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It has often argued that firms become multinationals (MNE's) because they are able to exploit a non tradable firm specific advantage. When that advantage is in product innovation they may hold ownership to sales subsidiaries and some development activities located abroad. (; Buckley, 1987, 1990; Buckley & Casson, 1985; Casson, 1987 ; Hennart, 1991; Hymer, 1976; Rugman, 1986; Teece, 1985). In the static model of internalization the firm advantages are taken to be exogenous to the firm and allow them to overcome the liability of foreignness in a market dominated by local producers. However, increasingly MNEs find themselves competing against other MNEs who also posses firm advantages. In such an environment MNE's have to continuously improve and develop their initial firm specific advantages to keep up with both the competition from both domestic firms and other MNE's (se for example, Bartlett & Goshal, 1990; Dunning, 1992; Kogut, 1983,1985). In doing so, the MNE may desire to tap into knowledge and innovative input from many different locations in ways that could not be achieved through market transactions (Dunning, 1992). Thus, foreignness must be turned from a liability to an asset allowing the MNE's to use it's international position to source innovative input and build dynamic capabilities (i.e. by creating what Bartlett and Goshal, 1990 call a globally linked innovation process).

Managers in globally oriented MNEs must address such questions as: where to source innovative input, what product development activities should be located near to the head quarter and what activities should be located near to the relevant markets or to other product development units? The answers to these decisions in part depend on whether the MNE pursue a modular product development strategy. In this paper I address the interdependent issues of organization and location of product development activities. The starting point is that MNEs face a trade off between taking advantage of location specific factors and on the other hand ensuring efficient coordination of interdependent product development activities. MNE's location decisions regarding R&D units are constrained by the difficulties that they may face with respect to the transfer of relevant information and knowledge needed to coordinate the product development activities. Modularization in product development impact on these constraints since it reduces interdependencies in product development activities such that issues of co-location become less important[1]. The MNE can to a much larger extent base its location decisions on exploitation of location advantages. In turn this should put the MNE in a favourable position to build dynamic capabilities by locating R&D units in ways that allow it to tap into excellent sources of innovative capabilities. However, an MNE with a widely nationally decentralized R&D faces the issue of how to re-combine and re-integrate its dispersed R&D knowledge in order to create dynamic capabilities. Thus, decentralization may come at a cost in terms of the MNE loosing its potential for creating dynamic capabilities through recombination of knowledge.

The structure of the paper is as follows: In section II I discuss insights from location and product development theory in order to establish what the main benefits are that multinational firms derive from locating their product development in foreign market. Section III introduces the notion of modularization in product design. I discuss how it impact on task definition and information interdependencies in product development activities. Section IV addresses the impact of decentralized and globally located R&D activities on MNE's ability to foster dynamic capabilities.

II: Location Advantages in Product Development Activities

Traditional thinking in the area of management of innovation has mainly focused on firm internal factors when explaining firm differences in innovativeness (se e.g. Leonard Barton, 1992; Metcalf and Gibbons, 1986; Nelson and Winter, 1982). Although the capabilities and knowledge posed by a firm is important to its innovativeness the external environment for innovation is at least as important. The market oriented part of the innovation literature has explored how linkages to customers in positive and negative ways may influence firms' innovativeness (Christensen and

[1] *Modularization* is a product development strategy that is based on a product architecture that is defined prior to the detailed design activities, and where different functions of a product are implemented by different and relatively independent physical components. The definition of the interfaces is part of the definition of the architecture (Garud & Kumaraswamy 1993; Sanchez & Mahoney, 1996). This differs from an *integral* product development strategy, where the architecture emerges during the detailed design process, and where each function is implemented in many different components.

Rosenbloom, 1995; Shaw, 1985, 1998; Von Hippel, 1976, 1988). Lead uses and other customers of value to a firm may be located across different nations indicating a potential benefit to the firm from having sales and/or R&D subsidiaries at different locations. Moreover, firms that possess the adequate absorptive capacity also gain innovativeness from having contact to local experts and firms engaged in competing or complementary activities (Cohen & Levinthal, 1990). While nations differ in their institutional set up and ability to foster innovations (Nelson, 1993) they also host different clusters of capabilities and these clusters tend to be difficult or close to impossible to imitate or to transfer to other settings. (Armstrong & Taylor, 2000; Piore & Sabel, 1984; Porter 1990; Porter & Stern, 2001). The knowledge and innovative ideas that are produced in those clusters are typically difficult to trade or even to transfer across settings (Pinch & Russel, 1996). Following trade theory, firms located by a cluster should be able to gain a comparative or absolute advantage from specializing in innovations that build on these capabilities. Alternatively, firms that are specialized in innovations that benefit from input from a particular cluster's capabilities may gain an advantage over competitors from locating their product development activities by the relevant cluster.

