KNOWLEDGE FLOWS AND INDUSTRIAL CLUSTERS

AN ANALYTICAL REVIEW OF LITERATURE

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I. Introduction

A significant amount of research has been done on the industrial clusters in developed and developing countries. The European evidence in the 1970s and 1980s suggested that horizontal collaboration between small and medium sized enterprises could yield collective efficiencies in the form of reduced transaction costs, accelerated innovation through more rapid problem-solving and greater market access. Besides, positive externalities are generated by agglomerations through the availability of: (a) skilled labour and inputs; (b) certain types of infrastructure; and (c) innovation generating informal exchanges. These processes of networking and clustering contribute to the competitiveness and growth of the "participating" firms. Further, political and social institutions along with various policies can play a crucial role in supporting the emergence and development of partnering activities among firms and stimulating the transformation of such networks into broader systems of innovation and production. In fact, in most of the European success stories of networking in industrial clusters, regional and local governments played a crucial role. (See Schmitz and Musyck, 1995).

The empirical evidence that got built up on developing countries in the 1990s reflected significant diversity. Broadly, however, the evidence suggested that even in these countries clustering and networking helped small and medium sized firms (SMEs) to raise their competitiveness. The role of public policy in this process, however, remained unclear. This was partly due to the fact that case studies of clusters (even in developed countries) emerged from diverse industrial and trade regimes. Consequently, generalizations became difficult (Nadvi and Schmitz, 1994). It was, however, suggested that networking can increase the leverage of public resources with groups of enterprises. Such an approach has lower transaction costs and facilitates mutual learning (Humphrey and Schmitz, 1995). Further, concentration of firms in a given geographical space may enhance the efficiency of various kinds of investments relating to infrastructure. While the role of the "local government" was extensively analyzed in many cluster studies during this period, the impact of policies at the macro level and the general policy environment did not received adequate attention (Basant, 1997a). Broadly, the literature suggested that clustering helps small firms to overcome growth constraints and become export competitive. It was also recognized that these are not automatic outcomes of clustering (Schmitz and Nadvi, 1999).

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The interest on cluster studies re-emerged in a big way during the late 1990s when researchers from different disciplinary backgrounds explored various explanations of dynamism and persistence of competitiveness among industrial clusters all over the world. The expected erosion and decline of the clusters due to competitive pressures emerging from globalization and liberalization did not take place. The role of macro-economic polices (read liberalization) in the functioning of industrial clusters, therefore, became an important research focus in this period. Moreover, along with liberal economic policies, globalization has been facilitated by a significant decline in transport and communication costs. Despite this, there has been an "increase in the importance of firm clustering, especially in high technology, information-intensive sectors- sectors which, given the enormous recent developments in information technologies, one might have expected to be least sensitive to the need for geographical proximity" (Lawson, 1999: 151).

Several developing countries continue to liberalize their domestic and external policies adding to the competitive pressures faced by the local firms. At the same time, they search for policy initiatives to increase the competitiveness of their enterprises. The infrastructural constraints on the growth of the industrial sector in most of these countries are also significant and growing. Under these circumstances, identification of the sectors and location for infrastructural support is crucial if the limited resources are to be utilized efficiently and productively to raise competitiveness of domestic enterprises. The industrial clusters consisting of viable and dynamic enterprises provide a good infrastructural investment opportunity. Besides, there is some evidence to suggest that clusters located in small or intermediate towns have been more dynamic and successful in comparison to clusters in large towns. (Humphrey and Schmitz 1995). Therefore, focus on clusters in small and medium sized towns is likely to mitigate pressures on larger cities.

The dynamism and persistence of competitiveness among industrial clusters, even in the wake of globalization and liberalization, led researchers to explore the causes of dynamic efficiencies at the cluster level. The earlier cluster studies tended to focus on static advantages of clustering that essentially emerge from lower transaction costs, vertical disintegration of production with high degrees of specialization within the cluster, availability of skilled manpower through "labour pooling" and inter-firm interaction. More recent studies have, however, focused on dynamic efficiencies that emanate from learning at the cluster level. This has necessitated a more rigorous exploration of cluster specific innovative activities and the role of knowledge flows (especially of the tacit variety) in industrial clusters. The "knowledge focus" of cluster studies is of recent origin and we know very little about the nature of knowledge flows and their determinants.

Given the policy focus and researchers endeavour to explore long term competitive advantages of industrial clusters, dynamics of geographically bounded industrial clusters remains an important area of research.

And a better understanding of the innovation processes at the cluster level will facilitate the identification of the right policy instruments. An earlier review of available evidence, mainly from developed countries, showed the following to be the main attributes of dynamic industrial clusters (Schmitz and Musyck, 1995; Nadvi and Schmitz, 1994):

- **Geographical proximity**: A large number of predominantly *small and medium* sized firms are located in geographically bounded space.
- **Sectoral specialization**: The cluster as a whole specializes in a specific industrial sector. Besides, there is significant intra-sectoral division of work, whereby different units within the cluster specialize in specific processes or component manufacturing.
- **Close inter-firm collaboration**: Close inter-firm linkages substitute for vertical integration of all activities within a firm.
- **Inter-firm competition**: Competition among firms is essentially based on innovation rather than on basis of lowering wages.
- **Social embeddedness**: A socio-cultural identity that facilitates trust, reciprocity and social sanction.
- **State support**: Very supportive regional and municipal government complements the work of active self-help organizations.

Do these continue to be important sources of dynamism for industrial clusters? As mentioned above, recent studies have suggested that, apart from other factors, the extent and nature of knowledge flows within its geographical boundaries often affect dynamic efficiency of a cluster. Earlier studies that identified the above mentioned sources of dynamism for industrial clusters also highlighted, albeit in an unsystematic manner, how these characteristics facilitate generation and dissemination of knowledge within a cluster. Using this insight as the starting point, this paper seeks to assess the role of knowledge flows in the functioning of industrial clusters in developed and developing societies. This will be attempted through an analytical review of the available literature.

Broadly, it will be argued that the nature and quantum of knowledge flows in a geographically bounded cluster would depend upon three *inter-related* dimensions:

(a) Internal characteristics of the cluster (e.g., capabilities, internal structure, linkages etc.);
(b) Types of external linkages of the cluster; and
(c) External policy and economic environment faced by the cluster.

Each of these dimensions encompasses a variety of characteristics that distinguish one cluster from the other. In effect, therefore, the paper hypothesizes that knowledge flows are a function of cluster characteristics, a hypothesis that may appear somewhat mundane. It is hoped, however, that once we review the type of relationships between various cluster characteristics and knowledge flows that emerge from the literature, this general hypothesis will reflect more content and value. While it will be our endeavour to highlight the role of these characteristics in the generation and flows of knowledge within the cluster, it must be stated at the outset that many of the relationships are still being explored and no consensus has emerged. We will make an effort to identify areas where more work is needed to understand the determinants of knowledge flows in industrial clusters.

It may be useful at this stage to flag another issue raised in the literature on clusters. The emerging consensus in the literature is that clustering facilitates upgradation of production and related activities. It is less clear how this upgradation takes place. Many studies assume that it is a 'spontaneous process of deepening specialization, of spilling over of know-how and of synergies'. Some recent studies have, however, stressed the role of 'consciously pursued private participation' and public policies (Schmitz, 1999; 1630). It follows from this that any study of knowledge flows needs to understand the processes through which such flows take place in the context of a cluster and how firm and policy initiatives facilitate these flows.

The rest of the paper is divided into five sections. Recent studies on industrial clusters have emerged from different intellectual and disciplinary backgrounds. This paper has taken an eclectic approach, combining different intellectual and disciplinary traditions. Given this variety, it is important to highlight some key definitions that have been followed in the literature and in this paper. Consequently, the next section provides some conceptual building blocks and definitions to better appreciate the studies reviewed here. The next three sections summarize the available evidence on the relationships between the three dimensions defined above and the flow of knowledge. Section 3 explores the linkages between internal characteristics of the cluster and knowledge flows. Section 4 discusses the available evidence on the role of external linkages in determining the extent and nature of knowledge flows. And Section 5 analyses how policy and economic environment in which a cluster operates influences generation and transfer of knowledge. The concluding section identifies the research gaps and issues that need further research effort.

II. Clusters, Knowledge Flows and Capabilities: Some Building Blocks

Cluster studies have used a variety of definitions of industrial clusters. Besides, no systematic conceptualization of knowledge has been used in these studies. It is important to discuss these conceptualizations here as the understanding of knowledge flows in clusters may vary according to the conceptualization one uses.

II.1 Defining Clusters

Most studies use a broad definition of an industrial cluster – a large group of firms in *related industries* located in a *specific region* (Swann and Prevezer, 1998). One can notice that while 'specific region' provides a geographical dimension to the definition of a cluster 'related industries' adds a technological dimension. It implies that the groups of firms are similar in products or processes and are linked through the technology supply chain.

Often such geographical agglomeration of firms is centered around a strong science base as is the case with the Silicon Valley and the Cambridge clusters. Typically, firms group together to take advantage of a strong demand in the region, large supply of skilled (scientific) manpower and the network of complementary capacities in other firms of the region. More on this later.

II.2 Characterizing Knowledge/Technology

In order to understand knowledge flows, one needs to define knowledge in such a fashion that its flows can be identified. While a variety of characterizations are available, broadly technology can be characterized by the knowledge which is embodied in the three Ps: products, processes, and practices[2] (including organizational routines) (Basant and Chandra, 2002). Knowledge on technology is not very systematically defined in cluster studies.[3] Several studies however, provide instances that suggest that knowledge relating to all the "3Ps" is transmitted across enterprises in a cluster. Besides, knowledge embodied in these "3Ps" can vary in terms of (a) the extent of tacitness; (b) context specificity; (c) cumulativeness; (d) incrementality; and (e) appropriability. The nature and quantum of knowledge flows are likely to be affected by these characteristics of knowledge. It is to discussion of these issues that we now turn.

Firms have impacted on one or more of the three entities to bring about technological change. This conceptualization takes "a whole business perspective". The role of managing technology boils down to

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[2] This conceptualisation of technology is drawn from Chandra (1995). Lipsey' (2002) has a similar conceptualisation; a significant difference may be the way we define practices (including the *knowledge re-generation process*) which is wider in scope than Lipsey's organisational routines. Many recent studies (e.g. Mytelka and Farinelli 2000, Bell and Albu 1999) take an approach close to that of Lipsey (2002). In fact, Bell and Albu (1999) also refer to the 3Ps: "products, processes and production organisation" (p.1720).

[3] See Bell and Albu (1999) for an excellent critique of cluster studies for their failure to capture technology adequately. They argue that for most cluster studies changes in machinery is viewed as technological change. We shall use some of their insights in the later part of the paper.

effectively employing combinations of the suitable types & different levels of each of the Ps and in designing systems which will assist in the regeneration & development of the underlying knowledge. In this conceptualization the ability to undertake these tasks is technological capability. In other words, *technological capability* involves effective and efficient usage of knowledge embodied in the three Ps and the ability to modify them to change the knowledge content of the three entities.

This conceptualisation, as mediated by the three Ps framework, captures the technological activities at a more disaggregate level of a firm or a unit within a firm as compared to the more aggregate technology using and technology modifying conceptualisation of Bell and Pavitt (1997). But the distinction between "technology changing" and "technology using" a capability is an important one and needs to be explicitly recognised, both at the conceptual and empirical levels. We shall revert to this issue again in the final section of he paper[4].

The 3P conceptualization helps us in identifying the type of knowledge that is flowing into a cluster. While knowledge embodied in each "P" needs to be disseminated for full appropriation of benefits; partial knowledge flows (one or two "Ps" at a time) can also be quite useful for cluster firms. This conceptualization is useful for another reason: it allows the designers of industrial and technology policy to identify and address specific technology components that would enhance the effectiveness of policy. It also enables firms to "unbundle technologies" and design effective technology strategies to develop technological capability and better manage technology within the enterprise or in a cluster. In other words, appreciation of the *three Ps of technology* helps the policy maker and the manager/entrepreneur to focus attention on specific aspects of technological capability.

Bell and Albu (1999) seem to share these concerns and emphasize the need to distinguish between the 3Ps:

> "...analysis of change in a firm's production technology must encompass much more than just its machinery-embodied technology. Technology is a much more complex bundle of knowledge, with much of it embodied in a wide range of different artifacts, people, procedures and organizational arrangements. These embodiments of knowledge include at least: product specifications and designs; materials and component specifications and properties; machinery and its range of operating characteristics; together with various kinds of know-how, operating procedures and organizational arrangement needed to integrate these elements in an enormously variable range of different production systems. Moreover, as these elements of technology are highly interconnected, improvement in something as simple as product quality may require changes to be made across several linked elements of the bundle, e.g., in machine hardware or

[4] Similarly, this conceptualisation of technological capabilities is somewhat different from that of Lall (1987) (See, Basant and Chandra, 2001 for details). It has been operationalized in Basant, Chandra and Sastry (1999) to evaluate the technological capabilities of the SME's in the Indian auto-component sector.

> operating procedures, the organization of production flows, or the specification or treatment of materials". (p.1717).

Viewing this description through the lens of the 3Ps may make conceptualization and data collection on knowledge flows more accessible.

II.3 Nature of Knowledge Generating Activities[5]

Various inter-related features of technology, technological change and innovative activities have been identified in innovation literature that can impinge on the potential of knowledge generation and transfer across firms. While these features have been identified in the context of firms, they are equally relevant in the case of geographically bounded clusters. These specific features of the knowledge generation process are discussed below. Some of the implications of these features for knowledge flows are also identified. Such implications in the context of clusters are, however, discussed in subsequent sections.

Tacitness: A significant part of knowledge developed by enterprises is tacit; it is difficult if not impossible to codify. This is particularly the case in the early phases of technology development; codification usually increases as the technology matures. Tacitness also arises due to the *circumstantial specificity* of technologies. Technologies often need to be adapted to suit *local conditions of production*, including climate, raw materials, labour management relations and social institutions. Tacitness has significant implications for the transfer and appropriability of technology. Broadly, as tacitness increases, appropriability goes up but transfer becomes increasingly difficult, requiring significant efforts on the part of the buyers and sellers of technology. We shall see later that tacitness of knowledge has been seen as one of the most important reason why geographical proximity is critical for knowledge transfer.

Differentiated Learning: Innovation related activities are highly differentiated. Specific technological skills in one field (e.g., developing pharmaceutical products) may be applicable in closely related fields (e.g., pesticides), but they are of little use in other fields (e.g., designing automobiles). While differentiated learning narrow the technological space in which an economic entity (firm, cluster or nation) can operate, there can be synergies across sectors. For example, technological change in computing can create technological and market opportunities for software developers. Such inter-sectoral linkages can be significant sources of knowledge flows. (See discussion below).

Path Dependency and Cumulative Nature: Technology often evolves in certain path dependent ways conditioned by what are usually referred to as technological paradigms. What an enterprise (cluster) has been able to do in the past strongly conditions what they can hope to do in future. New product and process developments for an enterprise (cluster) are likely to lie in the technological neighbourhood of previous successes. Consequently, technological change is often *incremental in nature based on continuous cumulative learning; discrete/ quantum* changes in technology are few and far between. Moreover, cumulativeness like tacitness adds to appropriability of technology but once again may make transfer more difficult.

Irreversibilities: Economic entities often get locked into certain technologies due to the path dependency referred to above and because of the specialized investments (fixed and sunk costs) associated with an innovation. This, along with differentiation in innovative activities, reinforces the path dependencies. We shall see below that such lock-ins take place among clusters as well. Irreversibilities along with path dependencies and technology life cycle may affect the ability of the incumbent firms in a cluster to absorb knowledge flows.

Technology Supply Chain: Technological interrelatedness plays a crucial role in technological development. We shall see later that linkages with upstream and downstream technologies (users) may hinder or induce technological change in specific enterprise segments of a cluster. If a cluster is seen as a network organization, the supply chain can be seen as an important source of knowledge flows for firms in the cluster.

Interaction among Functional Groups: Strategic decisions to move into new areas, development and implementation of new technology involves continuous and intensive collaboration and interaction among functionally specialized groups like R&D, marketing, production, organization and finance. In fact, linkages with other technologies and complementary assets are crucial for knowledge flows and the success of innovations. Once again, if the cluster is seen as a network of firms performing these functions, interaction among different groups becomes critical for the generation and transmission of knowledge.

High Transaction Intensity: Innovative interactions are transaction intensive. Consequently, any dimension (e.g. distance), that enhances transaction costs, reduces transaction intensity and therefore the likelihood of innovation taking place. This partly explains geographical clustering of innovations (DeBresson, et. al. 1996).

Uncertainty: Innovative activities are highly uncertain. Three kinds of uncertainties have been identified. *Technical* uncertainty relates to whether R&D will successfully generate technology and if so when. *Market* uncertainty relates to the likely impact of the technology when it hits the market - by how much will the process innovation reduce costs, what kind of a demand curve the new product will attract. An extension of the market uncertainty relates to the *conduct of rivals*: how rivals will react; will they match R&D

[5] This sub-section is based on Basant (1997b) which reviews various studies on the subject.

programmes, attempt to win the innovation race, or will they imitate? It has been argued that being part of a cluster reduces these uncertainties (Baptista, 1998, DeBresson et.al., 1996).

Appropriability: Despite various legal provisions for protecting intellectual property, appropriability of an innovation is *never* complete. How far the results of the R&D activity be internalised and how far will they constitute a public good depends on a large variety of factors including tacitness and complexity of technology, market structure and access to complementary assets etc. What is not appropriated by the innovating enterprise *spills over*. Technology spillovers in a sector determine the potential for imitation in that sector. Besides, knowledge spillovers can also take place across sectors.

Given the above characterization of knowledge and knowledge generating activities, clustering can facilitate knowledge flows through following processes (adapted from McCormick, 1999):

Market Access: This is an important external economy for clustered units. Clusters of similar enterprises attract customers from near and distant places improving thereby the market access of these firms. And improved market access brings more customers and the associated knowledge.

Labour Market Pooling: Specialized skills get concentrated in clusters. Such concentration is a result of up-gradation of skills within the clusters due to enlarged market size and/or competition. Besides, skilled labour is drawn from other places. Availability of skills facilitates learning and knowledge transfer. Knowledge flows are further enhanced when the 'labour pool' consists of scientists, researchers etc when clustering is around educational/scientific institutions.

Intermediate Input Effects: Emergence of specialized suppliers of inputs and services in a cluster also enhance the potential of vertical knowledge flows. As in the case of skilled labour, such specialization can emerge from internal processes of differentiation or when concentration of producing firms attracts suppliers from outside.

