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CHAPTER 9

Integration of Manufacturing and Development in Emerging Markets

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ABSTRACT

The chapter investigates the problems related to the functional integration between manufacturing activities and research and development (R&D) activities in emerging markets within multinational companies. A framework to this end is developed and illustrated through four case studies from multinational companies, which have established R&D and manufacturing in China or India. The findings point to the importance of adopting cross-function co-location drivers and contingencies, such as clockspeed and technological complexity, as well as the extent to which local adaptation is needed as an integral part of corporate relocation decisions.

INTRODUCTION

There are many reasons for multinational companies (MNCs) to internationalise their research and development (R&D). One of these reasons is to locate R&D alongside manufacturing activities which have already been offshored to emerging markets. As a result, R&D internationalisation may decrease the negative impact which physical distance is known to have on knowledge flows (Allen, 1977). Internationalisation of R&D thus makes it possible to take advantage of the proximity to well-established manufacturing units in order to reduce

administrative overhead, as well as to draw on existing links to the external environment in terms of access to labour, supply and technical and legislative conditions. However, these benefits are likely to differ across companies. Different implications for innovation performance are likely to exist across companies in relation to whether or not foreign-invested R&D is co-located with manufacturing activities in emerging markets.

Co-location is a well-recognised strategy for coordinating a complex task environment (Galbraith, 1994), and it is particularly beneficial as a means for coordinating activities, which should result in productivity growth and innovation (Porter, 2000). Previous research has primarily focused on the interface between R&D and marketing (e.g. Lu & Yang, 2004), rather than R&D and manufacturing (Song et al., 1997). This chapter, therefore, sets out to explore differences in the innovation performance of foreign-invested R&D subsidiary locations in emerging markets as a factor of core technology – and more specifically, interdependencies related to whether or not R&D and manufacturing is co-located. We are therefore pursuing the following research question: What determines the need for co-location of R&D and manufacturing in emerging markets?

In the following, this chapter will provide a framework relevant to understanding the dynamics related to functional interdependencies and resulting co-location needs of foreign-invested R&D and manufacturing activities in emerging markets. Subsequently, this framework will be illustrated in the empirical findings and analysis sections, which also provide evidence of the specific advantages experienced by multinational companies co-locating R&D and manufacturing activities in emerging markets, before relevant conclusions are outlined.

THEORETICAL FRAMEWORK

The need to align choices about process, product and structural arrangements is by no means new (Galbraith, 1994) and co-location is one key mechanism for this alignment. When manufacturing and R&D are located closely together and structurally tightly coupled, R&D person-

nel may direct more attention to problems experienced by manufacturing personnel. Thus, a risk may exist that R&D personnel will be excessively exposed to existing short-term problems of the company rather than the unknown future problems of the company. In addition, one can speculate that when R&D activities are closely integrated with manufacturing activities, R&D personnel have a tendency to disturb manufacturing somewhat, e.g. by conducting frequent test runs on manufacturing equipment. In other words, close integration and co-location of R&D activities and manufacturing activities may not always be beneficial. However, in the following, we will outline a couple of conditions under which it may indeed be advantageous.

Local industrial resources

Nobel and Birkinshaw (1998) outline a typology of roles for foreign-invested R&D units comprising 'local adaptors', 'international adaptors' and 'international creators'. Their findings indicate that for local adaptors and international adaptors alike, manufacturing units constitute the main communication partners within the company. However, whereas local adaptors primarily interact with local manufacturing, international adaptors primarily interact with an international network of manufacturing units, with which they are most likely not able to be co-located. However, the interaction between local adaptor R&D units and the local manufacturing units they support is likely to benefit from co-location.