Thus, the literature indicates that firm may exploit location advantages from being located near to sources of input to the innovation process such as input from lead uses and/or from nations and clusters holding particular innovative capabilities. Having easy (low cost, fast and accurate) access to such input may improve a firm's innovativeness. However, a MNE need not locate all of its product development activities in one location. First, a MNE may have different product lines that benefit from capabilities or lead users in different locations. Second, The MNE may face a situation where there are different location advantages for different kinds of product development activities. That is, product development is often described as a process of distinct but interlined activities (Kline and Rosenberg, 1986). For example, Ulrich and Eppinger (1995) group product development activities into five categories, namely 1) concept development, 2) system-level design, 3) detailed design, 4) testing and refinement, and 5)-production ramp-up. The MNE can in principle locate each of these distinct activities in different countries or locations. Moreover, the MNE may split up any of the distinct product development activities into sub tasks that are organized and located in different subsidiaries. The extent to which the MNE may desire to do so depend in part on the location advantages it may reap for sub-tasks in part on the organizational cost and benefits of splitting the process into differently located sub-task. I shall return to the latter in the follow section. For now I concentrate on the possible location benefits an MNE can reap within each of the distinct product development activities.

The purpose of the concept development phase is to generate the product concept for a new product.[2] Product designers interpret market information and turn it into knowledge embodied in a product concept. The product concept specifies the main functionalities of the product. In case the product is a mountain bike the main functionalities are transportation, steering, stopping, ease of ride, comfort of ride etc. Market information is an essential input into concept development stage and a MNE may gain location advantages from locating concept development activities close to lead uses. This is particular true when market information is sticky (Szulanski, 2000; Von Hippel, 1976) due to context specific factors such that being physically present in the local market is important in order to interpret the market information correctly. At the system-level of design alternative product concepts are evaluated and major sub-systems are defined. Two inputs are needed. One is the information contained in the product concept and the other is technical skills that are used when designers transform the specified functionalities into technical statements. A MNE's ability to tap into technical skills of high quality and low costs may require that system level design activities are located where such skills reside. The detailed design activities consist of the development of the specific design solutions. If the product under development contains elements or solutions that build on different technological knowledge it may be beneficial to the MNE to locate the detailed design activities across location where it can reap location advantages from taping into local clusters of different expertise. In the testing and refinement processes the actual design is being tested and modified before production ramp up which is the final stage. Testing and product ramp up also require technical skills and tapping into such skills may give rise to a location issue. However, legal constraints and interest group

[2] A product concept "... is an approximate description of the technology, working principles, and form of the product" (Ulrich and Eppinger, 1995, p.78). Ulrich and Eppinger use the word product concept in a different way compared to the general use in the marketing literature where a product concept is considered to be a unique package of functions.

pressures such environmentalist protection of animal rights may also be of importance for the location decisions.

In principle product development activities even in a single product line MNE could be dispersed across many location and nation. However, this would only be the case if there were no need for coordination among the product development activities. In most product development processes the five distinct activities are linked through product and information and knowledge flows and there may to varying degrees be feedback between the different activities. For example, if the testing reveals that the product does not live up to expectations there will be feedback to the prior stages. The more interdependent the activities are in terms of input and information flow the more acute is the trade off between location advantages and coordination costs. The follow section takes up the issue of how modularization in product development impact on the organization of product development activities into tasks and the coordination of the remaining informational interdependencies among these tasks.

III: The Impact of Modularization on the Organization of Product Development Activities

It is a standard assumption in much of the organization design literature that organizations are shaped by their purpose, the coordination problem they face and their environment[3] Product development organizations often have to fulfill many purposes such as minimize time spend on the development of a new product (lead-time), ensure accuracy in fulfilling design specifications, introduce new variants or radically new products that better fulfill customer wants or eases manufacturability. The different aims may introduce many different and sometimes incompatible organizational design principles thus requiring a trade-off between achievements of the different aims (Garud & Kumaraswamy, 1995; Sako, 2002). In order to analyze the impact of modularization on MNE's organization of innovative activities the aim of the product development organization must be

[3] From the contingency theory of organization theory (Lawrence & Lorsch ,1967; Thompson, 1967), we know that different types of technology, and especially differences in the nature of interdependencies between technological tasks are important contingencies in shaping organizations. In the product development literature it has been pointed out that the overall purpose of the product development effort influence organizational design. For example, Fujimoto (1989) has argued that the choice of strategy (volume producer or high–end specialist) shapes organizations. Moreover, Wheelwright and Clark (1992) point out that the organization of product development depends on whether the aim is to develop a totally novel product of to incrementally improve existing products.

fixed. Thus, I assume that the MNE has a firm specific advantage in terms of lead-time (making internalization of R&D activities necessary) and that it desires to organize its product development activities to support this advantage.

