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Knowledge flows and the modelling of the multinational enterprise

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Abstract

This research develops a location–allocation, mixed integer linear model that simultaneously evaluates a substantial number of multinational enterprise (MNE) location and control configurations to yield an optimal network, considering R&D, production and marketing facilities, produced in-house and/or outsourced. The model places special emphasis on the role of intra-firm, inter-firm and extra-firm knowledge flows in addressing cost minimisation considerations of MNEs. A simulation analysis is undertaken to evaluate potential solutions from such a framework and to analyse their consistency with theoretical expectations.

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Introduction

The significance of knowledge flows in explaining the emergence of multinational enterprises (MNEs) has been long acknowledged by international business scholars. This is evident from the central role that knowledge flows play in various theories explaining the MNE phenomenon.

The prime explanation for the emergence of MNEs, according to the *internalisation school*, is often argued to be the failure of external markets to transfer proprietary knowledge, which in turn motivates firms to establish or acquire wholly owned foreign subsidiaries (Buckley and Casson, 1976; Rugman, 1981, 1986; Dunning, 1988; Hennart, 1993). Gupta and Govindarajan (1994, 2000); Kogut and Zander (1993, 1995) go a step further and position knowledge flows as the ultimate reason for the emergence of MNEs. Such scholars conceive the MNE as the most efficient mechanism for the transfer of knowledge across borders, claiming that MNEs are 'social communities' that are better able to transfer knowledge that is simultaneously complex, non-codifiable and non-teachable (Kogut and Zander, 1992, 1993). This view asserts that it is not necessarily a failure of the market for knowledge that leads to the emergence of the MNE, but rather MNEs emerge because of their relative efficiency in transferring knowledge compared with firms choosing alternative foreign market entry modes (Kogut and Zander, 1993; Madhok, 1997; Martin and Salomon, 2003). Likewise the concept of the transnational corporation put forward by Bartlett and Ghoshal (1989) emphasises the importance of knowledge transfer between different foreign subsidiaries as a key success factor of MNEs.

The role of knowledge flows as the dominant trigger for the emergence of MNEs is becoming increasingly more popular, possibly as a result of the combination of economic and behavioural approaches in explaining the MNE phenomenon (Foss and Pedersen, 2004).[1] Nevertheless, in discussing 'intra-firm' knowledge flows within MNEs, 'inter-firm' knowledge flows between MNEs and other firms, and 'extra-firm' knowledge flows between MNEs and their customers, different literature strands offer often contradictory insights. For instance, while concentration of activities within a geographical space is expected to facilitate the transfer of intra-firm knowledge (Buckley and Carter, 2004), their dispersion in various target markets should encourage bilateral extra-firm knowledge flows (Hirsch, 1989; Simonin, 1999). In a similar vein, while the externalisation of downstream activities (marketing and distribution) to local parties in foreign markets may facilitate the flow of knowledge between MNEs and their foreign customers (Kogut and Singh, 1988), it is likely to result in excess inter-firm knowledge flow costs (Kogut and Zander, 1993; Martin and Salomon, 2003). Hence concentration *vs* dispersion dilemmas, as well as internalisation *vs* externalisation dilemmas, that are central to MNEs' operations are often left ambiguous. Moreover, the need to simultaneously make decisions for multiple activities and multiple countries with regard to the location of and control over MNE operations is likely to be extremely complex.

The current paper offers a first step in reconciling the above-mentioned dilemmas and others, by introducing a location–allocation model that permits an evaluation of a relatively large number of location and control configurations and identifies optimal configurations, based on a specific treatment of intra-, inter- and extra-firm knowledge flow costs, in addition to other costs. Under the title of *location configurations*, we refer to the question of where to locate specific activities around the globe, and how to allocate the total workload between these activities (Kogut, 1985; Porter, 1986). Under the title of *control configurations* we refer to the question of whether to internalise or externalise such activities (Buckley and Casson, 1976, 1998; Kogut and Zander, 1993; Martin and Salomon, 2003; Buckley and Hashai, 2004). Through the integration of knowledge flow costs directly into a location–allocation model we are able to simultaneously evaluate a large number of variables, yielding optimal location and control configurations. The size of the problem is likely to make such evaluations difficult for an MNE manager to analyse without a mathematical framework providing a decision aid (Casson, 2000: Chapter 4).

Various models have been detailed in the literature analysing the MNE phenomenon,[2] but such modelling efforts are focused on *tangibles* such as production costs, logistic costs and finance, whereas *intangibles* such as knowledge flows are virtually ignored. Bearing in mind the central role of knowledge flows in theories explaining the MNE phenomenon, we present a framework that incorporates knowledge flow costs directly within a mixed integer linear program (MILP) that is capable of assessing multiple location, allocation and control configurations.

In what follows we detail the basic features of our proposed model and its underlying assumptions. Next, we demonstrate how the proposed model garners further insights regarding the location and control configurations of MNEs, based on several simulation experiments. Then we discuss the empirical considerations of the proposed model and highlight possible extensions to the model. Finally, we conclude by outlining the expected contribution of the suggested approach as well as its limitations.

The model

Conceive the MNE as an integrated network of value-adding activities that are interconnected through knowledge flows. The MNE seeks to minimise its costs by optimising its location and control configurations. An MNE's optimal location configuration emerges from two sets of decision variables: where to locate each value-adding activity, and how to allocate the output of R&D, production and marketing between the various facilities and end customers respectively. An MNE's optimal control configuration considers the question of which value-adding activities to internalise (so creating intra-firm knowledge flows) and which to outsource to other parties (so creating inter-firm knowledge flows).

Following Buckley and Casson (1976), Hirsch (1976), Casson (2000), Buckley and Hashai (2004) and others, we focus on three major value-adding activities:

- R&D – the creation of knowledge and consumable technology and other proprietary organisational know-how;

- production – the transformation of inputs into outputs;
- marketing – which specifically relates to extra-firm interactions with customers during the processes of promotions, sales, distribution and post-sale services.

As schematically depicted in Figure 1, these value-adding activities may be located in *N* potential locations and are interconnected by unidirectional knowledge flows (denoted by thin lines) while production sites deliver products to customers via transportation flows (denoted by thick lines). The *N* possible locations are referred to as *nodes*. Each node represents a demand point (i.e., a market) and a potential location for the different value-adding activities (R&D, production and marketing).

The objectives of the model formulated below in Eq. (1) are to determine the most appropriate location for R&D, production and marketing activities, including predicting production levels and the distribution of R&D and marketing activities within the MNE. The decisions as to where to locate R&D centres, production facilities and marketing sites and how to distribute the total workload between them are dependent on: the relative cost of operations at the *N* nodes (Kogut, 1985; Porter, 1986; Dunning, 1993); the distance between the nodes, which is assumed to affect product and knowledge flow cost; and the location of expected customer demand, which affects the cost of transferring products and knowledge to customers (Dunning, 1988, 1993; Hirsch, 1989; Krugman, 1991, 1995; Hirsch and Hashai, 2000). In addition, the model determines the relative share of production and marketing activities to be outsourced based on a trade-off between the fixed and variable costs of executing various value-adding activities internally and/or externally (e.g., Buckley and Casson, 1981), as well as differences between intra-firm and inter-firm knowledge flow costs (Buckley and Casson, 1976; Rugman, 1981; Kogut and Zander, 1993; Martin and Salomon, 2003).

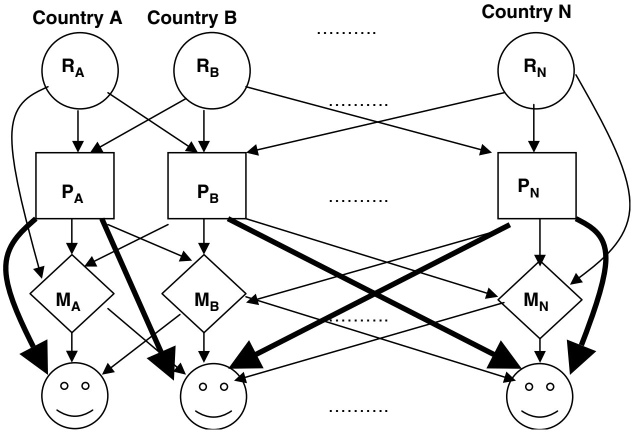

Figure 1 The MNE as an integrated network. R=R&D, P=production, M=marketing, ☺=customers.