Technology Spillovers: Diffusion of knowledge as closeness permits rapid flow of information/know-how among firms operating in proximity. Such spillovers can facilitate up-gradation of clusters to a higher technological base. However, spillovers may also create disincentives for knowledge generation due to lower appropriability.

Joint Action: Cooperation among firms within cluster facilitates knowledge flows. Inter-firm linkages and networks among firms in close geographical proximity create opportunities for such collaboration.

II.4 Industry/Sector Characteristics

Observed sectoral patterns of technical change are often seen as a result of the interplay between various kinds of market inducement, and opportunity and appropriability combinations. Structural and technological characteristics of industrial sectors affect opportunity and appropriability conditions and, therefore, impinges on technological strategies of firms in these sectors. Given these sector specificities, clusters specializing in specific sectors will face different opportunities of knowledge generation and dissemination.

II.41 Structural Features[6]

Technology effort is often seen as an investment to create entry barriers, i.e., strategy (conduct) to influence the structure of the sector. The Schumpeterian view is that monopoly power and large size of the firm facilitate/induce technological advance. This is so because the large oligopolistic firms are better able to internalize the benefits of innovation and are generally more certain of their environment. Such firms have the wherewithal to exploit new technology quickly largely due to better access to finance and complementary assets like manufacturing facility and capacity and marketing infrastructure. Therefore, oligopolistic industries are expected to be more innovative. Empirical studies, however, have not been able to discern any neat pattern of linkages between market structure and technological activity. It is recognized, however, that the market structures of both the *technology generating and technology using industry* are relevant for determining the nature and level of technological activity.

While the importance of complementary assets cannot be denied for any innovation, the Schumpeterian logic is probably more apt for breakthrough innovations rather than continuous improvements of the *Kaizen* variety. It is not clear if the empirical investigations are able to make a clear distinction between these two types of innovations. Furthermore, differences across and within industries in terms of product/industry life cycles can complicate empirical investigations. The product and technology life cycles within an industry often overlap and factors influencing appropriability during the *invention*, *innovation* and *standardization* phases may be significantly different (Magee, 1977). Similarly, effectiveness of intellectual property rights (IPRs) has been found to differ across industrial sectors. For example, patent protection is considered to be relatively more effective for chemicals and pharmaceutical sectors than other sectors like industrial machinery etc.. Will lower appropriability result in lower technological activity by firms in a sector due to lower incentives? This may not happen if faster imitation create higher competitive pressures to stay ahead and reap first mover advantages. Besides, non-innovators may also undertake R&D to absorb spillovers. In fact, Cohen and Levinthal (1989) have shown theoretically that the spillovers associated with imperfect appropriability may actually increase R&D in the industry equilibrium. They argue that there is a positive effect of spillovers on the marginal productivity of the firm's R&D as the firm's own technological effort improves its ability to

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[6] This subsection partly draws from Davies et.al (1991)

assimilate the technological developments of others. Therefore, if this effect is sufficiently strong it can overcome the disincentive of imperfect appropriability, resulting in an aggregate R&D higher than the level it would have reached in the case of perfect appropriability.

The structural characteristics of clusters differ across locations and industries. Many clusters are hierarchical while others have a flat structure. A large number of clusters access complementary assets internally and even encompass the entire technology supply chain. Besides, proximity and intense interaction may make appropriability levels low and potential of knowledge spillovers high. Clusters may also be 'located' in different stages of the 'global supply chain', and the market structures on the 'input' and the 'output' side may impinge on the nature and quantum of knowledge flows. Finally, clusters may be at different stages of the technology/product life cycles (TLC/PLC). In fact, as we will suggest below, they may have a life cycle of their own (CLC). The role of these structural features has not been systematically explored in the literature on clusters. We will argue below that the available rudimentary evidence suggest that these structural characteristics are likely to have a significant influence on knowledge generation and diffusion in a cluster.

II.42 Technological Features[7]

Many studies have emphasized the existence of significant inter-sectoral differences in the nature, sources, determinants and objectives of innovative activities and resulting innovations. On the basis of sectoral specificities observed in developed countries, certain categories of these sectors have been identified.

*Supplier-Dominated Sectors***:** Innovation is exogenous to this sector, embodied in purchased inputs. R&D efforts are low and mainly adaptive due to limited technological opportunities. Appropriability and cumulativeness of technological capabilities are relatively restricted. Typical sectors are textiles, clothing, leather, wood, agriculture. The threat of entry faced by the incumbents in this sector usually emanates from machinery suppliers who control most of the technology.

Interestingly, most of the traditional clusters fall in this category. The use of the 3Ps perspective would suggest that supplier domination in knowledge flows may exist essentially for process related embodied knowledge and to some extent knowledge embodied in new materials. The locus of knowledge generation relating to products and practices can still be within the cluster firms engaged in making the final products in the sector. We shall see later that in many of these traditional clusters, inputs on product design and various organizational practices have come from within.

[7] This subsection is based on Dosi (1988), Pavitt (1984; 1990), and Pavitt, Robson & Townsend (1989).

*Specialized Suppliers***:** Firms in this sector focus on product innovations that enter other sectors as capital goods. Formal R&D is low but abundant innovation opportunities are exploited through *tacit* design and engineering capabilities. Idiosyncratic and cumulative skills make for relatively high appropriability of innovations. Typical sectors are engineering, instruments, etc. The firms in this group may face user sector firms as potential competitors through vertical integration. Few clusters of specialized suppliers are found except probably in instrumentation. The engineering clusters that are found in many places mainly make machinery components and not capital goods. Many of these engineering clusters do have some specialized suppliers. Consequently user-supplier linkages become possible.

Scale-Intensive Sectors: Innovation is endogenous to this sector as part of production activities in large complex production systems. Production engineering and learning-by-doing are major sources of technology. R&D expenditures are high as these forms generate their own process technology in many cases and integrate vertically to make their own equipment. Appropriability is also high due to vertical integration and cumulativeness of learning. Besides, the threat of technology based entry is unlikely to be strong, given the relatively small size of the technologically strong suppliers. Typical sectors are transport equipment, glass, metal, cement etc. Once again few clusters of this type are found, the auto-clusters being the notable exception. This is also the sector where vertical disintegration has been quite significant.

*Science-Based Sectors***:** Innovation activity is endogenous to the sector but is located in labs and based on rapid developments in underlying sciences. Technological opportunities are high resulting in high R&D expenditures. The entry barriers in the sector are high due to large R&D investments and high appropriability. Product innovations from this sector enter a wide range of sectors as capital or intermediate inputs. Typical sectors are electronics, chemicals, drugs and bioengineering. Scientific advances often enable horizontal diversification into new product markets. Therefore, similar science based firms diversifying horizontally into related product markets are the potential competitors for firms in this sector. Most of the leading edge clusters fall in this category. Science-technology linkages are important in the cluster with scientific institutions/universities playing a key role in knowledge generation and flows.

It should be noted that the characterization of these sectors could change over time. Broadly, as compared to other sectors, technological opportunities are higher in science based firms (given munificence in underlying technologies) and in specialized suppliers (given continuous pressures to improve production efficiency in user sectors). Firms in these sectors also emphasize more on product innovations vis-a-vis process innovations. We shall see later how this *technological specificity* of various industry groups and therefore clusters that house them can influence knowledge generation and flows.

II.5 Sources of Knowledge Flows

Acquisition of knowledge can take three forms: (a) creation (make); (b) purchase (buy); and (c) imitation (copy). Of course, these three acquisition routes are not always substitutes of each other; they can complement one another. Purchased knowledge can take the form of a new product design (product knowledge), new machinery or material (embodied process knowledge) or new shop-floor practices (e.g. just in time) that a hired consultant implements (practices). These can be purchased outright or acquired through a license agreement.

The knowledge embodied in the 3Ps can also be acquired through the so-called spillover effects. Knowledge spillovers can take different forms including imitation and knowledge transfer through employee turnover. Given the conceptualization of knowledge and the sources of knowledge, buyer-supplier relationships or sheer proximity of enterprises producing similar products can facilitate acquisition of knowledge in an industrial cluster. And if spillovers from manufacturing and technology development activities are highly localized in a geographical sense, then firms will tend to locate near manufacturing and R&D activities in order to exploit these spillovers.

In recent studies, knowledge flows to incumbents have been distinguished from knowledge flows facilitating new entry. Entry of new firms in a cluster is seen as an important source of exploiting the spillover potential of the knowledge available in a cluster. It has been argued that often the tacit component of the knowledge embedded in a cluster is utilized when new enterprises are created by employees or other individuals who have been part of the cluster and who have internalized this tacit knowledge. Moreover, new enterprises may also be setup by outsiders to exploit the existing knowledge base (including spillover possibilities) of the clusters. (Swann and Prevezer, 1998; Athreye, 2000). In this sense, new entry in a cluster reflects flows of knowledge.

The subsequent sections will provide some qualitative estimates of the role of various sources of knowledge flows in geographically bound clusters.

III. Internal Characteristics of the Cluster and Knowledge Flows

A variety of cluster characteristics can impinge on the generation and diffusion of knowledge. This section discusses some of these characteristics and their role in determining knowledge flows.

III.1 Sector Specialization of the Cluster

A cluster may be diversified in terms of sectors, products and technologies (e.g. Cambridge, UK, Route 128, USA) or may be focused on specific sectors, products or technology. (E.g. textiles in Prato, Italy and

Tiruppur, India). Sector specialization of a cluster is likely to be important for knowledge generation and diffusion in two ways:

- As discussed earlier, technological opportunities differ across sectors. Besides, potential for intra-sectoral spillovers and learning possibilities may also be different for different sectors.
- Technological opportunities emerging from inter-sectoral linkages can be significant for certain sectors enhancing the potential for inter-sectoral technology spillovers.

Studies have shown that clusters with strong computer hardware, components and systems sectors are more successful in attracting entry into software, peripherals and services. Evidently, these inter-sectoral synergies and spillovers contribute significantly to knowledge flows and to the development of computer industry clusters. The UK computing industry, for example, has very little core hardware and manufacturing of components. Unlike in the US, it lays greater emphasis on peripherals, software, distribution and services. Higher degrees of diversification in the US clusters could have contributed to higher growth of these geographical entities. (Swann and Prevezer, 1998). Such cross-sectoral effects may have also contributed to higher growth of the Indian software sector in Bangalore. But such links have not been explored.

In the same vein, the experience of Route 128 seems to suggest significant synergistic knowledge flows across sectors/technologies. Massachusetts has had historical strengths in telecommunications equipment, instrument engineering and medical devices. The marriage of technological knowledge in these industries with information technology contributed to the resurgence of Route 128 firms in the 1990s (Best, undated).

Overall, however, the cluster studies have not explicitly explored the links between sector specialization and knowledge flows. Moreover, sectoral specificities interact with a variety of other cluster characteristics. Consequently, it becomes difficult to delineate the role of sectoral specificities in influencing knowledge flows. We shall revert to this issue later.

III.2 Knowledge 'in the Air': Social Capital, Untraded Interdependencies or Contextual Knowledge

Several authors have argued that geography clearly matters in the transfer and/or sharing of knowledge particularly of the tacit variety. The transmission of tacit knowledge combines language and observation, imitation and practice. It is facilitated by socialization in a regional context as it creates a common knowledge base. (Cohendet et.al., 1999). Tacit knowledge spills over between firms in the same cluster through staff mobility and informal interactions between employees of different organizations. Consequently, a firm based in a cluster is best placed to absorb such spillovers.

Earlier contributions to the cluster literature used division of labour, transaction costs and agglomeration to explain the phenomenon of clustering. The vertical disintegration of production results in increased transaction costs which in turn induces agglomeration as economic agents make efforts to reduce transaction costs arising from geographical distance. However, the focus of these studies was on *traded* relations, typically conceptualized as input output linkages. More recently, the focus has shifted from *traded* to *untraded* interdependencies. Storper (1995) has argued that these untraded interdependencies cannot be captured through input-output transactions but involve technology spillovers, conventions, rules and languages for developing, communicating and interpreting knowledge. More importantly, untraded interdependencies generate observed input-output linkages but are more enduring. As Storper (1995) argues, Silicon Valley continues to be a dynamic agglomeration because 'geographically-constrained untraded interdependencies outlive geographically-constrained input output linkages' (p.209).

Agglomeration economies are complex outcomes of interactions between scale, specialization and flexibility in the context of proximity. Untraded interdependencies between enterprises in a cluster, apart from input-output linkages, contribute to knowledge flows and learning. (Storper, undated).

> "Organizations are knit together, their boundaries defined and changed, and their relations to each other accomplished not simply as input-out relations or linkages, but as untraded interdependencies subject to high degree of reflexivity. Territorial economies are not only created, in a globalizing world economy, by proximity in input-output relations, but more so by proximity in the untraded or relational dimensions of organizations and technologies. The principal assets – because scarce and slow to create and imitate – are no longer material but relational." (Storper, undated: 40).

Following the logic of relational assets and untraded interdependencies, agglomeration ceases to be a mere result of individual maximization. 'Once proximity becomes an input into the social division of labour by allowing firms to make choices between what they do internally and what they buy externally', - it provides firms with choices to opt for different degrees of specialization than would otherwise be possible. This choice impinges on the dynamics of technological development. (Storper, undated: 64).

Relational assets have a variety of dimensions. They include 'reciprocity, trust and the nature of ties within and between firms; the conventions and routines that bind agents and corporate cultures, past and present; and the rationalities of behaviour and action, and the cognitive base for collective learning and adaptation' (Amin and Wilkinson, 1999: 125). If these properties are geographically circumscribed they facilitate learning and contribute to the competitiveness of the cluster firms.

Just as untraded interdependencies and relational assets facilitate knowledge flows so does social capital. In fact, there appears to be an overlap between the two conceptualizations:

> "*Social capital* refers to the values and beliefs that citizens share in their everyday dealings and which give meaning and provide design for all sorts of rules. The use of the word *capital* implies that we are dealing with an asset. The word *social* tells us that it is an asset attained through membership of community. Social capital is accumulated within the community through processes of interaction and learning. But social capital is not a commodity for which trade is technically possible or even meaningful (Maskell, 1999: 2. *Emphasis ours*).

It is well known that arms length market interactions may fail to transmit qualitative information between users and producers due to asymmetrical distribution of information between the seller and the buyer regarding the key characteristics of what is offered for sale. Such market failures for exchange of knowledge can be overcome if 'stable and reciprocal exchange arrangements based on trust' replaces spot open market interactions. Building such trust, however, requires relation specific investments by participating firms (Maskell, 1999; Maskell and Malmberg, 1999). Such investments are in some ways equivalent to sunk costs because if the relationship breaks these investments cannot be recovered. Maskell (1999) argues that when firms utilize social capital, they require insignificant relation specific investments as the 'community's beliefs of good behaviour' are well known. In industrial clusters, social capital facilitates knowledge flows even when the cluster is not embedded in familial ties. Clusters like Silicon Valley that are characterized by large stocks of social capital constrain unethical behaviour even by new entrants.

Empirical work suggests that at a regional level, 'where firms share the same values, background and understanding of technical and commercial problems, a certain exchange of tacit knowledge does take place'. And this ability to exchange 'purely internal information' provides competitive advantage to a cluster of firms (Maskell and Malmberg, 1999: 172).

Social capital often has its roots in social networks. Such roots are found both in developed and developing countries. For rural clusters in early stages of development, social capital was found to be crucial for reducing transaction costs in Indonesia. This was so essentially because social networks stimulated clustering in rural Indonesia. The overlap of rural society and economic organization safeguarded social control and stability, which in turn reduced transaction costs. Well-to-do farmers or traders seeking opportunities to diversify and use their capital and labour surpluses generally initiated such networks. Using family networks to attract additional labour, these farmer-trader entrepreneurs gradually created a number of satellite enterprises. Such evolution of networks facilitated trust and therefore order and labour sharing along with long term subcontracting relationships (Weijland, 1999).

The diesel engine cluster in Rajkot, India had similar evolution of the cluster that facilitates interaction at various levels (Basant, 1997a).

In essence, therefore, existence of social capital in industrial clusters contributes to innovation through knowledge flows as it reduces the inter-firm transaction costs. These costs include search and information costs, bargaining and decision costs, policing and enforcement costs. Consequently, quantum and efficiency of knowledge flows even of the tacit variety, are significantly higher in clusters than among fragmented enterprises.

These contributions of social capital can provide an explanation for the continued competitiveness of many industrial clusters in recent periods of globalization and liberalization. Simultaneously, they also provide at least partial explanations for stickiness of regional specialization patterns (due to limited 'flow' of social capital and therefore knowledge across locations) and of continued prosperity of low tech firms in high cost regions of Western Europe (Maskell, 1999, Maskell and Tornquist, 1999).

Another way of looking at the knowledge available only to cluster firms is contextual knowledge that is largely tacit and *embedded* in the cluster. This type of knowledge can only be learned through experience and is essential for effectively utilizing any codified knowledge obtained in the market (Maskell and Malmberg, 1999).

While social capital seems to be a very powerful determinant of knowledge flows and therefore the dynamism of the cluster, many aspects of this conceptualization are still "in the air". Even Maskell (1999) admits that though effect of social capital is visible and measurable, measurement of social capital as input still remains elusive. This probably can be an area of further research.

The 'competence theory of the region' advocated by Lawson (1999) may prove to be a good starting point for this effort. He argues that the emergence of concepts like untraded interdependencies, relational assets and social capital (discussed above) along with others like *industrial atmosphere*, and *milieu* represent convergence of ideas among scholars working on clusters. The focus is moving away from simple input-out linkages to more enduring but less concrete relationships, which are 'in the air' or 'untraded'. Lawson (1999), however, argues that theories of firm competencies can be adapted to reduce the empirical intractability of these concepts for a cluster:

> "... the convergence is upon sets of relationships which emerge from social interaction and exist at a different level to the events such as practices, is precisely these factors that I am suggesting underlie, or constitute, the regions competencies or capabilities. ...our understanding of such factors can benefit from reference to a growing literature on the nature and importance of firm-

> based competence and capabilities, but they are not simply 'in the air' or 'untraded'. They are real factors which *emerge from*, and are *reproduced through*, the interaction of agents where some systems of interaction are better, more competent, at facilitating some kinds of outcome than are others" (Lawson, 1999: 160. *Emphasis ours*).

