

Mathematical Model of the Influence of Knowledge Transfer on the Location Choice of a Multinational Company.

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ABSTRACT

Introduction: Research works haven't yet shed much light on the performance of the location choice of multinational companies. The aim of this publication is to highlight the link between the transfer of knowledge flows and the location of a multinational company.

Methodology: We put forward a conceptual approach allowing to formulate the equations of a mathematical modelization of its consequential performance.

Results and Discussion: Our research has led us to highlight some types of managerial behaviour which will ensure the location performance within a cluster.

Conclusion: We have shown that the embedded knowledge is very important for the location choice of a multinational company. We concluded model for this location choice.

Keywords: cluster, knowledge flows, location, mathematical equations, performance

1. INTRODUCTION

The trend of research concerning organizational approach based on knowledge has gradually emerged as the main perspective aiming at explaining the movements of multinational companies [1]. The most recent publications underscore that the idea of bringing together learning on the one hand and the cluster's prospects on the other hand opens up a fruitful and promising way of studying the competitiveness of multinational companies [2]. For instance, Gupta and Govindarajan conceptualize multinational firms as being networks for transactions, functioning via knowledge flows [3]. Davenport and Prusak define a knowledge flow as being a fluid combination of experiments, a running exchange of essential values, of contextual information, and of shrewd expert evaluations [4].

Firstly, new implantations provide multinational companies with an access to their partners' knowledge, as they combine their own amount of knowledge with that of their partners [5]. In this perspective, the geographical location of a multinational company is a key-concern of research in international management [6], [7].

Secondly, research work concerning organisational approach based on knowledge has focused on the study of contexts in which knowledge flows are highlighted. In this perspective, a good deal of research work has been undertaken in order to elaborate the theory of clusters, based on knowledge. [8]. A cluster has therefore been conceptualized as

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a site in which the creation of embedded knowledge is stimulated, as a consequence of the geographic and organizational closeness of local companies [9](p 50). This research work has shown the assets of clusters, which influence the choice of multinational companies as far as their location is concerned [10].

However, the significant indicators in order to predict the long-term efficiency of a new location contemplated by a multinational company are still unknown [11]. Our conceptual representation of the localization of a multinational company derives from the general concept of space and spatiality, applied to this issue of localization by [12]. Originating from this statement, the question which has prompted our reflection can be expressed in the following words: how to predict the location performance of a multinational within a cluster?

Min and Melachrinoudis propose a research work regarding the optimization of a location choice made by a multinational company for its production units [13]. However, this optimization does not take into account the influence of knowledge transfer.

We shall first put forward a conceptual approach of the location performance of a multinational. This research aims at showing the influence of knowledge flows transfer on the efficiency of the location choice. Then we shall formulate the equations of a mathematical modelization. The mathematical model actually shows that, when the multinational company is not capable of integrating such knowledge into its structure, the local business relationship breaks off. We shall then be able to submit our views to a discussion, and to underline the fact that there is indeed a link between the transfer of knowledge flow and the success of the location of a multinational company within a cluster.

2. LOCATION OF A MULTINATIONAL COMPANY AND THE TRANSFER OF KNOWLEDGE: AN INGENIOUS LINK?

For a long time, it has been generally assumed that this was a one-way transfer, from multinational companies towards local businesses [14]. Nowadays, as competition between multinational companies has become harder and harder, their location choice has become a major strategic issue, and local actors' knowledge may very well have an influence on its success [15]. Referring to Spicer's new terminology, we shall therefore consider knowledge transfer of a convergent type, that is to say, from local to international level [16].

2.1 Learning and location

As they look for new sources of external knowledge flows, multinational companies select some specific geographical sites for their implantation. As the major part of an organisation's knowledge is deeply rooted in expertise and the individual experience of its members, within multinational companies, learning implies the creation, transfer and integration of knowledge flows. The newly acquired databank provides a key-stone for an effective development and for the renewal of the organizational structure, and therefore represents a major competitive asset. Porter underlines the fact that competitive advantage is determined by an appropriately located innovation process, and underscores the crucial importance of the location choice made by the multinational company [6](p. 37). Most costs and risks are consequently linked to obstacles raised by distance and their immediate result on the effective transmission of explicit and tacit knowledge [17].

2.2 Organisational knowledge

The usual distinction between tacit and explicit knowledge derives from the articulate or implicit nature of the considered knowledge. Tacit knowledge is inarticulate, it is essentially personal by nature; such a knowledge is difficult to transfer [18]. On the contrary, explicit knowledge can be codified and transmitted much more easily [19].

