simultaneous interaction include that adequate support by the internal network will lead to important external network linkage. On the other hand, well-managed external network linkages will provide key R&D sources for the internal network. The main caveat in this interaction is to maintain an optimal balance between the two network linkages in order to avoid dispersion and information leakage in the external network linkage and a too strong control by headquarters and/or other R&D sites in the internal network linkage.

This paper attempts to provide a more systematic approach to this interaction between internal and external network linkages. Four scenarios in this interaction have been depicted in Figure 1 and are explained in more detail below.

Type 1: Loosely linked R&D subsidiary

This type of R&D subsidiary is dislocated from the main R&D sources of the internal R&D organisation as well as of the external R&D network. As Hobday (1995) correctly states, this isolation makes it difficult for the R&D subsidiary to reach a higher technological level. The number of internal relationships the R&D subsidiary is engaged in is low. This refers to all types of tie modalities, namely human resources, innovation and information. No critical human resources development and acquisition from external resources takes place. There are no external innovation impulses and no information exchange with external parties.

Overall, the R&D subsidiary is of low strategic importance. It does neither contribute to the
internal R&D organisation in a significant way nor it is seen as a critical partner in the external R&D network. Therefore, the loose simultaneous interaction of the two network linkages negatively affects the competitiveness of the R&D subsidiary. It is particularly difficult for this type of R&D subsidiary to leave this stage and to reach a level of higher strategic importance.

Management needs for this type of R&D subsidiary include identifying critical partners both internally and externally. Communication is key within the internal R&D network to report progress on ongoing R&D projects in order to increase trust. This in turn allows the internal R&D organisation to assign more technologically complex R&D projects to this type of R&D subsidiary and contribute to the development of human resources in this R&D subsidiary. In the context of late-industrialising economies, it is crucial to develop external relationships, especially with the respective government bodies, which can provide both information on the external network as well as R&D grants.

**Type 2: Semi-linked, externally oriented R&D subsidiary**

The R&D subsidiary is regarded as critical partner in the external R&D network, however is considered of low importance by the internal R&D organisation. Overall, the R&D subsidiary is of medium strategic importance. The critical human resource acquisition and development takes place from the external network only. With regard to innovation, the R&D subsidiary is isolated from core technologies from the corporate R&D organisation, but receives innovation impulses from the external network. Information-wise it is loosely connected with the internal R&D organisation. The information flow with the internal R&D organisation is infrequent and at a low level in contrast to the external information flow which is frequent and mutual.

It is of paramount importance to communicate to the internal R&D organisation that the R&D subsidiary has managed to be a critical partner in the external network and that the knowledge of this external network is important and should be effectively used and transmitted in the internal R&D organisation. This, in turn, would allow the R&D subsidiary to balance the interaction between internal and external network linkage more towards the internal network linkage.

**Type 3: Semi-linked, internally oriented R&D subsidiary**

This type of R&D subsidiary is the opposite of R&D subsidiaries belonging to type two, but also of medium strategic importance. It has none to few relationships externally, but is highly interlinked in the internal R&D organisation. Critical human resource acquisition and development takes place internally only. Furthermore, the R&D subsidiary actively participates in the internal global R&D program, but receives no external innovation impulses. The information exchange takes place mostly internally. Obviously, the interaction between internal and external network linkage allows an efficient internal connectivity, but not sufficient local autonomy for the R&D subsidiary. The R&D subsidiary is not engaged in crucial external research collaborations.

The R&D subsidiary should hence start and/or increase external collaborations to be perceived as critical external party, to be able to tap into the external knowledge and to receive new external innovation impulses. This will also allow the R&D subsidiary to increase its strategic importance in the late-industrialising economy.

**Type 4: Fully linked R&D subsidiary**

The last cluster is the ideal case so to speak. The R&D subsidiary is perceived as critical partner both internally as well as externally. This allows the R&D subsidiary to have the ‘best of both worlds’, that is strong internal as well as external tie modalities. Internally, it is connected through critical human resources, core technologies and mutual information exchange. Externally, the R&D subsidiary can access critical human resources, complementary and new knowledge and is able to receive grants by the local government since it is considered critical for the economic development in the late-industrialising country.

To reach this stage has been considered by various respondents as a ‘fine line to walk’. The management of this type of R&D subsidiary requires a constant balance between internal and external R&D management needs. If this balance can be maintained, this type of R&D subsidiary may reach the same status as R&D subsidiaries in the triad nations.

**4. Methodology**

An exploratory study consisting of several in-depth interviews with R&D managers of MNCs...
was conducted before starting the fieldwork in Singapore. This exploratory phase, which allowed to get close to the phenomenon under investigation, led to the development of a questionnaire and was also used for pre-testing the survey instruments and as a cross-check against questionnaire responses, thereby improving internal validity and the interpretation of findings. As the basis for in-depth interviews with the respondents served this questionnaire.

In this questionnaire, R&D managers were asked about their internal and external R&D network linkage. In respect to the internal R&D network linkage, three criteria were used to determine the degree of internal R&D network linkage (low, medium, or high internal R&D network linkage; also see Figure 2). Overall, respondents were asked about the human resources flow, the innovation flow and the information flow between their R&D sites, other R&D sites and R&D headquarters as well as external parties. Respondents indicated to what extent they were able to gain and develop critical human resources (acquisition, development and training of critical human resources) through the collaboration with external parties. They were also asked to what extent external parties are important for the R&D subsidiary in terms of innovation. With regard to information, R&D managers were asked to what extent they are free to interact with external parties and how important such an information exchange is for the R&D subsidiary. And finally, questions were asked about the interaction of the internal and external R&D network linkage, for instance to what extent close internal R&D network linkage impacts external R&D network linkage.