This approach would suggest that a rigorous empirical focus on the 3Ps in a cluster context can probably reduce a bit of what remains 'in the air' of the 'industrial atmosphere'. This may prove to be a useful research focus.[8] Baptista (1998: 23, 27) suggests that 'globalization heightens the importance of differences in the ability, endowment and milieu of different locations. While classical factors of production become more accessible due to globalization, specialized factors and skills remain differentiated between regions'. Thus, one can also take a 'skill' view of 'social capital' to enhance its empirical application. We shall revert to this issue in section 4.

III.3 Structural Features of the Cluster

Initial work on industrial clusters tended to assume, explicitly or implicitly, that the clusters broadly conform to the Marshallian model of industrial districts. Subsequent work has shown that industrial clusters not only vary a great deal across sectors and space but also change their structural characteristics over time. As a result, researchers have made efforts to develop 'structural' categories of clusters. The structural features embodied in these categories are likely to be important for the nature and quantum of knowledge generation/dissemination related activities and therefore for the dynamics of a cluster.

Guerrieri and Pietrobelli (2001) develop an interesting typology of industrial clusters. The four-fold categorisation of clusters defined by them focus on three main features: firm size, inter-firm relations and internal v/s external orientation. It also effectively reflects the power of the large firms, MNCs and the state. Table 1 reports the essential features of these categories.

In the *Marshallian clusters* small firms in the same industry realize economies of scale external to the firm through co-location. Several studies of clusters in Third Italy, the Silicon Valley and also in developing countries have emphasized the role of long-term socio-economic relationships among local firms involving trust and a blend of collaboration of competition in the superior performance of these clusters. These relationships, contribute to the 'industrial atmosphere', or social capital discussed earlier. The role of local institutions has also been highlighted for such clusters.

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[8] Guerrerie & Pietrobelli (2001) refer to another study by Pietrobelli (1998 – reference not available), wherein an empirical test of the concept of 'industrial atmosphere' in a sample of Italian industrial clusters is explored.

The *hub-and-spoke* cluster has been observed in several locations especially in the auto-industry (Toyota in Toyota city, Ford, GM, Chrysler in Detroit and Fiat in Northern Italy). Such clusters, however, are not restricted to auto industry but also in others like bio-pharmaceutical industry in New Jersey. They key feature of this cluster is that one or more firms/facilities *within* the region act as hubs of the regional economy; with suppliers and related activities spread around them as spokes of a wheel. The relationships (often long term) between suppliers and the hub may be weak or strong having implications for knowledge flows. *Within* the cluster these linkages are typically hierarchical, with 'hubs' dominating the suppliers cooperation among competitors in these clusters is generally absent.

The external linkages of the 'hub' are equally important for knowledge generation and dissemination within the cluster. The hubs have substantial linkages with suppliers, competitors and customers outside the cluster. These linkages enable the transfer of new ideas and knowledge to the 'home' cluster.

The *satellite platform* cluster is a congregation of branch facilities of *externally* (external to the cluster) based multi-plant firms. Public policies to attract investments in a region often induce such congregation. Firms in such clusters are spatially independent having no linkages with upstream and downstream suppliers as well as other competitors in the region. Limited cooperation among platform firms is also due to the fact that they are often engaged in different activities and industries. Since the anchor/hub (often an MNC) is not locally based, all the key decisions are made outside the cluster.

Since local linkages are limited and no industry specific trade associations exist in such clusters, knowledge flows are also likely to be limited. The links with the external hub are the main sources of knowledge for the satellite platform firms. It may be useful to explore if there are any knowledge spillovers in such clusters. Absence of critical mass in a particular industry may reduce the potential of such spillovers but the possibilities of inter-sectoral synergies cannot be denied.

In the *state anchored* cluster, the activities are 'anchored' to a region by a public or non-profit entity, such as a military base, a defence plant, a university or a concentration of government offices. Typically, politics plays an important role in the development of such clusters. Science/technology parks built through a state initiative will fall in this category. Links with university may induce the emergence of new firms based on the technology developed at the university. The links with anchor institutions, apart from industry specificities, may determine the nature of knowledge flows in such a cluster.

The categories of clusters defined above are somewhat 'pure' categories and in practice clusters are combinations of one or more types. The Silicon Valley, for example, is seen as an industrial district of the Marshallian type in electronics. Besides, it hosts hubs (Lockheed, Hewlett Packard, Stanford University) and platform branches of large corporations like IBM, Oki, Hyundai, and Samsung. Moreover, it is also the fourth largest recipient of military spending (Guerrieri & Pietrobelli, 2001). Besides, over time clusters may mutate from one type to another. This process of evolution or dynamics is likely to have significant implications for knowledge generation and flows. Irrespective of what type of mutation takes place, it is clear that given the variety of clusters, the analysis of knowledge generation and flows needs to move beyond the boundaries of a regional cluster with a focus on international knowledge flows.

Building on Visser's (1999) typology of clusters Altenburg and Meyer-Stamer (1999) differentiate between three types of clusters in Latin America: (i) survival clusters of micro- and small-scale enterprises; (ii) clusters of more advanced and differentiated mass producers; and (iii) clusters of transnational corporations (TNCs). These categories of clusters also show differences in knowledge flows.

(i) Survival clusters are the most common and produce low quality consumer products for local markets. The entry barriers are low and so is inter-firm specialization and cooperation. Lack of trust among entrepreneurs precludes development of such cooperation. Since imitation of other firms is the main mechanism of transferring knowledge, little upgrading occurs. As links with large firms and other external entities are absent flows of external knowledge do not take place.

(ii) Clusters of advanced and differentiated mass producers comprise a heterogeneous mix of enterprises; firms of different sizes and capabilities co-exist. In most cases, these clusters make standardized consumer goods. Some firms are integrated with global commodity chains but mainly in price sensitive product ranges. Except for supplier driven innovations (new machinery, improved inputs) no technological change takes place. Such clusters prospered during the import substitution phase when imported machines and licensing or copying of foreign products provided the basis of knowledge flows. Besides, degrees of specialization and cooperation are limited in these clusters primarily because of small size of the market and absence of competitive pressures. However, potential for learning through spillovers/benchmarking exists as some world class manufacturers are located in these clusters. Some policy induced benchmarking and collaboration in testing and training demonstrated the usefulness of such endeavours.

(iii) The TNC clusters are engaged in technologically more complex activities like electronics and auto industries. Given the large gap between capabilities of local enterprises and the technological requirements of the TNCs, hardly any linkages between the two have developed. Investments by TNCs have attracted suppliers from their home countries to Latin America. Significant interaction between these "foreign" suppliers and TNCs takes place and local labour pool has been enriched in the process. The main weakness of the TNC clusters, however, derives from the low degree of technological spillovers involved, especially the failure to develop dynamic local entrepreneurship. Due to large technological gaps the ability to absorb such technological spillovers among local firms is virtually non-existent.

We can see that empirical implementation of cluster categories tends to combine structural features with several others including linkages, product features and so on. Several other categorizations of industrial clusters are available. For example, Mytelka and Farinelli (2000) identify three types of 'autonomous' clusters: informal, organized and innovative (Table 2), policy induced or constructed clusters being a separate category. Unlike the categorization described in Table 1, which is essentially based on structural (input) features, these categories reflect conduct and/or performance (output) features. Informal sectors by definition are technologically underdeveloped and inactive having low cooperation while innovative clusters are just the opposite. It can be argued that for analyzing knowledge flows a 'structural' categorization of clusters may be more useful as the structural features are not 'endogenous' to the system. Knowledge flows in clusters are likely to affect their performance in terms of innovative output and, therefore, the 'performance' categories to which they belong.

In terms of methodology, it may be useful to first categorize clusters according to structural features and then divide each structural category into performance categories defined above. Knowledge flows in each of the structure-performance categories can then be explored. Given that sectoral specialization can impinge on such flows, sectors can form another dimension of categorization. We shall revert to this issue in the concluding section.

Just as structural categories of clusters mutate, the performance categories may also undergo changes. An informal cluster may evolve into an oragnised or an innovative cluster. We shall discuss some of these issues in a later section when we relate cluster life cycle to knowledge flows. We now turn to the discussion of the linkages between customer, suppliers and competitors in a cluster, an issue that has received a great deal of attention.

III.31 Horizontal and Vertical Networks: Customers, Suppliers and Competitors

Dahlman (1979) suggests that there are three types of transaction costs attached to links external to a firm: search and information costs, bargain and decision costs and policing and enforcement costs. Clustering tends to reduce all these costs. This section will explore how networks in a cluster contribute to the reduction of such costs.

Inter-firm learning may have limits. Maskell (1999) argues that knowledge bases of firms should be sufficiently apart for interaction to result in learning. At the same time, if the cognitive distance between firms becomes too great for firms to bridge, inter-firm learning will not take place. This argument is similar to the technology gap hypothesis which suggests that if the distance between the technology leader and follower becomes too large, the possibilities of catching up decline as the follower is no more in a position to absorb new technological developments. Co-localization of firms is seen as the key facilitator of observation and exchange among cluster firms, including that of knowledge:

> "The cluster thus exists, it is often implied, because co-location of firms cut the expenses of identifying, accessing or exchanging products, services or, not least knowledge between firms" (Maskell, 2000: 7).

Typically, in a cluster, one finds two groups of firms, one making similar products and those making complementary products. Maskell (2000) refers to them as horizontal and vertical dimensions of a cluster. While complementarity creates scope for fruitful exchange, similarity in activities implies contest and competition. Consequently, firms linked vertically in a cluster are likely to collaborate while firms located on the horizontal dimension are likely to be rivals. Thus, the interaction and consequent learning among the vertically linked firms is expected to be more prominent in a cluster than among competitors. Besides, as firms become more specialized more knowledge flows may take place due to learning by doing effect.

Given the peculiarities of knowledge generation activities discussed earlier and firm specific differences in beliefs, perceptions and capabilities, firms located on the horizontal dimension may come up with divergent solutions to the same problems faced by them. As Best (undated) suggests, an industrial cluster expands the number of simultaneous experiments that can be conducted. While a vertically integrated firm may carry out several experiments at each stage in the production chain, a cluster can exploit very many more simultaneously. Best (undated) also argues that such simultaneous experimentation may reduce the barriers to introducing innovations in firms that already have significant capabilities around competing technologies. While this may be true, technology lock-in does take place in clusters, an issue that we will revert to later. In such a situation, despite the lack of interaction among rivals, knowledge flows may take place in a cluster as the rivals find themselves in a situation where difference in the solutions chosen can be observed and compared. Thus, the feasibility of observation on the horizontal dimension can explain the existence of a cluster:

> "...the cluster exists because of *locational economies that are independent of the internal degree of interaction* at least in principle. The sole requirement is that *many firms undertaking similar activities* are placed in circumstances by co-locating where they can monitor each other constantly, closely and almost without effort or costs" (Maskell, 2000: 11. *Emphasis ours*).

Noteboom (1999) also suggests that variety (subject to the problem of cognitive distance) and proximity (due to the importance of tacit knowledge) encourages learning. In such a scenario, if the empirical evidence suggests that such observation is feasible, it may be safe to assume that knowledge flows are taking place. But such evidence is not easily forthcoming.

Given the relevance of technology supply chain in the knowledge generation process, a tight relationship between customers and suppliers becomes extremely critical for this process. This ensures a smooth exchange of complex information. While physical proximity is not essential for such an exchange, it facilitates such transactions. In addition, if the customers in the supply chain are demanding, the knowledge creating process is further enhanced (Porter, 1990).

Several studies have documented the linkages between customers, suppliers and competitors in a cluster. Pillai (2001), for example, shows that about 65 per cent of innovations in the diesel engine industry in Coimbatore (India) were the outcome of such linkages. In general, clusters that have more interactions have been found to be more competitive. In what follows, we discuss some salient examples of such interactions.

The High-tech Clusters

Despite high expectations Cambridge, a high technology cluster in UK has failed to produce large multinational firms to rival those of the Silicon Valley. Firms tend to remain small, and when they grow they are taken over by firms external to the cluster (Lawson, 1999). This state of affairs has been attributed to the region's lack of effective inter-organizational networks, either between Cambridge University and firms spun out of the University or between firms in the region. There is some evidence to suggest that in the late 1980s there was no interaction – social or technical – among firms of the Cambridge cluster (Saloman, 1988, quoted by Lawson, 1999).

Lawson (1999), however, suggests that the University has provided a highly skilled pool of labour and has been an important source of ideas and knowledge. It has fostered spin-off activity in the region, mainly through 'informal channels, as personal relationships are maintained between people in both the University and firms, encouraged by a particular college system that enables the maintenance of close relationships through the occupancy of college fellowships'. University-firm linkages, apart from creating an academic type culture also facilitate transfer of information about prospective employees, hiring/borrowing possibilities of equipment etc. (Lawson, 1999: 162). Athreye (2000) provides some estimates to show that the interaction of cluster firms with the Cambridge University is quite varied (Table 3). Interestingly, however, for most types of interaction (e.g., collaborative projects, research consortia, training etc) the role of outside universities is equally, if not more, significant than the

Cambridge University. Besides, Cambridge and other universities are important locations for recruitment for research and managerial staff (Table 4). Athreye (2000) also provides interesting accounts of how individuals or small groups of individuals contributed to information flows and enhanced the links between Cambridge University and the economic activity in the cluster.

The Cambridge cluster also has significant external linkages. Lawson (1999) suggests that a large number of such links reflect the fact that many tasks need to be performed externally. However, many horizontal, research and knowledge transfer oriented links also exist between firms in the region. Apparently, such collaboration is facilitated and encouraged by 'small scale niche orientation of many firms, allowing substantial overlap in activities without direct competition.' Athreye (2000) provides some estimates to assess the importance of inter-firm linkages in Cambridge. While vertical linkages seem more important than horizontal ones, for all types of linkages, the links outside the Cambridge cluster are more important than the inside ones, the service links being the only exception (Table 5).

The information on the Cambridge cluster does not seem to be very definitive on the importance of proximity for sourcing of knowledge by firms in clusters; while case studies tend to highlight the importance of proximity, survey results show "outside" links to be equally, if not more important. A recent study on Europe, however, provides estimates to show that proximity does matter for transfer of knowledge from public research institutions and universities to firms (Arundel and Geuna, 2001). The authors' contention is that there are two main reasons for the differences in the importance of public research organizations in their study as compared to earlier survey based research. One, their research is limited to Europe's largest firms, which are more likely than smaller firms to use knowledge from such organizations. Two, unlike in their study, results of other studies are typically not weighted by a proxy for innovation outputs. This implies that the results of other studies largely measure the importance of proximity to public organizations for knowledge flows to smaller and less innovative firms, which make up the vast majority of their respondents. The results of Arundel and Geuna (2001) for Europe are consistent with the results of Adams (2001), who has studied the firm-university links in the United States. Adams (2001) concludes that firm-university interactions tend to be more localized than interactions with other private firms. These interactions include outsourcing research, faculty consulting, licensing university patents and hiring engineering graduates.

Apart from the interactions discussed above, many links also arise due to corporate spin-off activity in the Cambridge region. Region's technical consultancies provide an excellent example of this process. In the process of performing consultancy tasks within a firm, solutions to problems of specific customers are routinely generated. If there is a potential to develop the idea behind the solution into a more generally saleable product, a firm is spun out to develop the product itself. The formal and informal links with the "parent" continue even after a new entity is formed (Lawson, 1999: 162)[9].

The role of 'spin-off' or 'start-up' processes has also been documented in various other clusters like Silicon Valley and Route 128 (Best, undated). This process seems to be more dominant for high tech clusters than for traditional ones.

Two high technology clusters in the U.S., Silicon Valley and Route 128 have attracted a lot of research attention. While the Route 128 cluster faced a significant decline during the late 1980s and early 1990s, Silicon Valley continued to prosper and grow. Significantly, during this period of decline, the research intensity of the Massachusetts (Route 128) region continued to be high. The differential performance has been attributed to the differences in the business models of the two regions. The model based on horizontal integration, institutions of cooperation and collective learning fostered and commercialized innovations much faster in the Silicon Valley than Route 128 (Saxenian, 1994). Best (undated), however, argued that while this business model argument explains the decline of the Route 128 cluster, it does not provide an adequate explanation for its resurgence in the late 1990s. In fact, the conventional explanation of resurgence in terms of increased cooperation among industry leaders and research intensive universities fostering techno-entrepreneurs is only a reflection of the underlying structural changes.

According to Best (undated), a strategic shift of Route 128 firms towards a different type of systems integration. They moved from *vertical* to *horizontal* and from *closed* to *open* systems of integration. This shift fostered techno-diversification and drove down the cycle time for new product development. Besides, such integration was the underlying source for horizontal interaction observed even in the Silicon Valley.

> "(Systems integration) signifies 'horizontal integration', multi-enterprise integration, 'open systems' networked, or affiliated groups of specialist enterprises. ... it forms a diverse pool of collective knowledge or an 'invisible college'. It is an institutional support for the collective learning noted by Saxenian (1994) as a source of Silicon Valley's regional advantage" (Best, undated: 464).

Through this strategic shift to a new business model of systems integration, Route 128 has acquired the capability of combining knowledge underlying precision equipment and instruments and information technology. This has given the cluster competitive advantage in the production of low volume industrial

[9] This is supported by the estimate available in Athreye (2000). About half of the sample firms reported that their former employees have set-up new firms in the new Cambridge region. Three fourths of these start-ups continue to

electronics and the ability of rapidly developing new products. Underlying this capability is the flows of knowledge across firms operating in very specialized technology areas within industrial electronics. Thus, from this perspective, the key to the resurgence of Route 128 is not the transfer of institutions of cooperation and collective learning; these are manifestations of the application of the principle of systems integration to production and organization.

Best's concept of systems integration as the new business model of technology management in Route 128 also throws up interesting issues vis-a-vis the 3Ps perspective of understanding technology in a cluster. The industrial clusters of 'third Italy' have been known for their design capabilities in the so-called traditional industries like shoes, garments etc. Recent developments in high tech clusters like Silicon Valley and Route 128 suggest that these have also developed similar capabilities for rapid design changes. Besides, systems integration seems to enlarge the possibilities of design modularization already existent in a cluster. This process diffuses design capabilities and thereby the knowledge embodied in the first P (i.e. product). Best suggests that modularization has decentralized and diffused design capabilities for new product development in much the same way as TQM (the third P-practice) diffused experiments for continuous improvement.

Some Insights from Traditional Italian Clusters

A 1998 survey of three clusters in Italy: Prato (textiles), Teramo (textiles and clothing) and Carpi (clothing) provided some interesting insights regarding knowledge flows. While Prato and Teramo are old clusters, Carpi is in a relatively early phase of the cluster life cycle. (Guerrieri and Iammarino, 2001).