Lead-time is traditionally measured as the length of time from the initiation of a concept generation to market introduction (Clark, Chew and Fujimoto, 1987)[4]. Lead-time is influenced by many different factors among which are the competencies of those involved in the design activities and the way in which product development is organized internally. [5] MNEs that want to improve lead time may benefit from locating product development activities to tap into clusters of local capabilities. Moreover, MNE that want to improve lead time are likely to pursue modularization in product development. Cusumano (1997), for example, has argued that modularization makes it possible for the firm to organize product development activities in ways that reduce the need for iterations of information between teams and enables a greater use of parallel product development activities. Both of these characteristics improve lead-time.

In order to more fully asses the impact of modular product development strategies on MNEs' location strategies one must focus on the level at which interdependencies among product development activities arise. The lowest level at which these interdependencies arise is at the task level.

Defining Product Development Tasks to Improve Lead-time

Defining tasks is one way of breaking up large-scale problems up into small scale problems that can be managed by small teams (Cusumano, 1997). There are many reasons why it is efficient to divide design activities of a large project among different individuals and an important one is that it may improve lead-time in product development. Tasks may loosely be defined as the

[4] In this paper I investigate only improvements in the time from concept generation to product design, rather than the time from product initiation to market introduction. Lead-time in product development is perceived of as a very important variable in product development (Meyer, 1993; Smith & Reinertsen, 1995).
[5] Other factors of importance are the level of ambition in the development project and the extent to which components can be reused.

partitioning of product development activities in a way, which delimit the activities that are carried out by one individual from those activities that are carried out by another individual.[6] It will improver lead- time in product development most when tasks are defined in ways that simultaneously economize on bounded rationality, improve productivity and innovativeness[7] all of which may give rise to different criterion for task definitions.[8] Modularization allow the MNE to define task taking all these criteria into account while allowing for a definition of tasks and teams in ways that give rise to only low levels of interdependencies among tasks. [9]

Economizing with Bounded Rationality: One implication of bounded rationality is that there are sharply diminishing returns to problem solving, as problems become more complex.[10] This may show up as inferior solutions or as more than proportional time spent on problem solving (Simon, 1969). Task definitions, which economize on bounded rationality, are the ones that solve some of the coordination problem by reducing the need for communication the most Simon (1969). In the context of product design, Eppinger, Withney, Smith & Gebala (1994) find that iterations between product development tasks are reduced most when tasks are defined on the basis of a chart of the interaction between the design parameters specified by designers (se also Von Hippel,1990). Thus, from this I derive the following criteria for task definition when the aim is to improve lead time:

[6] I distinguish between activities, tasks and teams. Tasks may encompass one or more discrete separable types of activities. Teams are formed by grouping tasks.

[7] Innovativeness is the ability of an individual "... to retrieve a potentially useful piece of information from one's memory and then adapting that information to the problem in hand" (Ulrich and Eppinger 1995, p.88) – which is to recombine knowledge in new ways.

[8] At one extreme, all task definition takes place at the very beginning of the product development project; at the other; it is part of the ongoing process of product development. Furthermore, task definition may be performed by the person(s) appointed as responsible for the entire project or it may be allocated to different broadly defined teams (Johne, 1984; Clark & Wheelwright, 1992; Lundquist, Sundgren & Trygg, 1996). However, the economic principles behind task definition remain the same.

[9] I discuss task definition in modular products where the architecture is well specified before detailed design. I also assume that the existence of technical interdependencies among components is perfectly known as are the range within which component changes influence these interdependencies. I also have to set a side a number of issues that are of relevance to firms in defining their tasks such as incentive issues, the allocation of fixed number employees or the sharing of large scale equipment across tasks (Barzel, 1989) or task duration and the degree of dependence with respect to task communication time, functional coupling, physical adjacency etc (see Eppinger, Withney, Smith & Gebala (1994)

[10] Complex in the sense that it is "…. made up of a large number of parts that interact in a non simple way" (Simon, 1969, p.86)

Criteria 1: *when specifying design tasks, one need to consider how to reduce the amount of design variables to be considered within in each task while at the same time reduce the amount of information each person needs to receive and communicate.*

If all product interdependencies are well specified tasks should be defined to minimize the complexity in solving for the optimal design. If instead interdependences are known to exist but are not specified product design entails experimentation in order to specify the nature of the interdependency. Task definition must take into account the need for iteration between product development activities as well as making the complexity of problem-solving manageable to individuals. When there is technical uncertainty one also needs to take into account how task partitioning influences the speed with which designers discover solutions to incompatibilities in product designs. Improving innovativeness in this manner is the subject of the following sections

Improving Innovativeness: Improving innovativeness has much to do with being able to access the right knowledge at the right time (Bower, Langely & Simon, 1983; Simon, 1985). In many phases in the product development process much of the knowledge that underlies skills is tacit and for that reason difficult to access for others. For example, designers may posses certain skills in concept generation and in the design and execution of experiments needed to test technical solutions. Moreover, the cognitive elements of tacit knowledge may create problems of communicating between specialist in area such as marketing, product design, and production functions.