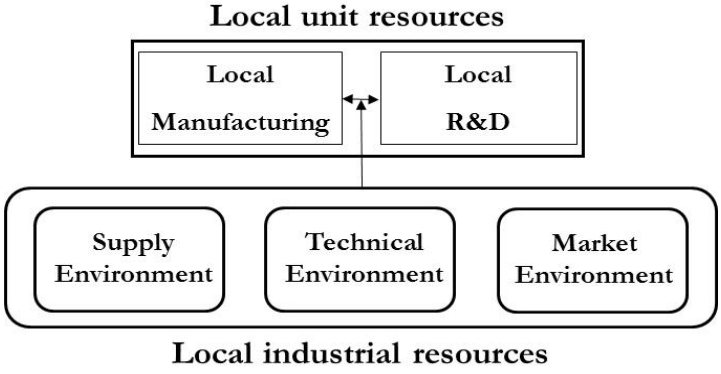
In emerging markets, locally available industrial resources are likely to differ from the industrial resources available in more mature and developed markets. As illustrated in Figure 1, this is liable to have implications for the interface between local R&D and manufacturing, and whether this interface is needed. The market environment may differ, e.g. in terms of customer needs. Through adaptation to local needs, the competitive position of a product can be strengthened (Hill & Still, 1984); however, the extent to which local adaptation is needed may differ substantially. Local manufacturing may need more R&D support than otherwise if much local adaptation is needed. It may be possible to source such R&D support from the local market. On the other hand, in emerging markets, this may be more difficult for the MNC to

do than in developed markets, e.g. it may be difficult to find knowledge suppliers who have the necessary level of competence or specific experience. In addition, the risk of negative knowledge spillover in the often weak intellectual property regimes present in emerging markets may make captive R&D offshoring the preferred solution to mitigate such risks in relation to knowledge-intensive activities such as R&D. Hence, different companies may find it more or less relevant to co-locate R&D and manufacturing in a certain location, depending on the local industrial resources. In particular, the need for local adaptation of products may be important.

Clockspeed

Fast-paced clockspeed industrial settings are described as the fruit flies of competitive strategy. This is due to their fast pace of change with regards to underlying technologies, business models and supply chain relations, which are believed to illustrate a likely future for slow-

Figure 1: The interface between local manufacturing and local R&D in emerging markets.



er paced industries (Fine, 2000). Fast technological development and the frequent introduction of new products in the market indicate high clockspeed. In industries characterized by high clockspeed , competitive advantages are found in the capability related to designing and redesigning value chain interfaces, and thus call for dynamic capabilities

(Teece, Pisano, & Shuen, 1997). Demand volatility is higher upstream than downstream in the value chain; however, clockspeed is most often lower upstream than downstream (Fine, 2000). This indicates that position in the value chain matters for the design of functional interdependencies, and potentially also for the need of functional co-location.

Codification is 'the process of conversion of knowledge into messages that can be processed as information' (Cowan & Foray, 1997, p. 596). The cost of codification, and thereby implicitly the anticipated benefits related to codification of knowledge, may often depict whether knowledge gets codified or not. When clockspeed is high, little time is available to benefit from investments made in the codification of innovation-related knowledge. Thus, such investments will most likely be more risky than they would be when clockspeed is low. Hence, innovation-related knowledge may often be less codified than otherwise when clockspeed is high, i.e. because less time is available to benefit from codification investments. From previous studies, it has been well established that codified knowledge is more easily transferred than noncodified or tacit knowledge, and that weak ties between units in distributed organisations assist knowledge search, while it takes strong ties to transfer and absorb complex knowledge (Hansen, 1999). Socialisation and face-to-face interaction nurture the transfer and creation of tacit knowledge (Nonaka & Konno, 1998), e.g. in the interface between R&D and manufacturing activities in emerging markets. This interaction is thereby particularly likely to benefit from co-location when clockspeed is high. The opposite may be the case where clockspeed is low and mature technologies may dominate. Mature technologies tend to be easier to transfer, since they are often more codified than emerging technologies (Kogut & Zander, 1993). Needed knowledge transfer between R&D and manufacturing is in that case likely to be possible from a distance, and the need for co-location may be smaller.

Technological complexity

Complex technologies make use of components, which are highly complementary or co-specialised (Teece, 1986). Technological complexity characterises 'applied systems whose components have multiple interactions and constitute a non-decomposable whole' (Singh, 1997, p. 340).

In relation to technological complexity, it can be beneficial to distinguish between product complexity and process complexity. According to Elmaraghy and Urbanic (2003), 'Product complexity is a function of the material, design and special specification for each component within the product. Process complexity is a function of the product, the volume requirements, and the work environment' (p. 363).

Modularity and the general decomposability of the product architecture affect boundary decisions within the firm, but also as we look beyond the firm and include the whole supply chain. It has been argued that a product's architecture oscillates between modular and integral, while firms simultaneously contract and expand their boundaries, i.e. outsource and insource work (Fine, 1998). Modularisation is one way to control technological complexity. However, this is only feasible in decomposable systems where complexity can be confined to modules.

