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Dr. M. Caniëls and Dr. H. Romijn

Eindhoven Centre for Innovation Studies, The Netherlands

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Marjolein C.J. Caniëls[1] and Henny A. Romijn[2]

ABSTRACT

Two bodies of literature have contributed significantly to our insight into the forces driving competitiveness and economic growth. Regional agglomeration studies emphasise the favourable impact of geographical proximity on regional economic performance, particularly through knowledge spillovers. However, the firms that constitute those agglomerations largely remain black boxes. In contrast, studies dealing with technological learning explain economic performance at firm level without systematically taking account of the effects of geographical proximity. The aim of the paper is to propose a possible way to bridge this gap. This contributes to our understanding of the determinants of economic growth in industrial clusters. An empirical illustration of a capital goods cluster is elaborated.

Keywords: Industrial clusters, Regional agglomerations, Technological learning, Technological capability, Knowledge spillovers, Regional innovation systems

[1] Open University of the Netherlands (OU), Department of Business Economics and Business Administration (EBB), P.O. Box 2960, 6401 DL Heerlen, the Netherlands. Tel: +31 45 572724; Fax: +31 45 5762103.
E-mail: marjolein.caniels@ou.nl

[2] Eindhoven Centre for Innovation Studies (ECIS), Faculty of Technology Management, Eindhoven University of Technology (TUE), P.O. Box 513, 5600 MB Eindhoven, the Netherlands. Tel: +31 40 2474026; Fax: +31 40 2474646.
E-mail: h.a.romijn@tm.tue.nl

1. Introduction

Two bodies of literature have contributed significantly to our insight into the forces driving competitiveness and economic growth[1]. One is the literature about regional industrial agglomeration, which mushroomed after the publication of Piore and Sabel's (1984) study *The Second Industrial Divide*. Following this, the 1990s have witnessed a boom of research effort devoted to analysing and explaining regional agglomeration from many different disciplinary perspectives (Malmberg and Maskell, 2001). The other body of literature concerns research about the contribution of technological learning in organisations, particularly firms. The evolutionary theory of the firm is an important contribution in this line of research (Nelson and Winter, 1982; Nelson, 1991; Dosi *et al.,* 1988).

The two bodies of literature are quite distinct: the perspective taken in the regional agglomeration studies is a meso-economic one, whereas the technological learning literature adopts a micro-economic perspective. Either body of literature yields only partial insights. The regional agglomeration studies emphasise the favourable impact of geographical proximity on regional economic performance; but the firms that constitute those agglomerations largely remain black boxes. In contrast, studies dealing with technological learning explain economic performance at firm level without systematically taking account of the effects of geographical proximity.

Surprisingly, there is little integration between the two approaches. The objective of this paper is to contribute towards filling this gap in the literature. This is achieved by taking two well-defined approaches as a point of departure, one with a regional agglomeration focus and the other with an intra-firm learning focus.

The different contributions that make up the two literatures (meso and micro) are reviewed in section 2. In section 3 we show a possible way of linking the two levels of analysis. For this purpose we use two approaches that have been commonly used in studies focusing on less developed economies, since it is easiest to start by establishing the link in that setting. The literature pertaining to economically advanced countries is characterised by a multitude of partly complementary, partly competing approaches. In contrast, the number of approaches that have been used in less developed countries are few and well defined. Only one meso-approach and one micro-approach dominate the scene. This preliminary exercise should thus be seen as a first step in a broader research effort aimed at establishing a full integration of the two analytical levels. In section 4 we apply the combined meso-micro framework to an empirical case study about capital goods manufacturing in Pakistan's Punjab Province, which brings out the added value of the combined approach. In the concluding section 5, we elaborate on the implications of this exercise for further theorising about competitiveness and growth in economically advanced countries.

2. Review of relevant literatures

We first review a number of different approaches have been used for studying industrial dynamism from a meso-economic point of view. An important contribution in this field comes from the so-called new economic geography (Krugman, 1991; Audretsch and Feldman, 1996; Feldman, 1994, 2000). This body of research deals with questions such as how the spatial pattern of innovation comes about, and to what extent innovations affect the growth (and decline) of regions. The rise and growth of clusters of firms is an important consideration. These studies emphasise the importance of knowledge spillovers, and the

[1] In the following discussion we have listed some key publications for each body of literature without being exhaustive. Some strands of literature contain a very large number of publications.

advantages of geographical proximity in that connection. However, they do not explore the mechanisms by which these knowledge spillovers take place. Caniëls (2000) fills that gap in the literature, by modelling the ways in which these spillovers occur, and assessing their impact on regional economic growth.

Another prominent line of research is the 'milieu innovateur' approach (Maillat, 1991; Aydalot, 1986; Aydalot and Keeble, 1988; Camagni, 1991). A milieu innovateur is '... a complex which is capable of initiating a synergetic process, ... an organisation, a complex system made up of economic and technological interdependencies ... a coherent whole in which a territorial production system, a technical culture, and protagonists are linked'. (Maillat, 1991:113).

