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Industrial agglomerations as localised networks: the case of the Portuguese injection mould industry

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Abstract. A resurgence of interest in industrial agglomerations can be found among many different academic disciplines. This trend has been accompanied by a focus on how spatial proximity and the emergence of links between colocated actors may generate benefits for firms, namely, in the generation and diffusion of knowledge. By conceiving industrial agglomerations as territorially based networks, we argue that the dynamics in connections internal to those networks affect and are affected by local institutions as well as connections external to the territory. Our study of the injection mould industry cluster at Marinha Grande in Portugal suggests that firms profit from the emergence of relationships between colocated actors and other agglomeration benefits. However, we suggest that the potential of the industry to generate new knowledge appears to be founded on the patterns of interfirm connections, which selectively connect diverse capabilities both within and outside the agglomeration.

1 Introduction

Despite the growth in transport and communication infrastructure and the possibilities it has opened, there has been a renewed interest in industrial agglomerations or the spatial clustering of firms operating in the same or closely related industries. The vast literature on the subject has emphasised almost obsessively as Hudson (1999) notes, access to and generation of knowledge when firms are spatially close to each other (Amin and Cohendet, 1999; Brown and Duguid, 2000; Kirat and Lung, 1999; Lawson, 1999; Maskell and Malmberg, 1999a; 1999b; Morgan, 2001).[(1)] Although some previously important locational factors have been converted into ubiquities, industrial agglomerations seem to maintain a role as enablers of learning processes, and this may help explain the decisions of firms to locate themselves in specific territories (Dupuy and Gilly, 1999).

Maskell and Malmberg (1999a, page 168) go as far as arguing that the "knowledge creation of even the most globally oriented firms or sector is, at least to some extent, influenced by differences in the economic properties of their place of location." The relevance of these localised capabilities is often approached through the notion of the territory as "an historically constituted set of inter-linked economic activities [R&D, design, manufacturing, commercialisation] coordinated in a variety of ways by firms, research centres and other economic agencies and by local governments and other such socio-political institutions" (Dupuy and Gilly, 1999, page 208).

According to Lawson (1999), the diverse literatures on industrial agglomerations converge in associating the benefits of agglomerations to the emergence of connections between local actors. These benefits, encompassing both the productivity and the

(1) We refer to the bodies of literature on industrial districts (Becattini, 1990), innovative millieux (Camagni, 1991), clusters (Bell and Albu, 1999; Porter, 2000), and the strands associated with the 'Californian school of economic geography" (Storper, 1995).

innovation dimensions, depend on personal relationships, face-to-face communication, and interacting networks of individuals and institutions (Porter, 2000; 2001). But, as Sayer and Walker (1992, page 140) argue:

> "Territories operate in a loose and informal manner, akin to inter-firm networks, and students of industry often jump from those networks to territorial clusters without recognizing the two things are independent. Networks take a spatially concentrated form only when there are particular kinds of inter-firm (and intra-firm) relations and under the impress of territorially-based systems of governance."

The roles of agglomerations are given varying emphasis depending on the researchers' theoretical perspective. Dicken and Malmberg (2001) contend that some approaches emphasise the clustering of firms within a limited geographical space and neglect their embeddedness in a wider industrial system. In contrast, others start with a functional perspective about the industrial system and tend to neglect the spatial dimension of interdependencies between firms.

More recently, some authors have approached the phenomenon of industrial agglomerations, starting from a functional view of the industrial system and discussing the relevance of colocation for the activities and relationships of firms.(2) In this paper we also take a functional view and approach the territorial dimension from the logic of connections between colocated firms and local institutions. We combine a capabilities view of industrial coordination mechanisms (Loasby, 1998a; 1998b; Richardson, 1972) with a network view of industrial systems (Axelsson and Easton, 1992; Håkansson and Snehota, 1995) in seeking to interpret how the spatial agglomeration of firms operating in the injection mould industry in the Marinha Grande district of Portugal may facilitate certain local practices that contribute to the success of individual firms and of the cluster as a whole. Additionally, by focusing on interfirm relationships, we are led to analyse the interplay between homogeneity and heterogeneity in the types of relationships found in the cluster. We argue that this interplay reflects differences in the ways interfirm relationships and relationships between local institutions and firms are connected. These differences suggest that spatial proximity and cluster-specific institutions matter in a variety of ways for local firms, as they use and develop localised capabilities through deliberate and purposeful actions both inside and outside the area (Maskell and Malmberg, 1999b, page 11).

The paper is structured as follows: in section 2 we briefly review arguments related to the generation and diffusion of knowledge, stemming both from spatial proximity and from the emergence of localised relationships. In section 3 we suggest that the relevance of spatial agglomeration can be better understood by focusing on relationships as a mechanism to coordinate, access, and disseminate knowledge. Section 4 starts with an historical perspective of the injection mould industry in Marinha Grande. Next, in section 5, we provide a description of some of the challenges firms face in designing and producing moulds. This helps us understand some problems firms often face and, in particular, their need to develop and access distributed knowledge related to the design and production of moulds. In section 6 we focus on the contrasting trajectories of the two local lead firms and describe their use of direct and indirectly connected relationships both within and outside the cluster. In section 7 we present some concluding comments on what appears to be a healthy tension between homogeneity and heterogeneity, which, we suggest, is related to the diversity found in the ways firms are embedded in connected and counterpart-specific relationships. The collective health of the cluster is associated both with deliberate strategies to promote

(2) As Sayer (2000, page 112) argued, "Space is certainly important, but to say what that importance consists in, we normally have to move to a more concrete kind of analysis where we identify particular kinds of objects, relations and processes constituting it in concrete spatial conjunctures."

shared practices and knowledge frameworks and with the cumulative, emergent, and unplanned effects of relational practices within and without the cluster.