R&D expenditures in the clusters were found to be low. The survey showed that 69 per cent sample firms did not introduce any product innovation (improved products *new* to the firm) during the reference period of three years. About 29 per cent introduced incremental innovations (new to the firm) while only 2 per cent claimed to have introduced totally new products (new to the sector). Incremental product innovations that are new to the firm may have been a result of spillovers (imitation).

Interestingly, about 50% responding firms reported process improvements essentially through new machinery and computer assisted technologies. It may also be recalled that textile industry is 'supplier dominated' industry where process improvements are expected to flow from equipment manufacturers. Table 6 provides some estimates of important sources of technology for firms in the three clusters. The respondents judged customer and equipment suppliers as crucial sources of technology; about 63 per cent of them reported these sources as critical. Trade fairs, other suppliers, consultants and industry

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have formal and informal links with the parent firms.

associations were other important sources of technology. Very few firms cited horizontal partnerships, universities or public research institutions as important sources of technology. The role of spillovers seemed evident from the fact that about 20 per cent firms reported recruitment as an important source of technology.

A comparison of evidence across the three clusters suggests that intensity of local linkages was higher in the older clusters of Prato and Carpi than the younger cluster of Teramo. Besides, the level of internationalization in terms of sources of technology was also much lower in the younger cluster (Guerrieri & Iammarino, 2001). This suggests that while the older clusters have a well-established system of 'internal' and 'external' networking, the younger clusters have lower levels of interdependence.

Clusters in Developing Countries[10]

Tiwari's (1999) account of Ludhiana's (India) woolen knitwear cluster provides an excellent example of how links with customers can facilitate knowledge flows and provide competitiveness to the cluster firms. The Ludhiana cluster, like other dynamic clusters benefited from vertical linkages (especially with local knitting and distribution network), rapid diffusion of knowledge across firms, (although local firms tend to hide designs and processes from competitors) and local pool of highly skilled workers. The cluster also managed to attract domestic and overseas buyers. However, not all firms in the cluster benefited from clustering to the same extent. The author argues that two kinds of firms were more successful as they learnt from customers. These firms included those, which produced:

(a) high quality (low volume) branded items for the upper and competitive domestic market alongside low and high volume exports for a stable market in the Soviet Union, and

(b) high quality low volume export garments for Western European markets along with products for the domestic market.

Firms of the *first type* operated in two quite different markets simultaneously. This forced firms to manage a diverse supplier base and organize complex distribution networks. The extensive experience of managing production for two diverse markets provided problem solving skills to these firms that proved critical when the market in the Soviet Union collapsed and these firms needed to shift to new, more demanding external markets. Typically, these problems related to quality customization and productivity.

[10] This section mainly focuses on one recent study that is very insightful. Somewhat similar descriptions for the earlier period are available in several other studies. For brevity these are not summarised here. For reviews of these studies see, Pillai (2001), Schmitz and Nadvi (1999), Nadvi and Schmitz (1994), Humphry and Schmitz (1995). Some more recent work on the changes in interaction will be reviewed later in the paper.

The description of the knowledge generated through simultaneously operating in these diverse markets suggests that knowledge embodied in all the three Ps was addressed.

- To compete in the high end domestic market required development of new products and building of networks that facilitated tracking of new designs;
- Large volume production with low margins required minimization of wastage and overheads. This was partly achieved through better practices within the firm and extensive systems of local subcontracting and task-based specialization.
- Imitation-adaptation of imported machines in the cluster enhanced process capabilities and reduced costs by lowering wastage.
- Multi-skilling through in-house training also lowered costs and enlarged the clusters' labour pool. In fact, some larger firms in the cluster setup skill development centers that are open to other firms and the general workforce.

Firms in the *second category* developed several capabilities through small-scale contracts with demanding customers in Western Europe. These first time exporters learnt from small but consistent orders as the customers provided useful feedback. Importantly, these firms not only changed processes (new machines) but also developed better quality designs and made organizational changes. These changes modified processes and practices and included "hiring more designers and specialists, nurturing skilled workers within the firm, insisting on greater documentation of production procedures, instituting more accountable production practices within the firm and upgrading certain core functions such as cutting, designing, finishing, and packaging as well as preparation of samples and sales. Successful firms have also restructured their relationship with their suppliers and buyers... they are paying their downstream fabricators better rates to elicit good and reliable quality, but are also holding them responsible for rejections and timely deliveries, and are aggressively seeking out feedback and tutelage from key buyers" (Tiwari, 1999: 1665).

Apart from highlighting the role of knowledge embedded in the 3 Ps for competitiveness of cluster firms Tiwari's (1999) study brings out two questions that need further exploration:

(i) Under what circumstance complementarities between domestic and export markets can potentially exist and contribute to learning of cluster firms? Domestic markets should not be always seen as less demanding ones. Operating in diverse markets can facilitate learning. How does one strategically maximize such learning?

(ii) How and when exports contribute to learning? Large volume exports may not necessarily lead to knowledge flows even if customers are large and demanding, if channels of feedback are weak. Medium sized a small external buyers with smaller ability to substitute their suppliers at will may have greater incentives to provide the feedback to their suppliers. Is learning through smaller but quality intensive orders absorbed better than large volume ones, especially by smaller first time exporters? Should policy facilitate such links for slower but dynamic learning processes?

Innovation, Cluster Dynamics and Interaction

An indirect way of measuring the role of knowledge flows through various interactions in a cluster is to analyze the likely outcome of such flows – the innovative activity. Baptista and Swann (1998) explore a very interesting question if firms in clusters innovate more. The broad hypothesis, though not explicitly stated by the authors in these terms, is that larger knowledge flows in cluster facilitates higher innovative output. The authors argue that:

(i) Informal and tacit nature of knowledge embodied in *new* technologies (in early stages of the lifecycle), flows more easily locally than over long distances. Consequently, clusters generate more knowledge spillovers and, therefore, more innovative output.[11]

(ii) The dense supply and demand side linkages in a cluster provide a set of knowledge inputs, which constitutes its technological infrastructure and supports innovative activity. Such infrastructure is location specific and relatively immobile.

(iii) Knowledge spillovers associated with coexistence of complementary technologies in a cluster create opportunities for innovation.

(iv) The cumulative nature of innovative activity manifests itself not just at the firm and industry levels, but also at the cluster level. This cumulativeness creates advantages and opportunities for firms located in areas that have been innovative in the past and are abundant in innovative resources.

Overall then, knowledge externalities and spillovers, especially those associated with new technologies tend to be geographically localized. Once certain clusters accumulate sources of such spillovers, they

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[11] There is evidence to suggest that knowledge spillovers are locally bounded (Jaffe, Trajtenberg & Henderson, 1993; Anselin, Varga and Alis, 1997. This is also consistent with the evidence available in Arundel & Geuna (2001) discussed above.

attract and support innovators enhancing innovative activity. Baptista and Swann (1998) use regional employment as a measure of a cluster's strength. They find for UK firms that a firm is more likely to innovate if located in a region where presence of firms in its own industry is strong. Interestingly, the complementarity hypothesis is not supported, as the effect of proximity of firms in other industries is not significant. While this is only an indirect way of assessing the role of knowledge flows and spillovers on innovative activity, the results are promising. A follow-up of this line of enquiry with better measures and data may be very useful.

These results seem to be broadly consistent with some earlier work on clustering of innovative activities. (DeBresson, et al, 1996). But there are important differences. As mentioned earlier, innovative activities are transaction intensive. And to innovate, transaction costs will need to be minimized. Since geographical proximity of innovators is one way to reduce these costs, creative interactions among innovators may have strong incentives to be localized. In a globalized situation 'information' may be readily available but its use for innovation purposes in a specific context requires closer interaction:

> "...it is not the richness of information that matters but how economic agents require interactions to use this varied information for innovative endeavours. And this is where transaction costs are important." (DeBresson et al, 1996: 229).

DeBresson et al (1996) provides estimates to suggest that innovative activities are strongly polarized in geographical space in Canada, Italy and France. However, the geographical concentration is not very narrow and firms in these regions reach out to more distant regions for interactions. Besides, their findings on Italy are particularly interesting. They show that the third Italy, which is the center of Italian clusters, contributed very little to innovative activity in the early 1980s for which data are available. Moreover, large firms were present in most, if not all, innovative networks in Italy. Thus, the role of exclusive small firm networks in innovation was limited. *This would suggest that even the Marshallian clusters of Third Italy (Table 1) had significant external linkages for innovative activity.*

It is difficult to draw very robust conclusions about the role of local knowledge flows in geographically bound clusters in innovative activities from these studies on location of innovation. We have already discussed the problems associated with the differences in the nature of sample firms included in various surveys. Additional problems crop up because the definitions of innovation vary across studies.[12] It is likely that all innovations are not captured, especially the incremental ones. Besides, "practice" innovations are unlikely to have been captured.

[12] For example, in the case of Baptista and Swann (1998), it is based on the survey of science experts to identify significant innovations in UK, while DeBresson et al (1996) analyse estimates generated from surveys of enterprises wherein data on product and process innovations were compiled.

III.32 Role of Labour Markets

The linkages between various entities in a cluster through the labour market have also been found to be extremely important for knowledge generation and dissemination. Lawson (1999) suggests that in the Cambridge, UK cluster, apart from providing access to a vast range of technical skills, the frequent movement of employees between firms, and from University to firms, has facilitated knowledge flows. Employees not only take a 'once and for all' stock of knowledge with them but they also maintain relationships with personnel in previous firms or the university. Such ongoing links with 'a history, trust and mutual understanding', facilitate knowledge flows on a continuous basis.

As mentioned, labour market pooling is an important source of location externalities in a cluster. Geographical concentration of firms in the same or related industries creates a pooled market for workers with the same/similar skills. This reduces the uncertainties about the availability of manpower and therefore the availability of knowledge and skills. While these facets are recognized, the spillovers and knowledge flows associated with human capital in a cluster are not adequately explored. Movement of employees from one firm in a cluster to another can create a self-augmenting process of knowledge generation and diffusion. More importantly, movement of employees facilitates transfer of *tacit* knowledge. Brenner (2000) identifies three conditions that required making labour mobility in a cluster a continuous source of knowledge augmentation and transfer:

(i) Human capital that is required and created by different firms in a cluster is similar enough to be used across firms;

(ii) Employees have to be immobile enough so that the advantage of human capital created by firms within the cluster is locally bounded. At the same time, they should be willing to move from one firm in the cluster to the other or found their own enterprise in that location.

(iii) In order to create a positive feedback loop, the cluster firms need to create (on average) more human capital than they need. Only then the amount of human capital in the region continually increases.

While the first two conditions seem plausible, the situations under which the third condition will be satisfied is not entirely clear. Brenner (2000), however, argues that high entry or start up activity and the expansion of other firms (along with willingness of employees to move across firms) might force firms to create more human capital than they need. Thus high rates of cluster growth (and entry) may result in such an outcome.

Another dimension of the labour pooling relates to the availability of new skills and competencies in research oriented clusters, which are located close to large research institutions. Firms are not only able to access the pool of trained workers and scientists but also the Ph.D students who are working on the frontiers of knowledge (Mytelka and Pellegrin, 2001).

In general, role of skilled manpower has been found to be quite pervasive in all types of clusters and in all types of economies. For example, labour pooling contributes to high-tech clusters in the Silicon Valley and Cambridge as well as in the software clusters in India (Bordia and Martins, 1999). It played a key role in the 'traditional' clusters of Italy as well as Thiruppur, India. (Swaminathan and Jeyranjan, 1997).

Another aspect of the labour market functioning needs to be emphasized. Virtually all clusters provide instances of employees graduating to the entrepreneurship status. Such mobility of employees is rarely seen in non-cluster labour markets. It is interesting that high-tech as well as low-tech clusters experience these processes. Moreover, in many instances, the employers facilitate such a transition of employment status. These tendencies also exist in all clusters but probably more in traditional clusters and in clusters located in developing countries.

While upward mobility of workers in labour markets in clusters contributes to diffusion of knowledge, another type of process if prevalent may be equally important for dissemination of knowledge. Basant (1997) shows that a large variety of 'labour groups' were operating in the diesel engine cluster in Rajkot, India. These groups moved from one firm to the other undertaking specific jobs on a contract basis. These jobs included assembling, casting, painting, grinding and even inspection! Often these groups make innovations in one enterprise and carry it to other units as well. These innovations are generally incremental in nature and focus on the process and the practice domains.[13]

Apart from upward mobility of labour and the possible existence of specialized groups, one should also emphasize the heterogeneity of the 'labour market' in clusters. Stand-alone workers may compete with tiny enterprises in the informal sector by moving in and out of various employment statuses adding to the flexibility of the cluster. Baptista (1998) refers to Brusco's (1982) work to make a similar point:

> "(In the Emilian Model), in addition to supportive local networks and institutions, a key factor is the presence of a 'secondary' industrial sector. This sector consisting of mainly small, competitive and innovative enterprises, provides flexibility to the productive structure of the 'primary', internationally competitive, industrial sector, which is composed of larger firms. This secondary sector provides labour or absorbs redundant labour over the business cycle, and responds to subcontracted orders with a guarantee of high quality performance" (Baptista, 1998: 42).

[13] See Basant (1997) for some examples of such innovations.

Thus, mobility and flexibility in the local labour market not only reduces the redundancy costs but may also facilitate adaptation and dissemination of knowledge embodied in the 3Ps.

III.4 Cluster Life Cycle and Entry of Firms

One of the arguments has been that the role of clustering changes with the maturity of the clusters. And that clustering may be particularly relevant for the incipient clusters as it facilitates growth of small enterprises through "riskable steps" (Schmitz and Nadvi, 1999).[14] One can extend this argument to hypothesize that the nature of knowledge flows will change with the maturity of the cluster. This section puts together the available evidence on this issue.

It has been argued that clusters have a life cycle that is conceptually different but related to the life cycle of the technologies produced in the cluster. Moreover, the forces that influence the growth and entry of firms in clusters are not only related to the stage in the technology life cycle (TLC) but also to cluster's life cycle (CLC) (Swann and Prevezer, 1998).

It has been suggested earlier that tacit knowledge is difficult to transmit. In the early stages of the life cycle of a product or a technology (especially in high-tech industries) use and transfer of *tacit* knowledge is critical for successful development. While distances do not matter for the transfer for *codified* knowledge (e.g. through manuals, blueprints, patents etc), personal contact is essential for transferring tacit knowledge and hence geographical proximity matters. Since cluster life cycle is tied to the technology life cycle, the levels of codification may increase with successive stages in these life cycles. If this happens, incentives for clustering to absorb tacit knowledge that is only feasible through proximity may decline.

The links between cluster life cycle, technology life cycle and knowledge flows become more interesting when we juxtapose these with the evidence highlighted in Nelson (1993). He found that academic research is more important for technological development in the early stages of the industry/product life cycle than in its maturity. It is possible that in high-tech clusters industry and academic research grow apart at later stages of the industry life cycle. These issues have not been explored.

Since entry of new firms is a mechanism through which knowledge gets diffused across enterprises, the cluster life cycle can be seen as an important influence in knowledge diffusion. Clusters that are strong

[14] The basic argument is that 'clustering facilitates the mobilisation of financial and human resources, that it breaks down investment into small riskable steps, that the enterprise of one creates a foothold for the other, that ladders are constructed which enable small enterprise to climb and grow. It is a process in which enterprises create for each

in a particular technology tend to enjoy faster growth of incumbent firms and higher entry than other regions due to positive feedback effects. However, agglomeration economies and positive feedback may not continue indefinitely. As clusters become larger they tend to get congested slowing down growth as well as entry. Besides, older clusters are likely to have firms 'locked-into' older technologies. Also as older technologies in older clusters are likely to have lower spillover potential than newer technologies in newer clusters, entry to absorb these spillovers may slowdown as the cluster passes through its life cycle (Swann & Prevezer, 1998).

While it is true that entry typically takes place to absorb knowledge spillovers in a cluster, Swann and Prevezer (1998) highlight another interesting dimension of the process. If, due to the knowledge enhancing activity of the incumbents in the cluster, spillover potential is generated, other incumbents in the cluster can utilize this potential and grow. However, the incumbents should have the ability to absorb these spillovers. If incumbents do not have such ability, entry of new firms to utilize the spillovers will get enhanced. Consequently, if maturity of the cluster implies that a large number of incumbents are locked into specific technological trajectories, incumbents may not be able to absorb radical changes in technology. In such a situation entrants may be in a better position to exploit technology spillovers.

Entry of new firms can also be seen as a means of utilizing existing knowledge for new purposes. Swann and Prevezer (1998) suggest that 'diversified' clusters tend to survive longer than the 'single technology clusters'. This is so because diversified mature clusters are able to attract new firms into new industries. Extending the same argument one can hypothesize that clusters with a diversified knowledge base or skills with wide applications will survive the longest as it can move from one product to the other. The Rajkot (India) diesel engine cluster, for example, that was on the decline due to foreign competition is being availed by new auto-component firms that use similar skills.

We have already referred to the fact that employees in existing firms often 'enter' the cluster as entrepreneurs, so do researchers and scientists. As mentioned, this happens in the case of Cambridge cluster (Athreye, 2000). Similar evidence is available from developing countries as well (e.g., Basant, 1997a). A survey of three textiles related clusters in Italy showed that a significant proportion of entrepreneurs had previous work experience in a family business (46%) or in other local SMEs (33%) located in the cluster. About 10 per cent had experience in large national firms, about 4% in MNCs and only 2% in a university. (Guerrieri & Iammarino, 2001).

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other – often unwillingly, sometimes intentionally – possibilities for accumulating capital and skill" (Schmitz and Nadvi, 1999: 1506).

McCormick's (1999) comparative study of different types of clusters in Kenya, Ghana and South Africa brings out additional insights into the links between cluster life cycle and knowledge flows. The author distinguishes between three types of clusters that represent different levels of industrialization of the economy in which they are located:

(1) *Groundwork* clusters lay the foundation for industrialization by building a productive environment that 'prepares the way for the emergence of collective efficiency;

(2) *Industrializing* clusters have much clearer signs of emerging collective efficiency. These have greater degrees of specialization and differentiation than groundwork clusters; and

(3) *Complex* industrial clusters where the levels of differentiation and specialization are even higher. Firms of various sizes exist and small firms tend to depend on large firms for their markets. Moreover, the market reach of these clusters is global rather than restricted to local markets.[15]

The evidence reported in McCormick (1999) suggests that nature of knowledge flows will differ in these types of clusters. (See, Table 7). Potential knowledge flows through improved market access were universal but the nature of access varied among the three groups of clusters. The markets accessed by firms in 'groundwork' clusters were still mostly localized and low income. Industrializing clusters also mainly catered to local markets, though some linkages were built with distant more demanding customers. The 'complex' clusters operated in high level national and export markets.