A closely related school of thought works with the concept of regional networks. Its central tenet is that there exist so-called regional systems of innovation within countries that are partly related to the existence of industrial clusters (Cooke, 1996; Asheim and Isaksen, 1996; Oerlemans *et al.,* 1998, 2000). A closely related notion is the learning region, in which regions are conceived as learning entities. Institutional actors are seen to play a central role in promoting and facilitating regional innovative behaviour (Morgan, 1997; Florida, 1995).

Other scholars work with yet another similar concept, namely the industrial district (Scott, 1988; Storper, 1995; Amin and Thrift, 1992; Best, 1990; Pyke and Sengenberger, 1992). This is a highly geographically concentrated group of companies that 'either work directly or indirectly for the same end-market, share values and knowledge so important that they define a cultural environment, and are specifically linked to one another in a complex mix of competition and co-operation' (Rosenfeld, 1995:13). Key sources of competitiveness are elements of trust, solidarity and co-operation between firms, the result of a close intertwining of economic, social and community relations (Harrison, 1992).

Within the regional agglomeration research, there also exists a separate group of so-called 'collective efficiency' studies, which focus specifically on clusters in less developed countries (Schmitz and Nadvi, 1999). These studies are mainly inspired by the above-mentioned industrial district literature about developed countries, but they have evolved their own concepts and analytical framework. They emphasise competitive advantages arising from joint action by parties, which is driven by mutual trust and supportive institutions.

Contrasting with this set of regional approaches are studies that adopt a micro-perspective for studying economic growth and competitiveness. The evolutionary theory of the firm is a prominent contribution in this line of research (Nelson and Winter, 1982; Nelson, 1991, Dosi *et al.,* 1988; Cohendet *et al.*, 1998). In this view, firm-level technical change results from a continuous learning process through activities to absorb, adapt and create technology. Technological learning is conceptualised as '...any way in which a firm increases its capacity to manage technology and to implement technical change' (Bell, 1984:198). The growth and competitiveness of firms are a function of the organisational routines that they build up as a result. Most of the learning is not passive and automatic – it requires purposeful investment of resources. Scholars of strategic management also address intra-firm technological learning as a key part of broader organisational learning processes in organisations (Dodgson, 1991, 1993; Hitt *et al.*, 2000).

Somewhat loosely inspired by Nelson and Winter's evolutionary theory, there are a number of so-called technological capability studies that focus specifically on technological mastery and catch-up in countries that are far away from the technological frontier (Lall, 1992; UNCTAD, 1996). They share a number of similarities with the learning studies in advanced countries. Yet, the capability approach has evolved its own set of concepts and operationalisation, reflecting differences in institutional and economic context.

Both regional and firm-level approaches have limitations arising from their bounded focus. Therefore they can yield only partial insights. The regional agglomeration studies emphasise the favourable impact of geographical proximity on regional economic performance; but the firms that constitute those agglomerations largely remain black boxes. In contrast, the studies dealing with technological learning explain economic performance at firm level without systematically taking account of the effects of geographical proximity.

Since the two levels of analysis are complementary, one may expect that new insights into the driving forces of industrial competitiveness and growth could emerge from integrating them conceptually. Not much work has been done so far in this direction. Only a few writers have attempted to combine insights from the two camps. Good examples are Lundvall's (1988, 1993) writings about interactive learning, in which he outlines how technological learning in firms is affected by their being part of a larger innovation system. Starting from the opposite perspective, Humphrey and Schmitz (2000) have attempted to incorporate firm-level upgrading into their analysis of dynamics of small-firm industrial clusters in less developed economies. Malmberg and Maskell (2001), Maskell and Malmberg (1999), Maskell (2001) and Bell and Albu (1999) investigated cluster dynamics from a knowledge creation point of view. However, much work still remains to be done in this area in order to achieve a full conceptual integration of the two levels of analysis.

3. Regional agglomeration, collective efficiency, and technological learning[2]

In this section we elaborate a possible way of linking up the meso- and micro-level literatures. We choose to concentrate on the developing-country approaches in view of the fact that there is only one well-defined meso- and one micro-approach in the research relating to that part of the world. Hence, it is considerably less complex to bring about an analytical link between the two levels of analysis in a developing-country setting than in advanced countries, where a diversity of approaches exists.

As mentioned above, the research about clusters of small- and medium sized firms in less developed countries has been dominated by the collective efficiency (CE) approach. The main idea in this line of thought is that small companies' competitiveness could be boosted by being part of regional agglomerations of firms engaged in similar and complementary activities (Schmitz, 1995; Schmitz and Nadvi, 1999). From the point of view of the objective of this paper, the relevant question is how the phenomenon of CE could stimulate, facilitate or otherwise enhance activities aimed at technological capability acquisition, or learning, in the companies that make up these clusters. Thus, we need to address two questions. Firstly, which exactly *are* these agglomeration advantages that are subsumed under the umbrella concept of CE? And secondly, what is the nature of the link between these advantages and intra-firm learning?

Regarding the first question, the CE approach puts forwards the argument that clustering is seen to spur economic dynamism through two main mechanisms: Marshallian externalities and co-operation. Marshallian externalities, also termed 'passive CE', have in common that their benefits "...fall into producers' laps without deliberate efforts to bring them about" (Schmitz and Nadvi, 1999:1505). These contrast with 'active CE', which materialises only as a result of purposive actions aimed at generating co-operation and networking. Taking the distinction between active and passive CE as a point of departure, we first identify the nature of the agglomeration advantages that might be subsumed under these two categories. Then we address the second question, by tracing the effects of these various agglomeration advantages on intra-firm technological learning.

