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Technological Learning and Innovation in Industrial Clusters in the South

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For a life-long lesson in the benefits of learning I thank my grandmother, Professor Marie Jahoda. For getting me through, I owe everything to Kate Alexander

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Chapter 1
Introduction

1.1 Introduction

This dissertation investigates claims for the long-term competitive advantages which derive from a particular form of industrial organisation involving predominantly small firms. 'Industrial clusters' are dense sectoral and geographical concentrations of inter-linked firms which, due to the characteristics of this form of production organisation it is suggested, have the intrinsic potential to be especially dynamic and innovative. In order to investigate this, I will use insights and conceptual thinking from the field of technological learning: a body of literature about the processes by which firms acquire, adapt, enhance and master technology so as to sustain efficient and competitive industrial production in the long-run.

The literature on industrial clusters has attracted much attention from those concerned with industrial policy in developing countries. Research has been interpreted as indicating that "clustering" creates effects which help sustain long-term competitive production systems, even when they comprise predominantly small firms. In referring to this conclusion, Nadvi and Schmitz write that the most successful clusters are felt:

> "…to have an indigenous growth potential, to be resilient in the face of economic crises and to be conducive to a process of sustained innovation particularly via the dynamics of technical learning resulting from user-producer interactions." [Nadvi & Schmitz, 1994:3]

From the perspective of technological learning literature, processes of sustained innovation are indeed thought to be crucial to sustaining competitiveness. Therefore the claim that 'clustering' helps achieve this in potentially novel ways is worth investigating. This dissertation therefore sets out to explore what the clusters' literature and research has to say about issues of long-term sustainability in the production systems it investigates; and in particular whether it sheds light on the processes of technical change they experience.

1.2 Background to the Research on Industrial Clusters

It is worth remembering that at least one and a half billion people still live in extreme poverty, marginalised and excluded from the benefits of mainstream economic growth [Todaro 1997:153]. Most of them live in countries where even average incomes are less than 10% of those in the industrialised nations[1]. Although these countries have primarily agricultural economies, they face expanding urban populations, and a secular decline in the terms of trade for agricultural products. There is therefore pressing need to promote forms of industrial development which include the excluded in the South.

Since the 1960s interest has grown in small enterprise promotion as a means of generating inclusive economic growth and employment. Small producers it is argued tend to use technology better suited to local resources and relative factor prices; and they operate on a scale more appropriate to the size of local markets, and the depth of available managerial and institutional capabilities. In addition, expansion of the small enterprise sector is believed to have dynamic long-term benefits in terms of developing indigenous entrepreneurial and management capabilities; and increasing opportunities for training and human resource development at a lower cost than otherwise available through formal institutions or large firms [Steel & Webster 1992: 426]. In theory at least, small firms might enjoy certain advantages over large competitors, such as greater flexibility in responding to changing opportunities, or the ability to serve small and specialised niche markets. Nevertheless, much of the research conducted in the past thirty years suggests that in general small producers are either marginalised by large-scale business or subordinated in ways which prevent them appropriating the benefits of technical change. Unable to accumulate, they tend to be squeezed into constricting economic spaces where cut-throat competition undermines any prospect for developing their human or technological resources.

Given this scenario, it is not surprising that a great deal of interest was raised when examples of internationally competitive industries composed of predominantly small and medium-scale firms began to be highlighted in the 1980s. The examples were associated with localisation of production: that is with sectoral agglomerations or *clusters* of firms. The clothing, footwear, ceramics and light engineering

[1] Low-income and lower-middle income countries as defined by the World Bank: World Development Report, 1996

districts of northern Italy became particularly famous; attracting a label as the 'Third Italy'. These cases became a source of inspiration to many researchers in industrial development, since it is felt they share many characteristics which can be found in abundance in the South, for example: artisanal manufacturing traditions, informal and flexible work practices and structures of social co-operation. As Amin observed, to some onlookers clusters appear to defy forecasts of the demise of small firms, and to offer a relatively inexpensive solution to industrial development that draws on local resources [Amin 1994:51].