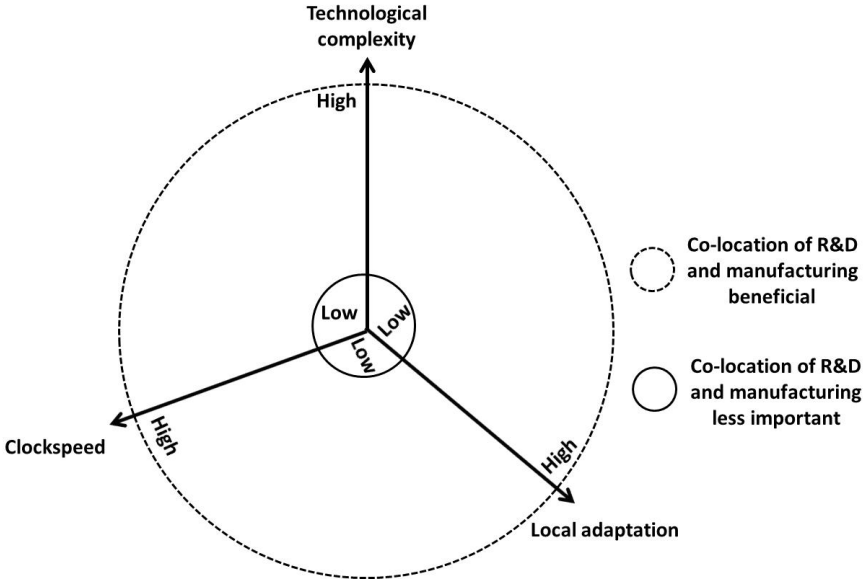
As outlined above, multiple interactions, or multiple interfaces, are an indication of technological complexity. As component suppliers most often deal with one single interface, their technological complexity may often be lower than it is for system integrators. Integration is required for the successful development of high-complexity technologies (Singh, 1997). Co-location is a relevant way to nurture and facilitate such integration.

In summary, the co-location of R&D and manufacturing activities is likely to be especially beneficial for companies manufacturing products which require a high degree of local adaptation. It is also likely to be especially beneficial for companies experiencing high clockspeed and high technological complexity, as illustrated in Figure 2.

METHODOLOGY

Extensive qualitative empirical material has been collected from four Scandinavian high-tech companies and reported in four exploratory case studies (Yin, 2003). It is believed that rich contextual information is pertinent to facilitating a deep understanding of the phenomenon, as we have quite extensive knowledge of drivers of global R&D, but

Figure 2: Characteristics affecting the importance of co-location of R&D and manufacturing in emerging markets.



do not fully understand the process related to how it is operationalised. The abductive approach (Alvesson & Sköldberg, 1994; Dubois & Gadde, 2002) forms the methodological strategy for this inquiry, where more than 50 in-depth interviews were conducted. These interviews lasted between 40 minutes and two hours, and they have been fully transcribed. The empirical findings triggered a search for theory and theory development through continuous interchange and pattern matching (Yin, 2003) between the empirical data and theory in order to find support for the theoretical framework. The interviewees were mainly employees within the R&D organisations of the case companies. Interviews were carried out in person and by telephone, both in Scandinavia and Asia, with employees at different management levels. Employees without management responsibility were also interviewed.

EMPIRICAL FINDINGS

Med Tech

This company develops and manufactures pharmaceutical products. It primarily provides medicine which makes it possible to live with conditions that most often cannot be fully cured. The company has R&D activities located in Beijing and manufacturing activities located in Tianjin, outside of Beijing. There is very little interaction within the company between these two business functions in China. The motivation behind the establishment of R&D in China was, on the one hand, to ease the further growth of the company in China by showing commitment to the overall society in the country, i.e. in conducting R&D rather than merely selling products in China. Another reason was to get better access to the developing talent in China.

Local adaptation. So far, the company has not needed to adapt its products much to local markets around the world. For instance, the company does not make much use of pulmonary technologies. Since lung sizes, etc. can differ a bit in different parts of the world, the use of pulmonary technologies would probably instigate the need for higher local adaptation than is currently the case. The strict regulations and norms stipulated by institutions such as the US Food and Drug Administration (FDA) make it expensive to make product modifications. This is one reason why the products are similar across the globe.