[2] The discussion in sections 3 and 4 draws from Romijn (2002).

3.1 Types of agglomeration economies

Going back to Marshall and others, one can identify two broad categories of external effects that have commonly been found to operate in clusters. The first comprises *economies of scale, scope and transaction*, all kinds of cost advantages that accrue from firms locating close to each other (for example, Marshall, 1920; Richardson, 1978). The second category consists of *technological or knowledge spillovers*, intellectual gains through exchange of information for which a direct compensation to the producer of the knowledge is not given, or for which less compensation is given than the value of the knowledge (Marshall, 1920; Audretsch and Feldman, 1996; Feldman and Florida, 1994; Caniëls, 2000). Knowledge spillovers are real gains, not pecuniary advantages.

Both passive and active CE consists of these two main types of external effects – cost advantages and spillovers. The only difference between the two would be, that in the one case they accrue spontaneously to firms as a result of co-location, whereas in the other case their occurrence requires some purposive facilitation in the form of co-ordination of activities carried out by different firms.[3] In sum, we are looking at four basic categories of agglomeration advantages, namely: (I) spontaneous cost advantages; (II) facilitated cost advantages; (III) spontaneous spillovers; and (IV) facilitated spillovers (see Table 1).

The CE writers put great store by the active CE mechanism (i.e., categories II and IV). After examining and comparing a number of empirical case studies, it appeared that clusters in which a lot of active co-operation and networking took place appeared to be more dynamic than those where this sort of behaviour was lacking. Hence, policies and programmes aimed at strengthening institutions that facilitate and stimulate joint action, inter-firm collaboration and networking are usually recommended (Schmitz, 1995; Schmitz and Nadvi, 1999; Ceglie and Dini, 1999; UNCTAD, 1998). On the other hand, the passive, spontaneous, non-collaborative externalities (i.e., categories I and III) have not received much attention, as they are not seen to play a substantial role in boosting regional competitiveness and growth. However, for the purpose of this paper it is preferable at this point to keep an open mind on the relative importance of the different agglomeration mechanisms, and to let the empirical evidence speak for itself. We will explore how all four catagories of agglomeration advantages affect intra-firm technological learning, giving equal attention to the four cells of Table 1.

Table 1: Classification of agglomeration advantages

		Main types of agglomeration advantages	
		Cost savings (pecuniary gains)	Spillovers (real gains)
Occurrence	Spontaneous (passive collective efficiency)	I	III
	Facilitated (active collective efficiency)	II	IV

3.2 Technological learning

One critical ingredient is still needed before we can proceed to fill the four cells, namely an adequate conceptualisation of intra-firm technological learning and of the activities firms undertake to make it happen. For this purpose we take recourse to the extant literature on

[3] Although the CE writers reserved the term Marshallian externalities only for the passive CE effects, the name turns out to be no less applicable to the active CE advantages. In order to avoid confusion, the term Marshallian externalities is therefore avoided in the remainder of the text.

technology and development, also known as the 'technological capability approach'. The concept of technological capability was first coined in the early 1980s by researchers probing intra-firm technological dynamics far from the world's technological frontier.[4] Inspired by upcoming evolutionary theories of technological change (later culminating in Nelson and Winter, 1982; and Dosi, 1988), they showed importation of new technologies by itself to be insufficient for enhancing productivity and inducing self-sustaining industrialisation. Mere access to foreign technology – whether in the form of plant and machinery or documentation and blueprints – does not imply mastery over it (Dahlman *et al.*, 1987). Tacitness associated with new knowledge, and the fact that foreign technologies are less than perfectly suited to specific local needs and conditions, can be powerful barriers to the effective implementation of new technologies in a new setting. Acquisition of new technological capabilities (or 'learning') will usually be required, and this is not a spontaneous and costless process. It requires considerable technological effort – investment in time and resources aimed at assimilating, adapting and improving known technologies, and (ultimately) creating new technologies in-house.

3.3 Linking agglomeration economies to technological learning[5]

Applying the above insights to Table 1, the task is now one of finding out how the four different types of agglomeration advantages specified in section 3.1 may affect technological effort in companies that make up an industrial cluster. The main points emanating from the discussion are summarised in Table 2, which is an expanded version of Table 1.

Many examples can be found with which to fill cell I in the table. First of all, several writers have drawn attention to the fact that clustered firms face lower unit costs of production compared to non-clustered ones. Cost savings can emanate from high local demand for goods and services, which enables local suppliers of parts and components to reap more economies of scale compared to non-clustered ones (Swann, 1998). They may also arise from intense local competition among suppliers of parts and components, which reduces input costs for local firms that use these inputs (Nadvi, 1999). In principle, then, cost savings imply that clustered firms of different kinds are left with more financial resources for technological effort than non-clustered ones, although it remains to be seen whether these extra funds would actually be allocated to technological effort in all circumstances.