2 Relationships in industrial agglomerations

In the recent past, researchers seeking to account for factors explaining the existence and dynamics of spatial agglomerations emphasised the generation and diffusion of knowledge, in particular tacit knowledge (Lawson, 1999; Maskell and Malmberg, 1999a; 1999b). Schmitz (1999) argued that the benefits generated and spread in agglomerations might involve the operation of deliberate forces that involve bilateral or multilateral cooperation between firms. These deliberate processes contribute to unplanned collective efficiency, as knowledge generated in these contexts "seeps out through multiple sources: workers who socialise with workers of other enterprises, workers who change employers, and suppliers or repairers who have multiple clients" (Schmitz, 1999, page 474).

In this context the development of a common language—that is, shared norms, rules of conduct, routines, and expectations about future business—may be viewed as essential for the growth of mutual understanding and the generation of trust among parties (Nooteboom, 1992; 1999). Nooteboom (1992, page 292) resorts to the notion of 'cross-firm economies of learning' to stress the roles of the links between local actors in accessing different experience.[3] These links can be complementary (between clients and suppliers) and/or similar (between competitors), and they can involve strong and weak bonds, strong bonds being seen as especially useful for accessing and transferring tacit knowledge.

However, the knowledge system of an industry does not perfectly map the structure of the production system. Bell and Albu (1999) suggest that local institutions may have a role to play in the acquisition, generation, and diffusion of new knowledge. In particular, large firms and technological institutes have the potential to operate as 'gatekeepers' or, in the words of Lazerson and Lorenzoni (1999), as 'pollinators'. Through a deliberate posture to explore new opportunities, and by connecting local and external knowledge systems, 'gatekeepers' may contribute to the introduction of variety in the local system and avoid lock-in or the decline of the cluster.[4]

Thus, the emergence of relationships between local actors can be associated with the generation of benefits in the creation and diffusion of knowledge, which may be supported by deliberate actions. Such actions involve the mobilisation of local firms, the reduction of cognitive distances through the development of a common language, and access to new knowledge developed both inside the industrial agglomeration and outside.

However, it can be argued that these accounts emphasise the collaborative dimensions of the cluster at the expense of rivalry. As Malmberg and Maskell (2002, page 444, emphasis added) put it:

> "a 'nice' and collaborative atmosphere might not at all characterize most relations between firms in a spatial agglomeration. Firms may dislike each other and refuse to talk but can still, *indirectly*, contribute to each other's competitive success in the global market."

In short, perspectives centred on territorially defined clusters appear to neglect their embeddedness in a wider industrial system. A functional perspective may be more

[3] "While economies of scale, scope and experience can only be achieved by a combination of different activities in one context (firm), this economy of learning can only be achieved in linkages between different contexts (firms), ie. firms which are sufficiently independent to have their own categories of perception and interpretation, associated with different paths of experience."

[4] To Bell and Albu (1999, page 1726) the "... key features of the knowledge systems of clusters include not just their internal mechanisms for circulating the knowledge already available and for acquiring the new knowledge from experience of various kinds of 'doing'. Possibly more important is their openness to knowledge flows from outside."

sensitive to the relevance of indirect connections and to how "different configurations within the cluster might influence its knowledge-creating abilities" (Maskell, 2001, page 938). Even if sections of interfirm networks take up a spatially concentrated form, variety within each specialism may be important for understanding industrial agglomerations from a knowledge-creation or learning perspective (Loasby, 1999).

3 Industrial agglomerations as 'localised' networks

As suggested above, we may approach the dynamics of the colocation of firms in particular territories starting from a view of the wider industrial system. The role of relationship as coordination mechanisms in the context of industrial organisation can be traced back to Richardson (1972), who argued that planned coordination does not stop at the boundaries of the firm.[5] Complementary activities must be coordinated, but such activities do not have to be similar in terms of the knowledge, experience, and skill (that is, capabilities) that underpin them. Closely complementary activities (that is, those requiring quantitative and qualitative matching) demand planned coordination, either within a firm or through relationships between firms. Relationships between firms are favoured when dissimilar capabilities have to be deployed in closely complementary activities. The role of such relationships goes beyond mere access to existing capabilities, as several other benefits (for example, the development of new products and processes) may result precisely from the connection of very dissimilar and closely complementary capabilities (Loasby, 1998a).

From a functional or relational perspective, 'localised clusters' are the nexus where the territorial and the industrial dimensions meet (Dicken and Malmberg, 2001). Maskell (2001) and Malmberg and Maskell (2002) proposed that the learning benefits of colocalisation ensue not so much from the vertical dimension of the cluster, developed by finer divisions of labour and the development of specialisms, but rather from the horizontal dimension of the cluster, which is associated with variations in the frames of reference of competing firms. In the horizontal dimension, observed ability and comparability are two elements that help explain the existence of a cluster. Many colocated firms undertaking similar activities

> "can monitor each other constantly, closely, and almost without effort or cost. Variation emanates naturally when firms with somewhat similar bodies of knowledge must act on incomplete and uncertain information" (Malmberg and Maskell, 2002, page 439).