Clockspeed. It takes a very long time to develop new products for the company, even as long as 12–13 years. This seems to slow down clockspeed. In terms of technologies, the company has always focused on protein drugs and related technologies.

Technological complexity. Once the right recipes for a medicine developed by Med Tech has been found, the actual contents are simple compounds. Hence, there are not many different product components and interfaces to handle. Complexity is mainly found in the extreme demand for a stable and reliable manufacturing process, which entails high establishment and maintenance costs. The R&D centre in China carries out drug discovery, but so far not much large-scale manufacturing process maturation. This, however, may change in the future.

Wind Tech

This company is active within the wind turbine industry. Wind Tech has established an R&D unit in India in relative proximity to manufacturing activities the company already had established there beforehand. However, due to the poor infrastructure, it can take two hours to drive between the R&D unit and the manufacturing unit in India. In spite of this, the engineers in the Indian R&D unit meet regularly with employees who work in the local manufacturing unit of the company. By meeting with people from the manufacturing unit, the R&D engineers can better understand what challenges exist, when manufacturing the products of the company. In this way, they get inspiration concerning how to improve manufacturing processes of the company, such that new products can be manufactured faster and simpler. This has so far resulted in improved accuracy and quality in the manufacturing of the products of the company. The Indian engineers have also come up with a way to decrease emissions from the manufacturing process. Another benefit of having manufacturing activities nearby, experienced within the R&D unit, is that newly recruited engineers can obtain hands-on experience with the company products, in the manufacturing unit. Thus, the interaction between R&D and manufacturing in India is not intense, but it has still created some benefits for the company.

Local adaptation. There is not much need for local adaptation of the products of the company. Within the wind turbine industry, whether a wind turbine functions under onshore or offshore conditions is of course important, as well as whether it needs to work in the Arctic or other types of weather conditions. However, these differences normally do not lead to big, market-specific adaptations of products, and the case is no different in India. However, since the company's products are large, it is relevant to carry out manufacturing near the market.

Clockspeed. The clockspeed is relatively high, i.e., it normally takes no more than two or three years to develop a new product. Many customers also manufacture their own blades, so supply chain relations can change rapidly.

Technological complexity. The company manufactures blades for wind turbines. Hence, it can be considered a component supplier. Different skills are used; for instance, structural and aerodynamic calculations are very important, but there are not many different components and interfaces which the company needs to orchestrate in the development and manufacturing of products.

Pack Tech

This company is active within the packaging industry. In China, the R&D centre is co-located with supply chain management organisation, which is responsible for procurement in relation to equipment and machines. Concerning these things, the company does not carry out manufacturing in-house. Much is sourced in China, but certain things can only be found outside of China. Pack Tech manufactures packaging material in four different places in China, which is exclusively manufactured in house. The nearest of these facilities is located 100 km away from the R&D centre. However, the packaging material plant, with which most interaction takes place in relation to test runs, etc., is located more than 1,000 km away. R&D employees developing equipment are a bit annoyed with the supply chain management organisation, since they seem to favour lead time and cost rather than performance. In addition, supply chain organisation management requires a lot of technical support, and this disrupts R&D employees' focus on their own work. Moreover, according to R&D personnel, employees in the packaging material manufacturing plants are sometimes annoyed when they are disturbed by R&D employees who want to carry out test runs. Packaging material manufacturing employees are incentivised to minimise production stops, and test runs do not benefit their bonus. Otherwise, the interaction seems to run smoothly.

Local adaptation. In China, there are special requirements for downstream distribution equipment, which are not as evident elsewhere. This is largely related to the local need for secondary packaging, which comprises packaging that facilitates the easier and safer transport of smaller packages.

Clockspeed. There is relatively low clockspeed and slow technological

development in this company. It can take many years to develop new products. The technologies underlying the company's products have largely been the same for many years. The focus on in-house manufacturing of packaging material is very stable.

Technological complexity. As a full system supplier, the company provides packaging material, as well as the full range of filling and packaging machines needed. Complexity is found in solutions engineering, which draws on standardised manufacturing services.