Due to the difficulties of transmitting the relevant knowledge firms face a trade-off between accumulating a certain depth of knowledge and accumulating a certain width of knowledge. On the one hand innovativeness requires a certain "[i]ntensity of effort" and "….important aspects of learning how to solve problems are build up over many practice trails on related problems"[11] (Cohen and Levinthal, 1990:131). Moreover, in order for boundedly rational individuals to learn effectively from experience the complexity of the problems they solve will often have to be reduced by a

[11] Much problem solving knowledge is cumulative in the sense that knowledge of prior advances within a field is necessary in order to assimilate information on new advances. In such cases the rate, at which new knowledge can be accumulated increases with the stock of existing knowledge (Cohen & Levinthal 1990).

decomposition of the problem and a rather narrow definition of the problem solving tasks (Levinthal & March, 1993). These factors call for a narrow definition of tasks.

On the other hand, a certain width of knowledge and therefore width in task definitions may also be important with respect to facilitating innovativeness. Cohen and Levinthal (1990) point out that "… in settings, in which there is uncertainty about the knowledge domains, from which potentially useful information may emerge, a diverse background provide a more robust basis for learning because it increases the prospect that incoming information will relate to what is already known" (p.131).

At the organizational level this problem could be remedied by employing experts of diverse backgrounds. However, the creation of new knowledge often requires interaction between different knowledge elements. When experts only posse highly specialized knowledge, they may be unable to communicate with specialist in other sub-fields because there is not sufficient knowledge overlap. There are, as argued by Nonaka (1994), different means of facilitating communication between specialists in sub-fields. This implies that although a narrow definition of tasks create specialist knowledge containing tacit and explicit elements, these may be brought into contacts through various interactions, of which some require overlapping activities and close interaction.

Criteria 2: *When specifying task it is important to distinguish between situations where new solutions most likely emerge from existing bodies of knowledge and where they most likely emerge from new bodes of knowledge. In the former case tasks should be defined to ensure repetition or intensity of effort in the performance of the tasks. In the latter case tasks may have to be defined more broadly.*

How broad tasks have to be defined depends on the extent to which the confinement from knowledge specialization can be overcome by the creation of knowledge transfer mechanism such as close links or overlapping teams in product development[12]

[12] In fact, the importance of knowledge sharing as a way of enhancing communication between specialists may explain the many recommendation of establishing close links between for example marketing and design or design and manufacturing (Clark & Fujimoto, 1987, Larson & Goblei, 1988, Clark & Wheelwright, 1992)

In the above I have been concerned mainly with product development as a unique problem solving activity. However, product development can also be viewed as an ongoing activity that consists of a number of recurrent activities. When viewed in this manner improving lead-time centres on improving productivity in product development by defining tasks to increase labor productivity.

Improving Labor Productivity: Productivity gains arise from improved skills and time that is saved from avoiding having to switch from one task to another (Adam Smith, 1776). In product development almost all activities have some element of skill. For example, designers use heuristics and technical insight to decompose design problems or to search for conceptual solutions. Repetition of the same types of activities over and over is the key to accumulation of all these diverse skills (Cohen & Levinthal, 1990). To increase the rate of accumulation of skills, tasks will have to be defined around activities, which can be repeated by solving the same type of problems. This criterion for task definition may also lead to a reduction of "switching costs". In product development "switching costs" may arise when it takes time for an individual to change his mindset in order to perform a different type of activity. Such switching costs arise, for example, if one has to switch between market analysis activities and concept development activities or even if one has to switch between different types of components.

Criteria 3: *When defining tasks one must ensure that tasks are narrowly defined around repetitive activities.*

However, with very narrow definitions of tasks much more communication may have to be undertaken between product developers in order to ensure coordination of those activities that cannot be pre-planned. Thus, there is a trade-off between criteria 1 and 3 in that narrowly defined tasks increasing productivity in individual product development tasks but may increase time spend on communication between tasks.