Knowledge generation and flows through labour market pooling were weak in most clusters. Since mainly unskilled labourers were attracted to "groundwork" and 'industrializing' clusters, no internal up-gradation of skills took place, labour market pooling did not result in capability up-gradation in these clusters. Even among the 'complex' clusters, only in one cluster such pooling had a positive impact.

The intermediate input effects were also weak for all clusters except the 'complex' ones. Similarly, the possibilities technological spillovers existed only in 'complex' clusters but here also few firms learnt from rivals who had adopted newer technologies to improve quality and efficiency. In the 'groundwork' and 'industrializing' clusters such possibilities were weak as very few enterprises developed or adopted new technologies. In fact, at times rivals passed on bad practices!

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[15] These categories are somewhat similar to the cluster categories used by Mytelka and Farinelli (2000); informal, organised and innovative. (See earlier discussion). However, the 'complex' clusters are not necessarily very innovative.

Finally, no clear pattern emerged vis-a-vis joint action or collaborative arrangements in different categories of clusters. In general, institutional structures for collaboration were weak in most clusters and whatever cooperation existed was ad hoc in nature. Only one of the 'complex' clusters showed signs of institutionalized formal joint action.

McCormick's (1999) comparative study shows that mechanisms for knowledge transfer are unlikely to emerge automatically. The author argues that the idea of collective efficiency (that is based on the assumption of knowledge flows through various mechanisms discussed above) may not be very relevant for underdeveloped locations like Africa:

> "The small size of markets, over supply of labour, and weak institutions characteristic of many African countries mean that external economies and joint action do not always work in the ways predicted by the collective efficiency model... We need... to look at the social and economic environment for clustering. ...clustering can help to overcome barriers to firm growth and development, but sometimes these barriers are so big that power of the clustering dynamic is seriously reduced. For example, clustering facilitates access to markets, but if the market is very small, the access may still not bring about much growth. The problem is even worse where trading networks are under developed. This is the situation faced by many small enterprise clusters in Africa..." (McCormick, 1999: 1547).

An interesting implication of this study is that while evolution of a cluster is associated with changes in the nature and quantum of knowledge flows, the transition to more complex clusters is not automatic. Size of the market and the institutional arrangements play a critical role in this transition.

IV. External Linkages of the Cluster

One can argue that on average the capacity to absorb and implement external knowledge is higher for a cluster than for a firm, as some firms in the cluster will always have this ability. Once few firms in a cluster assimilate external knowledge, its diffusion within the cluster becomes easier.

There is evidence to suggest that even in very backward regions like Nigeria, international links provided access to information that did not exist in the country clusters. Such knowledge flows typically related to 'modern medium scale production technologies that Asian firms were beginning to outgrow'. (Oyelaran – Oyeyinka, 2001).

The role of export linkages or of demanding international customers has already been discussed in the last section. This section focuses on the role of foreign direct investments and the emerging global production networks.

IV.1 Role of Foreign Direct Investment

The opportunities for knowledge transfer and innovation have made clusters like Silicon Valley, Route 128 and partly Cambridge UK a major attraction for high tech firms and entrepreneurs from all part of the world. Investments in these regions are a way to gain entry to the opportunities generated by a diverse technology pool and skill base. Moreover, given the inherent uncertainty of technological developments and the speed of technological change, participation in the high tech clusters is also a method of keeping abreast of emerging technologies and platform shifts (Best, undated).

The importance of proximity in the context of conversion and creation of tacit knowledge is also seen in the context of MNCs in search of new knowledge and competencies in the Silicon Valley. Available evidence suggests that the success of the MNCs in the region depends to a large extent on their ability to become 'part of the local relational fabric' and to absorb high-tech related tacit knowhow. These studies also show that the process of acquisition of new knowledge cannot take place without 'tight coordination between the local entities and the central unit'. In effect, the transfer of knowledge depends on the proximity – both geographical and cultural – which provides access to local relational networks. (Cohendet, 1999: 232).

It is widely accepted now that multinational corporations (MNCs) can be an important source of knowledge flows for host countries as they transfer new knowledge and management practices to these locations. However, a variety of factors may affect the nature and quantum of FDI-linked knowledge flows. For example, the knowledge flows in clusters where FDI is high may also depend on the autonomy of the MNC subsidiaries (ability to link up with local entities) and their capabilities. In an interesting econometric exercise of European and North American clusters, Birkinshaw and Hood (2000) show that foreign owned subsidiaries can only contribute to cluster dynamism if they are strongly embedded in the local economy and are autonomous enough to interact freely with entities in the cluster. Two of their findings, although tentative, are striking:

(i) Clusters with high levels of foreign ownership have subsidiaries that in general are less autonomous and have weaker capabilities; and

(ii) Subsidiaries in export intensive, leading-edge industry clusters tend to be more autonomous, more embedded in the local cluster and have more international market scope than their counterparts in other industrial sectors.

This MNC's behaviour vis-a-vis knowledge sharing seems to be influenced by the levels of dominance of MNCs in a cluster (e.g. an enclave like situation may reduce interaction with local entities) and the capability levels of the cluster (e.g. higher capability inducing more interaction). The dynamics of such linkages needs to be explored further.

IV.11 Relocation of MNC Activity

Often MNC restructuring and other strategies transform the nature of knowledge flows within a cluster. In the 1990s, many MNCs shifted certain operations of electronics production from Singapore (Johen) to low wage Penang area of Malaysia. The know-how and value added from engineering intensive activities was not transferred even though the manufacturing operations were conducted in factories located in Malaysia. Significantly, in some of these cases of 'relocation', manufacturing was supervised by Malaysian engineers working for MNCs with regional headquarters in Singapore (Best, 1999).

The transformation of the Singapore electronics cluster, essentially driven by MNC strategies was very interesting. In its initial stages Singapore operations focused increasingly on more engineering intensive activities including automation, product redesign, design for manufacture and various logistics functions. During this phase the repetitive manufacturing activities were shifted initially to Malaysia but later to Thailand, Indonesia and China. Most of the manufacturing in Malaysia related to unskilled labour intensive operations in consumer electronics industries. Subsequently, Singapore electronics industry gradually became a horizontally integrated manufacturing services sector with ever increasing development of complementary services relating to manufacturing.

In effect, Singapore was going through the kind of transition that Route 128 underwent in the early 1990s; horizontal integration inducing technological diversity and fostering a diverse pool of collective knowledge, referred to as 'invisible college" (Best, 1999). As described above, this process has contributed to significant knowledge flows on product design and process re-engineering, the first 2 Ps of the 3 Ps framework.

In its own way Penang, Malaysia is also a successful electronics cluster as it has attracted many leading electronics firms. However, as mentioned, the Penang cluster is involved in low value added manufacturing segment and has not yet made a transition to high-end activities as is the case with Singapore. This does not mean, however, that knowledge flows have been absent here. Available evidence suggests that significant knowledge regarding 'practices' has been transferred. Best (1999), for example, provides evidence that many US and Japanese firms invest continuously in shop-floor skills.

> "In fact, the 'invisible college' of company skill formation is considerable in Penang. An audit of the quantity and quality of 'invisible college' graduates from these programmes would reveal a considerable regional asset or 'social capital'. These skills represent a sizeable regional asset which have been accumulated over 25 years." (Best, 1999: 25).

This 'skill' view of 'social capital would also suggest that one can move towards a more systematic measurement of 'social capital'. In fact Best (1999), refers to a skill survey (Lim, 1998) which can be a starting point such a measurement.[16]

Best's (1999) own examples of knowledge flows in the Penang cluster provide ample evidence of the fact that MNC participation in a cluster can potentially enhance capabilities of a cluster that is still focusing on low-end manufacturing. In such a situation, the knowledge flows primarily relate to 'practices', but involve process know how as well (Best, 1999: 26-27).

- Hitachi, in Penang uses small group activity (SGA) system of work organization that many Japanese companies are known for. The MNC has implemented the continuous improvement, *Kaizen* work system in Penang which has resulted in significant improvements in the productivity at the level of the shop floor.[17]
- Motorola's suppliers development programme involves industrial cooperation and networking with senior colleges to develop curriculum and to train the trainers. A local firm, BCM, is a beneficiary of Motorala's supplier development programme. A systematic 5-year technology transfer methodology has been developed with two complementary activities: manufacturing systems know-how and engineering know-how.[18]
- Dell computer has co-sponsored a hands-on work experience and training facility for chief executives. It gives senior managers real experience of using IT.

What type of knowledge spillovers these MNC initiatives generated in the Penang cluster? The answer is not clear but the potential seems very high. As Best (1999) suggests, SGA is a pre-requisite for making a transition from lower to higher levels of technology management (see Table 8) as it provides the flexibility and shop-floor problem solving capability required for mixed-product flow. As it is a building

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[16] Unfortunately this paper is not readily available.

[17] Hitachi-Penang, however, does not re-locate applied research and manufacturing operations and does not integrate, locally, applied and developmental research (Best, 1999: 26). This may limit knowledge flows and therefore productivity enhancement.

[18] Manufacturing know-how transfer involved the following sequence: (i) back end manufacturing of accessory products (1993-4); (ii) front end build of accessory products (surface mount technology transfer, skill transfer) 1995; materials procurement, stockroom and storage management (planning, buying, vendor interface, minibank) 1996; turnkey management (materials sourcing, materials procurement) 1997. Engineering know-how passess through the following steps: (i) materials quality engineering (failure analysis, vendor development, vendor process characterization) 1996; (ii) process/reverse engineering (internal process characterization, root cause analysis and design of experiements, statistical process control methods, product enhancement, prototyping, pilot manufacturing) 1997; (iii) research and development procurement (phone systems, radio frequency technologies) 1998. (Best, 1999: 26-27).

block for higher levels of knowledge generation (industrial innovation), its diffusion will have a significant impact on the skill formation of the region. This spillover process can be facilitated through a supplier base of SMEs that shared between MNCs and other firms. Once a critical mass of such a supplier base develops in a region the 'culture' of continuous improvements may get embedded in the cluster.

Motorola and Dell Computer's programmes in some sense are also meant to diffuse knowledge in a region. But such spillovers are likely to be a function of existing capabilities in the region. Best's (1999) account suggests that educational institutions in the region are not contributing significantly to enhance these capabilities so that spillover potential of MNC activity can be exploited. The type of linkages that existed in Silicon Valley, Route 128 and Cambridge with educational institutions are absent here. The skill pool is limited and if that is not enhanced the electronics industry in Penang may stay trapped in low skill generating and using trap.

IV.12 Policy Liberalisation and Changes in MNC Strategies

Cassiolato, et al (2001) analyze the changes in the technological capabilities of clusters located in the Mercosur area during the recent phase of liberalization. They argue that capabilities accumulated during the import substitution period are being rapidly eroded, as economic agents have changed their strategies. In most cases the MNC subsidiaries have increased the import content of their products and FDI has focused more on market access than import substitution. Most important aspects of the technological learning process are located outside the local chain. Analysis of a variety of clusters especially in tobacco, auto, telecom and other industries, the authors draw the following general conclusions:

- MNC subsidiaries have significantly reduced their technological activities in the clusters in the 1990s;
- Innovation and even production related efforts within the local clusters are on the decline. This has adversely affected capabilities of the firm and their learning;
- Existing production and innovation networks are being disarticulated and new foreign investments have limited links with local R&D infrastructure;
- The level of employment of specialized personnel within these clusters has decreased. Besides, the specialists who remain employed are undertaking less complex tasks now.

Overall, the argument is that the role of MNCs in facilitating knowledge transfer in the clusters has declined in the 1990s. The authors also suggest that the key focus of MNC interaction with cluster firms seem to be achievement of 'technical efficiency' rather than 'development of technological capabilities. Their description seems to suggest that for the achievement of technical efficiency only a limited knowledge transfer relating to practices (and to some extent processes) take place. Inter-firm cooperation relating to product and process development/improvement that was prevalent earlier, has been discontinued.

The two experiences of MNC activity in a cluster may seem contradictory. But if one takes the view that transfer of knowledge embodied in process and practices is also important for a cluster's growth, MNC activity may be seen as contributing to local capabilities even in Brazil during recent years.

IV.2 Role of Long Distance Alliances

Mytelka & Pellegrin (2001) emphasize the increasing role of long distance alliances of French biotechnology firms located in close geographical proximity. Even research alliances and alliances of new firms in a cluster have a significant share of non-cluster ties. Interestingly, many of these long distance research alliances are with research institutions. Are long distance research partnerships substituting for short distance ones?

It has been pointed out earlier that in most clusters, linkages are not restricted to firms and research institutions in geographical proximity. In fact, many clusters, (including those in third Italy, other parts of Europe and the US) have significant linkages outside the cluster. If physical proximity was critical for locating in a cluster, one would expect firms to partner with other entities in the cluster. However, some studies reviewed earlier show that extra-cluster partnerships are quite important. Mytelka and Pellegrin (2001) show that firms in a French biotechnology cluster have significant local and extra local linkages. Moreover, many of the extra local linkages are with research institutions rather than enterprises. The authors argue that the local and external linkages complement each other and most of these linkages are for accessing knowledge. Therefore, the changes in the market of knowledge are necessitating such technology-based alliances. Given our discussion of methodological issues earlier, this does not mean that proximity is not important for knowledge flows from research organizations and other firms, especially the former.

Several studies have documented the role of international alliances in knowledge flows. Mytelka (2000) suggests that in new traditional industries the agglomeration effects in geographically bounded clusters may only be realizable if complemented by international networking. There is evidence to suggest that international R&D alliances of firms located in a cluster can contribute significantly to knowledge flows to the partner firms and also to others in the cluster. As these alliances mature, the nature of knowledge flows may also change.[19]

[19] See Basant et al (1999) for examples R&D alliances among the software firms in Bangalore cluster, India.

It has also been suggested that for developing country firms such alliances have a number of advantages over equity arrangements (Mytelka, 2000: 23).

- They allow greater room for growth and redefinition of the firm's core business, its product lines and its markets.
- They are a means for local firms to keep up with a rapidly moving frontier by providing windows on the world and opportunities to leverage their own R&D resources.
- As the difficulties encountered by local firms in obtaining licenses to produce products with frontier technology increase (Mytelka and Ernst 1998), strategic technology partnerships and OEM production relationships provide an alternative means to access new knowledge.

It needs to be analyzed if firms in a cluster in fact use such alliances to develop capabilities. If yes, what facilitates this process of knowledge up-gradation.

IV.3 Global Production Networks and Potential of Knowledge Flows[20]

The earlier discussion dealt with a variety of external linkages a cluster may have – exports, customers, suppliers, FDI and R&D alliances. Another type of external dimension has attracted some research attention in recent years. Trade liberalization and other liberal economic policies have facilitated the growth of production networks spread across continents. The emergence of new technologies, especially those relating to information and communication (ICTs) have further facilitated the growth of these global production-networks (GPN). In a situation where GPN activities are on the rise and new technologies such as ICTs are reducing barriers to knowledge flows, the competitive advantage of geographically bounded clusters may get eroded. As Ernst (2001) suggests, spread of GPNs is an organizational innovation which may enable a firm to gain quick access to higher quality or lower cost foreign capabilities that are complementary to its own competencies while maintaining an effective home base for innovative activities. Theoretically, these opportunities can be exploited by entities located in a cluster or by the cluster as a whole provided they become part of the GPN. GPNs, therefore can become an important conduit for knowledge flows for a cluster of firms. Thus, globalization and ICTs have created new opportunities as well as challenges for the development and upgrading of industrial clusters.

GPNs, it has been suggested (Ernst et al, 2001) are an organizational innovation that enables network flagships to combine concentrated dispersion with systemic forms of integration. The potential of

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[20] This section draws heavily from Guerrieri & Peitrobelli (2001), Guerririeri & Iammarino (2001) and Ernst et al (2001). I am extremely thankful to these authors for sharing these unpublished chapters with me.

knowledge flows through GPNs is extremely high as these networks integrate a wide variety of entities to which the flagship is linked: subsidiaries, joint ventures, affiliates, suppliers, subcontractors, distribution channels, R&D alliances and other cooperative agreements such as standards consortia. Given this elaborate network, knowledge flows to a cluster will probably depend upon the 'location' of the cluster in this network and on the strategy of the network flagship. Ernst (2001) argues that even when GPN activities do not involve formal R&D, considerable learning can take place. Knowledge flows can relate to proto-typing and ramping-up, tooling and equipment, benchmarking of productivity, testing, process adaptation, product customization and supply chain coordination.[21]

It has been argued that spread of ICTs and globalization processes apply to all sectors. It may require significant reorganization of industrial clusters to become open systems with a capacity to learn from local and global networks through interactive modes of knowledge creation. Clusters may face erosion of competitive advantage if such restructuring does not come about.

An important research question to address in this context is how these changes – spread of GPN and ICTs – are going to affect industrial clusters in terms of their internal organization, location, knowledge generation and dissemination. Arguably, rapid globalization of economic and technological activities and diffusion of ICTs have created three conditions which may undermine the competitive advantages of clustering:

- Information and technologies increasingly become generic and codifiable apart from becoming readily available via globalization.
- Firms find it increasingly necessary to create knowledge through linkages with other organizations.
- The growth and diffusion of ICTs permits 'proximity' over long distances. This was earlier possible only within a localized cluster.

How widespread are these conditions? Are these relevant for all types of clusters? There is evidence to suggest that cross-border geographical dispersion of economic and knowledge generation activities is heavily concentrated in a limited number of specialized local clusters. Such cross-border extensions are concentrated and a few clusters within the Triad and some emerging economies. Consequently, not all clusters may be able to 'integrate' with the emerging GPNs.

Some scholars have identified a significant shift in the structure of Italian districts during the late 1980s (Guerrieri and Iammarino, 2001: 41), weakening some of the distinct features which were specific to

[21] Also see for similar arguments, Ernst and Kim (2001).

these clusters. According to the authors, these shifts are induced by the acceleration in globalization process in recent years which has enhanced the competitive pressure from LDCs and NIEs:

- *Re-internalization* of phases of production, especially those relating to product quality (e.g. vertical linkages). This process initiated by large firms is now being imitated by SMEs and is significantly changing the subcontracting systems in the clusters.
- *Decentralization* of production (or sourcing) *outside* the cluster (especially of low value added activities) to counter price competition.
- *Hierarchisation* of *inter-firm* relationships due to competition on innovation. This has modified the horizontal linkages encompassing competition and collaboration.