Mechanic Tech

This company is a leader in the manufacture of automation equipment, and has established R&D activities in China near the manufacturing activities of the company. An important reason for the establishment of R&D is this it makes it possible to better support local manufacturing, e.g. when adapting existing products to the Asian market. The R&D establishment is part of the overall strategy of the company to increase its global footprint, which makes it easier to, e.g. carry out sourcing in low-cost countries. However, it was also a motivating factor to make use of Chinese engineers to develop new products. There is quite a bit of interaction with local manufacturing. All parts for the company's products are manufactured by global suppliers. However, it can be difficult to find suppliers of the right quality in China. In order to secure on-time deliveries and lowest cost, the company strives for dual sourcing, thereby including local suppliers.

Local adaptation. Customer requirements in China are less demanding in general than they are in Europe. Therefore, local customers demand cheaper solutions, and this brings about the need to adapt the products of the company to local needs.

Clockspeed. The technological development of this company can be considered fast. New products can typically be developed in less than two years, but when introducing new technologies, it takes longer. Technologies utilised in the products of the company evolve rapidly.

Technological complexity. The company assembles the different com-

ponents, which are manufactured by suppliers. Hence, there are many interfaces for the company to manage.

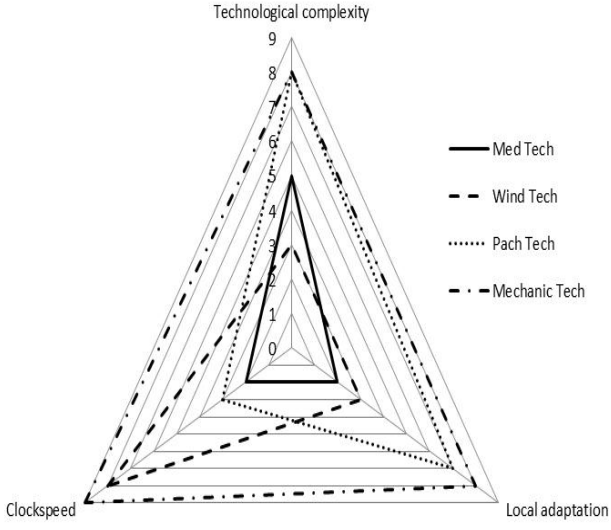
ANALYSIS

The interrelationships between R&D and manufacturing are clearly influenced by proximity; cognitive and physical distance matters to knowledge transfer and inter-unit communication. However, as seen within Med Tech, co-location and proximity does not always mean that intense interaction takes place. Wind Tech seems to benefit more from its relative co-location of R&D and manufacturing activities in India than Med Tech does. One benefit for Wind Tech is that R&D personnel receive input from manufacturing people in terms of how to improve the manufacturing processes of the company. To some extent, this points to the iterative nature of innovation, which may not always follow strict sequential stages. However, this also points to the need to differentiate between different forms of R&D and that, as a minimum, we need to distinguish between R&D activities, as they clearly exhibit different colocation needs with the manufacturing function. For example, the interaction between Med Tech R&D China and the manufacturing activities of the company in China seems to be less apparent than that between R&D Scandinavia and manufacturing activities in China. A reason for this is that Med Tech R&D China works with early drug discovery, which is, most often, subsequently further matured in Scandinavia by Med Tech R&D Scandinavia. Ensuring good interaction between Med Tech R&D Scandinavia and the manufacturing activities of the company may therefore be more important than ensuring good interaction between Med Tech R&D China and the company's manufacturing activities. Hence, one should not neglect the particular role of different units when optimising R&D, or the manufacturing footprints of companies, so that the two may be interlinked in beneficial ways. Different kinds of manufacturing may also have different kinds of needs in terms of facilitating good interaction between R&D and manufacturing, as illustrated in particular by the Pack Tech case. The supply chain management organisation focusing on outsourced manufacturing of equipment and machines on the one side, and the packaging material manufacturing plants on the other, seem to have

different needs for co-location. In the Pack Tech case, outsourcing also seems to necessitate closer interaction among R&D and the supply chain organisation than between R&D and packaging material manufacturing. The supply chain organisation in charge of procurement in relation to machinery, equipment, etc. depends to a large extent on the technical competence available in the R&D organisation.

In Figure 3, the four case companies are plotted into a polar diagram similar to that in Figure 2, which was initially presented as the theoretical framework underlying the chapter.