Summing up: Task Definition and Location of R&D Activities

Modularization implies that definition of product concepts and creation of a product-architecture are separated from detailed design activities Sanchez (2000). This indicates that tasks can be grouped round the repetitive activities of concept generation, architectural creation, and component design to enhance productivity without evoking a great need for communication. Thus, concept generation, architectural design and component designs can be undertaken as relatively independent projects in the sense that designers can mainly rely on information within the team in making design decisions. Defining tasks and teams around these activities ensures that the organization is able to economize on bounded rationality, and on costs of communications while achieving high productivity from learning by doing in component development, concept generation and architectural designs. Moreover, defining task in this way in principle allows for the geographical separation of these activities such that location advantages within each can be pursued.

However, in principle modularization also allows for a geographic dispersion of sub activities within the detailed design activities. The reason is that each product function is implemented in the product by relatively independents components. For most incremental improvements of functions the important interdependencies between design variables to be explored are likely to be concentrated within components rather than between components. This implies that a definition of design tasks in the detailed design activities in accordance with the components that have to be developed will be the one, which economize the most on bounded rationality. Moreover, modularization implies that much of the uncertainty in problem solving is confined to the development of the individual components and, by defining tasks very narrowly around components one may increase productivity and innovativeness by improving accumulation of component specific knowledge.

So far it has been argued that modularization makes it possible to 1) economize on bounded rationality, 2) maximize productivity in tasks, and 3) increase innovativeness in component design simply by defining tasks in accordance with the interdependencies in product design so that each tasks can carried out relatively independent of all other tasks or be grouped into relatively independent teams. In principle this allows an MNE to pursue a very high degree of dispersion of its R&D activities across locations and nations so as to reap location advantages. However, when design problems are not fully decomposable there will always remain some interdependencies in problem solving no matter how tasks are defined. These interdependencies have to be managed by creating efficient informational structures. In the following sections tasks definitions are taken as given and the informational structure is investigated assuming that tasks have been defined to improve lead-time.

Defining Informational Structures to improve lead-time

Informational structures are defined as procedures that are implemented in order to ensure proper communication of information between given tasks and teams.[13] From team-theoretical and information-processing perspective efficient informational structures are the ones that economize most with information processing costs given the way tasks/teams are defined. [14] Information processing cost consists of the costs of transmitting information, costs of investing in information channels, non-optimal decisions due to error in communication[15] or costs of obtaining information through investigations (Carter, 1995; Casson, 1994; Marschak & Radner, 1977). Many of these costs arise because time has to be spent on obtaining and transferring information or on correcting errors in decision making due to faulty communications. That is, time that adds to lead-time.

The decomposition of the design problem and the way sub-problems are allocated to tasks/teams play an important role with respect to determining the design of informational structures since it is the interdependencies in problems solving that define the need for communication between tasks/teams. Three characteristics of the decomposed product design problem are important for choice of informational structures. The first important characteristic is what Casson (1994) refers to as "*decisiveness*", the second important characteristic is what Radner (1992) refers to as "*associative operations"* and finally, it is also important to the choice of informational structures whether the

[13] Galvin (1999) points out that in connections with product modularity the term informational structure is often used to denote only the type of product design information that is captured in what Baldwin & Clark (1997) call visible design rules. In team theory the term informational structure is used in a broader sense to cover the entire spectra of information required for decision making.

[14] The team theoretical approach is an economic based information processing perspective on organizations. Some of the primary proponents of this approach are: Aioki, (1986); Carter, 1995; Casson, 1994; Marchak & Radner,1977. In the following analysis of efficient informational structures the standard team theoretical simplifying assumption of incentive compatibility is assumed to apply

[15] Errors in communication can, for example, be interpreted as a small probability that the wrong decision premises are communicated because tacit information is incorrectly encoded into memos, plans or interface standards (Carter, 1995).

decomposition of the product development problem requires that *tacit/sticky* knowledge be transmitted between tasks (Nonaka, 1994).

Design problems are to varying degrees characterized by *decisiveness* with respect to the communication of information where "... [d]ifferences in decisiveness mean that some problems have a logical structure, which supports solutions without consultation and some do not" (Casson 1994:50). Natural decisiveness occur when there is sequential interdependence (Eppinger et al. 1994; Thompson, 1967) between two decision takers (A and B) and when decision taker B only needs to know the decision and not the premises for the decision reached by A (or visa versa). For example, the concept generation process and the detailed design are characterized by decisiveness when the choice of a product concept can be carried out on the basis of information about customer preferences alone independent of information about the constraint set by knowledge about product technologies and design solutions. Moreover, the team that works on the system level design only needs information about the product concept chosen and not about the actual customer requirements. [16] Decisiveness is important when the premise for the decision is more costly to transmit than information about the decision that has been reached. This may, for example, be the case if the premise is information of a sticky or tacit kind. Decisiveness has implication for location decisions since a high degree of decisiveness reduce the need for co-location as decision premises need not be transmitted.