92 However, the distinction between tacit and explicit knowledge should not be considered as a
93 dichotomy but rather as a spectrum with both types of knowledge – tacit and explicit – at the
94 extremes [20]. The consideration of transfer speed in an organization as far as knowledge
95 flows are concerned (a notion first mentioned by Davenport and Prusak is undoubtedly
96 useful in order to evaluate how long these transfers will take, and how much they will cost)
97 [4]. In their research work, Inkpen and Wang have observed that tacit knowledge is difficult
98 to assess, and, consequently, that a company in a phase of learning often keeps on
99 concentrating on its explicit knowledge which is easier to transmit (and which is less
100 valuable) [19].

101 Embeddedness is another significant feature of knowledge which has an influence on
102 learning capacity. Its transmission requires face-to-face interactions [21], [22]. Companies
103 holding a common knowledge use it to form corporate alliances and to organize themselves
104 so as to create innovative networks within an industrial cluster [23].

105 Companies should transfer their knowledge according to difficulty, starting with the easiest
106 category: explicit knowledge, then tacit knowledge, then embedded knowledge. The
107 estimation of transfer duration and costs in each category is obviously dependent on
108 increasing difficulty, therefore on the order in which this transfer is made. Consequently,
109 embedded knowledge transfer, which does exist in some branches of industry, is the final
110 learning stage. Distance hardly ever influences the duration and costs of a transfer of explicit
111 knowledge, whereas distance is important when the duration and costs of a transfer of tacit
112 and embedded knowledge have to be estimated.

113

114 **2.3 The context of an industrial cluster**

115

116 Research work has more and more highlighted the geographic issue as being crucial in the
117 location strategies of multinational companies. For instance, Knickerbocker underscores the
118 direct movements of investments made by American multinational companies towards
119 clusters [24]. Porter gives the following definition of a cluster: “a geographically close
120 compact group of inter-related companies with common institutions of their own”. Knowledge
121 is embedded within a cluster, that is to say within small innovative companies each of them
122 part of a cooperative, regional, industrial ruling system [25](p.254).

123 This knowledge is essentially accessible to the actors at work within the limits of the cluster.

124 At the same time, recent studies demonstrate the geographic concentration of innovation,
125 and show that knowledge developments are directly dependent on the networks formed by
126 companies which are embedded in the same region [26]. The major specific feature of
127 innovation, revealed in research work about clusters, corresponds to the necessity of
128 transferring tacit knowledge flows through organisational frontiers. The geographic nearness
129 of partners reduces the importance of issues linked to tacit knowledge transfer because it
130 allows as higher frequency of face-to-face interactions [17](p.11). On the contrary, explicit
131 knowledge can be easily codified and transferred in a formalized language. Therefore,
132 geographic nearness is not crucial as far as the transfer of explicit knowledge flows is
133 concerned.

134

135 **3. MATHEMATICAL MODEL**

136

137 The aim of our model is to propose a mathematical tool to determine the long-term financial
138 results for a multinational which is looking for a new location. This is a problem of complex
139 complementarity mentioned by [27](p.381). The objective for our model proposed is to
140 enable the group to choose the best location for a future site.

141 A feature of locating a multinational in a cluster is the transfer of knowledge between the
142 companies in the cluster and the multinational. Transferring knowledge from the cluster
143 towards the multinational leads to interactions between this new knowledge and the
144 knowledge already present in the multinational. This results in innovation, gains in