In the initial phase of this shift, the Italian clusters were able to avoid traditional price competition by delocalising the most labour intensive phases of the value chain and focusing on quality and more value added activities including design. Consequently, the traditional character of these clusters did not change significantly. In the 1990s these shifts have deepened and inter-firm linkages have taken a more structured and formal form with equity linkages and well defined hierarchies. Dispersion of production is no longer restricted to low end activities in some of these clusters. These tendencies are especially evident in clusters involved in less traditional sectors, such as metalworking; in traditional sectors such as textiles, clothing and shoes, the informal relations with subcontractors and local institutions have not changed significantly. However, the ability of the cluster leaders to source assets external to the original cluster seems to have positive influence on the cluster's economic performance.

It has been argued that the shift from MNCs to global network flagships has expanded both the mechanisms and the volume of knowledge transfer. Typically MNCs relied heavily on FDI, licensing, turnkey plants and technical consultancies to penetrate protected markets or for exploiting differential factor costs. In contrast flagships disseminate knowledge not only through these mechanisms but also through informal technical assistance. Consequently, overall GPN flagships tend to transfer more knowledge to local suppliers than vertically integrated MNCs (see for details, Ernst and Kim, 2001).

Ernst (2001) argues that GPNs have the capacity to create niches for small, specialized suppliers by 'increasing' the length of the value chain. Since outsourcing agreements have become more demanding, firms tend to learn rapidly through these arrangements. In high tech industries with short product life cycles (PLCs) speed to market has become critical. Since overseas production frequently occurs soon after the product launch, key design and other information is shared more freely within the GPN enhancing knowledge flows. Does this happen in GPNs of traditional industries as well? This needs to be explored.

Thus, while GPNs can increase mobility of firms/cluster specific capabilities reducing their competitiveness, network participation may provide opportunities for accessing knowledge for cluster firms. Which of these processes will dominate is an important question. GPNs have facilitated knowledge flows to the Taiwanese computer cluster (Hobday, 1995, Ernst and Kim, 2001). India's software cluster also seems to be benefiting a great deal from these alliances (Basant & Chandra, 2000; Basant, Chandra and Mytelka, 1998). In both these clusters, firms have sought a diversity of linkages, pursuing different approaches in parallel. This tendency is not dominant in the Italian clusters (Ernst et al, 2001). It is not entirely clear if it is due to the fact that these are clusters of a traditional variety.

Schmitz (2000) raises similar concerns about knowledge flows in clusters that are part of global commodity chains. He argues that the interests of the 'national' and 'global' networks may not coincide having adverse implications for capability up-gradation of the clusters in developing countries. Since global networks are coordinated from elsewhere, up-gradation of only those capabilities will take place, which do not conflict with the interests of entities coordinating the global production network. Consequently, process up-gradation (new machine, reorganization of the process of production) and product quality improvements may be facilitated but knowledge flows that provide new design or marketing capability may not take place.[22] Design and marketing capabilities may not get upgraded as this may help the cluster (or firms in the cluster) to new stages in the value chain, repositioning the cluster in the global chain. This is likely to conflict with the interests of other players in the global network. In this case the interests of local producers and global lead firms are likely to coincide. The author, however, recognizes that being part of global commodity chain does enhance process and practice capabilities of the cluster firms, enhances which in turn their competitive position.

The key implication of this insight is that one needs to systematically explore the interaction between the clusters and the global chain. Several issues will need to be looked into: the location of the cluster in the commodity chain (value addition, technological complexity), the levels of competition in various segments of the chain, the nature of products, and capabilities of cluster producers and so on.[23]

A significant amount of clustering in recent years has happened in high technology industries. As suggested above, in information industries, and particularly in computing, the ever-increasing power and

[22] Schmitz (2000) refers to the latter as 'functional upgradation.' Some examples of this kind are discussed in the next section.

[23] Schmitz (2000), for example, suggests that the producer driven chains (e.g. auto-industry) provide lower upgradation possibilities than consumer driven (textiles, garments, shoes) chains. More exploration is required in this area to come up with robust results.

bandwidth of information and communication networks are eroding the motives of clustering. The rise of information and communication based technologies (ICT) may have created conditions for de-clustering in other industries as well. However, clustering continues to remain an important phenomenon even with the onslaught of ICT, even in the computer industry. (Swann and Prevezer,1998). The key question in this respect is why this is so? How do such technological changes impinge on the motives of clustering?

One plausible explanation, discussed earlier, is that tacit knowledge remains an important part of a cluster knowledge base. Since accumulation of tacit knowledge is contextual and a result of cumulative learning, it cannot be easily codified and transferred. Face-to-face contact and therefore proximity may remain essential for its absorption, which is feasible only in a geographically bounded cluster.

The conventional wisdom has been that knowledge generation activities are immobile or sticky despite geographic dispersion of markets, finance and production because the interactive nature of such activities. And co-location facilitates a continuous, intense and rapid exchange of new ideas relating to the 3Ps. Moreover, the tacitness also contributes to the stickiness of these activities. In the context of the external linkages of a cluster, especially its interface with GPNs and ICTs, the following inter-related research questions may require further exploration:

- Does the spread of globalization and ICTs reduce the relevance of factors that contribute to the stickiness of knowledge generation?
- What is the relationship between local and global linkages? Can global linkages substitute for the role of localized linkages in the knowledge generation and diffusion process?
- Will the diffusion of ICTs and the experience with long distance linkages reduce the tacitness of knowledge and make it increasingly codified and/or codifiable?
- Will proximity matter only when clusters become more open and globally integrated systems of innovation?
- Will sectoral and structural characteristics of cluster play an important role in mediating the linkages between external linkages and cluster dynamics?

V. Policy and Economic Environment

The impact of macro-policy environment on the dynamics of industrial clusters is an under-researched area. Consequently, the links between macro-policy changes and knowledge flows in clusters have not been adequately explored. Recently, a few studies have focused on responses of some industrial clusters in developing countries to implementation of liberal economic policies, especially trade liberalization. These studies primarily focus on changes in inter-firm relations due to policies of liberalization. The idea is to ascertain if there are efforts to enhance collective efficiency through inter-firm collaboration in response to competitive pressures unleashed by liberal policies. This section will review these studies in order to gain some insights on the links between policy changes and knowledge flows in a cluster.

V.1 Liberalization and Globalization: Cases of Four Traditional Clusters

A special issue of World Development has recently put together four fascinating papers on how clusters in India, Pakistan, Mexico and Brazil have changed due to the competitive pressures unleashed by liberalization and globalization. As a result of these pressures, firms in these clusters are forced to perform to global standards, with low costs, good quality, and high speeds of response and flexibility. How did these firms acquire knowledge to perform to these standards? By and large, these studies show that high competitive pressures prompted greater horizontal and vertical cooperation for accessing knowledge. But there were significant differences across clusters. In what follows, I summarize relevant aspects of these papers to highlight key insights on the linkages between policy and knowledge flows.

Rabelloti (1999) analysed the links between trade liberalization and inter-firm cooperation in Guardalajara, a traditional shoe cluster in Mexico. During the pre-liberalization period, making money in the sector was easy due to a captive market and excess demand. However, in the second half of the 1980s when trade was liberalized, it increased incentives for introducing product and process innovations, improving quality, increasing productivity and lowering costs.

Prior to trade liberalization there was hardly any cooperation among various players in the Mexican shoe cluster (Rabellotti, 1997, quoted in Rabellotti, 1999). In recent years, the relationships in the cluster have become more collaborative. Table 9 provides some estimates of the nature and extent of collaboration. The nature and modes of cooperation listed in the table suggest that knowledge flows of all the three types – product, process and practices are taking place through these collaborative arrangements. The table is self-explanatory, a few insights from the survey need special mention (for details see, Rabellotti, 1999). Increasingly, the manufacturer-supplier links are focusing more on quality, variety of products and fashion content, including more intelligent imitation processes. The export oriented manufacturers (and to some extent large firms) tend to have more collaborative links with suppliers than others. The manufacturers association also initiated a joint initiative with the main suppliers to evolve a common system of standards. Finally, post liberalization, the role of catalogue selling and the power of the retailers, and US brokers has increased. However, some of them share more information on *processes* and *products* than earlier, although the larger firms tend to benefit more from these processes of knowledge flows.

The post liberalization experience of knowledge flows in the Mexican shoe cluster is extremely interesting in another sense. In a situation of extreme crisis many existing linkages broke down and new ones did not get created. It was only when policy intervention (devaluation, moderate protection) reduced the degree of competition, various collaborative arrangements emerged. Does this mean that severe competition may undermine certain types of knowledge flows associated with different types of collaborative arrangements? Are knowledge flows of this kind high when competition is 'moderate'?

Knorringa (1999) analysed the developments in the Agra (India) shoe cluster in the 1990s, another traditional and old cluster. He found that liberalization and globalization accentuated the need for local firms to enhance their capabilities. And enterprises that targeted dynamic and demanding market segments increased horizontal and vertical cooperation more than those operating in less demanding market segments. Apparently, in a more competitive scenario the need for knowledge flows was felt more by the enterprises that were linked to demanding markets. The other interesting finding was that a majority of Agra shoe firms were able to respond to emerging market needs by improving quality and speed. And a large majority increased cooperation in *vertical* inter-firm linkages (except with sub-contractors), rather than in *horizontal* ones. (Table 10).

Nadvi's (1999) study of The Surgical Instruments Cluster in Pakistan also showed that policy induced globalization brought into sharp focus the importance of conforming to international quality assurance standards for the surgical instruments cluster in Sialkot, Pakistan. His documentation suggests that the enterprises in this cluster were able to tide over the quality related crisis and, in fact, expanded sales by upgrading their manufacturing practices. And increased vertical and horizontal collaboration facilitated this up-gradation. Table 11 provides some changes in the modes of cooperation. Some conclusions of Nadvi's study have interesting implications for knowledge flows. While vertical ties have been strengthened, but such increases in co-operation were mainly limited to exchange of information and quality improvement. Quality concerns are resulting in some move towards internalisation and changes in subcontracting practices. Greater horizontal co-operation has been mainly through the trade association. The association helped connect local producers to external technical know-how, allowing SMEs to access knowledge that was very costly. However, such joint action has not occurred to take care of problems relating to infrastructure, sanitation, safety and health standards. Finally, the increase in inter-firm cooperation aimed at bringing about improvements in labour training has been extremely limited. The traditional/artisanal skill base of the cluster has been one of the key factors behind the Sialkot clusters competitiveness. The quality control crisis showed that the nature of markets is rapidly changing and requires new skills that undermine traditional practices. These new skills will be critical for the sustainability of the cluster.

Schmitz (1999) shows that enterprises in the export oriented Sinos Valley shoe cluster in Brazil stepped up their *vertical* cooperation in response to intensified global competition. Such cooperation contributed significantly to improvements in product quality, speed of response and flexibility. Table 12 summarizes the changes in various modes of cooperation. The estimates show that horizontal cooperation has not changed in any significant manner. There is some improvement though in exchange of information and quality up-gradation. Vertical cooperation, however, has seen a significant increase. The increase in cooperation with subcontractors for labour training, production 'technology' and quality up-gradation is particularly interesting.

Schmitz's (1999) survey also highlighted the possible conflicts between local and international cooperation. An ambitious programme of multilateral (essentially horizontal) cooperation was designed in the Sinos Valley to move up the value chain. This programme failed because some leading local enterprises put their alliance with a major global buyer above cooperation with local manufacturers. The state was not able to mediate and resolve the conflicts between business associations and entrepreneurial alliances. Interestingly, many of these leading and very large enterprises have integrated vertically over the years, reducing their economic interaction with the cluster. High levels of vertical integration close collaboration only among themselves and complete reliance on one/few foreign buyers resulted in a situation that these politically influential buyers held up the joint action for up-gradation.

The structure of the linkages of leading players and how they change with economic environment have a direct bearing on knowledge flows. The 'enclave like' situation in Sinos Valley may mean that 'external networks/linkages' will facilitate knowledge flows to a few entities. Besides, the conflicts between 'external' and 'internal' linkages may constrain cooperation at the local level in response to changing economic environment. This in turn may imply lower quantum of knowledge flows and diffusion within the cluster. Schmitz (1999) argues that such conflicts may become more important as the cluster matures. Learning by exporting is enormous in the early years of manufacturing when buyers not only provide a trading link but also help in upgrading production capacities. In subsequent stages when manufacturers wish to move up the value chain through the acquisition of design capabilities and brand names, their interests may conflict with those of the foreign buyers. Consequently, the foreign buyers may not be interested in facilitating knowledge flows for such a transition for a cluster. Higher the degree of concentration among buyers, higher may be such barriers to knowledge flows.

A few patterns from these four studies on the impact of changes in policies and/or economic environment can be highlighted (see Schmitz and Nadvi, 1999 for details):

1. Increased competitive pressures seem to increase *vertical* cooperation among cluster firms to upgrade technological capabilities, especially the ones relating to quality and delivery. The vertical knowledge flows are consequently enhanced.

2. Bilateral *horizontal* cooperation did not increase in any significant manner. Apparently, high competitive pressures within the cluster preclude such knowledge flows among competitors. Interestingly though, there is an increase in the horizontal exchange of information and experiences. To what extent it results in knowledge flows, especially of the tacit variety needs to be ascertained.

3. Multilateral horizontal cooperation has increased in some clusters with local trade associations playing a critical role of channeling external know-how to local firms. Such cooperation has been particularly important in responding to significantly higher quality demands.

4. Not all firms respond similarly to changes in policies and environment. Larger enterprises and those that face a demanding market seem to strive harder for mechanisms (e.g. cooperation) to upgrade technological capabilities. These firms may also be better placed to take advantages of the opportunities.

A larger question that emerges from these experiences relates to the links between policy-induced change in environment and the associated change in the *nature* of cooperation for knowledge generation and diffusion. Under what circumstances, cooperation for labour training will emerge? Interestingly, imperfections in the technology markets are partly being taken care of through cooperation via trade associations. Under what circumstances market failures in the labour market will get addressed?

V.2 Transition from Import Substitution to Import Competition and Globalization: Some More Examples

Meyer-Stamer (1998) analyses the impact of macroeconomic policies and environment on three clusters in Santa Catarina Brazil. In the pre-liberalization (import substitution) period (1980s, early 1990s) these clusters (textiles, ceramic tiles and metal engineering) showed impressive performance in growth and exports. The enterprises in these clusters, however, were vertically integrated and internalised as many activities as were possible. According to the author such a strategy was rational as it reduced uncertainty and transaction costs. Besides, excessive vertical integration and lack of externalities were not penalized in a protective market environment. Besides, a turbulent macroeconomic environment, especially the chronic high inflation environment added to the transaction costs and made inter-firm transactions difficult. Consequently, an extremely non-cooperative business culture evolved in these clusters.

Interestingly, while German migrants set up the textile and metal engineering cluster to Brazil in the late 19th early 20th centuries, the ceramic tile cluster was the result of the entrepreneurial activity of the

Italians who immigrated to the country in 1950s. While ethnic similarity could have facilitated knowledge flows and interaction, but emotional stress and intra family feuds in the small community along with the structure of the industry did not foster these processes. The metal engineering and ceramic tile clusters were both dominated by medium and large firms; a few small firms acted as suppliers to these larger firms but did not compete with them at any level. The textile/knitwear cluster had a dualistic structure: medium and large vertically integrated firms operated in the formal sector while the smaller firms partly operated in the informal sector. While there was no direct interaction between the two types of textile firms, the small firms provided competition to the larger firms and often copied their designs.

Apart from the design related spillovers, knowledge during the 'non-cooperation' phase essentially flowed from outside. Given their antecedents, entrepreneurs in these clusters sought to build firms that matched their European counterparts. Consequently, most of these firms consistently invested in new equipment, in-house training for employees and R&D departments. They also invested heavily in 'practices'. In fact, at times the Brazilian firms were ahead of their European counterparts:

> "... while visiting well known, competitive Italian spinning and weaving firms ...the owners and CEOs of some leading textile firms from Santa Caterina were surprised to see that, unlike their own firms, many of those firms used neither brocade systems (which are an important element in rationalizing intrafirm logistics) nor last vintage cutting technology (which can reduce the waste ratio substantially and save time due to CAD/CAM integration." (Meyer-Stamer, 1998: 1510).

Meyer-Stamer's (1998) account does not provide any clues about knowledge spillovers generated within the cluster due to the various technology-related investments in the pre-liberalization period. The potential was clearly high but limited cooperation and interaction may have hampered it. Apparently, cooperation was limited to waste water treatment in the textile cluster and to the literacy programmes for workers in ceramic clusters.

The move from import substitution to the import competition has resulted in significant shifts in inter-firm relations. Vertical dis-integration is on the rise. A number of textile and metal engineering firms are persuading their employees to set-up their own small firms and supply their formal employer. Moreover, with the end of inflation and reduction in macro-economic instability, inter-firm transactions are less risky. Deverticalisation, cooperation with suppliers and just in time delivery is on the rise. Owner managers of textile firms, in fact, visited Italian industrial clusters in order to learn about practices, especially those relating to inter-firm links and supporting environment. The ceramic tiles cluster, that was the first to face import competition, has many mechanisms of cooperation and has experienced the most significant shift in inter-firm relations:

- Business associations play a crucial role in enhancing cooperation as also the education levels of the ceramic workers. This has facilitated the diffusion of various practices within the cluster.
- There is substantial informal exchange between professionals of tile producers. Unlike other sectors, they visit competitors' factories on a regular basis.
- The manufacturers claim that 'production technology is on the whole standardized so that there is little risk of losing crucial secrets; competitive advantages lie rather in specific design and in logistics, i.e. the ability to deliver a wide variety of products fast without having huge stocks.' (Meyer-Stamer, 1998: 1505).
- Suppliers of inputs and vendors of equipment stimulate exchange of knowledge among firms. For example, if a vendor (typically an Italian firm) has set-up given equipment in one of the firms, it is used for demonstration to other firms.
- Some large firms have set-up technical schools, which are open to students of competing firms.
- The cluster has built close links with the Italian tile clusters, essentially for input and equipment supplies. Inter-cluster cooperation/demonstration effects seem to be significant.

The experience of the three Brazilian clusters seems to suggest that significant shifts in external environment and policy may result in an increase in inter-firm collaboration. This in turn will enhance knowledge exchange. Three features of this experience are worth highlighting. One, knowledge relating to all the 3Ps is exchanged, but process and practice related knowledge probably dominates. There is, however, no systematic documentation of this phenomenon. Two, inter-cluster knowledge flows seem to be on the rise. Is this a phenomenon specific to traditional clusters? Finally, the links between business and government (local and state) have not changed even in the post-liberalization period. Will this constrain knowledge flows in the subsequent period?