In cases where, the design problem is not characterized by natural decisiveness it may sometimes be efficient to *impose* decisiveness on problems by dispensing with the communication of the decision premises. As an example the firm can choose to take customer preferences or technological knowledge as given and make that the "normal state". When an unusual state occurs (and is discovered) decisions will have to be made in a consultative manner otherwise it can be made in a sequential manner[17]. Modularization often is an imposed decisiveness in product development activities. That is, the architecture and the interface specification of the product are determined independently of the development of the specific technological solutions that implement the various

[17] Sequential decision-taking requires that the knowledge that has to be transferred is not tacit or sticky in the sense, that common experience is required in order to interpret the information.

product functions. The interfaces specified in the architecture is the natural state of the environment which is to be taken for granted in the choice of the specific design solutions. Interface specifications simply eliminate changes in the decision premises caused by interdependencies between design solutions. When interface standards "freezes states" it creates informational independence between problems. In this way modularization improve lead-time by allowing for the use of one way communication structures, elimination of investigations of states, and the use of concurrent design.. At the same time modularization allows for concept development, system-level design, and concurrent detailed design activities to take place in differently located subunits.

Another important way of improving lead-time is to make extensive use of parallel problem solving. The implementation of parallel problem solving is eased when design problems have a structure that allows for what Radner (1992) calls "*associative operations*" Associative operations refers to problem solving, where some of the information processing activities can be carried out completely independently of other information processing activities (pooled interdependencies Thompson, 1967).[18] Associative operations greatly reduce problem solving time since it allows for parallel information processing organized into hierarchical structures of information accumulation. Many of the activities that take place in product development can be characterized as associative operations. Linear information transformation and pattern matching are the two paradigm cases of associative operations. An example of linear transformation is the transformation of customer statements into target specifications. Individuals with the same education and experience may employ some of the same tacit heuristics in performing this activity making it possible to allocate the activity to different individuals and have them perform the translation in parallel. Pattern matching takes place when a set of data is compared with a reference set of data in order to find the closest match. An example of this is the comparison of dimensions of many different design solutions to a specific design problem in order to find the one that matches a set of specifications.

[18] It should be noted that the logical structure of problems, which gives rise to natural decisiveness is different from those, which gives rise to associative processes. Decisiveness and associative processes do not preclude one another. In the case of associative processes there is no logical sequence to follow. However, the communication will be structured by the way, in which one has chosen to organize problem solving into an efficient hierarchical network (Radner, 1992).

Associative operations can be carried out by defining tasks so that groups of individuals compare sub-sets of solutions and each find the best solutions to the sub-sets problems. Sub-problems are synthesized by sequentially eliminating or transforming sub-solutions until a final solution is arrived at. Lead-time in for example, detailed design can be improved by having many teams working on discovering solutions to well specified detailed design problems.[19] Modularization allow for a more extensive use of parallel problem solving within detailed design because the product is intentionally designed in a way that create relatively independent product development problems. The hierarchical structure of a product-architecture provides the information as to how the individual solutions are to be aggregated into an overall solution. Moreover, the structure of the problem allows different teams engaging in the parallel problem solving to be located at whatever location provides the most advantages.

Although modularization transform problem structures into ones characterized by decisiveness and associative operations there may still be tacit knowledge to be transmitted in order for efficient problem solving to take place. *Tacit or sticky* refers to the situation where costs of transferring information is high due to the way, in which it is encoded or due to the lack of " absorptive capacity" of receivers of the information (von Hippel, 1998). Receivers may, for example, lack an understanding of the context, in which the information is derived. For example, it can be important for designers of complementary components to know how a certain solution reacts to changes in test conditions rather than just to know the solution. Sanchez & Mahoney (1996), state that "… information and assumptions underlying upstream design decisions may not be transferred intact to downstream stages of development. Technical incompatibilities between interdependent components may actually be 'designed into' downstream components" (p. 69). Overlapping teams may be required when important tacit knowledge can only be transferred between teams through direct observations and co-

[19] However, there are diminishing returns to this kind of parallel problem solving[19]. As argued by Nelson (1959) the costs of using several teams during the initial stage of design is small relative to the benefits that may accrue from the information gathering. Increases in teams add costs in a linear fashion while the probability of discovering a better solution increases in a hyperbolic fashion moving asymptotic toward 1 this determine an upper bound on the efficient number of teams (Arditti & Levy, 1980) Also, based on a study of two different design projects Marples (1961) finds that parallel search for design solutions are most likely to occur when organizations have sufficient manpower and when the problem is not felt to be so difficult that a number of feasible solutions seem improbable.

development (Nonaka, 1992; Wheelwright & Clark, 1992). Alternatively, the MNE may a project manager who follows the project through some or all of the phases and accumulate much of the tacit knowledge about the project.