One way of identifying optimal location and control configurations is by focusing on cost minimisation as a means of studying profit maximisation strategies (e.g., Buckley and Casson 1976; Hirsch, 1976; Rugman, 1981; Hennart, 1993; Martin and Salomon, 2003). Assuming that demand is independent of the location and control configuration chosen for specific value-adding activities, cost minimisation and profit maximisation are equivalent for MNEs. Breaking this assumption is discussed in the section on future directions.

The basic assumptions of the proposed model are as follows:

(1) Two product types are modelled. We assume that the MNE produces one or more products for sale and one intangible by-product, namely knowledge (copyrights, patents or any other form of explicit or tacit knowledge), per product for both production and marketing purposes.
(2) Vertical information flows alone are modelled. Both 'product' and 'process' knowledge (Abernathy and Utterback, 1978; Cohen and Klepper, 1996) are produced in the R&D centres, and then flow to the production facilities and marketing sites respectively (Buckley and Casson, 1998; Casson, 2000: Chapter 3; Buckley and Hashai, 2004). Marketing then passes product knowledge on to the end customers (Hirsch, 1989; Simonin, 1999; Almor *et al.*, 2006), thus acting as a trans-shipment site. Consequently, we assume that the knowledge demand is derived from product demand. The production facilities are connected by product flows to the MNE's markets, and marketing sites are connected to customers by knowledge flows. Horizontal flows between value-adding activities of the same type are ignored (see Figure 1).
(3) It is assumed that the knowledge flow costs per unit output behave as an S-shaped logistic curve, increasing linearly for short geographic distances, exponentially over medium distances, and reaching a saturation level beyond 10,000 km. Two logistic curves are formulated,

one for transfer of knowledge from R&D to marketing and production and another from marketing to the end customer. In addition, we also use cultural distance (Hofstede, 1980; Kogut and Singh, 1988) as an alternative determinant of knowledge flow costs. Knowledge flow costs are expected to rise in cultural distance owing to the need to communicate in two or more languages and accommodate different legal and social systems (Hymer, 1976; Kogut and Singh, 1988; Rangan and Adner, 2001; Shenkar, 2001; Buckley and Carter, 2004); however, these costs reach saturation at extremely high levels of cultural distance.

(4) The home country of a MNE may be predetermined by adding a constraint to the model requiring one R&D facility to be located in a specific country.

(5) Average production costs change in a piecewise linear manner, decreasing to a minimum efficient scale (MES) and subsequently increasing. The production facilities are capacitated under this mathematical formulation.

(6) An R&D facility is uncapacitated and costs are purely fixed, so an MNE considers the opening of a second or third R&D facility only if knowledge flow costs are sufficiently high.

(7) The fixed facility costs represent the amortised value of building a facility and paying for it over time, as well as the fixed running costs. These costs need to be covered by the yearly budget the MNE possesses.

(8) At each node there is a maximum of one facility per type.

(9) There is no inventory, and demand is fixed, known and must be satisfied.

Following the above assumptions the proposed model is specified as follows.

Inputs

$i, j, l, r, p \in N$	indices belonging to the set of nodes N
R	index representing a research and development site
P	index representing a production facility
M	index representing a marketing and sales site
S	set of facility types where $R, P, M \in S$
h_i^{τ}	demand at node i in thousands of dollars per product type τ
d_{ij}	distance from node i to node j in kilometers
rd_{ij}	relevant distance from node i to node j for example, cultural distance
FC_i^s	fixed amortized cost of setting up type s site at node i
B	budget for facility fixed costs
$c_i^{s\tau}$	variable cost of type s site at node i per \$1000 of output per product type τ
t_{ij}	transport cost to move \$1000 of output per kilometer from node i to node j
f_{ij}	cost of knowledge flow from node i to node j per relevant distance
α^{τ}	knowledge by-product (as a percentage of basic product) requested by facility per product type τ
a_{lg}	output level in thousands of dollars at production facility located at node l under returns to scale g
MES	minimum efficient scale production in thousands of dollars
$\vartheta_l^{s\tau}$	outsourced cost of type s site at node l per \$1000 of output of product type τ
ε	additional percentage cost of transferring information inter firm that is, $\varepsilon \geqslant 1$

Decision variables

X_{pi}^{τ}	fraction of demand at node i served by production facility at node p per product type τ
W_{rpi}^{τ}	fraction of process knowledge produced by R&D facility at node r for production unit at node p serving demand node i per product type τ
λ_{lg}	output at production facility at node l under returns to scale g
$O_{li}^{p\tau}$	fraction of outsourced production bought at node l to serve demand at node i per product type τ
$O_{jki}^{rp\tau}$	fraction of process knowledge bought at node j for production facility at node k to meet demand at node i per product type τ
$O_{jki}^{rm\tau}$	fraction of product knowledge bought at node j moved to marketing facility at node k for end node i per product type τ

$O_{jki}^{m\tau}$	fraction of marketing outsourced at node *k* drawing on knowledge from node *j* for end node *i* per product type τ
$I_{jki}^{rm\tau}$	fraction of product knowledge ⩾ produced internally at node *j* moved to end customers at node *i* per product type τ
$I_{jki}^{m\tau}$	fraction of marketing produced internally at node *k* drawing on knowledge from node *j* for end node *i* per product type τ

$$z_i^s = \begin{cases} 1 & \text{if facility type } s \text{ is located at node } i \\ 0 & \text{otherwise} \end{cases}$$

$$F_{l1} = \begin{cases} 1 & \text{if production facility at node } l \text{ produces} \\ & \text{less than or equal to the minimum} \\ & \text{efficient scale} \\ 0 & \text{otherwise} \end{cases}$$

$$F_{l2} = \begin{cases} 1 & \text{if production facility } l \text{ produces} \\ & \text{more than the minimum efficient scale} \\ 0 & \text{otherwise} \end{cases}$$

$$b_j^s = \begin{cases} 1 & \text{if outsourcing of type } s \text{ occurs at node } j \\ 0 & \text{otherwise} \end{cases}$$

The objective function minimises total costs for a multi-product firm as presented in Eq. (1).

$$\begin{aligned} \underset{\substack{x_{li}^{\tau}, w_{jli}^{\tau}, z_i^s, F_{lq}, \\ \lambda_{\lg}, O_{jki}^{s\tau}, I_{jki}^{s\tau}}}{\text{Min}} & \sum_s \sum_i^n FC_i^s Z_i^s + \sum_l \sum_{g=1}^3 c_{lg}^p (a_{lg}) \lambda_{lg} \\ & + \sum_l \sum_i \sum_\tau h_i^\tau \{ d_{li} t_{li} (X_{li}^\tau + O_{li}^{p\tau}) + \vartheta_l^{p\tau} O_{li}^{p\tau} \} \\ & + \sum_j \sum_k \sum_i^n \sum_\tau \alpha^\tau h_i^\tau \\ & \times \left\{ \begin{array}{l} rd_{jk} f_{jk} W_{jki}^\tau + (\varepsilon rd_{jk} f_{jk} + \vartheta_j^{rp\tau}) O_{jki}^{rp\tau} \\ + rd_{jk} f_{jk} I_{jki}^{rm\tau} + (\varepsilon rd_{jk} f_{jk} + \vartheta_j^{rm\tau}) O_{jki}^{rm\tau} \\ + (rd_{ki} f_{ki} + c_k^{m\tau}) I_{jki}^{m\tau} + (\varepsilon rd_{ki} f_{ki} + \vartheta_k^{m\tau}) O_{jki}^{m\tau} \end{array} \right\} \end{aligned} \tag{1}$$

subject to:

$$\sum_l (X_{li}^\tau + O_{li}^{p\tau}) = 1, \quad \forall i, \tau \tag{2}$$

$$\sum_j (W_{jli}^\tau + O_{jli}^{rp\tau} - X_{jli}^\tau - O_{li}^{p\tau}) = 0, \quad \forall l, i, \tau \tag{3}$$

$$\sum_j \sum_k (I_{jki}^{rm\tau} + O_{jki}^{rm\tau}) = 1, \quad \forall i, \tau \tag{4}$$

$$\sum_j \sum_k (I_{jki}^{m\tau} + O_{jki}^{m\tau}) = 1, \quad \forall i, \tau \tag{5}$$

$$I_{jki}^{rm\tau} + O_{jki}^{rm\tau} - I_{jki}^{m\tau} - O_{jki}^{m\tau} \geqslant 0, \quad \forall j, k, i, \tau \tag{6}$$