145 productivity and so financial gains. For the multinational, the performance which results from
 146 this location is equal to the difference between the financial gains and the costs produced by
 147 the knowledge transfer.
 148 However, the gain in performance for the multinational company may result in an increased
 149 competition between the multinational company and the cluster, and the effect of this may be
 150 a drop in the financial results and a loss of performance for the companies of the cluster.
 151 The knowledge to be transferred is selected so as to maximize the global performance, that
 152 is to say the total amount of performance achieved by both the multinational companies and
 153 the companies in the cluster, deriving from all the transfers which were carried out as the
 154 new implantation was under way. In order to ensure the stability of the new location, the
 155 performance of the multinational company and of each company in the cluster must be
 156 positive, which means that the knowledge transfers should globally be profitable to all
 157 partners. Obviously the necessity of stability lessens the performance of the implantation
 158 under way, but it also avoids a rupture of the local partnership. It ensures a long-term
 159 knowledge transfer until the ultimate stage of embedded knowledge is reached, generating
 160 more and more performance.
 161 The evaluation of gains and drops of the financial results linked to knowledge transfer can
 162 only be made from a thorough examination of the structure of the companies in the cluster,
 163 and of the structure of the multinational company. The cost of a knowledge transfer can be
 164 calculated from the general structure of the knowledge (K) involved which is partitioned into
 165 a "n" number of groups – K_j with "j" ranging from 1 to n. This partitioning is established so
 166 that K_1 only contains explicit knowledge whereas K_n only contains embedded knowledge.
 167 Each group of intermediate knowledge (K_j with j ranging from 2 to n-1) contains both tacit
 168 and explicit knowledge which are not independent, and the proportion of tacit knowledge
 169 gradually increases with "j" (in reference to Inkpen and Dinur's knowledge spectrum,
 170 1998)[20] . The transfer of the knowledge group K_j from the cluster to the multinational
 171 company takes place in T_j days and has a financial cost of F_j . As distance has a greater
 172 influence on the transfer of tacit and embedded knowledge than on the transfer of explicit
 173 knowledge, T_j and F_j are functions related to j. Therefore, the complete knowledge transfer
 174 takes a time $T = T_1 + \dots + T_j + \dots + T_n$ for a total cost of $F = F_1 + \dots + F_j + \dots + F_n$. In the transfer costs we
 175 can certainly include the costs related to geographical distance.
 176 We suppose that the knowledge transferred from the cluster to the multinational during the
 177 time period i, defined as:

$$178 \quad [T_i, T_{i+1}[\text{ for } i=0, n \text{ with } T_j = \sum_{k=1}^j T_k \text{ for } j=0, n \text{ and choosing } T_{t_{n+1}} \gg T_{t_n},$$

179 are only operational – and intervene effectively in the calculation of performance- after the
 180 total transfer of each of the packets of knowledge (K_j for $j=1, n$); so the total operational
 181 knowledge transferred during the time period i after implantation of the new site is:

$$183 \quad Ct_i = \sum_{j=1}^n K_j \text{ for } i=0, n,$$

184
 185 Generally, the total knowledge acquired by a firm is broken down at a moment of time t into
 186 three parts according to its end use ([28], [29]):

$$188 \quad Ca_{\alpha}(t) = Ca_{\alpha}^1(t) + Ca_{\alpha}^2(t) + Ca_{\alpha}^3(t) .$$

189
 190 From this, the Greek lower index (here α has a value of 1 for the multinational and 2 for the
 191 cluster company. As for the upper index, it relates to the type of knowledge:
 192

193 If $i=1$, it represents knowledge leading to improvements in production processes,
 194 If $i=2$, it represents knowledge associated to product innovations,
 195 If $i=3$, it represents knowledge with no direct incidence on production.

196
 197 To take account of the speed with which the knowledge is created at the moment t ,
 198 represented mathematically by the total derivative of the function Ca_{α}^i corresponding to the
 199 rate of fresh knowledge generated at time t and denoted traditionally as $\frac{dCa_{\alpha}^i(t)}{dt}$, we use a

200 Cobb-Douglas type function ([30], [31]):

201
 202
$$\frac{dCa_{\alpha}^i(t)}{dt} = \lambda_{\alpha}^i H_{\alpha}(t)^{\gamma_{\alpha}^i} Ca_{\alpha}^i(t)^{\Phi_{\alpha}^i} X_{\alpha}^{\theta_{\alpha}^i}, \quad (1)$$

203 with $\lambda_{\alpha}^i > 0$, $\gamma_{\alpha}^i > 0$, $\Phi_{\alpha}^i > 0$, $\theta_{\alpha}^i > 0$,

204

205 in this function $H_{\alpha}(t)$ and $Ca_{\alpha}^i(t)$ represent respectively research activity and the total
 206 knowledge acquired at the moment t ; $X_{\alpha}(t)$ is a local variable which influences innovation
 207 positively, for example the share capital or the structure of the local economy at moment t .
 208 The performance of the multinational ($\alpha=1$) or of the cluster company ($\alpha=2$) over the period
 209 of time i ($i=0, n$), resulting only from the benefit of the acquired knowledge, can be written
 210 using the concept of complementarity which mathematically leads to the use of the
 211 supermodular class of functions ([32], [29])

212
 213
$$\Pi_{\alpha i}(A_{\alpha i}) = \pi_{\alpha i}(q_{\alpha i}, i_{\alpha i}, r_{\alpha i}) - R_{\alpha i}(r_{\alpha i}, e_{\alpha i}, f_{\alpha i}, m_{\alpha i}) - I_{\alpha i}(i_{\alpha i}, f_{\alpha i}, a_{\alpha i}, h_{\alpha i}), \quad (2)$$