Initial findings from research into industrial clusters in the North encourage debate. The suggestion that industrial clusters are conducive to processes of sustained innovation is especially interesting since, typically, small firms of the South are not well endowed with change-generating resources. They thus find it difficult to generate and adopt new technologies on their own. Perhaps in various ways, agglomerations of small firms in industrial clusters generate processes of technological learning. If collectively-generated resources or mechanisms do enable successful clusters to generate and manage technical change this would have potentially important policy implications.

1.3 The Dissertation Questions

In carrying out this dissertation, my underlying aim is to find out whether the research on industrial clusters provides any operationally useful conclusions about policy for improving the long-term sustainability and dynamism of industrial production systems in the South.

As far as I am aware, despite assertions about the dynamic, innovative and sustainable nature of the production systems created in the most successful industrial clusters, there has been no systematic and rigorous investigation of these claims. This dissertation sets out to build just such an investigation, starting from the conceptual foundation laid out in the literature on technological capabilities and learning. I will assume that the capability to implement technical change is a basic prerequisite for maintaining the long-term competitiveness of production systems. Beyond this, I will be exploring how well industrial clusters accumulate and internalise the technological capabilities to generate new technical changes (or innovation).

The central questions of this dissertation are therefore:

1. How well does the research on industrial clusters in the South explain the long-term sustainability of the production systems it investigates?
2. What does the research on industrial clusters have to say about the technological capabilities of clusters, or about other factors behind the processes of technical change which they experience?

1.4 Structure of the Dissertation

The subject of this dissertation is an investigation of technological learning processes in industrial clusters in the South.

Chapter 2 begins by reviewing the main findings and insights of the technological learning literature. Some key theoretical foundations are identified which relate to the nature of technology, the process of its creation and diffusion, and the characteristics of learning. On the basis of these, a new conceptual model of knowledge-acquisition in firms is developed in the later part of the chapter. This model adopts the conceptual approach found in the technological learning literature, and abstracts it into a form that can be applied to studies in another context, that of industrial clusters.

Chapter 3 approaches the whole issue from the opposite direction, by reviewing the main findings and insights of the industrial clusters literature. As well as describing and defining what is meant by "clustering", the chapter distils out and critiques some of the analytical approaches used in the literature to explain why industrial clusters might have a particular potential for dynamic or innovative performance.

Chapter 4 brings the two previous chapters together. An analytical shift is required in moving from the study of a single organisation to the analysis of networks of interacting firms. With this in mind, the abstract model of knowledge-acquisition systems developed in chapter 2 is shaped to provide a simple concrete framework for investigating learning processes in clusters of firms.

Chapter 5 then applies this framework to five case studies of industrial clusters in the South from recent doctoral research. In each case, I extract and analyse whatever evidence these studies provide of technological capabilities and learning processes in the clusters. I also compare the results with the authors' interpretations of their findings and explore how their analytical approaches to technological issues influenced their investigations.

Finally, in chapter 6 some conclusions are reached about the value of the clusters' literature findings when reviewed through the conceptual perspective of the knowledge-acquisition model. Some deficiencies are noted in the way in which dynamic processes in industrial clusters have been studied in the existing literature, and suggestions made for future research directions.

Chapter 2
Technology and Learning

2.1 Introduction

It is hardly controversial to argue that economic development should aim at more than merely increasing national production. Policy-makers of all schools are increasingly willing to contemplate indicators which capture some broader sense of the quality of lives as well as the quantity of consumption. The UNDP's Human Development Index established in 1986 is one example. An important insight underlies this trend which is not always articulated. Development is not just about increasing the resources available to society, but perhaps more importantly, it is about expanding people's capabilities to do valued activities[2] with those resources. Doing valued activities very often involves using technology in some form, and therefore the mastery of technologies forms an important subset of the human capabilities vital to development [Romijn 1996].