$$I_{jki}^{rm\tau} \leqslant Z_j^r, \quad \forall j, k, i, \tau \tag{7}$$

$$I_{jki}^{m\tau} \leqslant Z_k^m, \quad \forall j, k, i, \tau \tag{8}$$

$$X_{li}^\tau \leqslant Z_l^p, \quad \forall l, i, \tau \tag{9}$$

$$W_{jli}^\tau \leqslant Z_j^r, \quad \forall j, l, i, \tau \tag{10}$$

$$\sum_s \sum_i^n FC_i^s Z_i \leqslant B \tag{11}$$

$$\sum_i \sum_\tau h_i^\tau X_{li}^\tau = \sum_{g=1}^3 \lambda_{lg} a_{lg}, \quad \forall l \tag{12}$$

$$\sum_{g=1}^3 \lambda_{lg} = 1, \quad \forall l \tag{13}$$

$$\lambda_{l1} \leqslant F_{l1}, \quad \forall l \tag{14}$$

$$\lambda_{l2} \leqslant F_{l1} + F_{l2}, \quad \forall l \tag{15}$$

$$\lambda_{l3} \leqslant F_{l2}, \quad \forall l \tag{16}$$

$$F_{l1} + F_{l2} = 1, \quad \forall l \tag{17}$$

$$0.2 b_l^{p\tau} \leqslant \sum_i O_{li}^{p\tau}, \quad \forall l, \tau \tag{18}$$

$$\sum_i O_{li}^{p\tau} \leqslant b_l^{p\tau}, \quad \forall l, \tau \tag{19}$$

$$0.2 b_j^{rm\tau} \leqslant \sum_k \sum_i O_{jki}^{rm\tau}, \quad \forall j, \tau \tag{20}$$

$$\sum_k \sum_i O_{jki}^{rm\tau} \leqslant b_j^{rm\tau}, \quad \forall j, \tau \tag{21}$$

$$0.2 b_j^{rp\tau} \leqslant \sum_k \sum_i O_{jki}^{rp\tau}, \quad \forall j, \tau \tag{22}$$

$$\sum_k \sum_i O_{jki}^{rp\tau} \leqslant b_j^{rp\tau}, \quad \forall j, \tau \tag{23}$$

$$0.2 b_k^{m\tau} \leqslant \sum_j \sum_i O_{jki}^{m\tau}, \quad \forall k, \tau \tag{24}$$

$$\sum_j \sum_i O_{jki}^{m\tau} \leqslant b_k^{m\tau}, \quad \forall k, \tau \tag{25}$$

$$\begin{aligned} &X_{li}^{\tau}, Y_{jki}^{\tau}, W_{jki}^{\tau}, \lambda_{lg}, O_{jki}^{s\tau}, I_{jki}^{s\tau} \geq 0, \\ &Z_i^s, F_{lg}, b_j^{s\tau} \in \{0, 1\}, \quad \forall s, i, j, k, l, g, \tau \end{aligned} \tag{26}$$

where

$$c_{lg}^{p}(a_{lg}) = \begin{cases} c_{l1} a_{l1} & \text{for } a_{l1} = 0 \\ c_{l2} a_{l2} & \text{for } a_{l2} = \text{MES} \\ c_{l3} a_{l3} & \text{for } a_{l3} = \text{maximum production} \\ & \text{at facility } l \end{cases}$$

and

$$f_{ij} = \frac{K}{1 + \xi e^{-\psi d_{ij}}}$$

where K, ξ and ψ are parameters of the logistic cost function. In the objective function depicted in Eq. (1), the first expression sums the fixed costs of the different facilities, dependent on type and location. The second expression specifies the production costs required to meet the MNE's customer demand, based on the level of production in relation to the MES. The third expression computes the transport costs of moving the product, in-house or outsourced, from a production facility to the end customer, plus the variable cost of purchasing an outsourced product where relevant. The last line of Eq. (1) computes the costs associated with knowledge production and flow, and hence is multiplied by the level of knowledge demand ($\alpha^{\tau} h_i^{\tau}$). The first expression in the brackets accounts for transfer of in-house process knowledge followed by outsourced process knowledge purchase and transfer. Following Gupta and Govindarajan (2000) and Kogut and Zander (1993), the transfer of knowledge inter-firm, rather than intra-firm, will cost an additional ε percentage. The second expression computes the transfer of in-house product knowledge to the marketing sites, followed by outsourced product knowledge purchase and transfer. The last expression sums the marketing costs and marketing flow costs, in-house and outsourced.

Constraint (2) requires the in-house and outsourced production to meet all product demand per end node. Constraint (3) requires all product knowledge requirements to be met by R&D, whether in-house or outsourced. Constraints (4) and (5) require all process knowledge to be met at each marketing site and then passed to the end customer, whether in-house or outsourced. The constraints permit the MNE to choose between the make-or-buy decision as to the levels of product and process R&D. Eq. (6) requires the knowledge flow from the marketing staff at node k to be fed from R&D at node j – that is, preserves the knowledge flow requirements. Constraints (7)–(10) specify that a candidate node cannot be used as a specific facility in-house unless the node is designated as such. Constraint (11) specifies that the total, fixed, amortised costs per time unit of setting up and running the different facilities must be less than or equal to the pre-specified budget limit B. Constraints (12)–(17) are needed to compute the level of in-house production per facility, based on the piecewise linear production function (see Nemhauser and Woolsey, 1988). Eqs. (18)–(25) specify that if outsourcing is strictly positive, it must cover at least 20% of the demand for knowledge or product purchased at a particular node. This arbitrary capacity determination is done for reasons of simplicity in order to prevent the need to analyse negligible volumes of outsourced operations and to prevent very small purchases, which in reality are unlikely to occur. The equations in (26) represent the non-negativity and integrality constraints necessary for the logic of the model.

This model is a MILP based on a facility location model with interacting facilities and production/distribution systems (Daskin, 1995). Relatively small problems such as those considered in this research are solvable to optimality with standard MILP techniques using CPLEX. Large problems may require heuristic methodologies such as tabu search, Lagrangian relaxation or decomposition techniques, which are likely to achieve almost optimal solutions (see Owen and Daskin, 1998, for a review of the topic).

Computational experiments

A central attribute of the model is that it enables analyses based on evolving endogenous and exogenous variables (i.e., country, firm and product characteristics). This enables a comparison of the optimal costs of different configurations (e.g., configurations of MNEs producing different types of product, originating from different countries or facing different levels of demand). In order to demonstrate the usefulness of our proposed model several computational experiments based on different scenarios are presented below.

Location configuration

To start with, we focus on the location configurations of MNEs while ignoring possible outsourcing decisions.[3] We run our model on a world consisting of nine nodes (countries) where in each country a major city was chosen as a reference point. The countries and cities are: United States (Chicago), Canada (Montreal), Brazil (Rio de Janeiro), United Kingdom (London), Germany (Munich), Russia (Moscow), China (Shanghai), Singapore (Singapore) and Japan (Tokyo). The chosen countries represent a mixture of large and small as well as developed and developing countries located on three continents (America, Europe and Asia). For our base run, cost data were collected to reflect a realistic average distribution between R&D, production and marketing activities.[4] The data were normalised to reflect country-specific characteristics. Fixed and variable costs of R&D, production and marketing were multiplied by the ratio of per-country purchasing power parity (PPP) gross national income per capita (GNIPC) to the median PPP GNIPC (World Bank, 2005) to reflect inter-country cost differences. Demand data were expressed in thousands of units and were multiplied by the ratio of per-country PPP gross domestic product (GDP) to the median PPP GDP (World Bank, 2005) to reflect inter-country market size differences. The operations and demand data collected are detailed in Table 1, which further includes the initial values used for transportation costs, knowledge flow costs, plant capacity, knowledge intensity (α) and initial budget available.[5] In addition, the geographic distance between the respective cities was determined according to great circle distance in kilometers.