Besides this questionnaire, which allows inter-firm comparability, the researcher gathered firm-specific data and data on management issues the respondent (senior R&D managers, R&D directors and/or managing directors) considered highly relevant for managing the respective R&D subsidiary. This approach allows gaining standardized data by addressing a specific set of questions for each firm, but the researcher can also investigate important firm-specific issues, which enable the researcher to better understand the firm-specific context. Furthermore, due to the direct interaction between researcher and research subject, the researcher can immediately respond to the information given, can ask additional questions, can clarify doubts, and can gather supplemental information through observation (Emory and Cooper, 1991). This research method also allows the researcher to constantly improve the in-depth interview (e.g., questions can be more clearly phrased, interaction between respondent and researcher can be optimized). The unit of analysis is the firm specific R&D organisation (R&D site or R&D department). As unit of analysis the R&D subsidiary was chosen because it is relatively easy to identify, its size can be determined and an R&D subsidiary involves a more long-term commitment than for instance a sole research agreement (Kuemmerle, 1996). This study examines multinational firms, since they are particularly active in establishing R&D sites abroad (von Zedtwitz and Gassmann, 2002).

Overall, the researcher conducted 71 interviews with 53 R&D subsidiaries of MNCs, two research

![Figure 2](image_url). Classification of R&D subsidiaries according to their internal and external network linkages in our sample.
institutions (Singapore Institute of Manufacturing Technology and Institute of Bioengineering) and the two main government bodies (EDB and A*Star) in this cross-sectional study. A specific set of R&D subsidiaries was revisited several times to gain more in-depth insights into the internal and external R&D management needs facing the R&D subsidiary. Both the managing directors as well as the R&D managers for the different R&D departments were interviewed. Out of the 53 R&D subsidiaries, 10 are Japanese, 20 American, 19 European and 4 R&D subsidiaries with other nationalities. Overall, 15 R&D subsidiaries belong to the electronics sector, 9 to the information technology and communication sector, 15 to the biomedical sector, 5 to the engineering sector and 3 to other sectors (food and aviation sector). The industry classification is based on the National Survey of R&D in Singapore 2001, which is conducted annually by A*Star. According to this National Survey of R&D in Singapore 2001, there are 206 private firms (either wholly foreign-owned or have less than 30% local ownership) conducting R&D in Singapore in 2001 in the above-mentioned industries. The sample of 53 subsidiaries therefore translates into a response rate of 26%.

5. Empirical evidence

The 53 R&D subsidiaries have been classified according to the four types of R&D, which have been discussed in section three. The result of this classification is depicted in Figure 2.

As we can see from Figure 2, few R&D subsidiaries belong to type one or three, that is, their external network linkage is low, their internal network linkage low to medium. Most R&D subsidiaries seem to be semi-linked, externally oriented R&D subsidiaries that is they are critical partners externally, but fail to be perceived as critical R&D subsidiaries internally. Hence, it is of paramount importance to communicate to the internal R&D organisation that the knowledge of this external network is important and should be effectively used and transmitted in the internal R&D organisation. This in turn would contribute to a stronger internal network linkage and improve the interaction between internal and external network linkage in order to ideally reach cluster four.

Some R&D subsidiaries have indeed reached or are close to reach the stage of a fully linked R&D subsidiary. These firms belong mostly to the electronics sector. This result is not too surprising since Singapore’s economic policy has been effective in building up expertise in the electronics sector. The question arises if this development is replicable for the biomedical sciences sector, which is relatively new to Singapore’s economy. So far most R&D subsidiaries of MNCs belonging to the biomedical sciences sector are part of group two, that is, they are critical external partners, but not perceived as such in the internal R&D organisation.

6. Conclusion

Challenges for late-industrialising economies in attracting more and higher-level R&D activities are twofold. First, late-industrialising economies need to develop sufficient local expertise, in the case of Singapore especially in the newly created biomedical sciences. Currently, there is a shortage of high-level research personnel. For instance, only 8.2% of the 1,930 researchers in government research institutions are Singaporeans with PhDs, which amounts to only 160 PhD holders (Yong, 2003). For the development of critical human resources, an expansion and upgrading of the university system is necessary as well. Closely linked to this development of critical human resources is the challenge of changing the mindset of researchers from mere execution to more creativity. While lower-end R&D activities, which are closely linked to manufacturing (for a detailed discussion of R&D classifications, see Amsden and Tschang, 2003), require more execution skills, higher-end research projects require more creativity.

A second challenge refers to technological upgrading of the R&D subsidiaries. If R&D subsidiaries reach a higher level of technological complexity, their internal network linkage can be increased and they can be perceived as critical players also in the internal R&D organisation. The Singapore government has been proactive to upgrade the technological capabilities of the R&D subsidiaries by encouraging collaborations with government-owned institutes and research laboratories and funding corporate R&D training in the internal R&D organisation. The R&D subsidiaries themselves may also have to apply different methods of technological upgrading in order to increase their internal network linkage and be regarded as strategic partners.

Future research is suggested in the following directions. Future studies should include more late-industrialising countries in order to examine
if the results of this paper also apply to other late-industrialising countries and to examine potential differences between late-industrialising countries. Furthermore, future studies could investigate which performance measures both on a firm as well as national level are most appropriate to evaluate the government’s efforts of fostering R&D activities. The present paper represents only a first study analysing the internal as well as external R&D management needs arising from the late-industrialising context.

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