Inspired by industrial network research, we suggest that other dimensions of variety generation may be of help in discussing industrial agglomerations from a functional or relational perspective. Relationships between firms, as coordinating mechanisms, are partly counterpart-specific and may be connected differently at the level of each firm (Axelsson and Easton, 1992; Håkansson and Snehota, 1995). Below, we discuss the relevance of the specificity and connectivity of relationships and their role in variety generation. A focus on sources of variety is also important in the sense that industrial agglomerations, as communities of knowledge, can find themselves locked in a common set of connecting principles or shared assumptions (Loasby, 1999). This phenomenon of variety reduction or homogenisation has been associated with excessive closure and 'group-think' (Grabher, 1993) as well as with growing vertical integration and an increase in installed capacity (Best, 1990).

The establishment, development, and maintenance of relationships often involve counterpart-specific investments. The potential of these investments can be captured

[5] Richardson was indebted to the notion of the firm developed by Penrose (1959): that of a collection of resources organised under an idiosyncratic administrative framework, from which productive services can be extracted.

through the notions of 'joint learning' (Håkansson, 1993) or 'interactive learning' (Lundvall, 1993). They involve mutual learning about how to use the resources of a counterpart, interaction processes through which technical knowledge and communication codes are developed, and a shared understanding of the economic and social expectations of both parties. Even if we assume, with respect to the vertical dimension of the cluster, that reputation, trust, and bonding are best achieved at small spatial, cognitive, and cultural distances, to "build up knowledge exchange one must develop common understanding, which to a greater or lesser extent constitutes a relationship-specific investment" (Nooteboom, 1999, page 141).

Also, if firms gain a detailed perception of the needs of their clients and suppliers in industrial agglomerations, then another likely implication of geographic and cognitive proximity will be that "vertical integration is ... not necessary to ensure the alignment of closely complementary activities" (Loasby, 1998b, page 175). However, in a context where the relationships between firms are partly counterpart-specific, differences are to be expected in the ways complementary capabilities are connected. Variety at this level is important, because differences in the evolutionary paths of firms may affect the dynamics of the cluster in its vertical dimension, thus also allowing the considerable variety of firms' dependence on their local milieu referred to by Malmberg and Maskell (2002, page 437).

The differences in firms' dependence on their local milieu may also be related to their embeddedness in particular sets of connected relationships, which connect the vertical and horizontal dimensions, directly and indirectly. This means that the relevance of developments or practices related to the trajectory of individual firms, such as vertical integration, subcontracting, promotion of joint action, and access to other institutions (for example, technological centres) is set in the context of a network of relationships.

This matters in two important senses. On the one hand, the effects of firms' actions in the context of some relationships may be propagated through the network, including learning effects along the horizontal dimension of the cluster, without the requirement of direct interaction between rival firms (Best, 1999; Malmberg and Maskell, 2002; Maskell, 2001). On the other hand, the increased potential learning for the industry as a whole can be associated not only with the colocation of firms and the emergence of a common language or cognitive proximity (Loasby, 1998b) but also with the involving network of direct and indirect relationships between them (Araujo, 1998). In other words, diversity in the ways in which firms access and influence complementary and/or similar capabilities can be relevant for maintaining a 'collective experimental laboratory' in which parallel experiments are conducted (Best, 1999; Loasby, 1999). The effects of such experiments may propagate selectively, and not necessarily deliberately, through the network (Best, 1999; Schmitz, 1999).

Last, we may approach the potential for lock-in situations by considering the ways in which firms try to connect the set of relationships in which they are embedded. It must be noted that the "dense network of co-operation and affiliation by which firms are inter-related" (Richardson, 1972, page 883) does not have to be restricted to economic exchanges or even formal cooperation (Easton and Araujo, 1992; Håkansson and Snehota, 1995). Professional conferences, chance encounters, and other mechanisms may play a role in developing and connecting communities and networks of practice (Brown and Duguid, 2000). These aspects are usually associated with the particular institutional endowment of the agglomeration developed through time:

> "knowledge tends to become embedded, not only in individual skills and in the routines and procedures of organisations, but indeed in the milieus as such, or rather in the relations that connect different firms to each other and to the wider institutional context" (Maskell and Malmberg, 1999a, page 180).

Some additional comments on the relevance of variety in this context are needed, as this dimension acquires visibility only when it is recognised that the lock-in may be territorially defined—that is, that a set of institutions and practices developed over time can be spatially delimited.

Whether localised or dispersed, "coordination within an industry ... is easier if assumptions are shared and rivals are recognized as contributors to the growth of knowledge" (Loasby, 1999, page 83). However, as communities of knowledge, industrial agglomerations can find themselves locked in a 'common set of connecting principles' or shared assumptions (Loasby, 1999) that may involve "the cluster's particular set of institutions that has emerged as a response to the special requirements of the activities performed by the firms making up the cluster" (Malmberg and Maskell, 2002, page 441). Thus, institutional fit or adjustment may contribute to explain not only the successful development of clusters but also lock-in situations (Malmberg and Maskell, 2002; Whitford, 2001).(6)

Weak links are one of the mechanisms that can counter lock-in. This relates to their potential to introduce variety through the sharing of experiences gained in the context of relationships with third parties (Amin and Cohendet, 1999; Grabher, 1993; Håkansson, 1987). Technological centres and other institutions, for example, may connect diverse experiences. However, we may also look at the issue of lock-in considering internal variety and the interdependencies between variety within the 'localised' network and its connections to external firms. With respect to internal variety, local dynamics may be intimately associated with diversity in the trajectories or paths of local firms, which, partly, means different ways of connecting the set of relationships in which firms are embedded. In a sense, as Grabher and Stark (1997) suggest, the evolutionary strength of industrial districts might be based on the diversity or even discrepancy of the organisational activities found there, and variety might even work as an 'antibody' against the hegemony of best-practice organisational solutions.