The location configuration of the base run simulation is depicted in Figure 2. An additional constraint was included, requiring the location of an R&D facility in Chicago to represent an MNE originating in the United States. Such an R&D facility may be considered as a proxy for the

Table 1 Input data in base run

		Fixed costs per facility ($ thousands)			*Variable costs ($ per thousand units)*			
					Production			
Country	*Demand (thousands units)*	*R&D*	*Production*	*Marketing*	*For 1st unit*	*At MES*	*At max. capacity*	*Marketing*
United States (US)	63,463	17,262	46,032	575	284	32	789	1066
Canada	5420	13,328	35,541	444	219	24	609	823
Brazil	8093	3486	9296	116	57	6	159	215
United Kingdom (UK)	10,000	13,675	36,468	455	225	25	625	844
Germany	12,694	12,150	32,400	405	200	22	556	750
Russia	7688	4181	11,151	139	69	8	191	258
Japan	20,598	13,058	34,822	435	215	24	597	806
China	38,880	2403	6410	80	40	4	110	148
Singapore	645	11,558	30,823	385	190	21	529	714
Other costs ($ per thousand units)								
Transportation costs	0.015							
Knowledge flow costs	ξ	ψ	K					
R&D to production	0.001	50	10000					
R&D to marketing	0.001	50	1000					
Marketing to consumers	0.001	50	1000					
Capacity (units)								
MES	21,000							
Maximal capacity	90,000							
Knowledge intensity per unit, α	0.1							
Initial budget ($ thousands)	60,000							

headquarters of an MNE that produces and transfers firm-specific proprietary know-how. The location configuration solution proposes a second R&D centre in China and two production sites in China and Brazil, the two least-cost locations. The Chinese facility works at maximum capacity, producing 54% of the demand, and the remainder is produced in Brazil, since the capacity constraint is such that one production facility could not satisfy worldwide demand. As depicted in Figure 2, the plant in Brazil mostly serves the three countries on the American continent, whereas the Chinese plant serves Europe and Asia. Five marketing facilities are located in the United States, Brazil, Germany, Russia and China. These are either countries with a large domestic market or low-cost countries. This location configuration reflects how the relative low cost of operations in China and the substantial Chinese market (second largest demand after the US) lead to the location of R&D, production and marketing in this country, and further demonstrates how marketing facilities are located to minimise intra-firm knowledge flow costs (reflected by the proximity of R&D and marketing activities) and extra-firm knowledge flow costs (reflected by the location of marketing activities in proximity to large markets). The cost distribution of this configuration is detailed in the first row of Table 2. In order to check the sensitivity of the location configuration of the base run, we made extensive changes over all parameters of ±20%, and the location configuration proved robust.

In the continuation of this section we present a series of further analyses including changes in the knowledge flow costs, levels of knowledge required, demand levels based on the product life cycle, MNE country of origin, and cultural *vs* geographical distance effects. The first set of computational experiments is concerned with changes in knowledge flow costs. When intra-firm and extra-firm knowledge flow costs are set to zero (i.e., omitted from the analysis), the location configuration changes substantially: all R&D activity is concentrated in the US, and all marketing activity is concentrated in China (see Figure 3 and line 2 in Table 2).[6] As indicated by the last column of Table 2, the total costs in this case are reduced by 23% compared with the base run. The difference between the location configuration solutions reflects the central role that knowledge flow costs may well play in determining the location of R&D and marketing operations. Moreover, when intra-firm and extra-firm knowledge flow costs are doubled, marketing subsidiaries are required in all countries other than the UK, which is served from Germany, and an additional R&D facility is located in Russia (see Figure 4). Total costs (line 3 in Table 2) increase by 8% compared with the base run. These runs reflect the substantial effect that intra-firm and extra-firm knowledge flow costs

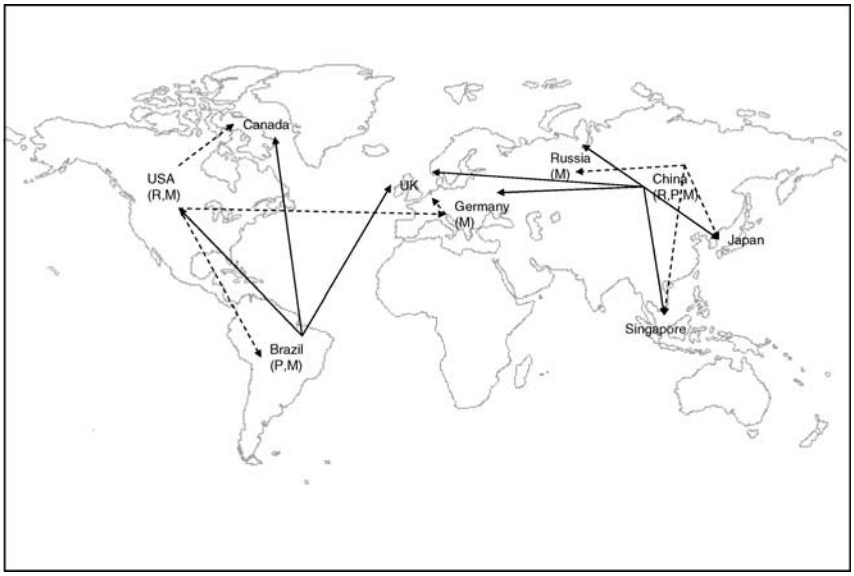

Figure 2 Location and allocation configuration in base run. R=R&D, P=production, M=marketing; solid arrows=product flow, dotted arrows=knowledge flow.

Table 2 Cost distribution of different location configurations

	Simulation characteristics	*Fixed costs (number of facilities)*						*Variable costs (%)*		*Transportation costs (%)*	*Knowledge flow costs (%)*		*Change in total costs (%)*
		R&D		*P*		*M*		*P*	*M*		*Intra-firm*	*Extra-firm*	
1	Base run (R&D site required in the US)	21%	(2)	17%	(2)	1%	(5)	24	11	14	4	7	
2	Knowledge flow costs set to zero	25%	(1)	22%	(2)	0%	(1)	31	4	19	0	0	−23
3	Knowledge flow costs doubled	24%	(3)	16%	(2)	3%	(8)	22	12	13	3	7	8
4	Knowledge intensity approaches zero	26%	(1)	23%	(2)	0%	(1)	32	0	19	0	0	−26
5	Knowledge intensity doubled	22%	(3)	14%	(2)	2%	(8)	20	21	12	3	7	20
6	Early stages of the product cycle	40%	(1)	7%	(1)	1%	(4)	10	10	10	11	10	−4
7	Mature stages of the product cycle	12%	(3)	40%	(4)	1%	(5)	24	7	10	2	4	60
8	The introduction of a new product generation	8%	(3)	30%	(5)	1%	(7)	39	9	9	1	4	225
9	No obligatory R&D location	3%	(1)	19%	(2)	2%	(5)	27	13	16	13	7	−11
10	R&D site required in Germany	16%	(2)	17%	(2)	1%	(5)	24	11	15	9	7	−1
11	R&D site required in Japan	14%	(1)	17%	(2)	2%	(6)	23	13	14	12	4	1
12	R&D costs normalised by skilled labour abundance	4%	(1)	18%	(2)	2%	(6)	25	14	15	16	5	−7
13	Cultural distance affects knowledge flow costs	3%	(1)	19%	(2)	3%	(8)	26	12	16	15	6	−9
14	Cultural distance+obligatory R&D site in the US	21%	(2)	17%	(2)	3%	(8)	23	11	14	5	5	1
15	Cultural distance+obligatory R&D site in Germany	16%	(2)	17%	(2)	3%	(8)	24	13	15	9	4	−1
16	Cultural distance+obligatory R&D site in Japan	17%	(2)	17%	(2)	3%	(8)	23	11	14	12	5	3

R=R&D, P=production, M=marketing.

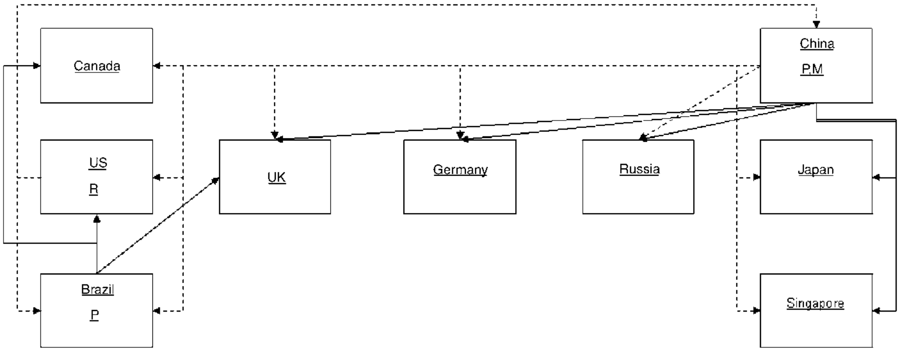

Figure 3 Location configuration when knowledge flow costs=0. R=R&D, P=production, M=marketing; solid arrows=product flow, dotted arrows=knowledge flow.

have on the worldwide dispersion of R&D and marketing activities.