Summing up: Modularization, Information structure and Location decisions

In sum, modularization should result in organizations with narrow task specialization, simple information structures and high degrees of autonomy within tasks/teams. The main reason for this is the specification of product interfaces serves as a means of replacing managerial or inter-team coordination with pre-planning. Tasks and teams can be specified narrowly around architectural and component design while communication to coordinate the remaining problem solving-interdependencies is kept at a minimum. [20] The need for investigation and communication is suppressed because the architecture and the interfaces are defined as the normal state. Firms can use one-way communication from designers of the product architecture to designers of components and designers of components can hierarchically aggregate design solutions into product solutions. Moreover, when the architecture of the product is fully specified tacit and sticky information is to a large extent confined within tasks. This also implies that there will be little use of overlapping tasks/team activities. All of these factors indicate that MNE that pursue modularization and have the aim of improving lead time are faced with relatively few constraints in choosing the optimal location for different design activities.

In the analysis presented in this paper I have set aside the allocation of a fix number of employees and fixed assets, assuming that there were no problems of sharing research talents, equipment and other facilities. I have also set aside the incentive issues. The allocation of a fixed number of talents and equipment among teams is another issue that impact on an organizational structure. When fixed assets have to be shared among teams it may be very costly to have teams independently determine the use of these assets. “Negotiation costs” from independent actions may simply be high compared to the use of planning and authority (Barzel, 1989) and this may impact on location decisions. Moreover, co location may be required in order to reap economies of scale in the use of equipment.

I have assumed that the MNE desires to improvement lead-time by means of its organizational design and through exploitation of location advantages. Since modularization give rise to modular organizations (Sanchez & Mahoney, 1996; Sanchez 2000) organizational issues poses few constraints on location decisions allowing the MNE to benefit from an organizational design that improves lead time as well as from tapping into location advantages (that may also help improve lead time). However, had the aim of the MNE been to facilitate easy mixing and matching of components or easing manufacturability, organizational constraints would have differed (Sako, 2002). Moreover, firms may choose modular product development strategies in order to pursue other objects than lead time. Garud and Kumaraswamy (1995) point out that when the aim of firms is to realize economic advantages from reuse of components firms have to create incentive systems that supports design of re-usable components as well as information and knowledge sharing that ensures that designers in detailed product development know enough of the design of the components to re-use and upgrade these. Thus, managerial attention becomes very important and coordination cannot to the same extent be replaced by product interface specifications. More interdependencies will be introduced and the informational structure becomes more complex. This will of course lead to a less modular organization and more constraints on location issues.

Finally, an important assumption in this paper is that the technical uncertainty in product development is low such that there is no need for adjustment of technical solutions as long as they fulfill interface specifications and that there is no need for changes in the architecture. For an MNE to handle fast changes in architectures and high level of technical uncertainty a different organizational structure are required. Teams working on different detailed design solutions may have to make many local adaptations through the use of intensive communication (Dessein & Santos 2006) when product designers are faced with technical uncertainty and when they do not know the rage at which component design variables critically change component interdependencies. The use of such intensive communication is facilitated by co-locating the detailed design activities.

Another problem that emerge with technical uncertainty is that product developers often do not know that they posses information that is valuable to other product developers. This creates what Hoopes & Postrel (1999) term “glitches” that are costly mistakes or costly duplications of work. According to Hoopes and Postrel such costs can be avoided though information integration mechanisms such as overlapping team activities. Those who have valuable information are likely to discover the need for communicating it to the relevant decision takers. This implies that in the choice of efficient information structure managers must take into account their ignorance of who poses what kind of valuable information. In experimenting with new solutions to component designs designers may extend the limits within which components can be independently changed and at the extreme changes in components may require the design of a novel architecture. However, product designers may not realize the influence of changes in component designs on the product architecture. According to Henderson & Clark (1990), modular product development organizations will not provide the organizational structure conducive for such discoveries. Instead modular organizations may strengthen core rigidities (Leonard Barton, 1992). Information channels in modular organizations reflect designers initially perception of physical product interdependences and block understanding of initial unrecognized interdependencies. The narrowly defined and relatively independent teams becomes experts on components and filter out information about components/materials that are not considered important to developments in focal component Finally, the decentralized R&D units' technical knowhow and the equipment supports a search for solutions that build on their prior experience with the product architecture. What designers need is to adopt new ways of searching for solutions. Instead the modular organization may strengthen core rigidities and these may hinder the discovery of new architectures (see e.g. Ethiraj & Levinthal, 2004 on the impact of too much modularization on problem definitions). Locating R&D units in different nations may further strengthen core rigidities.