There are likely to be more direct spontaneous effects from cost savings on technological effort as well. These are linked to economies of scale, scope and transaction in activities aimed at knowledge accumulation itself (rather than in production, as discussed above). For example, clusters can generate a critical minimum demand for new, specialised products or services that cannot be produced profitably elsewhere. This stimulates investment in efforts to master the production of these new items (Stewart and Ghani, 1991). Moreover, the local presence of suppliers of specialised inputs (such as machinery and parts suppliers, suppliers of training services, financial institutions, marketing agents, etc.) who are attracted by large local demand may lead to lower transaction costs associated with procurement of specialised inputs by user-firms. Hence, clusters act to reduce costs of various specialised inputs needed for technological effort (Tewari, 1999).

There are also some studies that can be used to fill cell II in the table. For instance, several writers have drawn attention to the fact that clusters offer possibilities for firms to join networks of innovators because of low transaction costs associated with local interaction (Freeman, 1991; DeBresson and Amesse, 1991). This leads to cost advantages from sharing costs and risks. Existing literature pointing to this mechanism relates primarily to economically advanced countries, so that the focus has been primarily on R&D, but it is no

[4] The capability literature is extensive. Lall (1992) and UNCTAD (1996) are good reviews.
[5] Parts of the discussion in this subsection make use of Caniëls and Romijn (2002).

less likely to work with respect to more informal types of technological effort found in less developed settings, such as training, information search and shopfloor-based experimentation aimed at making incremental improvements.

Table 2: Impact of agglomeration advantages on intra-firm technological learning: A taxonomy

		Main types of agglomeration advantages	
		Cost savings (pecuniary gains)	Spillovers (real gains)
Occurrence	Spontaneous (passive collective efficiency)	- I - a) Economies of scale due to high local demand leave local input suppliers with more resources for techn. effort. b) Keen local competition puts pressure on prices charged by input suppliers, leaving user firms with more resources for techn. effort. c) Critical local minimum demand for innovations makes it worthwhile for firms to invest in techn. effort needed to introduce them. d) Local presence of specialised suppliers attracted by large market reduces costs of various inputs needed for techn. effort.	- III - a) Changing attitudes and motivations favourable to innovation spread easily through demonstration effects and informal communication. b) Human capital formation (i.e., attitudes and motivations favourable to innovation, as well as assimilation of trade-specific technical skills) is facilitated through informal learning-by-doing. c) Technological transfer is facilitated through inter-firm movement of trained labour; trade journals, meetings, trade fairs and other fora for inter-personal exchange; and user-producer interactions.
	Facilitated (active collective efficiency)	- II - a) Low local transaction costs create possibilities for firms to team up in their techn. efforts, resulting in cost- and risk-sharing. b) Low local transaction costs create new possibilities for joint investment in large techn. effort-projects that are beyond the scope of individual firms.	- IV - a) Identical in content to IIIa b) Identical in content to IIIb c) Identical in content to IIIc However, in contrast to the spillovers in cell III, these spillovers can only occur as a result of deliberate inter-firm co-operation.

In another study pertaining to advanced countries (Baptista, 1998), it has been pointed out that pooling resources for technological effort will induce *more* R&D investment as well. This is because it becomes feasible to embark on large, costly projects that are beyond the capacity of individual investors. Proximity also allows parties to undertake new technological effort of the sort that requires mutual commitment, since they need to supply complementary R&D inputs for it. Again, there is no reason why these mechanisms would not work in less developed countries as well. Only the nature of technological efforts be would be different.

The mechanisms listed in cell III include spontaneous real information and knowledge gains that a firm receives from others. These essentially constitute free inputs that feed into the firm's learning process, complementing its own efforts and increasing the efficiency of learning. Proximity helps to bring about spillovers in various ways. Firms benefit from complementarity and synergy effects that arise from the technological improvement activities undertaken by other firms in the cluster. Spillovers are also facilitated by opportunities for firms to establish direct contact with each other in a cluster, such as through inter-firm labour mobility and formal and informal exchange of information and ideas (Nelson, 1993; Feldman, 1994; Von Hippel, 1988; Baptista, 1998).

Stewart and Ghani (1991) distinguish three important types of knowledge spillovers. *Changing attitudes and motivation* primarily work by exposing people to new ideas and artefacts in a particular environment. These act on people's mental predisposition in such a way that they will begin to favour change over stability, and thereby stimulate investment in the technological efforts needed to bring it about. *Human capital formation through informal learning-by-doing* likewise acts through changing attitudes, in this case attitudes towards work. In addition, learning-by-doing entails assimilation of a basic body of more specific production-related technical knowledge and skills that are common in a local industrial environment. Finally, spillovers take the form of *technological transfer*, which operates through three channels: (i) inter-firm movement of trained labour; (ii) trade journals, meetings, trade fairs and various other fora for inter-personal exchange; and (iii) user-producer interactions which often occur in the course of implementing and perfecting innovations in iterative fashion. Inter-firm movement of trained labour boosts skill levels through hiring of new staff; while communication fora and user-producer interactions are primarily sources of free new information and knowledge about technologies and markets, which complement the firm's own search and research efforts.

Cell IV in Table 1 consists of the same three categories of knowledge spillovers as listed in cell III. However, in contrast to the latter, the spillovers in cell IV cannot occur in the absence of deliberate activities aimed to bring about local inter-firm co-operation. Thus, these co-operative activities are the vehicles through which additional information, knowledge and ideas may travel from one firm to another, more than what would have occurred through 'normal' market transactions.