Some firms can play the role of 'gatekeepers', but this role may be intimately associated with specific configurations of connections, which support both the development of their capabilities and the access and development of capabilities of other local actors. For example, Loasby, in discussing the pathology of industrial districts, suggests that the long-term survival of a localised network "seems to depend on the presence of a firm, or preferably firms, which are unwilling, or preferably unable, to do without local partners but are nevertheless able to induce them to make major changes that might be necessary to preserve the competitiveness of the area" (1999, page 82).(7)

In summary, by emphasising a view of the wider industrial system as an evolving set of connections between capabilities we highlight the relevance of the counterpart-specific nature of interfirm relationships, their connectivity, and their contribution to the understanding of the dynamics of clusters. In this context, we may advance the notion of an agglomeration as a set of differentiated communities of knowledge embedded in different institutional settings (for example, firms, technical institutions, industry associations) and connected to each other, both directly and indirectly, through relationships internal and external to the agglomeration.

(6) This perspective also supports the idea that the relationship between institutional thickness and the success of specific agglomerations is not given or straightforward (Henry and Pinch, 2001). Hudson (1999, page 68) also argued "institutional thickness per se is no guarantee of successful regional economic adaptation and innovation as it can constrain rather than facilitate processes of collective learning and change."

(7) For recent analysis on relationships between industrial groups and territories, see Dupuy and Gilly (1999) and Talbot (2000).

4 The mould-making industry in Marinha Grande

In this section we give a short description of the local industry of injection moulds (for the injection of plastics) with particular emphasis on the uncertainty faced by firms because of the technical sophistication and uniqueness of each mould. The cases of the two local lead firms and the role of the technological centre are then used to assess the relevance of spatial proximity for the relationships of firms with local and external actors. The contrasting cases of both lead firms illustrate different trajectories as well as different ways of using relationships within and outside the cluster.

The study was carried out from 1996 to 1999, allowing for a longitudinal, and partly retrospective, approach. The research design reflected our interest in business relationships and the role of territorially based institutional actors. We adopted the method of an intensive study because it seemed adequate for our purpose of considering substantial relations of connection rather than formal relations of similarity and representatives that often characterise extensive research designs (Sayer, 1992, page 243).

Primary data were obtained through corporate interviews.(8) The format adopted was that of semistructured interviews, which are deemed particularly useful when "highly sensitive and subtle matters need to be covered, and where long and detailed responses are required to understand the matter the respondent is reporting on" (Ackroyd and Hughes, 1992, page 104). Two interviews were conducted, one with the director of the local technological centre and another with its chairman. Three to four interviews were conducted with the managing directors (MDs) and key staff in each firm. The interviews were recorded and subsequently transcribed and analysed. Primary and secondary data were also obtained from six other firms and two institutional actors connected to the industry, namely, the trade association [Associação Nacional da Indústria de Moldes (CEFAMOL)] and ICEP (the Portuguese government agency for the promotion of the Portuguese industry, trade, and tourism abroad). The research team attended a number of industry events and collected the proceedings of industry conferences. Firms' internal documents and interviews with suppliers (for example, with steel and machinery suppliers and software providers) were particularly useful in confronting different perspectives on historical events and developments related to the industry.

4.1 A short note on the Marinha Grande injection mould industry

The Portuguese industry making injection moulds included in 1997 some 280 small and medium sized firms, which together employed about 7500 people.(9) These firms are located mostly in Marinha Grande (61%) and Oliveira de Azeméis (24%);(10) see figure 1 (over). The Portuguese injection mould industry as a whole has frequently ranked among the top-ten largest world exporters: 90% of its total sales (€225 million in 1997) are exported to fifty countries across the world, mostly in the EU (60%), and to the USA and Canada (20%).(11) The relative weight of its client industries has changed from the early days. In 1997 those clients come from a variety of industries: appliances (32%), automotive (20%), electrical components (11%), containers (10%),

(8) For a discussion of corporate interviews as a data collection method in economic geography, see Healey and Rawlinson, 1993, Hughes, 1999, and Schoenberger, 1991).

(9) 46.9% have fewer than 10 workers and 44.5% of them have between 11 and 50 workers. The data are from DETEP-MTS (Department of Statistics for Work, Employment and Professional Training at the Portuguese Ministry of Work and Social Solidarity in Lisbon).

(10) A recent study, based on data from DETEP-MTS, shows a tendency for further concentration of the moulds industry in the district of Marinha Grande and neighbouring Leiria (see Urze et al, 2002). These data shown an increase of 33 firms, relative to 1996 (18 in Marinha Grande, 9 in Oliveria de Aeméis, and 4 in Oporto, but near Oliveira de Azeméis).

(11) Data obtained from ICEP.