Interestingly, when we set the percentage of by-product or knowledge required, α, to be close to zero, the location configuration appears as in line 2, and when we double the value of α, the location configuration appears as in line 3. While the total costs of these runs (lines 4 and 5, respectively, in Table 2) differ from lines 2 and 3 because of the additional marketing required, these results demonstrate the particular importance of knowledge flow costs for knowledge-intensive firms. Since α reflects the relative share of knowledge embedded in product output, we can see that changes in knowledge intensity of firms affect the location configuration of MNEs in the same way as changes in knowledge flow cost. This implies that knowledge flow costs are not only a major determinant of the boundaries of the firm (as predicted by Kogut and Zander, 1993; Martin and Salomon, 2003; and others) but are also central in determining its location configuration.

Another set of experiments investigated the differences in location configurations of MNEs operating over different phases of the industry life cycle. During the early phases of the product cycle knowledge requirements are expected to be relatively high, while demand is probably fairly low. On the other hand, during the mature phases of the industry life cycle knowledge intensity as well as variable production costs decline while demand increases (Vernon, 1966; Abernathy and Utterback, 1978; Klepper, 1996). As depicted in Figure 5 (line 6 in Table 2), when knowledge intensity and R&D expenditure double and demand in each country halves, the location configuration places one plant in China, one R&D site in the US, and four marketing entities in the US (owing to its large market and proximity to R&D), Brazil, Russia and China (the least cost countries). Further, when knowledge intensity, R&D and variable production costs are halved, and demand and the MNE budget double with respect to the base run, the resultant solution locates R&D, marketing and production sites on each continent (see Figure 6 and line 7 in Table 2). Since our base run indicates an intermediate case between growth and maturity, in reviewing Figures 5, 2 and then 6 in sequence, one can view the gradual enrichment in location configuration as the product develops over time. MNEs operating in early phases of the industry life cycle centralise their upstream operations and disperse only their downstream operations, while MNEs operating in mature industries disperse both upstream and downstream activities. Moreover, if we further increase demand and budget (triple it in comparison with the base run) a network configuration develops that is ‘regional’ in nature, whereby every continent is self-sufficient in terms of its production needs. This finding is consistent with the observation of Rugman and Verbeke (2004) that most of the world’s largest MNEs are,

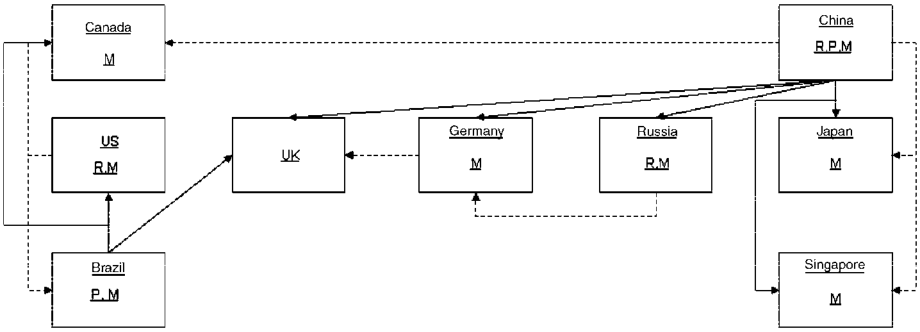

Figure 4 Location configuration when knowledge flow costs are doubled. R=R&D, P=production, M=marketing; solid arrows=product flow, dotted arrows=knowledge flow.

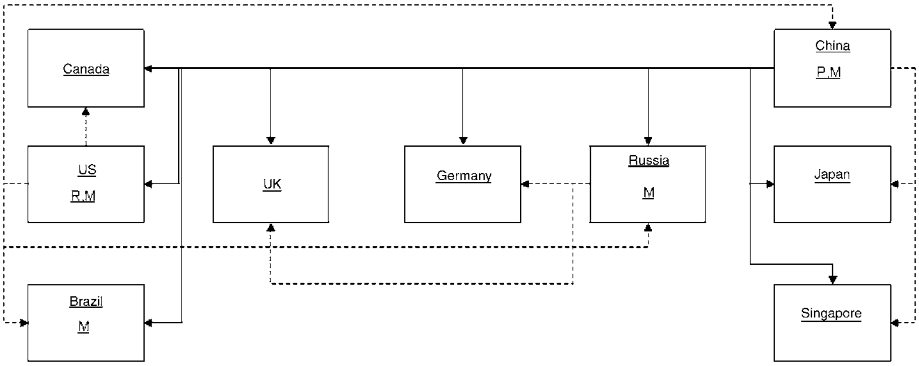

Figure 5 Location configuration in growing industries. R=R&D, P=production, M=marketing; solid arrows=product flow, dotted arrows=knowledge flow.

in fact, regional rather than global, in the sense that they serve mainly foreign markets within their home regions (either NAFTA, the European Union or Asia). This implies that, while MNEs operating in young industries are expected to supply global demand from a limited number of R&D and production sites, in mature industries the reduction in knowledge intensity and hence knowledge flow costs, the decrease in variable production costs due to product standardisation and the increase in demand volume create pressures to serve foreign markets from dispersed low-cost origins, by and large on a regional basis. By locating R&D, production and marketing activities in the least-cost country on each continent, MNEs are able to meet large volumes of demand while minimising knowledge flow and transportation costs.

While the specification of the proposed model is for multi-product MNEs, we have so far referred only to a single-product MNE. Let us assume that the MNE depicted in Figure 6 decides to introduce a new product generation in addition to the mature product it already produces. The new product is identical in terms of demand and knowledge intensity to the product produced by the MNE producing a single product in the growth phase (line 6). The location configuration of this MNE (as depicted in Figure 7) changes quite substantially. Another R&D laboratory is required in Russia, additional production facilities are required in Germany and Singapore, another marketing site is placed in Singapore, and instead of a production facility in Canada, a marketing site is required. This finding implies that it is quite complex for an incumbent to introduce a new product into the market, as it requires the opening-up of quite a few new facilities as well as closing existing ones. Moreover, as indicated by the last column of Table 2, this location configuration is more costly than the summed cost of the separate configurations depicted in lines 6 and 7. Hence we are able to explain the difficulties faced by incumbent firms competing with firms introducing new products (Cohen and Klepper, 1996; Hill and Rothaermel, 2003).

Next, we investigated whether there are potentially different location configurations for MNEs originating in different countries. First, a simulation run was analysed without the requirement of an R&D in a specific country (line 9), which resulted in an identical solution to that of the base run, without an American R&D facility. Releasing the constraint of R&D location has resulted in a reduction of 11% in total costs. Then we added a constraint locating R&D sites in Germany and subsequently Japan. With a German R&D facility (line 10) the base run solution was achieved simply with the US R&D site moved to Munich. With a required Japanese R&D site, the Chinese R&D facility moved to Japan (line 11). These results clearly identify China not only as a central location of the world's production, but also as an attractive location for R&D activities when considering cost alone. Only Japanese MNEs do not need to locate an additional R&D facility in China, probably because of the relative proximity between the countries, which reduces knowledge flow costs.

We decided to further test the attraction of R&D activities to China, by dividing each country's cost of R&D by the ratio of the total number of engineers and scientists per million inhabitants to the median number of engineers and scientists for all nine countries (World Bank, 2005). This procedure aimed to normalise R&D costs according to the relative abundance or scarcity of scientific manpower. Countries that are abundant with skilled labour are expected, comparatively, to have lower costs of R&D. The results of this run (line 12)

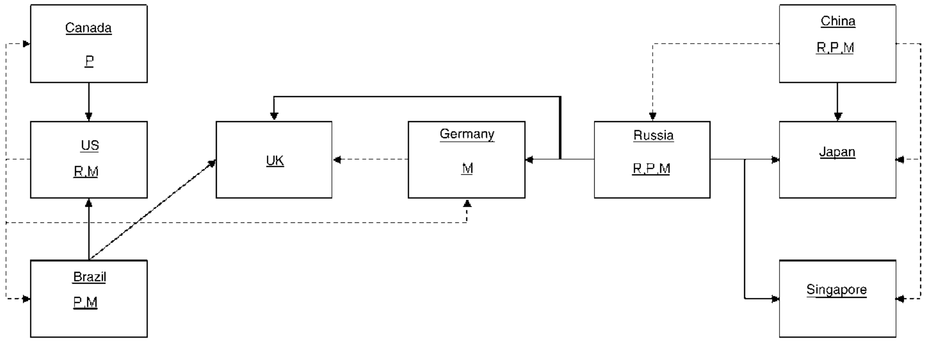

Figure 6 Location configuration in mature industries. R=R&D, P=production, M=marketing; solid arrows=product flow, dotted arrows=knowledge flow.

have shifted R&D activities from China to Russia. This interesting finding indicates that Russia has the potential to compete with China as an attractive location for MNEs' R&D activities, thanks to its unique combination of relatively low labour costs and skilled labour abundance.