Figure 3: Characteristics affecting co-location of R&D and manufacturing in the case companies



The analysis below motivate the evaluation illustrated in Figure 3. The guiding principle for understanding Figure 6 is that, the larger an area of the figure a company occupies, the more important co-location of R&D and manufacturing becomes, and vice versa. Hence, according to Figure 6, Med Tech has the lowest need for co-location, whereas Mechanic Tech has the highest. However, rather than simply using the mere intensity with which companies experience the three dimensions outlined in the framework (local adaptation, clockspeed and technological complexity) as a guideline for what to do, the specific combination of challenges faced by the individual companies is likely to have implications for location decisions within the company. For instance, it seems that Pack Tech, due to lower clockspeed in the industry, finds it less difficult to handle technological complexity than Mechanic Tech. Pack Tech essentially has more time to adapt to new technologies and faces less technological ambiguity as market standards are established early in the technology lifecycle. This may be one reason why we see less interaction between R&D and manufacturing within Pack Tech than within Mechanic Tech. Low clockspeed allows for more time to deal with the unanticipated events, which tend to take up most of the time related to knowledge transfer (Szulanski, 2000), and might make it more viable, e.g. to make use of traveling expert teams, rather than relying exclusively on the continuous local presence of R&D personnel.

In Table 1 brief descriptions of the situations the companies face in relation to the three dimensions are outlined and the case companies are evaluated accordingly with numbers ranging from 0 to 9, where a score of 0 means low levels of the dimension in focus and a score of 9 means high levels of the dimension in focus.

Table 1: Brief description of the case companies

Med Tech	**Wind Tech**	**Pack Tech**	**Mechanic Tech**
Local adaptation			
Identical products are sold around the world.	Very similar products are sold around the world, but the size of products calls for local manufacturing.	The need for secondary packaging is higher than in other, more mature markets.	Simpler and cheaper solutions are demanded in the local market whereby product adaptations are needed.
Score: 2	Score: 3	Score: 7	Score: 8
Clockspeed			
New product development can take 13 years. Focus only on protein research since the company was established. Stable supply chain relationships.	New product development takes at least 10 months (very rare), but normally two or three years. Many customers also manufacture their own blades, hence the supply chain relations can change fast.	New product development takes a minimum of four years, but more likely 6–7 or 10 years. Similar technological base for many years. Stable focus on in-house manufacturing of packaging material.	New product development normally takes less than two years. Technologies utilised in the products of the company evolve rapidly.
Score: 2	Score: 8	Score: 3	Score: 9
Technological complexity			
Simple compound products, but also extreme demands on a stable and reliable manufacturing process, which entails high establishment and high maintenance costs.	The company is a component supplier. It does not deliver a complete wind turbine to its customers.	The company supplies a full packaging system of packaging material, filling machines, downstream equipment, etc. There are many interfaces to handle.	The company enables automation processes in different sectors. This means the company has to integrate many different components and interactions among these.
Score: 5	Score: 3	Score: 8	Score: 8

Local adaptation. Wind Tech, and especially Med Tech, experience a lower need for local adaptation than Mechanic Tech and Pack Tech. When R&D and manufacturing is co-located, it is easier for R&D to carry out and support local adaptation. Such adaptation is more important for Pack Tech and especially Mechanic Tech than the other case companies. Both these industries rely on proprietary technologies and materials. Global market standards have not been established due to a multifaceted industrial scope and local demands.

Clockspeed. The task characteristics have a strong bearing on the interface between R&D and manufacturing. Tight relations are necessary for tasks with reciprocal interdependencies, due to the need for ongoing adjustments and mutual adaptation. Weaker relations are better suited for sequential interdependencies, where the relationship is formalised and arm's length. As we have seen across the cases, this is strongly related to the stability of the process, which may often be lower when the clockspeed is high. Where the technological clockspeed is fast, the need for tight relations is stronger due to the demand for continuous adaptations. This, however, is influenced by the level of standardisation of the process technology.