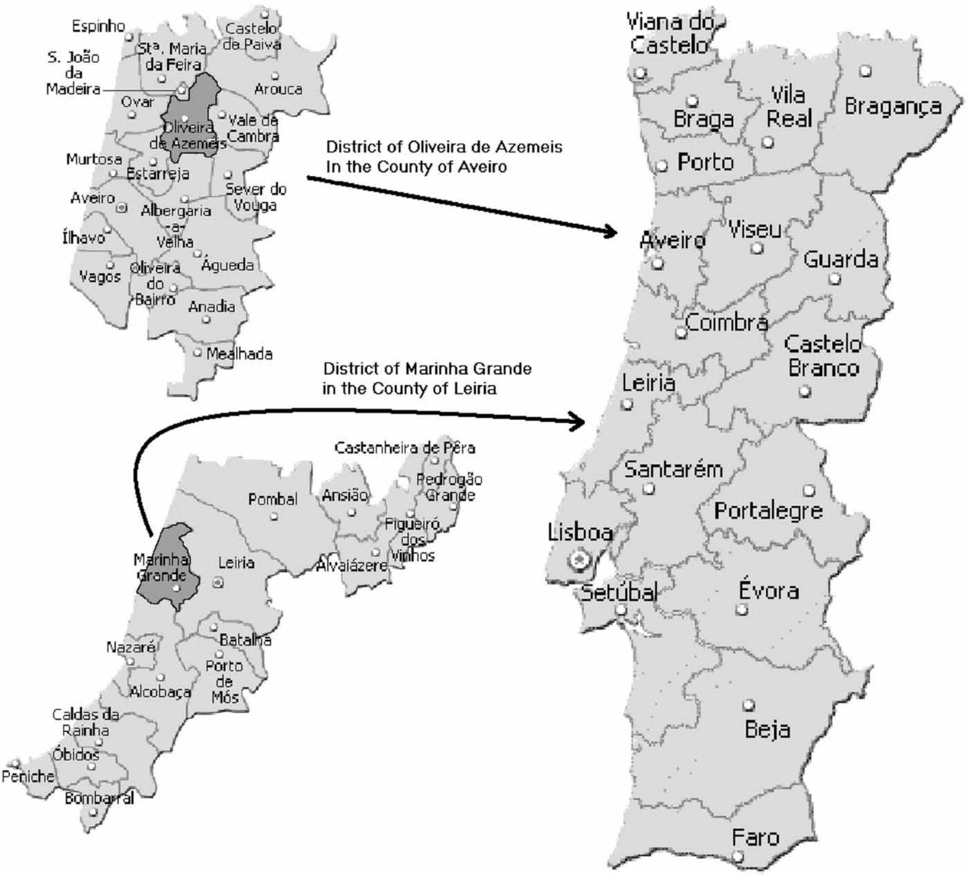

Figure 1. Locations of the Portuguese injection mould industry. Note: in 1997 there were 18 firms in Lisbon, 173 in Leiria (mostly Marinha Grande), 67 in Aveiro (mostly Oliveira de Azeméis), and 28 in Oporto. The distance from Lisbon to Oporto is 315 km by motorway. Marinha Grande and Oliveira de Azeméis are about 150 km apart.

electronics (9%), toys (8%), and sundry (10%). Aggregate export data reflect the success of local industry and illustrate its capability to establish and maintain relationships with such diverse and notable clients as Alcatel, Compaq, Electrolux, Ericsson, Ford, Fisher-Price, General-Motors, Hoover, IBM, Mattel, Nokia, Opel, Peugeot, Philips, Renault, Saab, Samsonite, and Volvo. Geographical distance to clients and the uniqueness of each mould, place particular demands on local firms.

One of our 'informants', the MD of Iberomoldes, one of the two lead firms in Marinha Grande, explained:

> "We have to make sure that moulds are exported with a one-way ticket only, that is, we do not want the moulds returned with quality problems. ... The business of selling moulds is fundamentally a business of trust where I receive the drawings for a product and the mould [for that product] takes months to make. In a way the client is dependent on our performance, on us being credible from the point of view of quality and delivery date, so that he can carry on with his business."

The Portuguese injection mould industry started first at Marinha Grande and, soon afterwards, at Oliveira de Azeméis, both districts with a tradition in the production of glass. Moulds for glass have little in common with plastic injection moulds but both require capabilities for carving out three-dimensional shapes in steel. The growth of the injection mould industry in Portugal can be traced back to the firm Aníbal H Abrantes (AHA), from Marinha Grande. Back in 1935 AHA started producing moulds for shaping bakelite. From 1946 the materials to be moulded have been thermoplastics, injected in a semiliquid state into the mould. AHA's fundamental role in the formation of the industry is often mentioned in Marinha Grande. It was the first local firm to produce and export moulds for plastics. At this time, the MD of AHA confronted with a scarcity of skilled workers locally, decided to train and coordinate workers for the various tasks required to design and produce moulds.(12) Such specialisation circumvented the problem of recruitment and training of unskilled workers but it posed serious coordination and control problems.

AHA was the progenitor firm from which a large number of other local firms hatched. These were generally formed by groups of 4–6 individuals, specialised in complementary activities in mould fabrication. They would get their first orders from clients who visited Marinha Grande, some of whom were clients of AHA. This spinoff process was replicated later with the firms created from AHA. The growing demand for moulds stimulated the creation of yet more manufacturing firms, and their number grew from about 20 in the early 1960s, to more than 100 in the 1980s, and 250 by the mid-1990s. Foreign clients and engineering and marketing firms located in Marinha Grande had important roles to play in this process. Availability of local subcontractors able to manufacture moulds was essential for the development of intermediary firms, and these intermediaries encouraged the creation and development of such subcontractors. However, a major problem for intermediaries was not just to foster the creation of further specialist firms but rather to learn *who* had the capabilities and potential to develop in certain directions and so which firms should be helped and supported. The MD of TEC, the largest local engineering and marketing firm, created in 1968, stressed (emphasis added):

> "Every year there were another two or three new firms .... We were more than a client for most those firms, we were like a tutor, although there wasn't any ownership link involved. The first client for most fabricators must have been TEC. When you have four or five people working in a garage, no foreign client will order a mould from them. *They do not know what is there, but I do*."