Next, geographic distance was replaced by cultural distance[7] as the explanatory variable with respect to knowledge flow costs. This was meant to test the impact of cultural distance on MNEs' location configuration. Without the R&D restriction on a 'home' country, the optimal location configuration computed is as depicted in Figure 8 (line 13 in Table 2). This configuration is characterised by the dispersion of marketing activities in all countries (other than the US, which is served from Canada), demonstrating the importance of locating downstream activities in proximity to customers in order to overcome cultural distance. When constraining a R&D facility in either the US, Germany or Japan (lines 14–16) a similar location network is assigned simply with R&D activities located at each such

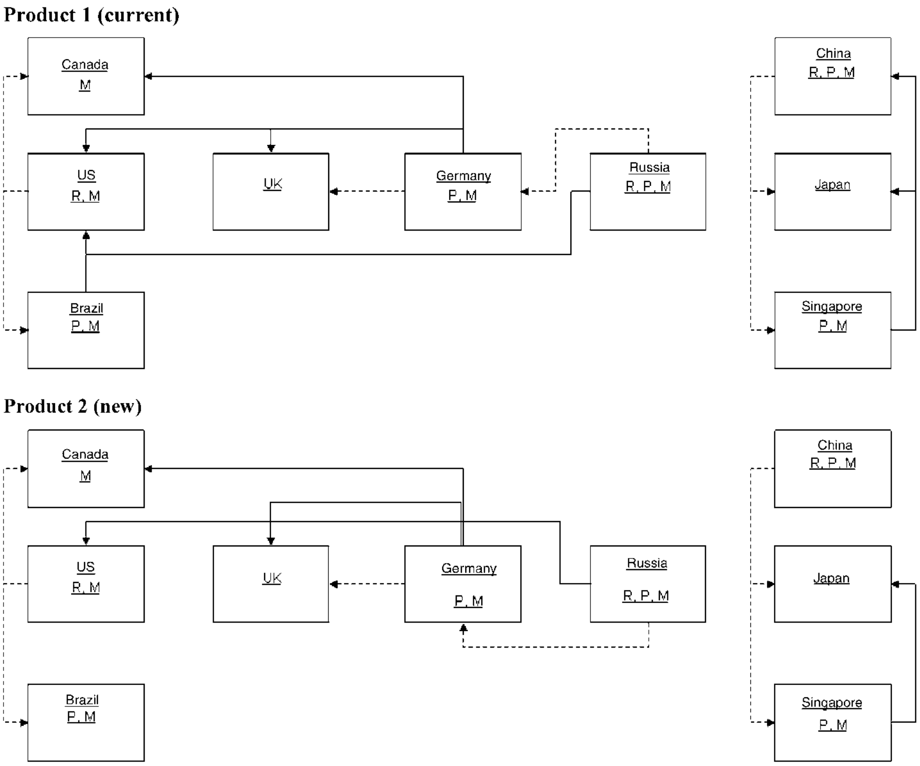

Figure 7 Location configuration, when introducing a new product generation. R=R&D, P=production, M=marketing; solid arrows=product flow, dotted arrows=knowledge flow.

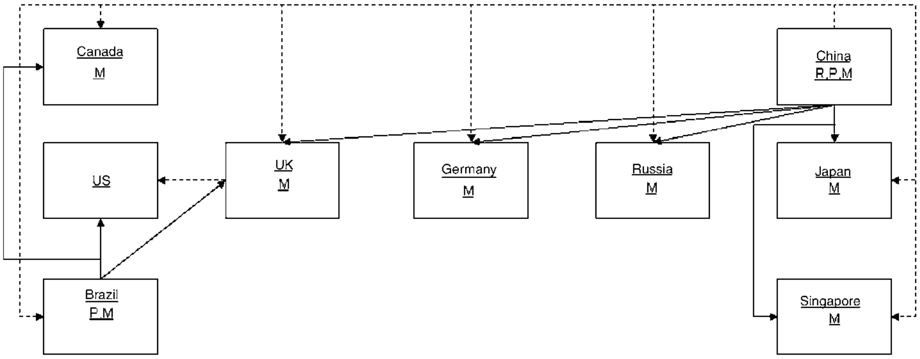

Figure 8 Location configuration with cultural distance. R=R&D, P=production, M=marketing; solid arrows=product flow, dotted arrows=knowledge flow.

country. However, as opposed to geographic distance, cultural distance leads a Japanese MNE to locate an additional R&D site in China too. This reflects the fact that cultural distance has a stronger impact than geographic distance when it comes to knowledge flows between Japan and China.

Control configuration

In order to consider the possibility of outsourcing we allowed firms to produce and market their output through external firms, but required the outsourced product or marketing to supply at least 20% of a demand node's requirements in order to avoid very small purchases.[8] Outsourced production is assumed to be 50% more expensive than the variable cost of producing the first unit in a plant; however, it is always less than the variable cost of production at maximal capacity. Outsourced marketing services are typically 33% more expensive than the variable costs of in-house marketing, which has a fixed component too. Finally, interfirm knowledge flow costs are arbitrarily assumed to be 20% higher than intra-firm knowledge flow costs.

The base run of the control configuration analysis also refers to a US-based MNE. The configuration of this base run is depicted in Figure 9. The chart depicts a MNE with R&D activities in the US and China, a production site in China, and captive marketing activities in the US, Germany and China. In addition this MNE has outsourced production in Brazil, Russia and China and outsourced marketing in Canada, Brazil, Russia and Singapore. Compared with the base run, when effectively no outsourcing is allowed, this MNE is clearly more dispersed geographically, thus demonstrating the important role of cooperative arrangements in MNEs' international dispersion. The various cost components of this configuration are detailed in the first line of Table 3, which indicates that outsourcing results in a reduction of 18% in total costs compared with the base run with no outsourcing.

In the continuation of this section we present some further analyses of MNEs' control configuration, including changes in the knowledge intensity and MNE size. The first set of experiments tested whether differences in knowledge intensity yield different control configurations. When α is set close to zero, outsourcing increases substantially, as depicted in Figure 10 (line 2 in Table 3). When the value of α is doubled, the control configuration requires less outsourcing, as depicted in Figure 11 (line 3 in Table 3). The two configurations are quite different. At extremely low levels of knowledge intensity, most of the MNEs' foreign operations are outsourced, whereas high levels of knowledge intensity lead to internalisation of many activities. We further tested the control configuration at intermediate levels of knowledge intensity (α halved). Here, as expected, the control configuration was less externalised than that of the former case, but more than that of the latter. These results support the notion that knowledge flow costs are a major determinant of the organisational boundaries of internationalising firms (Kogut and Zander, 1993; Martin and Salomon, 2003).

Another interesting experiment refers to the phenomenon of *born global* firms (Oviatt and McDougall, 1994; Knight and Cavusgil, 2004), namely small, young firms that are dispersed globally. Since in many cases such firms are knowledge intensive, resource scarce, and serve relatively small niche markets (Oviatt and McDougall, 1994; Knight and Cavusgil, 2004) we halved the demand and budget and doubled knowledge intensity relative to the base-run. The configuration depicted in Figure 12 (line 4 in Table 3) reflects a firm that has outsourced production facilities in all countries

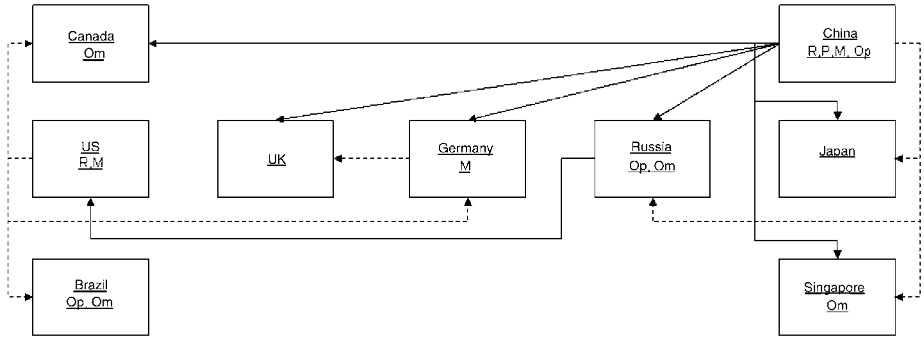

Figure 9 Location and control configuration with outsourcing. R=R&D, P=production, M=marketing, O=outsourced production, Om=outsourced marketing; solid arrows=product flow, dotted arrows=knowledge flow.