IV The impact of decentralized and nationally dispersed R&D activities on MNEs' dynamic capabilities

The ability to innovate is a key contributor to firms' global competitiveness (Goshal & Bartlett, 1988; Franko, 1989). Historically MNE's have performed most of their R&D in their home country (De Meyer & Mizushima, 1989; Terpstra, 1977). However, with increased global competition may change this pattern significantly. The more wide spread use of modularization in product development may as argued in this paper enable an MNE to decentralize and globally disperse its R&D to gain location advantages. Moreover, by establishing R&D in different countries the MNE may be able to obtain a more varied flow of information and knowledge.

However, MNEs will have to maintain integrative capabilities when they introduce new product varieties that require a redesign of the architecture, or if innovations in components introduce interdependencies in design decisions. This in turn requires an organization that is more integral than what is required for "ordinary" design activities –those, for which modules and interface standards are well specified. Moreover, technologies may sometimes shift from modular to integral and firms that have implemented a modular organization may because of organizational inertia be trapped in what Chesbrough and Kusunoki (1999) have called the modularity trap. It seems that in order for an MNE to exploit this varied knowledge it need to re-combine and re-integrate it – that is it need dynamic capabilities.

One strategy for an MNE to strengthen its dynamic capabilities is to invest in what Postrel, 2002) calls trans-specialist understanding. Trans-specialist understanding facilitates coordination across different domains of knowledge. Trans-specialist knowledge is "the means by which members of one specialty assess how effective another speciality is likely to be when faced with a given problem" (ibid. p.306). In product development trans-specialist understanding ensures that the specification of design concepts meets critical values to satisfy consumer needs, that interface standard are sufficiently detailed to ensure coordination and that the locus of problem solving is allocated to the speciality best equipped to handle the problem. If teams in detailed product development have much trans-specialist understanding they will select solutions that take into account the impact on design solutions in other teams whereas if they have much specialist knowledge they are better able to invent around the problems imposed by the design solutions selected by other teams (as pointed out by Leonard Barton 1992).

The MNE face an important trade-off between investing in specialist capabilities and trans-specialist knowledge because individuals have bounded abilities in knowledge accumulation. Specialist knowledge is fast accumulated by creating modular organizations with narrow tasks defined around the development of product components. However, the existence of trans-specialist knowledge implies that there are boundaries between bodies of knowledge. Creating modular organizations around components gradually shape these boundaries within the MNE. The result may be narrowly specialized R&D unit in which designers only know relatively few design parameters.

Building trans-specialist knowledge in product development units require that the MNE instead decompose the product development task such that interdependencies and the amount of design parameters that each designer needs to know are increased. With such a decomposition of the product development task there will be greater sharing of knowledge about the same design parameters within teams (se also Puranam & Jacobides, 2006). Accumulation of trans-specialized knowledge also requires that the MNE rotates employees, that they create cross-component development projects and that they use overlapping teams etc. Building trans-specialist knowledge impact on location decisions since, when the organization is less modular there should be less dispersion in the location of R&D activities due to the higher costs of communicating. Moreover, building trans-specialist knowledge requires more human resource management as cooperation and rotation is required. In turn this may impact on location decisions when costs of cooperation and communication are impacted by differences in languages and national cultures.

V Conclusion

The main purpose of this paper was to investigate how modularization could impact on MNEs' location decisions. The analysis of the link between modularization in products and location decisions has been pursued in three steps. The first, step was to investigate if and what type of location advantages a

MNE could obtain. The second step was to investigate the influence of modularization on the organization of R&D and its impact on location decisions. Finally, I discussed the impact of modularization on MNEs' dynamic capabilities.

Based on the analysis presented in this paper it is reasonable to assume that organizations pursuing a goal of improving lead-time through modularization will create modular organizations that allow for decentralized and nationally dispersed R&D activities

The analysis pursued in this paper has not systematically taken into account the nature of the knowledge and information interdependencies between architectural innovations and modular innovations in components. But it has been indicated in the literature (Chesbrough & Kusunoki; 1999; Clark & Henderson, 1990) that a less modular organization may be needed in order to facilitate trail and error learning processes and cross- component knowledge accumulation, required for architectural innovations. While modularization in product development reduces the constraints on location that stem from informational interdependencies in product development it does not seem to lessen the constraints on dispersion set by the need for integration of diverse bodies of knowledge. Thus it is an important research issue to improve our understanding of how MNEs handle the trade off between on the on hand obtaining varied knowledge input through dispersed location of R&D and on the other hand integrating and recombining this knowledge to produce new architectures or new product lines.

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