There is one important caveat to the above discussion. All mechanisms discussed so far refer to positive effects of agglomeration on technological effort and learning. However, clustering may give rise to major negative effects as well, which counteract the positive forces to some extent. These negative effects have not been listed in Table 2 in order to avoid excessive complexity. However, they cannot be ignored, particularly when it comes to deriving policy lessons.

At least two potentially important negative effects should be noted. First, strong competition among small producers who are incapable of differentiating their products substantially from each other may squeeze margins, leaving fewer resources for technological improvement. This will counter the effects of mechanisms Ia and Ib in Table 2.

Second, in clusters where secrecy is hard to maintain and legal protection of innovations is non-existent, knowledge spillovers may also have drawbacks as they reduce innovation incentives for the party that generates them. This may hold back technological effort in progressive firms, which will in turn lead to reduced knowledge spillovers (IIIa, b & c in Table 2). Leakage may also be a powerful barrier for progressive firms to engage in the sort of collaborative projects mentioned under IIa & b, and thereby limit the scope for facilitated spillovers (IVa, b & c).

4. Capability building in Punjabi capital goods firms: How did clustering matter?

In this section the framework laid out in Table 2 is applied to an important section of the capital goods sector in Pakistan, namely farm equipment manufacturing in Punjab Province. The Punjab is a fertile agricultural region known for its widespread adoption of modern cultivation practices from the late 1950s. Agricultural modernisation has been supported by a sizeable small-scale farm equipment industry. Manufacturing is concentrated in about eight major regional towns, each with its own agricultural hinterland. One cluster consists of roughly fifty to sixty firms, which employ approximately five to fifty workers each.

The industry emerged in the early 1960s in response to surging demand for irrigation equipment by farmers. Local manufacture of centrifugal pumps and slow-speed diesel engines had begun in the late 1950s in a few large engineering firms with colonial origins, using older imported designs. Quite soon, ex-employees of these firms began to set up their own small workshops in which they replicated the equipment. They competed on low prices and quick repair due to proximity to customers, even though product quality was typically lower than that of the equipment manufactured by the large companies (Child and Kaneda, 1975).

A second growth wave occurred in the 1970s, this time induced by farm mechanisation. Tractors soon began to be assembled in Pakistan by subsidiaries of large foreign tractor plants, such as Massey Ferguson and Ford (USA) and Belarus (former USSR). These firms also began to offer a range of equipment that could be used in combination with tractors, such as ploughs, seed drills, land levellers, rear and front blades, cultivators, and border formers. While tractor-assembly was beyond the capacity of the small-scale workshops, they did begin to copy a growing assortment of subsidiary equipment (Aftab and Rahim, 1986; Nabi, 1988).

Diversification and increasing complexity of the manufactured products occurred in the following years (Government of Pakistan, 1984). In the most recent survey of the industry in 1994, well over fifty different farm equipment items were counted (Romijn, 1997, 1999). The simple rigid structures of the early days were still being made in large numbers, but several firms had also mastered more complex machinery with internal transmission mechanisms, such as rotary cultivators, wheat and rice threshers and maize shellers. Incremental improvements to designs had also been made to increase capacity, safety, sturdiness and efficiency. Thus, it is evident that technological capabilities had accumulated in the clusters to some extent (*Ibid*.).

These capabilities had accumulated as a result of a range of technological efforts, including: internal experimentation to improve designs based on customers' feedback; hiring technically qualified consultants; training of staff; grooming junior family members by sponsoring their education at a polytechnic; searching for new designs by visiting trade fairs; contacting foreign farm equipment producers; or travelling to other regions to study the farm equipment in use there; and seeking interaction with local institutions concerned with research and development to adapt imported farm equipment to local conditions (*Ibid.*).

No hard and fast primary data have ever been collected about the ways in which geographical agglomeration has affected this process of knowledge accumulation. Some salient observations can nevertheless be teased out from existing studies that have documented the growth and development of the industry. The framework presented in Table 2 is used to structure the discussion. We start with cell I and then move on to II, III and IV, respectively.

4.1 The role of spontaneous cost advantages (mechanism I)

A useful starting point is the favourable market environment in the form of demand-pull arising from agricultural modernisation (Child and Kaneda, 1975). The industry emerged in the proximity of agricultural areas with fast increasing crop yields. Rising purchasing power of farmers combined with increasing seasonal labour shortages fuelled massive investments in mechanisation, which in turn induced a critical minimum local demand for many new types of farm equipment. There was an obvious impetus for producers to introduce new product technologies by reverse engineering prototypes imported by large engineering firms and wealthy farmers.

The demand-pull effects began to be relayed up the production chain. Specialist 'vendors' began to supply parts, components and machining services, investing in processes that require a critical minimum production scale to be economically viable (i.e., an example of mechanism Ic in Table 2). Investments took place in heavy machinery such as power cutting units, cylinder-boring machines, large furnaces (cupolas), honing and milling machines and power presses. What distinguishes these machines from the light equipment conventionally used in farm equipment workshops is '... that they are more expensive and *require considerable expertise in handling. Also there are economies of scale in their use*' (Nabi, 1988:59, emphasis added). These specialised investments extended and deepened the range of local manufacturing abilities, as vendors began to master the production of parts and components that had been hitherto imported or that had only been produced in Pakistan by one or two large engineering firms that were not part of the local clusters. A survey by the Punjab Small Industries Corporation in 1977-8 estimated the number of iron casting units at 419, employing well over 2,000 workers. It also reported 2,141 light engineering services units employing 10,500 workers (Aftab and Rahim, 1986:68).