Table 3 Cost distribution of different control configurations

	Simulation characteristics	*Fixed costs (number of facilities)*			*Variable costs (%)*		*Transportation costs (%)*	*Knowledge flow costs (%)*		*Outsourcing*				*Change in total costs (%)*
		R&D	*P*	*M*	*P*	*M*		*Intra-firm*	*Extra-firm*	*Outsourced P costs (number of facilities)*	*Outsourced M costs (number of facilities)*	*Transportation of outsourced P (%)*	*Inter-firm knowledge flow costs (%)*	
1	Base run: outsourcing	26% (2)	9% (1)	1% (3)	7	13	7	5	7	13% (3)	1% (4)	10	1	−18
2	Knowledge intensity approaches zero	34% (1)	12% (1)	0% (0)	10	0	10	0	0	18% (3)	0% (9)	15	0%	−44
3	Knowledge intensity doubled	25% (3)	7% (1)	2% (6)	6	24	6	3	7	10% (3)	1% (2)	8	0	2
4	Born global MNEs	43% (1)	0% (0)	2% (4)	0	13	0	12	4	17% (9)	2% (4)	6	1	−13

R=R&D, P=production, M=marketing.

as well as having half internalised and half externalised marketing presence in eight out of the nine markets. On the other hand, when the same parameters were used in the case where outsourcing is *not* allowed, the optimal solution utilises only one production site and four marketing subsidiaries. This result demonstrates nicely how relatively resource-scarce firms approaching small-sized markets utilise other firms' resources to gain worldwide presence (Oviatt and McDougall, 1994; Madhok, 1997; Knight and Cavusgil, 2004).

Empirical considerations

In the previous section we have demonstrated the usefulness of our proposed model by introducing several computational experiments based on crude proxies at the country level. Nevertheless, the proposed model is most useful when it is based on firm-level data, since such data are more accurate and enable a comparison of the predictions of the proposed model with the actual location and control configurations chosen by MNEs.

It is fairly easy to measure or collect data on various operation costs (of R&D, production and marketing) as well as on product transfer costs. Such data should be available from the financial reports of MNEs, or on databases that detail various financial data on firms (e.g., *Compustat*). Data that are not readily available from financial reports (e.g., transportation costs, costs per value-adding activity located in each country) are often documented by MNEs, and could therefore be collected by questionnaires and/or in-depth interviews with MNEs' representatives. This may be supplemented with data on demand per industry and costs in various countries taken from multiple sources (e.g., ILO, 2005; UNIDO, 2005a, b). Thus data on the tangible aspects of MNE configurations are generally available.

It is also reasonably easy to calculate the relative share of knowledge as a percentage of total sales or production costs, since these data are usually documented at the firm level (often proxied by the ratio of R&D costs to sales or total costs). However, it would appear to be more difficult to collect data on knowledge flow costs, since such intangible data are not usually documented. Nevertheless, some attempts have been made to collect data on knowledge flows and knowledge flow costs. Teece (1977) has divided knowledge flow costs into four groups: pre-engineering technological exchange cost; engineering costs in transferring the designs of process and/or product innovations; the cost of R&D personnel associated with technol-

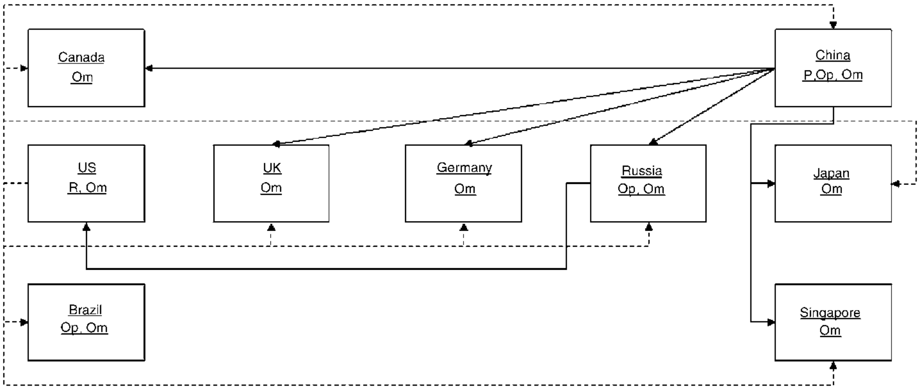

Figure 10 Location and control configuration when knowledge flow costs=0. R=R&D, P=production, M=marketing, O=outsourced production, Om=outsourced marketing; solid arrows=product flow, dotted arrows=knowledge flow.

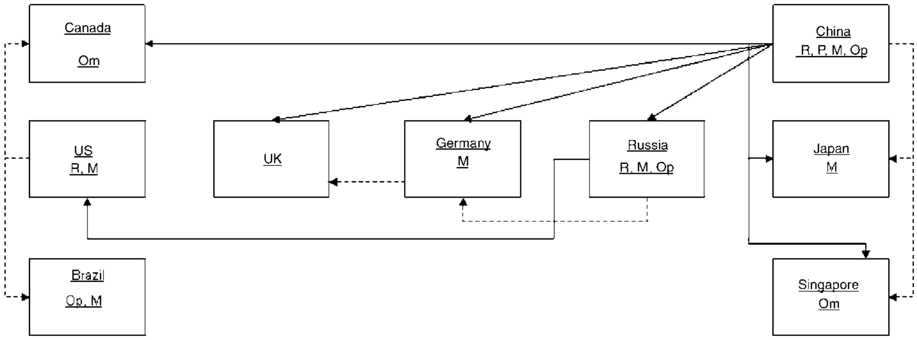

Figure 11 Location and control configuration when knowledge flow costs are doubled. R=R&D, P=production, M=marketing, O=outsourced production, Om=outsourced marketing; solid arrows=product flow, dotted arrows=knowledge flow.

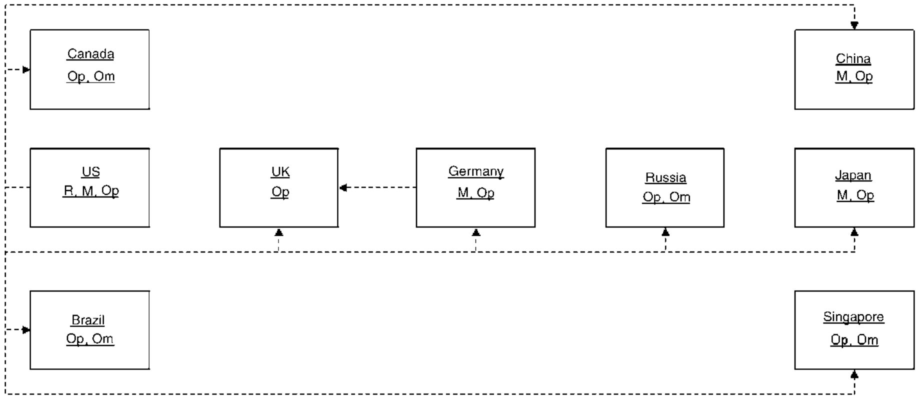

Figure 12 Location and control configuration (demand and budget halved, knowledge intensity doubled). R=R&D, P=production, M=marketing, O=outsourced production, Om=outsourced marketing; solid arrows=product flow, dotted arrows=knowledge flow.

ogy transfer and adaptation and pre-start up training; and debugging and learning costs. These costs were estimated for 26 international technology transfer projects of American MNEs. Galbraith (1990) refers to two types of knowledge flow costs: the cost of resource required to transfer knowledge (re-transfer planning and engineering costs as well as post-transfer management and control costs), and the loss in productivity and know-how as a result of knowledge transfer. These costs were collected for 32 intra-firm knowledge transfer projects based on internal company records and interviews with senior project engineers. Other scholars have used various proxies for knowledge flow costs. Examples include costs of domestic and foreign telephone communications, frequency of communication by individuals from different functions, frequency of communication between employees and customers, the *relative* frequency of telephone, e-mail or face-to-face communications, travelling costs accruing to employees as a result of transferring knowledge to other functions of the MNE or to customers and so forth (Van den Bulte and Moenaert, 1998; Sosa *et al*., 2002). Gupta and Govindarajan (2000) extensively evaluated knowledge flow intensities into a seven-point scale based on interviews with senior management of MNEs. Clearly such a procedure is also suitable to obtain estimations of knowledge flow costs. Another popular way to proxy the flow of knowledge is by using patent citation data to measure the spread of knowledge over geographical and organisational boundaries (see Singh, 2005). Such flow estimations can form the basis for computing a knowledge flow cost function (e.g., when 100% of the knowledge is transferred the cost is assumed to be low, when none is transferred the cost is assumed to be extremely high, and so forth).