Med Tech and Pack Tech experience slower technical development and slower clockspeed than Wind Tech and Mechanic Tech do, e.g. the documentation and test requirements related to pharmaceutical research and development further slow down clockspeed. In a sense, it also nurtures codification of innovation-related knowledge, which can make it easier to transfer in the interface between R&D and manufacturing, using weak ties as a channel. Hence, there is less need for co-location. Med Tech and Pack Tech are also companies in more mature industries than the other case companies. It may be that as product structures change over time, as industries oscillate between integration and disintegration, opportunities for disintegration have increasingly evolved. This may thereby have decreased the need for co-location, especially for Med Tech. Pack Tech and Med Tech seem to have more stable supply chain relationships and they seem to experience higher stability in terms of the technologies utilised in the company products, than Wind Tech and Mechanic Tech.

Technological complexity. With regards to technological complexity, it is clear from the cases that the development of new process technology matters more to the relationship than product technology. We have to distinguish between process and product complexity, because although they are naturally related, product complexity is often decomposable, whereas process complexity most often is not. Product complexity is thereby more prone to complexity-decreasing initiatives such as modularisation. Automation equipment inherently deals with processes, and it is clear that the need for integration between R&D and manufacturing is much higher within Mechanic Tech than, for instance, within Med Tech. Whereas the complexity for Mechanic Tech largely concerns complexity in relation to the creation of new processes, the complexity for Med Tech comes from the high demands for stability and reliability of the manufacturing processes of the company. The high costs of establishing and maintaining the manufacturing processes can also increase complexity, as these things make it more important to forecast demanded volumes, which may be difficult.

A well-functioning interaction between R&D and manufacturing also facilitates a company's abilities to access, assess and engage with external resources, which the company aims to appropriate. Mechanic Tech experiences problems with their suppliers in China. It is difficult to obtain the necessary integration with the suppliers, which may be needed in light of the technological complexity the company experiences. The local R&D presence seems to mitigate these problems somewhat.

Wind Tech and Med Tech experience lower levels of technological complexity than Pack Tech and Mechanic Tech. Unlike Pack Tech and Mechanic Tech, Wind Tech is a component supplier. A component supplier may often experience less technological complexity than companies like Pack Tech and Mechanic Tech, which assemble different components to a full system. A mix of skills is necessary for successful development of the products of Wind Tech. However, there are few interactions for the company to deal with. Hence the technological complexity can be considered somewhat low for Wind Tech, unlike Pack Tech and Mechanic Tech, as illustrated in Figure 3.

FUTURE RESEARCH DIRECTIONS

The investigated cases of R&D establishments in China and India can be described as captive R&D offshoring. One can speculate that in other types of business models, such as offshore R&D outsourcing to emerging markets, it is likely that alliance types with local companies may have important implications for whether R&D and manufacturing need to be co-located. Further research may elucidate this topic.

As our theoretical framework contains three dichotomous dimensions, the framework sketches eight different scenarios, half of which have been explored and illustrated through the four cases in the chapter. We have illustrated two quite extreme scenarios (Med Tech and Mechanic Tech). Even though these cases can be considered somewhat extreme, it may be possible to find even more extreme cases. The chapter has also illustrated two different relevant midrange scenarios (Pack Tech and Wind Tech). The four most relevant scenarios for the purpose of this chapter have thus been illustrated. However, it would be interesting for further research to investigate different cases from the ones investigated in this chapter in order to see whether similar conceptual relationships can be found in such cases.

CONCLUSION

Co-location of R&D activities and manufacturing activities in emerging markets is likely to be more important for companies whose products require a high degree of local adaptation, rather than a low degree of local adaptation. The upgrading of foreign sites from exploiting home base knowledge and technologies through standards set at headquarters, to augmenting these global inputs to serve local market or resource needs increases demands on co-location, as the coordination required cannot be covered by occasional exchanges. This is further intensified when clockspeed is high as innovation-related knowledge is likely to be tacit, and its transfer between R&D and manufacturing activities thereby depends upon socialisation, which is nurtured by co-location, as this may facilitate the kind of learning that occurs from repeated interaction between particular groups or functions. This type of learning is most important in situations where the critical knowledge is locat-

ed in the interface between groups or functions, and where interfaces have not been standardised. Under such conditions of high technological complexity – particularly process-related complexity – integration is necessary and co-location of R&D and manufacturing is beneficial. On the other hand, when there is a low need for local adaptation, and when clockspeed and technological complexity are low, co-location of R&D and manufacturing in emerging markets may be less necessary, although it is likely to have some benefits in any case.

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