Even though economies of scale within *individual* small farm equipment workshops were reportedly insubstantial (Child and Kaneda, 1975), the clusters as a whole did begin to reap significant scale economies due to the increasing vertical specialisation facilitated by expanding demand, noted above (Aftab and Rahim, 1986). More efficient horizontal division of labour through increased specialisation also occurred (Stewart and Ghani, 1991:585). These cluster-wide scale economies and interdependencies along firms in the industry helped to entrench the competitive advantages of small-scale production vis-à-vis imports and products made by large domestic manufacturers (Aftab and Rahim, 1986:66). It is not unreasonable to speculate that these economies would also have had the effect of freeing up resources for efforts to master new technologies (i.e., mechanisms Ia and Ib in Table 2), although these is no direct evidence to this effect.

The emergence of a range of specialised suppliers in the clusters also facilitated cheaper and easier access to specialised inputs needed for technological effort, due to reduced costs of transport, import duties, and so on (i.e., mechanism Id). This benefited existing farm equipment firms as well as aspiring new entrepreneurs, as it enabled people with limited means to establish themselves as tiny units which would basically only perform basic machining, finishing and assembly of purchased parts and components (Aftab and Rahim, 1986:66-8). In the earliest survey of one hundred diesel pump firms in the 1960s, only thirty-six were found to be fully integrated (Child and Kaneda, 1975:257). A more recent survey found that many workshops which such humble origins had expanded backwards in due course into technologically more demanding manufacturing, casting and forging operations (Romijn, 1999:284-5). In short, by attracting specialised suppliers, the clusters facilitated a gradual investment path and incremental technological learning trajectory for farm equipment producers.[6]

Technological-effort related benefits also have been associated with the presence of other types of specialised suppliers (again, mechanism Id). A local market for reconditioned

[6] This feature was referred to as 'structural flexibility' inherent in a network form of organisation already well before the advent of the contemporary studies about CE and regional industrial development (Aftab and Rahim, 1986:66-7).

second-hand machinery emerged, bringing essential good-quality foreign machines within financial reach of large numbers of aspiring entrepreneurs (Nabi, 1988:157).

Several clusters also began to attract technology-related support from national, provincial or local institutions (once more, mechanism Id). For example, several firms in Daska, one of the biggest clusters, had been approached by extension officers from the Farm Machinery Institute in Islamabad who were looking for suitable partners with whom they could commercialise farm machinery prototypes developed by them. Interested workshops would receive in-house technical training and counselling, enabling them to iron out teething problems of new equipment during the stage of field trials with local farmers (Romijn, 1999:243). Firms in another major cluster, Mian Channun, had benefited from the establishment of a Dutch-funded training and common facility project on the local industrial estate, run under the *aegis* of the Punjab Small Industries Corporation. Local firms received short training courses in heat treatment, properties of different metals and their uses, and use of jigs and fixtures. Moreover, they could make use of specialised machining services (*Ibid*.:243). One of the machines was capable of manufacturing bevel gears, which are needed in rotary cultivators. According to local workshops, they would not have embarked on (and hence: mastered) the manufacture of this complex piece of farm equipment without the local machining service, because the nearest alternative facility was a several hours' drive away in Lahore.[7] All these examples testify to the importance, for firms' technological efforts, of the local presence of specialised service suppliers that had been attracted by high demand for their services in the clusters (mechanism Id).

Yet more evidence supporting the importance of local specialised suppliers exists in the area of labour training. Diffusion of skills was assisted by technical and vocational training centres set up by the central and provincial governments (Aftab and Rahim, 1986). Moreover, some reputable firms began to assume the status of private training institutes. They issued certificates as evidence that apprentices had completed their training there. Since the authenticity of these documents and the reputation of the firms in question could be verified easily in the local community, this reduced transaction costs for workshops looking to hire labour in the local labour market.[8]

4.2 The role of facilitated cost advantages (mechanism II)

There is less abundant evidence about learning-effects emanating from cost savings deliberately achieved through local inter-firm collaborations. First of all, there is no tradition whatsoever of collaborations of the horizontal kind (basically mechanism IIa). The main reason is that the transaction cost advantages arising from being close to each other are offset by high costs of bargaining and protection needed to ensure an equitable distribution of the benefits from co-operation. This has a lot to do with the lack of an adequate property rights regime (Nabi, 1988:123; Stewart and Ghani, 1991:585). There is a fundamental lack of trust of competitors. The phenomena closest to collaboration are occasional machining services and trade credit given by a well-established workshop to a new outfit run by a member of the same *bradri* (caste).[9] This kind of assistance helps to get new entrepreneurs established in the industry by overcoming indivisibility problems (similar to the mechanism discussed above in respect of parts and components suppliers). Especially the large *lohar bradri* '...helps fellow lohars to acquire the technical knowledge that is crucial for them to enter the industry' (Nabi, 1988:25). However, it falls well short of anything resembling collaborative experimentation between ongoing firms. Competition and associated secrecy is severe, even among people who belong to the same lohar *bradri* (*Ibid.*:123).