Possible extensions to the model

Naturally, a wide range of potential extensions to the proposed model are possible. For instance, the model can be easily extended to relate to more than three value-adding activities (Porter, 1985). Similarly, specific activities may be broken into independent sub-activities to represent phenomena such as the division of labour during different production stages and hence also include the impact of tariffs and exchange rates on production costs at each node. Another extension might be to test the impact of asymmetric directional effects on the cost of knowledge flow between two nodes[9] (Shenkar, 2001). Yet another extension to the model would be to incorporate horizontal knowledge and product flows between value-adding activities of the same type, in addition to the vertical ones already included. Such flows might facilitate the testing of a more diverse set of hypotheses that includes the transfer of knowledge between R&D facilities or between marketing sites as well as the transfer of semi-finished products between production facilities to compare international, multidomestic, global and transnational strategies (Bartlett and Ghoshal, 1989). Another interesting extension might be to relate the trip time from country A to country B as an alternative measure to distance. This might enable an investigation of the impact of land, marine and air traffic systems on the flow of products and knowledge.

More specifically, we wish to offer two important extensions to the model that may increase its applicability in testing location and control configurations of MNEs. One extension refers to dynamics and the other to competition.

By building on work in the field of operations research (e.g., Wesolowsky and Truscott, 1975; Current *et al*., 1998), our model may be extended to consider dynamics over time. A good survey of the literature to date can be found in Revelle and Eiselt (2005). In each period the MNE needs to minimise its location and/or control configuration cost by taking into account, in addition to all the parameters detailed above, the costs of opening up new facilities and shutting down old ones as a function of changes in demand, operation costs and so forth in subsequent periods.

By adding dynamics into the model we can, for example, further investigate the combined role of knowledge flow and operation costs on firms' internationalisation *process*. For instance, highly knowledge-intensive firms are expected to start out their internationalisation via an internalised configuration, since such firms are mostly concerned with minimising knowledge flow costs (Hirsch, 1989; Kogut and Zander, 1993; Martin and Salomon, 2003). However, low sales volumes in early internationalisation stages are expected to create pressures for externalisation. This is because externalisation appears to be associated with a combination of high variable but low fixed costs, whereas internalisation typically requires up-front investments, which implies high fixed costs, combined with low variable costs (Buckley and Casson, 1981). The proposed extension of the model could be used to simultaneously compare the relative magnitudes of these two factors to further establish the dynamics in firms' control configurations during different stages of internationalisation.

The current model has ignored the role of competition in determining the location and control configurations of MNEs. Competition may be incorporated into the model by referring to the characteristics of consumers' purchase decisions (e.g., price, quality, brand, country of origin) and to competitors' characteristics (e.g., domestic firms, MNEs originating in other countries). If such data are available, we may build on the work of McFadden (1973) and Anderson *et al*. (1992), for example, and investigate how market share, quality and other issues may affect the location and control configurations of MNEs.

Discussion and conclusion

The computational experiments presented demonstrate several intriguing insights regarding the location and control configurations of MNEs. High knowledge flow cost and high knowledge intensity are shown to increase the dispersion of activities relative to low knowledge flow costs. MNEs in growing industries are shown to have a more concentrated configuration than those operating in mature industries (Almor *et al.*, 2006), which are in turn much more regional in scope (Rugman and Verbeke, 2004). China is shown to be not only an attractive location for production but also for R&D, while Russia is also identified as having the potential to attract R&D activities, owing to its skilled labour abundance. The location configuration of Japanese MNEs is shown to be less affected by China's dominancy compared with American or European MNEs. We further demonstrate:

(1) how outsourcing enables MNEs to be more dispersed owing to lower costs;
(2) how relatively high knowledge flow costs increase internalisation of activities within the MNE (Kogut and Zander, 1993; Gupta and Govindarajan, 2000; Martin and Salomon, 2003); and
(3) how relatively small knowledge-intensive firms gain global presence through outsourcing, albeit on a limited budget.

Hence, by using the proposed model, we are able to develop simulations that permit us to test the overall impact of different variables in order to empirically evaluate various theoretical predictions. The proposed framework therefore advances the modelling of MNEs within the international business literature, as it offers a coherent platform to test and confront different theoretical perspectives and empirical observations regarding the location and control configurations of MNEs.

Model limitations

The proposed model is rich enough to capture diverse and complex concepts while still being able to provide quantitative answers to the MNEs' location and control dilemmas, but it has some notable limitations that should be borne in mind. The fact that the model does not include bidirectional product and knowledge flows is one of its limitations. Since knowledge is often argued to flow both from R&D to production and marketing and vice versa (Bartlett and Ghoshal, 1989; Kogut and Zander, 1993; Birkinshaw, 1997) we are probably not able to capture the whole impact of knowledge flow costs on MNEs' configurations. The model is also unable to tackle various other important factors that affect the location and control configurations of MNEs. For instance, the role of different institutional environments (Khanna and Palepu, 1998, 2000; Guillen, 2000; Lewin and Volberda, 2003) in determining such configurations is becoming more and more apparent. The proposed model ignores this impact. Likewise the impact of operating in different tax regimes and transfer pricing considerations is ignored (although this could be modelled relatively easily), as well as the pros and cons of cluster agglomeration (Shaver and Flyer, 2000). Finally, the proposed modelling approach is deterministic, while it is well known that in real life many factors are unknown: therefore a stochastic approach capable of assigning probabilities to the various variables (e.g., the probability that knowledge will flow from point A to point B at a certain cost) is also greatly needed.

The major advantage of taking a modelling approach is that it enables us to explore directions that we otherwise could not. More specifically, the location allocation model of the MNE proposed in this paper enables a much more rigorous and complex, but still solvable, analysis of the location and control dilemmas facing MNEs than any other model known to us. The model enables the researcher to step outside the box of conventional home/host country models and combine market-, resource-, knowledge- and efficiency-seeking (Dunning, 1988, 1993) motivations within a single conceptual model. It handles the difficult task of *simultaneously* analysing the impact of a substantial number of location and control configurations, with a special emphasis on intra-, inter- and extra-firm knowledge flows, in order to obtain a complete picture of MNEs' location and control strategies.

Our computational experiments clearly show that the modelling of knowledge flow costs has a significant effect on the location and control configurations of MNEs, and thus should not be ignored, as is done in many other modelling efforts. Hence the incorporation of knowledge flow modelling into investigations regarding the location and control configurations of MNEs is likely to greatly advance our ability to hypothesise and test diverse MNE-related phenomena. Nevertheless, a lot of work still needs to be done to fully capture all aspects of the complex phenomenon of knowledge flows within the MNE.

Acknowledgements

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Notes

[1] A special issue of *JIBS* was recently devoted to the role of intra-firm and inter-firm knowledge flows (Volume 35, No. 5, 2004).

[2] Models within the fields of supply chain management, transportation and mathematical programming have been published in leading operations research journals (*Management Science*, *Operations Research*, *Interfaces*, *Journal of the Operational Research Society* and others) in an attempt to study the MNE phenomenon.

[3] This is achieved easily by setting outsourcing costs to very high values.

[4] Based on data obtained from OECD (2001), ILO (2005) and UNIDO (2005a, b).

[5] Based on data obtained from Davies and Lynos (1996), Frankel (1997), OECD (2001) and European Commission (1997).

[6] Production must be located in two countries because total world demand exceeds the capacity of a single plant.

[7] We used the familiar formula of Kogut and Singh (1988: 422) to calculate cultural distance, based on the four cultural distance dimensions of Hofstede (1980). The computed cultural distance values were then normalised to the magnitude of geographic distance used in the previous runs.

[8] For reasons of simplicity, we ignore outsourcing of R&D. Incorporation of R&D outsourcing into the model should not cause a problem, but it requires a different definition of the R&D cost function.

[9] Implying that the knowledge flow cost from A to B differs from the knowledge flow cost from B to A.

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