The informal network of social relationships, created throughout the years by spinoffs and rotation of personnel, led to the diffusion of practices and enabled cooperation between firms, a common phenomenon in other agglomerations (Pinch and Henry, 1999). It also facilitated the mobilisation of firms for several purposes. For example, since the 1980s, industry conferences, weekend meetings, and seminars have been regular occurrences. These events encourage participants to share experiences and concerns about technical areas (for example, CAD-CAM systems, and techniques for cutting steel). Regular meetings and a sense of shared problems and interests led to joint multilateral actions. For example, a recurrent topic has been the lack of common standards, procedures, and nomenclature for a wide range of products. The first *Handbook of Procedures for the Moulds Industry*, finished in 1996, resulted from a process that involved people from manufacturers, intermediaries, suppliers of steel and components, and so on.

A training centre and a technological centre were also created out of mobilisation involving several local firms and public institutions. Technicians from some firms

(12) The MD of Iberomoldes, himself a former AHA employee, told us: "Mr. Abrantes ... came to Lisbon for a miller. He got a turner from the cement factory. He had some men who knew how to carve steel and he divided knowledge ... among four or five people where each person knew a bit of the whole. All together they managed to do what he required: a mould for plastics. For the first few moulds they did not even have a drawing. They made it together, discussing and chatting. Then he hired a draftsman. I was one of the first few, maybe the third one."

taught the first classes in the training centre, using their own firms' equipment. This institutional fabric of established social relations, common language, rules of behaviour, and channels of interaction is intimately associated with the development of the industrial system. In the next two sections we describe some of the challenges faced by firms in the processes of designing and manufacturing moulds and the relevance of access to and integration of capabilities in this particular context.

5 Mould design and production

A mould is the result of a set of closely complementary activities and a unique combination of specific components (for instance, moulding surfaces) and standard components (for instance, heating and cooling systems, injectors, and hydraulic systems). Moulds differ widely in terms of size, tolerances, rate of output, interchangeability of components, and so on. The relevance of any such characteristic depends on how and where the mould will operate, and on the size, shape, tolerances, and usage context of the plastic pieces it will deliver. The uniqueness of each mould, even when the desired outcome has been clearly defined, contributes to the idea, widely shared in the industry, that the design and the manufacture of any mould is a challenge. This challenge includes the possibility of problems arising during the fabrication and testing of the moulds, with negative consequences for relationships with customers. As one of our interviewees, the MD of Iberomoldes, put it:

> "Problems can always arise in the production of a mould, and any one activity [for example, machining] which is planned for 20 hours may end up taking 40 hours. Timely control of the evolution of the work is crucial to ensure credibility and delivery times—that is, to repay the trust that the customer has placed on you when he granted you the order."

The sequence of activities for the production of a mould usually starts with a request by a client for a price quote and a time for delivery, given a drawing of the component to be produced by the mould and a set of specifications for it. The supplier will reply with an estimate, a technical solution, and, often, with alternative suggestions for the type of materials for carving and building the mould. The client's approval of the preliminary plans triggers the drawing of the final design or plans and the purchase of steels of the size and with the physical properties required for the mould. Fabrication will start next, and this involves a series of operations such as machining, thermal treatments, as well as grinding. Finishing of moulding surfaces, including polishing, will follow. The mould will then be assembled and a first assessment will be made of the quality of the finished mould. Finally, the mould will be tested on injection equipment. Only at the final testing stage can a definite assessment be made of the solutions adopted at the project and fabrication stages.

Testing is an important learning event. It allows manufacturers to find out whether the mould can produce components with the right characteristics and at the pace intended by the client. Insufficient knowledge about the behaviour of molten plastics inside the mould can be critical. In extreme situations it may be impossible to know beforehand that a certain component simply cannot be made. Thus it is fundamental to have the skills to make an accurate preliminary evaluation of clients' requests and of the existing (or potential) capabilities of producers to fulfil an order.

Often, injected materials or some mould components do not behave as expected, which requires corrective operations. Despite the recent development of simulation software, it is still difficult to predict exactly how molten plastic injected into the mould will behave against the internal surfaces of that mould, how it will flow inside moulding cavities, contract on cooling, and so on. The number and location of injection points and the standard components built onto and into the mould may have to be revised and amended. The parlance of the industry distinguishes *corrections* from *changes*, both involving additional operations on moulds. Suppliers are responsible for *corrections* and are accountable for the additional operations and costs involved. However, uncertainties may also extend to customers. Besides aesthetic reasons, customers may request *changes* after testing the plastic components in real operating conditions, when the mechanical or physical properties of those components may prove inadequate. Some customers, especially from the automobile and appliance industries, develop their components through iterative procedures. In short, the customer portfolio of each local producer reflects its own capabilities and its availability to deal with time-consuming and uncertain processes, which greatly complicates the programming and management of production activities.

Relationships with other professionals or local firms can be very important for dealing with such challenges. Given that each mould is in general a unique tool, 'having done something similar' or being able 'to talk with someone who has done something similar' may help to reduce the need for (or the consequences of) changes and corrections. Equally important is to know who has already worked for a particular client, and to be able to find out, by interacting with other suppliers, about a client's behaviour. Such local practices are intimately associated with the emergence of relationships between local actors, and are one of the ways in which local firms seek to deal with such problems. It may also be important to be able to access or participate in the development of knowledge about project technologies, machining, prototyping, the simulation of material behaviour, and even the usage and behaviour of new types of materials and solutions for the design and fabrication of moulds.