V.3 Policies and Technological Obsolescence

A study of the diesel engine cluster in Rajkot, India (Basant, 1997a) brings out how policies can limit knowledge flows in a cluster and contribute to technological obsolescence. The cluster consists of several hundred units engaged in assembly, casting, forging, and manufacturing specialized components. In addition, there are units making machine tools and small units undertaking jobs like machining, drilling and turning on a contract basis. All these firms are linked to each other through a complex web of input-output linkages. Over time, the degree of specialization has increased manifold and the cluster was the most competitive location for making low speed diesel engines in India.

The government policy defined engines up to 10 horsepower (HP) as being used for agricultural applications for which a very low excise duty of 10 per cent was charged.[24] The loan norms for the provision of subsidized credit to buy engines limited the finance to Rs. 7000 and also specified that only slow speed and low HP (< 10 HP) could be purchased through such loans. Moreover, the manufacture of slow speed diesel engines was reserved for the small-scale industries (SSI), which meant that no large-scale unit could provide competition to the small-scale producers in Rajkot.

Loan based purchases dominate in most states and these loan limits are rarely revised even when significant increases in raw material prices take place. Consequently, the manufacturers followed unethical practices to make reasonable profits and quality and technology suffered. The defining of reserved categories of engines on the basis of features (slow speed, low HP etc.) rather than functionally and subsidized credit being tied to slow speed engines also acted strongly against technological up-gradation. The protected market provided enough buffer for the manufacturers so that they did not worry about technological up-gradation. Since the diesel engine was the main "final" product of the Rajkot cluster and most firms in the cluster were linked to its production, the policy-induced demand for slow speed diesel engine effectively locked most firms to this obsolete technology.

The fear that the reservation policy may change and the liberalization phase may continue forced a leading firm in the cluster to resort to foreign collaboration at expensive terms with a buy back arrangement. But this firm was not able to deliver. It is in this regard that the reservation policy and its concomitants had its most adverse effect. The firm's edge was based on its sourcing from specialized and diffused vendors, a unique characteristic of the Rajkot cluster. But it was not able to make substantial numbers of its suppliers to invest to be able to supply the high quality components and parts. Small volumes that the firm was initially confident of were not a sufficient incentive to make many vendors make the shift. Unless the shift is made, the company would not be able to deliver at the low cost that is necessary if their collaborators have to buy from them. This problem is not specific to the firm, its generic in nature and pervades the entire cluster. Recently, four other firms in Rajkot have entered into technology licensing contracts with foreign firms and they are also concerned about the inadequacy of the technological assets available in the cluster to exploit the low cost advantages of SSIs in general and the Rajkot engineering cluster in particular. Thus, the policy induced final demand vector created a situation wherein firms in the Rajkot cluster got locked into obsolete technology and fresh infusion of technology was difficult to absorb and build upon.

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[24] In fact, till 1994, there was no excise on such engines. The slow speed engines were assumed to be used only in the agricultural sector and low excise rates were expected to enhance mechanization of irrigation.

Visser (1999) highlights another type of lock-in that might constrain the ability of the cluster firms to learn and react to policy induced shocks in the external environment. Drawing on the experience of the small scale clothing cluster in Lima, Peru, the author argues that most firms continue to rely on passive collective efficiency advantages after a one time decision to locate in a cluster. The clustered units in Lima were able to out compete standalone units due to fast cluster wide diffusion of (tacit) knowledge through direct observation and market trends (technology spillovers) and low costs of intermediary products due to fierce competition among upstream and downstream suppliers in the cluster. However, continued reliance on local technology spillovers resulted in the cluster firms being locked-in a 'local mental model based on imitation and low cooperation.[25] Table 13 summarizes the business process and linkages. Since local spillovers were often outdated and there were hardly any external linkages or internal cooperative linkages to outgrow this involutionery process, learning and innovation did not take place. The cluster not only remained locked into old technologies, the mental model did not allow them to move away from the 'local learning path' when liberalization brought in import competition as well as new external sources of knowledge. The Peru cluster and its business model had grown in a situation of closed domestic markets that were permissive with regard to quality but demanding with respect to price somewhat similar to Rajkot. Visser (1994) argues that knowledge flow, learning and innovation can only take place if the cluster changes the business model to get out of the lock-in and path dependence fostered by the earlier policy regime.

VI. Emerging Research Agenda: Some Observations

In recent years, some studies have emphasized that geographically bounded clusters should be viewed as systems of knowledge accumulation rather than just production systems (Bell and Albu, 1999). In the same vein, some others have argued that the focus should be on processes that convert the cluster based production systems 'into' innovation systems. (Mytelka and Farinelli, 2000; Mytelka and Rellegrin, 2001). In simple terms, 'combinations of internally organized capabilities with external knowledge resources, and the links between them' is referred to as innovation or knowledge systems (Bell and Albu, 1999: 1718). An application of 'innovation systems' concept to a cluster would require an analysis of capabilities internal to the cluster (or firms in a cluster) and their linkages with external knowledge sources including organizations like universities, R&D institutions, certification agencies, external firms, customers and so on. This paper has reviewed the available literature on these linkages. A research focus on the clusters' capabilities for generating and diffusing knowledge will in turn provide critical insights into the determinants of their long-term competitiveness. But this will need to be done in a more systematic manner.

[25] The model included among other things local spillovers of technology, price coordinated market linkages with traders, high degrees of vertical integration and limited cooperation with others.

Given this general context and on the basis of the discussion in the earlier sections, it can be argued that a broad research focus of future studies should be to systematically analyze the links between nature of knowledge, sources of knowledge flows, cluster characteristics (including capabilities) and policy initiatives. The discussion below elaborates on this basic theme of research.

VI.1 Recognizing the 3 Ps of knowledge

The review of available studies suggests that knowledge flows can take various forms. There is ample evidence to suggest that knowledge relating to the 3 Ps (products, processes and practices) gets transferred to cluster firms through a variety of mechanisms. However, cluster studies have typically not analyzed these knowledge flows in any systematic manner. Many studies consider new machinery as equivalent to technological change. Consequently, improvements in products, processes, materials, production organization do not always get 'counted' as technological change or knowledge up-gradation.[26] Any research on knowledge flows, therefore, must recognize the fact that knowledge is embodied in all the three Ps. An explicit recognition of this is critical for any future research in this area. *Once the three Ps are recognized, one can explore the factors that impact on the flows of different types of knowledge.*

VI.2 Sources of Knowledge

The review showed that geographically bounded clusters use a variety of sources for knowledge acquisition. Table 14 summarizes these sources. Bell and Albu (1999) have rightly pointed out that:

> "...research on clusters has emphasized the importance of interfirm links within spatially concentrated groupings. Intrafirm issues have attracted much less attention, inevitably involving only limited efforts to identify and understand the specific resources underlying technological change." (Bell and Albu, 1999: 1722).

The links between firm level resources with knowledge flows emanating from within the cluster and outside needs exploration. Such an analysis will automatically discard the notion of passive technology diffusion in clusters.

Related to the question of firm level learning in the context of geographically bounded clusters is the issue of the relationship among various sources of knowledge. The following questions may need further exploration:

[26] Bell and Albu's (1999) insightful review also strongly identifies this research gap.

- Can external (long distance) sources substitute for internal (cluster specific) sources? If yes, for what types of knowledge flows? For what types of knowledge do key complement each other?
- Do clusters need different types of sources for different types of knowledge?

Recent research has highlighted the role of "external" linkages in knowledge flows and it seems to be on the rise. A research focus on these will be extremely useful and should be accorded top priority. Some detailed research questions on this issue are discussed below.

VI.3 Nature and Determinants of Knowledge Flows

The paper reviewed the available literature on geographically bounded clusters to explore the determinants of knowledge flows in these clusters. The available evidence suggests that various dimensions of the cluster contribute to knowledge flows in the cluster itself. These cluster specific factors can include: size of the cluster, extent of diversification, division of labour (and the associated buyer-supplier relations), nature of products (hi-tech v/s traditional), levels of competition, nature of markets, location (developing/developed economy), links with other clusters and non-cluster firms (global networks, MNCs etc) and so on. Other important factors relate to public policy and macro-economic environment. Figure 1 summarizes the variety of factors and processes that impinge on knowledge flows in a geographically bounded cluster. In what follows, we highlight some of the key research gaps.

A large variety of variables have been identified that contribute to knowledge flows in a cluster. Table 15 provides a summary. Overall, the literature seems to have focused more on intra-cluster linkages than on linkages outside the cluster. This has changed in recent years but only to a limited extent. Moreover, *the cluster studies have not explicitly explored the links between sector specialization and knowledge flows.* Besides, sectoral specificities interact with a variety of other cluster characteristics. *Consequently, it becomes difficult to delineate the role of sectoral specificities in influencing knowledge flows. These need to be systematically analyzed.*

To initiate such a research endeavour, in terms of methodology, it may be useful to first categorize clusters according to structural features and then divide each structural category into certain performance categories. Determinants of knowledge flows in each type of cluster can then be explored. Tables 1 and 2 provide some leads for identifying key structural and performance features. Role of large firms, nature of subcontracting and other structural relationships and the location of the flagship firms can be key structural features (see below). Extent of innovation or degrees of competitiveness can be used as key performance features. Given that sectoral specialization can impinge on such flows, sectors can form another dimension of categorization. Following the summary of findings in Table 15 and the relationships highlighted in Figure 1, industries with specific features can be chosen for detailed enquiry. For example, the same set of industries can be chosen for each cell (high-tech, traditional, new etc.) to explore the nature and determinants of knowledge flows. Only when one controls for some of the structural, performance and few industry specific features, one will be able to analyze knowledge flows in a rigorous and systematic fashion. Once, clusters are systematically chosen in such a manner, the role of other factors mentioned in this review and summarized in Table 15 and Figure 1 can be explored. Of course, knowledge flows embodied in all the three Ps and all sources listed in Table 14 will need to be explicitly explored.

Performance Characteristics	**Dominant Structural Features**		
	Marshallian	*Hub-and-Spoke*	*Satellite platform*
Low innovation (Informal clusters)	♦ High/Low tech ♦ Traditional/New	♦ High/Low tech ♦ Traditional/New	♦ High/Low tech ♦ Traditional/New
Medium innovation (Organized clusters)	♦ High/Low tech ♦ Traditional/New	♦ High/Low tech ♦ Traditional/New	♦ High/Low tech ♦ Traditional/New
High innovation (Innovative clusters)	♦ High/Low tech ♦ Traditional/New	♦ High/Low tech ♦ Traditional/New	♦ High/Low tech ♦ Traditional/New

Once clusters are chosen in such a fashion, comparisons across rows and/or columns can probably provide us with interesting insights on the role and determinants of knowledge flows. As mentioned, the role of extra-cluster linkages is emerging as an important research issue and the complex interaction between "internal" and "external" sources of knowledge in a cluster also needs to be better understood. Consequently, it may be useful if the categories of clusters defined above are further classified according to the importance of "external" linkages for identifying clusters for study.

It may be argued that apart from "performance" based categorization of clusters, a classification based on "capabilities" may also be analytically useful. While there are likely to be overlaps between innovativeness and capabilities, the two may not be co-terminus as innovativeness of a cluster may be a result of leveraging "external" capabilities. For certain research questions, a capability-based classification may be more useful. For example, the MNC's behaviour vis-a-vis knowledge sharing seems to be influenced by the levels of dominance of MNCs in a cluster (e.g. an enclave like situation may reduce interaction with local entities) and the capability levels of the cluster (e.g. higher capability inducing more interaction). The dynamics of such linkages needs to be explored further and a capability-based classification may be useful.

Following the research priority of focusing on the role of "external" linkages in knowledge flows, one needs to identify a few more concrete areas of work. Research and other alliances, global production networks (GPNs) and exports are probably the most important "external" linkages for a cluster today. It was suggested earlier that the emergence of GPNs and ICTs has modified the external linkages of a cluster in a significant manner. Exports and alliances are also increasingly becoming important. The impact of these developments on knowledge flows needs to be systematically analyzed. It needs to be analyzed if firms in a cluster in fact use such linkages to develop capabilities. If yes, what facilitates this process of knowledge up-gradation. More specifically, the following questions on this issue can be systematically explored:

- Does the spread of globalization and ICTs reduce the relevance of factors that contribute to the stickiness of knowledge generation, making long distance linkages equally useful?
- What is the relationship between local and global linkages? Can global linkages substitute for the role of localized linkages in the knowledge generation and diffusion process?
- Under what circumstance complementarities local and external linkages can potentially exist and contribute to learning of cluster firms? For example, in what situations domestic and export markets can be complementary for learning purposes and be strategically used by cluster firms to maximize such learning?
- Will the diffusion of ICTs and the experience with long distance linkages reduce the tacitness of knowledge and make it increasingly codified and/or codifiable?
- Will proximity matter only when clusters become more open and globally integrated systems of innovation?
- Will sectoral and structural characteristics of cluster play an important role in mediating the linkages between external linkages and cluster dynamics? For example, are the answers to the above questions different for garment clusters than for auto or semi-conductor agglomerations?

VI.4 Some Specific Research Areas

The discussion above elaborated on the role of "external" linkages in knowledge flows in a cluster. This is seen as a priority area of research. While the coverage of the literature in this paper has been far from complete, some other specific research areas also emerge as potentially useful. These research issues can also be explored within the broad framework discussed in the last subsection.

- The links between cluster and industry dynamics need to be explored more systematically. Industry dynamics impinges on technology and market opportunities and on the survival of startups and SMEs (Mytelka, 2000). The review has shown that CLC and TLC interact in a very complex manner. These relationships need to be followed to understand the flows of knowledge under different circumstances. For example, one needs to ascertain whether in high-tech clusters industry and academic research grow apart at later stages of the industry life cycle.

- Is diversity of the cluster important for technology flows and cluster growth? Some evidence suggests that diversity may contribute to sustainability and resurgence of a cluster due to synergistic knowledge flows. This issue is important from the point of view of "designing" a cluster by policy makers.
- How does competition impinge on the quantum and nature of knowledge flows in a cluster? There is some evidence to suggest that increase in competition, policy induced or otherwise, enhances inter-firm linkages in a cluster and contribute to knowledge flows. At the same time, mainly vertical linkages develop during such period; horizontal links remain weak. Moreover, "moderate" and, not 'excessive competition' seems to enhance such processes. These issues need further exploration.
- A larger question also emerges from the experiences relating to the links between policy-induced change in environment and the associated change in the *nature* of cooperation for knowledge generation and diffusion. Under what circumstances, cooperation for labour training will emerge? Interestingly, imperfections in the technology markets are partly being taken care of through cooperation via trade associations. Under what circumstances market failures in the labour market will get addressed?
- Measuring the impact of 'social capital' can be another important area of research. As mentioned while social capital seems to be a very powerful determinant of knowledge flows and therefore the dynamism of the cluster, many aspects of this conceptualization are still "in the air". It has been suggested earlier in the paper that a rigorous empirical focus on the 3Ps in a cluster context can probably reduce of what remains 'in the air' of the 'industrial atmosphere'. This may prove to be a useful research focus.[27] One can also take a 'skill' view of 'social capital' to enhance its empirical application.
- The links between nature of markets and knowledge flows also seems to be an important area of work. The literature has clearly shown that exposure to demanding markets generally enhances knowledge generation and flows. However, a few issues remain unresolved. Should one always view domestic markets less demanding ones. Operating in diverse markets can facilitate learning. How does one strategically maximize such learning? How and when "demanding" buyers contribute to learning? Some studies have shown that large volume exports may not necessarily lead to knowledge flows even if customers are large and demanding, if channels of feedback are weak. Medium sized a small external buyers with smaller ability to substitute their suppliers at will may have greater incentives to provide the feedback to their suppliers. Is learning through smaller but quality intensive orders absorbed better than large volume ones, especially by smaller first time exporters?

Should policy facilitate such links for slower but dynamic learning processes? These questions need to be explored for a larger variety of clusters.

- The contribution of MNCs in the knowledge flows to different types of clusters needs to be analyzed. The explicit analysis of the flows of knowledge embodied in all the three Ps is essential here as well. Often the role of knowledge flows (including spillovers) relating to 'practices' are undermined. This may not be appropriate. Moreover, as stated earlier MNC's behaviour vis-a-vis knowledge sharing is influenced by the levels of dominance of MNCs in a cluster and the capability levels of the cluster. The dynamics of such linkages needs to be explored further.

In the end it needs to be re-emphasized that in order to pursue any of the research issues identified above, a rigorous methodology and survey instruments to capture the flows of knowledge embodied in the 3 Ps will be critical. This review has highlighted that there is no systematic documentation of knowledge flows. No new exploration in this area will be very useful without efforts do move in this direction.

[27] Guerrerie & Pietrobelli (2001) refer to another study by Pietrobelli (1998 – reference not available), wherein an empirical test of the concept of 'industrial atmosphere' in a sample of Italian industrial clusters is explored.