[7] Source: fieldwork by Romijn in 1994.
[8] *Idem.*
[9] *Idem.*

Technological collaborations have worked better across different stages of the production chain, because they are more complementary than competitive. Many firms have had collaborative arrangements with local subcontractors to assist in the innovation of components. This seems to be a case of projects that require complementary inputs from two parties in order to work (mechanism IIb). The description below highlights the learning-benefits of close physical interaction in these 'vertical' projects:

> 'Parent firms need of course to explain component design to vendor firms, but technical drawings are almost never used for the purpose. Instead, the usual practice is to hand over the prototype, which may have been imported or designed by a rival firm, to the vendor with few requirements for modification. While the component is being manufactured for the first time the parent firm actively supervises the process to ensure that specifications are met. This usually requires frequent visits by skilled machinists of parent firms.'....'Materials selection, too, actively involves the parent firm with the vendor... since the quality of the material as much as vendor's craftsmanship determines the life and quality of the components' (Nabi, 1988:121-2).

4.3 The role of spontaneous spillovers (mechanism III)

Spontaneous spillovers have substantially facilitated the diffusion of technological knowledge and skills in the clusters. Firstly, knowledge about new designs spreads rapidly in the industry due to co-location (mechanism IIIc). Technology transfer appears to result predominantly from informal contact and observation, although marketing leaflets, industry association meetings, and the annual Horse and Cattle Show in Lahore (which features new locally produced farm equipment) may be of some importance as well (Romijn, 1999). However, the advantages of quick diffusion are to some extent outweighed by appropriability problems encountered by the originators of the new knowledge. This reduces incentives for progressive firms to invest in technological effort. Their reverse engineering and improvement efforts are conducted behind closed doors in the slack season, when seasonal hired labour is absent. This procedure ensures that firms can reap just enough innovation rents from their efforts to make experimentation worthwhile (*Ibid.*). Local copies usually appear one year after the public launch of the 'original'. This appears to be one reason why only incremental modifications are made to the designs (Nabi, 1988:123).

Spontaneous motivational spillovers through demonstration effects have also been widespread (i.e., mechanisms IIIa & b). Young apprentices see many local examples of ex-trainees who have made it in business. This feeds entrepreneurial aspirations and attitudes in the industry (*Ibid.*). Not surprisingly, many ex-apprentices attempt to start their own workshop after completing their training. Thus, skills diffusion has also occurred through inter-firm movement of trained labour (mechanism IIIc) (Johnston and Kilby, 1975:373; Stewart and Ghani, 1991:85; Child and Kaneda, 1975:253). The process initially started with spin-offs from the large engineering firms in the area, later followed by proliferation of new entrepreneurs trained within the small-scale sector itself (Aftab and Rahim, 1986:62; Nabi, 1988:56, 138-9, 152).

4.4 The role of facilitated spillovers (mechanism IV)

In addition to the spillovers recorded above, a certain amount of collaboration-induced transfer of information, skills, ideas and knowledge appears to have taken place in the industry as well. Yet, in many cases it proved hard to judge whether a spillover should be classified as facilitated or spontaneous. Many spillovers appear to have occurred in the context of market transactions involving some loosely collaborative information exchange, but these are still a far cry from actual deliberately co-operative or joint projects that require people to team up and make commitments to each other.

Consider, for example, the vertical interactions between downstream companies and parts suppliers discussed in section 4.2. In addition to stimulating additional investments in technological effort by the participating parties (mechanism II), these interactions also made learning easier through free exchange of technical information and knowledge. Strictly speaking, these spillovers should thus be classified as facilitated technological transfer spillovers (i.e., as an example of mechanism IVc). However, the way in which they occurred seems to be more akin to a spontaneous process (i.e., mechanism IIIc, not IVc). Writing about the reasons why farm equipment producers and vendors tend to co-locate, Nabi observed that: '...It gives them the feeling of being in the market and of having easy access to information, whether about demand for their product, or about technological innovation. There is also considerable informal exchange of ... engineering advice' (Nabi, 1988:118).

More borderline cases between spontaneous and facilitated technological spillovers occur in the form of user-producer spillovers further downstream in the production chain. Progressive entrepreneurs pay regular visits to farms to field-test their products and get farmers' opinions. Farmers are particularly useful as sources of feedback for design adaptation. Equipment based on foreign designs often needs to be adapted to take account of local soil conditions, land quality and cultivation customs (*Ibid*.:141, 150). Regular face-to-face communication between manufacturers and farmers ensures that designs are in keeping with farmers' needs (*Ibid*.:138). Moreover, progressive farmers who buy imported farm equipment are sources of information about new product designs. Manufacturers generally try to reverse engineer foreign prototypes when they are passed on to them for repair and maintenance.[10]

In conclusion, there is no evidence of purely facilitated spillovers in this industry. Deliberate actions aimed at establishing active inter-firm co-operation for the purpose of technological improvement of products or production processes appear to have been rare, and hence there cannot be any spillovers associated with such collaborations either. The main reasons for the absence of such schemes have already been outlined in the preceding paragraphs. Keen competition and the inability to ensure effective protection of the fruits of one's innovations have effectively ruled out serious possibilities for collaboration among competitors.