Last, it may be necessary or advisable to subcontract to another firm part or all of the activities, because of the possibility of changes or corrections together with the supplier's perceived ability (or lack of it) to deal with often unanticipated requests by (multiple) clients, who differ in terms of their patterns for investment in new products and the number and size of moulds ordered. A producer may need to subcontract to other local producers or some specialised firms, and he or she may also be invited by a client to be part of a pool of producers. In such circumstances, in order to reach the required levels of quality and timeliness, it may be crucial to know who may be available and capable to do what, be it directly or in subcontract.

The relevance of relationships with other local actors, and in particular the role of those relationships as mechanisms to access and generate knowledge, can be better understood by looking at some aspects of the trajectory of two local leading firms who together accounted for 25% of the sales of the whole local industry in 1997. They are well known for their role as 'gatekeepers', but in the following discussion we will focus on their deliberate and varied actions to use and change the local network of capabilities, including connections to local institutions such as the technological centre.

6 Contrasting trajectories of gatekeepers: IB and TEC

IB and TEC are the two largest local firms in Marinha Grande. Staff that left other local firms founded them in 1975 and 1968, respectively. Both started as engineering and marketing firms. In their early days both IB and TEC were confronted not so much with the problem of accessing existing capabilities but rather with the need to promote the development of capabilities at their subcontractors. Soon, IB faced significant restrictions in accessing subcontractors that progressively became less than available to accept its requests for further developments. Also, IB found it more and more difficult to coordinate a series of activities assigned to various subcontractors. As a result, from 1976 onwards, IB opted for vertical integration as a growth strategy. It began establishing specialised firms to serve in-house requirements and other local firms.

Specialist firms owned by IB faced increased competition from other specialist firms in Marinha Grande, although they benefited from growing orders from IB's own clients. IB-owned firms gradually evolved into full-cycle firms, specialising by size of mould, with IB as virtually their only direct client. Detailed norms and procedures were developed for the IB group's firms. As the group grew, the need for training increased, and IB created its own training centre both to develop new recruits and to smoothen disruptions caused by the frequent losses of technicians to other firms. Much later, IB cooperated with other firms, creating an autonomous local training centre.

A few years later, IB adopted concurrent engineering and rapid prototyping in cooperation with some of its clients in order to reduce the time required for developing products and to minimise the need for changes and corrections. IB is already one of the largest European groups in the injection mould industry (employing about 600 people) but currently it has insufficient internal capacity, partly because of the deepening of its relationship with some clients. The variety of demands from IB's clients has been mostly accommodated in-house. Subcontracting is not seen as an alternative because those manufacturers that are seen to have adequate capabilities and potential are unwilling to work for IB. Its relationship with a few local firms have made little impact in the dissemination of knowledge in the local network.

IB was nevertheless confronted with the need to develop relationships in Marinha Grande. In contrast to its lack of links to local producers via subcontracting, it has been actively involved with the local technological centre. The usefulness of the centre and the perception its associates have of it is intimately dependent on its ability to mobilise and connect diverse capabilities held by a variety of actors (firms, universities, other technological centres, training centres, etc). Its creation, back in 1991, resulted from the involvement of several local firms together with the industry association (CEFAMOL) and other public institutions [for example, the Instituto de Apoio às Pequenas e Médias Empresas e ao Investimento (IAPMEI), a state-owned institute supporting small and medium-sized enterprises (SMEs) and investors]. It provides services such as training, mould design, flow analysis, rapid prototyping, and reverse engineering. It also carries out various activities related to the exploration and use of new technologies in the context of projects led by member firms. These projects include topics such as 'advanced techniques for the finishing of moulds and tools', 'the use of copper alloys for the production of moulds', and the creation of a 'national network of rapid prototyping'.

Rapid prototyping technologies, in which IB has played a key role, should be stressed among these developments. The Portuguese RNPR (National Network for Rapid Prototyping) project, begun in 1977, allows direct exploration of selective sinterisation by laser (SSL), a technology that IB has been tracking since 1986. SSL allows the production of plastic components by melting materials with use of laser beams and may potentially replace some of the existing rapid prototyping processes. So far, SSL has been applied only to small numbers of components because of the high unit costs and problems with material resistance and surface finishing. Still, the impact of SSL on IB and the injection mould industry may be very significant, as it is expected that eventually it will allow the production of plastic components without the use of moulds. If that is the case, then the industry may be facing a major reorganisation, requiring the development of new connections between capabilities and the development of new capabilities. Thus, IB draws indirect benefits from its participation in the technological centre, from the relationships between the centre and other actors, both within and outside the local network.

TEC, in contrast, never ceased being an engineering and marketing firm. Both firms see each other as competitors, particularly regarding large clients. This is a source of some rivalry but they acknowledge that the industry has gained from the coexistence of their distinct solutions or administrative frameworks in operating the same type of business. The MD from TEC also sits on the board of the local technological centre, but TEC's link with the centre is regarded as weaker than that of IB.

The fact that TEC remained an engineering and marketing firm is intimately associated with its performance in the context of its large network of relationships with some seventy local producers. Proximity and systematic interactions seemed relevant for TEC to develop knowledge about the capabilities and interests of its counterparts. Vertical integration was never considered a necessity. Its relationships with local producers have worked as mechanisms to access existing capabilities, to transfer knowledge, and sometimes to influence the development of producer capabilities. Its knowledge of the interests and capabilities of local producers has been essential to ensure the effective coordination of orders for a diversity of clients and consistent levels of quality in moulds often produced by different manufacturers but destined to fulfil the same order, or a set of technically interdependent moulds. Spatial proximity and the growth of lasting relationships involving mutual trust are important for the coordination of diverse capabilities among local producers. In some cases, subcontracting is straightforward. In other cases, TEC has to help the producer, for instance, by demonstrating a solution adopted by another local manufacturer or even showing samples of components made by another producer. In other cases, TEC is involved in the training of staff at the subcontractor, sometimes with the help of clients with whom TEC maintains a strong relationship.