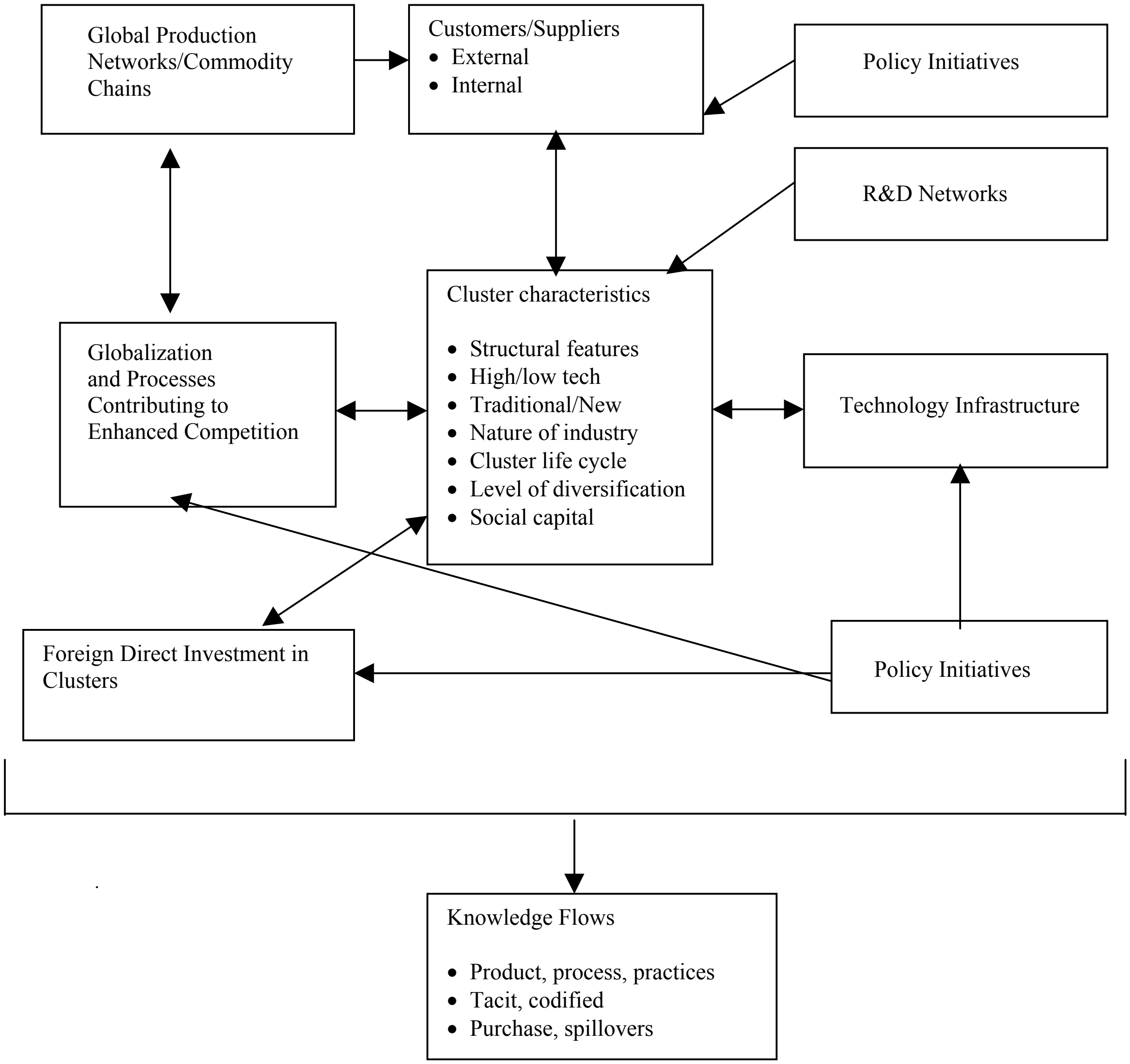

Figure 1: Cluster Characteristics, Linkages, Policies and Knowledge

Table 1: Features of Industrial District Types

Features	Marshallian ID (Italian variant)	Hub-and-spoke district	Satellite industrial platform	State-anchored industrial district
Prevailing market structure	Local SMEs	One/several large firms and suppliers	Large firms external to the district	One/several government institutions providing infrastructures
Economies of scale	Low	High	High	High
Local firms' level of activity	High	Low, except for services	Low to moderate	Low or none
Intra-district trade	Highly developed	Between large enterprise and suppliers	Minimal	High between institution and suppliers
Key investments	Local decision	Local decision, but globally dispersed	External decision	In local government or external to the ID
Buyer-producer cooperation	Important	Low	Low or none	Low
Regulation of relationships	Long-term contracts	Long-term contracts	Short-term contracts	Short-term contracts
Cooperation with firms outside the ID	Low	High	High with parent company	High with parent company (institution)
Labour market	Internal to the district Highly flexible	Internal to the district Flexible	External to the district, internal to the large enterprise	Internal (government capital), national from other institutions
Personnel exchanges	High	Medium	High, external origin	Medium/high (professional)
Workers' commitment	1st with ID, 2nd with enterprises	1st with large firm, 2nd with ID, 3rd with SME	1st with large firm, 2nd with ID, 3rd with SME	1st with govt. institution, 2nd with id, 3rd with SME
Labour immigration	High	High	High for high skills, management/low for low skilled labour	High
Labour (out) migration	Low	Medium	High for high skills, management/low for low skilled labour	Low, unless govt. institution leaves
Local cultural identity	Developed	Developed	Virtually absent	Developed
Sources of financing and technical assistance	Internal to the ID	Large firm	External	External (national or local government, military base, State University or research Centre, etc.)
Patient capital*	Exists	Scarce, out of the large firm	Non-existent	Non-existent
Local trade associations	Strong presence	Virtually absent	Absent	Weak
Role of local government	Important	Important	Important	Weak in regulation and industry promotion Important in infrastructure
Long-term growth outlook	Good outlook	Depending on large firm & industry dynamics	Threatened by relocalization of activities	Depending on government institution

Source: Guerrerie and Pietrobelli, 2001, pp 18-19.

Table 2: Types of Clusters and Their Performance			
	Spontaneous Clusters		
Types	Informal Clusters	Organized Clusters	Innovative Clusters
Examples	Suame Magazine (Kumasi, Ghana)	Nnewi (Nigeria) Sialkot (Pakistan)	Jutland (Denmark) Belluno (Italy)
Critical Actors	Low	Low to Medium	High
Size of Firms	Micro & Small	SMEs	SMEs & Large
Innovation	Little	Some	Continuous
Trust	Little	High	High
Skills	Low	Medium	High
Technology	Low	Medium	Medium
Linkages	Some	Some	Extensive
Cooperation	Little	Some, not sustained	High
Competition	High	High	Medium to High
Product Change	Little or None	Some	Continuous
Exports	Little or None	Medium-High	High

Source: Mytelka and Farinelli (2000), Table 1, p.12.

Table 3: Interaction of Cambridge Hi-tech Firms with Universities (% of all Firms)		
Type of Formal Interaction	Cambridge University	Other Universities
Academics on board	12	2
Collaborative projects with universities	28	36
Collaborative projects with government research establishments	6	14
Part-time secondment by academics	14	16
Research consortia or clubs	10	16
University staff acting as consultants	24	26
Licensing or patenting of university inventions	4	10
Training programmes run by the university	4	6
Total (includes others)	38	48

Source: Athreya (2000), Table 13.

Table 4: Research and Managerial Staff Recruitment (% of Firms)		
	Research Staff	Managerial Staff
University of Cambridge	19	6
Other Cambridge firms	35	39
Other UK universities	27	10
Other UK firms/organisations	41	58
Overseas universities	11	3
Overseas firms/organisations	8	23

Source: Athreya (2000), Table 12.

Table 5: Importance of Inter-firm Linkages Inside and Outside the Cambridge Area (% of Respondents)			
Type of Link	Within Cambridge	Outside Cambridge	Importance of Proximity
Customers	21	84	16
Suppliers/Subcontractors	45	45	39
Firms providing services	32	11	26
Research collaborators	11	24	13
Firms in own line of business	11	18	8
Others	3	0	3
Total	66	89	61

Source: Athreya (2000), Table 11.

Table 6: External Sources of Technology in the Italian Clusters of Prato, Teramo and Carpi, 1998	
Source	Percentage of reporting firms
Customers	62.5
Equipment suppliers	62.5
Trade fairs	60.0
Other suppliers	40.0
Consultants	27.5
Industry associations	22.5
Recruitment	20.0
Horizontal partnerships (formal + informal)	12.5
Publications	10.0
Universities	5.0
Public research & design institutions	5.0

Note: Licensing and government servicing were not cited as important sources of technology

Source: Guerrieri & Iammarino (2001), p 53.

Table 7: Comparison of Various Types of Clusters						
	Groundwork Enterprise		Industrializing Enterprise		Complex Industry	
Cluster	Eastlands Garments	Kamukunji Metalworking	Suame	Ziwani	Western Cape Clothing	Lake Victoria Fish*
External economies	Improved market access Some labor market pooling Weak intermediate input links No technological spillovers	Improved market access Disabling labor market pooling Weak intermediate input links Little technological spillovers	Improved market access Disabling labor market pooling Positive intermediate input effects Technological spillovers from engineering workshops to vehicle repairers	Improved market access No significant labor market pooling effects Weak intermediate input effects Weak technological spillovers	Market access Positive labor market pooling Significant intermediate input effects Potential for significant technological spillovers	Market access for fishermen and traders; little benefit for industrial processors Little or no benefit from labor market pooling Positive intermediate input effects for industrial processors No technological spillover effects
Joint action	Weak bilateral linkages No multilateral linkages	Few bilateral linkages Small wheelbarrow producers' group Association focused mainly on supply-side constraints	Extensive subcontracting Garages Association mainly an intermediary between firms and government Some (important) vertical links with engineering workshops	Extensive subcontracting Association dealing with both supply and market constraints No vertical bilateral links	Vertical and horizontal bilateral cooperation Vertical multilateral cooperation (common trading agents) Horizontal multilateral cooperation (two associations)	*Ad hoc* vertical bilateral action No vertical multilateral cooperation *Ad hoc* horizontal cooperation by industrial processors; ineffective fishermen's cooperative, welfare associations.

*"Lake Victoria Fish" refers to that portion of the total cluster comprising the industrial fish processors and related activities in Uhanya Beach. Other fishing beaches are not included.

Source: McCormick (1999), Tables 3, 4, 5, pp 1539-1542.

Table 8: Five Cases of Technology Management					
Technology of Management Stages	Case	Production Principle	Application	Performance Breakthrough	Organisational Capability
TM 1	Armory	Interchangeability	Replace Handfitters	Product Performance	Product Engineering, Special Mach. & Tooling
TM 2	Ford	Flow	Single Product	Cost	Process Engineering, Synchron.
TM 3	Toyota	Flow	Multiple Products	Cost, Quality, Lead Time	GT, Cellular Manu., Kaizen
TM 4	Canon	Flow, System Integration	New Product Dev., Generic Technology Integration	Product Innovation	Applied R&D, Proprietary Technology Dev.
TM 5	Intel	Flow, Systems Integration	New Product Concept, New System Design	Smart Products	Systems & Software Eng., Science & Technology Integration and Networking system transition.

Source: Best (1999).

Table 9: Post Liberalization Cooperation – Percentage of Sample Firms Cooperating a Lot with Suppliers, Subcontractors and Buyers, Guadalaraja Shoe Cluster, Mexico						
Nature/Modes of Cooperation	Competitors	Suppliers		Subcontractors	Buyers	
		Leather	Sole/Heel		Domestic	International
Information exchange	22.2 (44.4)	54.0	54.0	60.0	67.2	80.0
Negotiation for payment and delivery conditions	NA	55.6	41.9	52.0	60.7	60.0
Joint product development	7.9 (11.1)	44.4	50.0	NA	NA	NA
Technical assistance	NA	NA	NA	NA	18.0	28.0
Quality improvement/control	NA	46.0	52.4	80.0	63.9	80.0
Improving delivery time	NA	58.7	66.7	NA	NA	NA
Setting of product specifications	NA	NA	NA	NA	42.6	60.0
Production organization	NA	NA	NA	NA	13.6	20.0
Joint orders	9.5(12.7)	NA	NA	NA	NA	NA
Machinery lending	6.3(17.5)	NA	NA	NA	NA	NA
Joint sale	7.9(12.7)	NA	NA	NA	NA	NA
Joint training	3.2(6.5)	NA	NA	NA	NA	NA
Joint purchase	7.9(12.7)	NA	NA	NA	NA	NA

Source: Rabellotti (1999, Tables 2 and 4 pp. 1575-1579, NA: Not applicable/available.

Note: Figures in parentheses provide the percentage of sample enterprises reporting ‘a little cooperation’.

Table 10: Liberalisation and Changes in the Stability and Nature of Inter-firm Cooperation among Cluster Firms, Shoe Cluster, Agra, India, 1991-96						
	Decreased		No change	Increased		No. of Sample Firms
	A lot	A little		A little	A lot	
A. Changes in Stability of Cooperation with (% of firms)						
Leather suppliers	-	2	25	63	10	60
Soul suppliers	-	2	23	58	17	59
Subcontractors	-	-	89	9	2	58
Domestic buyers	3	5	19	68	5	38
Export buyers	-	3	6	91	-	32
B. Changes in Composite Indications of Cooperation (% of firms)						
Bilateral-horizontal	3	5	47	31	14	59
Backward-supplier	-	-	5	12	83	58
Backward-subcontractor	-	2	48	17	33	58
Forward	-	-	10	32	58	60

Source: Knorroinga (1999), Tables 2 and 3, pp. 1596.

Table 11 : Improvements in Cooperation with Suppliers, Sub-contractors and Buyers after the Quality Assurance Crisis, Sialkot Surgical Instruments Cluster, Pakistan				
Type of Cooperation	All firms	Small firms	Medium firms	Large firms
Suppliers				
Increase in exchange of information and experiences	55.0	61.9	50.0	53.0
Increase in cooperation to improve quality	30.0	23.8	31.8	35.3
Change suppliers less often than before FDA crisis	16.7	23.8	0	23.5
Subcontractors				
Increase in exchange of information and experiences	64.9	57.1	66.7	73.3
Increase in cooperation to improve quality	75.5	71.4	80.9	73.3
Increase in cooperation in technical upgrading	12.3	4.8	9.5	26.7
Increase in cooperation in production organisation	35.1	23.8	42.9	40.0
Increase in cooperation in labour training	22.8	14.3	23.8	33.3
Change subcontractors less often than before FDA crisis	36.9	23.8	47.6	40.0
Buyers				
Increase in exchange of information and experiences	61.7	47.6	63.6	76.5
Increase in cooperation to improve quality	65.0	61.9	81.8	47.1
Increase in cooperation in technical upgrading	16.6	4.8	18.2	29.4
Increase in cooperation in production organisation	3.4	0	9.1	0
Increase in cooperation in developing quality assurance system	29.3 (n=57)	30.0 (n=20)	27.2	31.3 (n=15)
Change buyers less often than before FDA crisis	26.7	9.5	27.3	47.0

Source: Nadvi (1999), Tables 1, 3, and 4, pp. 1614, 1617, 1618.

Table 12: Changes in Cooperation with Competitors, Suppliers and Sub-contractors, Shoe Cluster, Sinos Valley, Brazil, 1992-97 (Percentage of Firms)				
	Type of Cooperation	Increase	No. Change	Decrease
A.	Change in cooperation among shoe manufacturers (competitors)			
	Exchange of information & experience	32.3	63.1	4.6
	Quality improvement	21.5	75.1	3.3
	Labour training	13.8	84.6	1.6
	Marketing	4.6	92.3	3.1
B.	Changes in cooperation with suppliers of leather			
	Exchange of information & experience	63.1	35.4	1.5
	Improving quality	64.6	33.9	1.5
	Speeding up delivery	61.6	36.9	1.5
C.	Changes in cooperation with suppliers of soles			
	Exchange of information & experience	56.3	40.6	3.1
	Improving quality	60.9	37.5	1.6
	Speeding up delivery	64.0	31.3	4.7
D.	Changes in cooperation with subcontractors			
	Exchange of information & experience	60.0	35.4	4.6
	Technological upgrading	37.5	57.8	4.7
	Quality improvement	67.7	26.2	6.2
	Labour training	41.5	53.8	4.6
	Programming production	32.3	61.5	6.2

N=65
Source: Schmitz (1999), Tables 4, 5 & 7, pp 1635-36.

Table 13: Sources of Competitive Advantages of Clustered Producers, Clothing Cluster, Lima, Peru			
Business Process	Passive Collective Efficiency		Active Collective Efficiency
	Type of Effect		
	Technological	Pecuniary	Learning & Innovation
Transformation	Initial learning of basic technical and commercial techniques	Limited to finishing operations	Not observed
Transacting	Information at low costs and high speed. Negative features: - Outdated - Public - Limited relevance (Andean markets) - Local, insufficiently diverse (lock-in)	For producers and traders, in upstream and downstream transactions	Not observed
Strategic decision-making	Passive information advantages strengthen the local mental model of what it takes to successfully run a clothing business. Risk of 'entropic death'	Not applicable	Not observed

Source: Visser (1999), Table 5, p. 1565.

Table 14: Sources of Knowledge in Industrial Cluster	
A.	Intra-firm sources • Learning by doing (Passive experience of production) • Improved process and practices derived from trial and error experimentation • Adaptation and improvement of existing technologies (reverse engineering etc) • Aligning products, processes and practices within the firm.
B.	Intra-cluster sources • Knowledge spillovers/diffusion between producers • Knowledge spillovers/diffusion between users and producers of machinery/material or production related services • Intra-cluster mobility of skilled labour • Training and skill development through cluster based/mediated initiatives • Links between enterprises and cluster based technology institutions (technology development, adaptation, testing, certification etc) • Collaboration among cluster based enterprises for adaptation and technology development (machinery, product design) • Links between enterprises and customers located in the cluster (MNC, large firms)
C.	Sources outside the cluster • Customers and traders knowledge • Machinery and other input suppliers • Collaborative testing or technology development with technology institutions and enterprises outside the cluster. • Externally sourced training • Visits to outside clusters/firms

Note: Bell and Albu (1999) inspired the creation of this table.

Table 15: Determinants of Knowledge Flows in Geographically Bound Clusters – A Summary	
Factors	Likely Effect on Knowledge Flows (Empirical Evidence)
A. *Factors Internal to the Cluster*	
• Spatial proximity	Positive. Passive externalities and potential for active cooperation, flow of tacit knowledge
• Horizontal inter-firm linkages between firms producing similar products	Positive but collaboration generally weak
• Vertical inter-firm linkages (user-producer)	Positive, collaboration relatively strong
• Demanding customers	Positive
• High tech (tacit, complexity)	Generally positive but depends on production organization
• Traditional industries	Mixed results?
• Social capital	Positive, measurement difficult
• Cluster structure	
• Role of large firms	Positive? Limited evidence
• Type of clusters	Limited evidence
• Cluster life cycle	Higher during early phases
• Existence of facilitating institutional framework	(Tacit knowledge) critical
• Universities/R&D institutions	Critical for high-tech and some traditional
• Associations (standards, testing etc.)	Important for all types
• Nature of industry	Limited evidence, knowledge flows seem to be more important for science based industries
• Diversified/industry specific	Limited evidence Nature of knowledge flows may differ
B. *External Links of the Customers/Suppliers*	
• External customers	Positive if customer demanding and has less market power
• Links with equipment suppliers/R&D institutes	Generally positive
• Links with global production network or commodity chain	Important location in the network/chain matters
• Foreign direct investment	Depends on technology gap and objectives of FDI
C. *Policy Initiatives, Environment*	
• Enhancing competition (trade liberalization)	Encourage efforts to access knowledge Optimal levels of competition?
• FDI policies	Local manufacturing?

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