4.5 The Punjab case: conclusions

Recapitulating the evidence presented, it appears that geographical clustering of the Punjabi farm equipment companies has facilitated their technological learning in a number of ways. This fact has undoubtedly contributed to the remarkably fast development of the industry during the past half-century. We could not have reached this conclusion without the integrated meso-micro framework that was presented in section 3. This framework allowed us to throw light in a coherent manner on the different ways in which regional agglomeration has impacted on capability building in the Punjabi farm equipment companies.

The weight of the evidence points towards a considerable favourable impact of spontaneous mechanisms. Especially important have been cost-related incentives for learning that emanated from presence of specialised suppliers; and inducements to innovate associated with a local critical minimum demand for new equipment. Spontaneous spillovers of different kinds have also played a considerable role. Mechanisms relying on active inter-party co-operation of the sort that requires joint investments and durable commitment were not observed. Much more important appear to have been loosely interactive, semi-spontaneous market exchanges, especially active ongoing user-producer interactions, which have evidently given rise to considerable semi-spontaneous local knowledge spillovers.

Thus, the industrial experience of the Punjab does not follow the predictions of the standard CE model, which downplays the role of spontaneous agglomeration effects (passive

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[10] *Idem.*

CE) for industrial success. Instead, our case suggests that the dichotomy between passive and active CE may not be so useful for the purpose of analysing cluster effects on intra-firm technological learning. In some cases it may be preferable to conceive inter-party relationships in terms of a continuum ranging from pure arms-length market transactions on the one hand, to complete joint ventures on the other. The Punjab case suggests that the middle ground in the continuum may well form the most interesting and dynamic part of the scale, rather than mechanisms purely based on deliberate co-operation.

5. Conclusions and research agenda

The framework developed in this paper for analysing industrial competitiveness and growth from an integrated meso-micro perspective clearly yields considerable value added over and above the two partial approaches on their own. The case study about farm equipment manufacturing in the Pakistan Punjab showed that the region's economic success was not merely due to individual capability building efforts of a number of isolated firms. By superimposing a meso-level CE perspective on intra-firm technological processes, it became clear that regional agglomeration also played its part. Thus, using the integrated approach it is possible to provide a more complete explanation of regional economic success than has been possible with the micro-perspective on its own.

A similar gap remains to be bridged in the research focusing on advanced countries, in order to overcome the current dichotomy that currently exists in that literature. This could be achieved in a similar way as has been done in this paper. That is, one can take the key concepts from relevant micro- and meso approaches in that setting, and try to connect these to one another. We end this paper by making some suggestions about how this could be done, by looking at some concrete possibilities offered at the two analytical levels.

In the micro-sphere one may take recourse to the concept of 'core competences' (e.g., Prahalad and Hamel, 1990; Teece *et al.*, 1997), a widely used notion in the field of organizational learning and in the resource-based theory of the firm. This concept is somewhat similar to the concept of technological capability in the literature about developing countries. Core competencies are a set of differentiated skills, complementary assets and routines that provide the basis for a firm's competitive capacities and sustainable advantage (Dosi *et al.*, 1990). They include "… the ability to access, incorporate and use externally derived information and knowledge; the capability to learn and generate knowledge and information internally; the mastery of technologies and production; the applicability and effectiveness of problem-solving procedures; and the understanding of demand and users' requirements" (Dosi and Malerba, 1996, as cited in Amin and Wilkinson, 1999:121). A concept similar to core competences is 'absorptive capacity' (Cohen and Levinthal, 1990, 1989; Malerba, 1992). This has been defined as a firm's ability to identify, assimilate, and exploit knowledge from the environment (Cohen and Levinthal, 1989:569), or in other words, a firm's ability to learn.

Like the technological capabilities in the less developed country literature, core competences and absorptive capacity are accumulated under the influence of learning-by-doing, trial and error and organizational search (Amin and Wilkinson, 1999; Cohen and Levinthal, 1989). In sum, the way in which the firm-level learning process has been conceptualised in the advanced country literature constitutes a handle on the micro-economic level which meso-level processes could be hooked onto, in a somewhat similar manner as has been shown in this paper.

The way in which the meso-level processes have been conceptualised in the advanced country literature provides several possible entry points for establishing this link. For example, some writers in the regional innovation systems approach highlight how trust and social cohesion facilitate regional dynamism through interpersonal and inter-firm exchange and collaboration. In addition, scholars in the new economic geography and allied approaches highlight that the main benefits from such co-operative behaviour could lie in the sphere of local knowledge spillovers. Thus, there are obvious similarities between the concepts used in the developed country literature and the notion of active CE in the developing country literature.

Despite the apparent similarities between the developing and developed country approaches and concepts, it is to be expected that the development of an integrated framework for an advanced country setting will present a number of unique problems that stem from the existence of a whole plethora of partly competing approaches on either side of the analytical spectrum. The exercise performed in this paper can thus only be a first starting point for further work in this area.

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