Knowledge flows can also travel in the reverse direction. The possibility to access producer experience is seen as very important for learning new solutions in the design and fabrication of moulds. This includes not only the experience producers have acquired through their involvement in the technological centre but also the experiences they have gained in the context of their direct relationships with a diverse set of clients. Nevertheless, the selective connectedness of relationships between clients and manufacturers via TEC and between manufacturers and their other clients is a source of concern for some of TEC's clients. They worry that their competitors may access some of their solutions disseminated by TEC to various local producers in Marinha Grande.

Since the early 1990s TEC's growing emphasis on new solutions and the reduction of delivery times has led it actively to promote the creation of new firms that specialise in designing specific mould details. TEC recommends these firms to its subcontractors so that they too may benefit from knowledge about ongoing projects, thus easing the integration of contributions from various producers.

7 Concluding remarks

Firms, with their own attributes and histories, are embedded in particular territories, which also have their own attributes and histories (Dicken and Malmberg, 2001). Instead of trying to classify the Portuguese injection mould industry according to some typology of agglomerations, we have looked at the injection mould industry in Marinha Grande as embedded in a wider industrial network and have focused on the workings of a part of that network, concentrated in the Marinha Grande territory. Our findings support the arguments about the benefits flowing from practices facilitated by spatial proximity, associated with the emergence of economic and noneconomic relationships in an agglomeration. A common language has emerged through some of the historical processes that led to development of the Marinha Grande industry: the creation of firms through spinoffs, personnel rotation among firms, and the systematic organisation of industry events have led to more formal structures, such as the local technological centre.

The emergence of a network of relationships has supported and been fed by processes of mobilisation for bilateral and multilateral actions. The possibilities for subcontracting, sometimes involving the mobilisation of pools of producers, seems to have been critical for those generalist firms that have risen to the challenge of designing and producing moulds for a wide variety of end-uses. However, by looking at industrial agglomerations, with a focus on the interactions between firms, other aspects are highlighted.

First, even in an industry where everyone seems to know everyone else and what everyone else is doing, firms may diverge in the ways they deal with the coordination of complementary activities, in particular the design and production of moulds. This additional dimension for local diversity is well illustrated by the cases of the two lead firms, IB and TEC. The very existence of these two firms represents two alternative solutions for accessing, diffusing, and coordinating capabilities in the industry. Although both firms seem to have played important roles as 'gatekeepers' or 'pollinators' through time, they differ significantly in the mechanisms they have adopted in order to use and influence the territorial dimensions of the network. Despite competing for clients and, to a limited extent, for access to the capabilities of local firms, both IB and TEC seem to share the notion that they need each other for joint action and may need each other again in a future they cannot foresee.

Looking at both firms, especially at their historical and current practices as well as modes of relating to others, we see that spatial proximity and the emergence of a common language are highly relevant in their trajectories. But the role of IB and TEC in the dynamics of the cluster, along the horizontal and the vertical dimensions, is related to their embeddedness in networks of direct and indirect relationships. Economic relationships with other local producers with similar capabilities run deep in the case of TEC. Its evolution is intimately associated with relationships with external clients, and these require permanent adjustments to the ways in which the capabilities of its local counterparts are connected. Diversity of interests and capabilities at this level makes room both for new firms to emerge and for existing firms to explore new avenues of development. In the case of IB, in contrast, developments in its portfolio of clients did not have a direct impact upon other local firms. These effects were felt mostly via the technological centre (as illustrated by the rapid prototyping techniques), where other firms are invited to participate and services or training are offered. Likewise, we should stress the important role of the centre in connecting capabilities to deal with SSL technology, which may have profound impacts both on the local injection mould industry as a node and on the wider industrial network in which the injection mould industry is embedded.

Second, and related to the issue of generation of diversity, the relation between the benefits of agglomeration and the emergence of local connections should not blind us to the importance of the interdependencies between relationships internal to Marinha Grande and those that are external to the area. If local producers worked only as subcontractors to intermediaries or as suppliers of larger firms, without direct access to final clients, their horizons would be much narrower, and interfirm relationships within Marinha Grande would probably be of a different nature. Part of the variety in local capabilities and learning trajectories can be traced to direct relationships between local producers and external clients, diverse in their technical and market demands as well as in the networks in which they operate. For example, improvements to concurrent engineering or rapid prototyping could reduce the need for changes and corrections in the context of the relationships with some clients, but not with all of them.

In short, the apparently healthy tension between homogeneity and heterogeneity, the emergence of a common language, and the openness of the local system to external knowledge seem to be closely associated with the existence of diversity regarding how various firms are connected at the vertical and horizontal level of the cluster. Face-to-face interactions are important to knowledge diffusion and generation, including know-how and know-whom, and this is an important feature of a spatially concentrated network. But the case of Marinha Grande also supports the notion that the relevance of spatial proximity for learning in the industry depends partly on diversity and systematic interaction among the parties involved and partly on the connectedness between relationships at the level of each local firm.

The results of our study suggest that in Marinha Grande there are significant advantages arising from the colocation of firms associated with their access to and maintenance of diverse local capabilities. This includes the presence of rival firms and the possibility for the generation of variety within each specialism linked to the design and production of moulds. Our results also suggests that this diversity and the potential benefits stemming from its use and exploration are founded on networks of direct and indirect relationships between actors, which selectively connect capabilities both inside and outside this agglomeration.

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