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215 In the equation below, $A_{\alpha i} = (q_{\alpha i}, i_{\alpha i}, r_{\alpha i}, a_{\alpha i}, e_{\alpha i}, f_{\alpha i}, h_{\alpha i}, m_{\alpha i})$, $q_{\alpha i}$ represents the quantities
 216 produced over the period of time i ($i=0, n$), $i_{\alpha i}$ represents the average frequency of
 217 knowledge linked to an improvement in production processes over the period of time 0:

218

219
$$i_{\alpha 0} = \frac{Ca_{\alpha 0}^1}{T_{\alpha 0}}.$$

220

221 For subsequent periods of time ($i=1, n$):

222

223
$$i_{\alpha i} = \frac{Ca_{\alpha}^1(Tt_i)}{(T_{\alpha 0} + Tt_i)},$$

224

225 where $Ca_{\alpha 0}^1$ and $T_{\alpha 0}$ represent respectively the total knowledge leading to an improvement
 226 of production processes, and the age of company α at the moment of the purchase.

227

228 $r_{\alpha i}$ represents the average frequency of knowledge leading to product innovation over the
 229 period of time 0:

230
$$r_{\alpha 0} = \frac{Ca_{\alpha 0}^2}{T_{\alpha 0}},$$

231 For subsequent periods of time ($i=1, n$):

232

$$r_{ai} = \frac{Ca_{\alpha}^1(Tt_i)}{(T_{\alpha 0} + Tt_i)},$$

where $Ca_{\alpha 0}^2$ represents all the knowledge leading to product innovation in company α at the time of the purchase. Moreover $\pi_{ai}(q_{\alpha i}, i_{\alpha i}, r_{\alpha i})$ represents the operating profit and is a supermodular function of its three variables $q_{\alpha i}, i_{\alpha i}, r_{\alpha i}$. $l_{ai}(i_{\alpha i}, f_{\alpha i}, a_{\alpha i}, h_{\alpha i})$ represents the costs resulting from innovations in production processes. Moreover $(-l_{\alpha})$ is a supermodular function of its four variables $i_{\alpha i}, f_{\alpha i}, a_{\alpha i}, h_{\alpha i}$. $f_{\alpha i}$ represents the level of training of the workforce, $a_{\alpha i}$ represents the level of autonomy of the workforce given their knowledge of production processes, $h_{\alpha i}$ the level of horizontal communication. $R_{ai}(r_{\alpha i}, e_{\alpha i}, f_{\alpha i}, m_{\alpha i})$ represents the costs resulting from product innovation, moreover $(-R_{ai})$ is a supermodular function of its four variables $r_{\alpha i}, e_{\alpha i}, f_{\alpha i}$ and $m_{\alpha i}$. $e_{\alpha i}$ represents the efficiency of the design process, $m_{\alpha i}$ represents the manufacturing flexibility. So, the mathematical problem consists in finding the location which optimises the performance of the local structure at the moment Tt_{n+1} (which is seen as well downstream of the time Tt_n of transfer of all the knowledge), which means, using the performance of company α given by equation (2) looking for:

$$\left(\sum_{i=0}^n \sum_{\alpha=1}^2 \Pi_{ai}(A_{ai}) - F_i \right)$$

with the constraints or conditions for stability expressing that the performance of the cluster company ($\alpha=2$) must remain positive at the moment Tt_j ($j=1, n+1$):

$$\sum_{i=0}^{j-1} (\Pi_{2i}(A_{2i}) + \beta_i F_i) > 0, \quad (3)$$

$\beta_i \in]0, 1[$ being a coefficient making it possible to pay back to the cluster company the cost of knowledge transfer for the period i .

The non-respect of one of these conditions for a time Tt_j can result in the breaking off of the local alliance, as mentioned later in the discussion.

We obtain $Ca_{\alpha}^k(Tt_i)$ (for $k=1, 2$ and $i=1, n$); by integrating the differential equation (1) over the period i ($\Phi_{\alpha}^i \neq 1$) we see that the change in quantity of knowledge in company α is given by the following recurrence relation, for $i=1, n$:

$$Ca_{\alpha}^k(Tt_i) - \Phi_{\alpha}^{i+1} = \lambda_{\alpha}^i (-\Phi_{\alpha}^i + 1) \int H_{\alpha}(t)^{\gamma_{\alpha}^i} X_{\alpha}(t)^{\theta_{\alpha}^i} dt + Ca_{\alpha}^k(Tt_{i-1}) - \Phi_{\alpha}^{i+1} + (2-\alpha) C_i^k, \quad (4)$$

with the initial condition at the moment of implantation:

$$Ca_{\alpha}^k(0) = Ca_{\alpha 0}^k.$$

The last term of the second member of the equation (4) $((2-\alpha) C_i^k)$ corresponds to the quantity of operational knowledge transferred from the cluster company to the multinational (we obtain C_i^k for $\alpha=1$); of course it vanishes for $\alpha=2$ (cluster).

For example: the knowledge transfer might be associated to production of an identical product by the multinational and by the cluster company. If, after the knowledge transfer, the production cost per unit is lower for the multinational than for the cluster company (these costs can be quantified using the supermodular functions depending on A_{α_i}), production of this product should be halted in the cluster company. Thus the corresponding knowledge will no longer be included in the calculation of the frequencies i_{α_i} or r_{α_i} mentioned above, which will result in a reduction in the overall performance of the cluster company. However, if these production costs remain more or less identical for the cluster company and for the multinational, production can be maintained. Using data available on the multinational and the cluster company, the parameters used for equations (1) and (2) can be evaluated over each period of time. The supermodular profit functions (equation (2)) can be assumed to be quadratic [33].

4. DISCUSSION

Research works must systematically go on exploring how embedded knowledge within a cluster has an influence on the efficiency of the location choice by a multinational company. In this respect, Kale and Anand have suggested that the companies of a cluster are conscious of the fact that implantation attempts by multinational companies are intended to exploit learning opportunities [34]. Consequently, local businesses may become very cautious towards the implantation of multinational companies, and they will then do their best to increase their own learning capacities.

In this publication, we have tried to clarify the complex issues brought up by the location of a multinational company within a cluster, raising all along the following crucial question: what is the efficiency of such a location? Indeed, the decision to enter a regional cluster is usually taken whereas performance results are considered uncertain. Our whole reflection work has demonstrated that it is significant to take the transfer of knowledge flow into consideration in order to answer this question. The mathematical model shows that the multinational company chooses its new implantation with a view to reach an optimal level of performance.

In order to make this mathematical model operational, it is necessary to evaluate all the issues and distances involved: geographical, administrative (institutional), economic and linguistic, and their subsequent costs as the transfer are being activated [9]. Porter's research works highlight the fact that interactions between the companies of a cluster result in a larger volume of innovations (and of their subsequent competitive advantages) than the one which would have been generated in the companies of the cluster had operated separately [25](p. 32). This dynamics develops even more as knowledge flows are being transferred between the multinational company and the whole cluster. Therefore, the localization will be effectively optimized if the multinational company really participates in the local processes of knowledge transfers within the cluster [35], [36]. The question may actually be raised in the following words: considering the volume of innovations generated separately by the multinational company and the cluster, what volume of innovations can be expected in the event of their collaboration?

Other investigations would certainly be welcome to improve by a quantitative study that would make the link between the proposed mathematical model and the efficiency of the location of a multinational in a cluster. In order to illustrate the impact of knowledge flows on the performance of multinational companies after a new implantation, we could study an industrial cluster. For example, the French perfume industrial cluster (in Grasse) has attracted multinational agribusiness, cosmetic and pharmaceutical industries. These multinational companies have attempted to transfer the knowledge flows originating from the producers of aromas and perfume compositions, and from perfume creators. This knowledge remains tacit, private and personal, and cannot be transferred unless a direct contact is established.

5. CONCLUSION

Our research work has demonstrated that the transfer of knowledge flows (explicit, tacit and embedded) is crucial to assess the efficiency of the localization choice made by a multinational company. First of all, we elaborate a conceptual model in order to have a better understanding of the impact of knowledge flow on the efficiency of a localization choice made by a multinational company. Secondly, we deduce a mathematical model from this conceptual one. The mathematical model optimizes the performance of the multinational company by using supermodular functions introduced by [32]. On the other hand, we supposed that there was no blocking during the transfers of knowledge and the rate of new knowledge is assumed to be controlled by Cobb-Douglas type function.

COMPETING INTERESTS

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AUTHORS' CONTRIBUTIONS

"Dorota Leszczyńska introduced the conceptual problematic and the mathematical modelization has been proposed by Erick Pruchnicki. We read and approved the final manuscript."

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