Technology in a broad sense is "the science and art of getting things done through the application of skills and knowledge" [Smillie 1991:65]. Most authors who focus on technological issues recognise that the concept implies a subtle mix of know-how, techniques and tools.[3] Technology is vested in people – their knowledge, skills and routines – just as much as in the machines they use. Machines and tools are only the physical manifestations of a particular technology or technologies. Indeed, mere access to the physical elements of a technology – even if accompanied by instructions for their use, and time to build up experience in using them – does not automatically lead to "mastery" of that technology. For mastering technology is not just developing the capability to use a given technology efficiently. It implies the (technological) capability to use knowledge about physical processes underlying that technology in order to assimilate, adapt and / or create novel elements, in response to changing needs [Dahlman & Westphal 1982:106].

Why does the mastery of technology matter for economic development? In a market-orientated economy, economic development is based on firms' success at achieving and maintaining competitiveness. One general way to do this is by consistently performing specific activities better or differently than competitors do. In many sectors, the new competition is based not just on price, but on innovation and continuous improvement in products and services [Schlie 1996; Best 1990]. The need to perform activities differently and better means firms continuously need to choose, use and master technology which is novel (new to the user, if not the world). Technological capabilities: the capabilities to generate and manage technical change are therefore a key issue for firms [Barnett 1995:15].

In this chapter I examine the literature about technological capabilities and the learning processes which generate them, with the aim of developing an analytical model that makes these concepts applicable to studies of industrial clusters.

Section 2.2 describes some common preconceptions about technology, and how these influence ideas about innovation and technology diffusion. An alternative prospectus based on an evolutionary approach to technological change is offered, which suggests the distinction between innovation and diffusion is not a good model of the real world. This has important implications for how one interprets industrial development in the South.

Section 2.3 brings out an important distinction between the essentially static capabilities or resources (production capacity) that enable firms to produce goods at given levels of efficiency with given combinations of inputs, and the related dynamic capabilities or resources (technological capabilities) that enable firms to induce and direct technical changes, so as to adapt or enhance productive capacity. An illustrative framework is offered for distinguishing between the various activities which are supported by these two types of capabilities.

Section 2.4 examines a parallel distinction, that follows from the first, between the processes involved in building productive capacity, and the more profound learning involved in acquiring technological

[2] "Valued activities" include those that generate an income, but also the whole range of activities that contribute to physical, psychological and social well-being [Sen 1990].

[3] See for example the various authors collected in Gaynor [1996].

capabilities. Consideration is given to theoretical ideas about how learning takes place in cyclical ways, driven by both internal and external resources. The relationship between technological capabilities and production capacity is integrated with the notion of learning cycles, so as to construct a analytical model of a firm-level knowledge acquisition system. In an effort to operationalise the theory, points of contact are established between the analytical model and (potentially) observable evidence about firms and their learning environment.

2.2 Innovation and Technological Change

2.2.1 Technology equals Machines

It is still common to find technology being equated simply with machines and devices, in isolation from the human resources and social contexts of their use which give these tools their technological value. In this light, technology is a product, a package, that is produced by one set of firms or other institutions and consumed or used by another. For those firms that merely use technology, the process of technical change boils down to making investment decisions. New technologies are invented from time to time and diffuse out into the economy, more or less rapidly depending on their value, via commercial products and technology transfers.

Orthodox economics' treatment of technical change is also narrow. As firms all operate on a given production function, their technological task is merely to choose whichever technology is most appropriate to their local factor endowments and relative prices. It is assumed that all firms can shift their position on the production function effortlessly in response to changes in factor endowments or relative prices, since they all have equal access to a global technology shelf, and are able to immediately operate the technology chosen with optimal efficiency [Rosenberg & Frischtak 1985].

The observable fact that many firms in the South continue to operate with outdated or obsolescent technology is basically seen either as a sign of inadequate investment (the neo-liberal argument) or as a failure of the innovators to allow developing countries fair access to technology (the dependency argument). In either case, the distinction between *innovators* – the creators of technology, and *adopters* – the users of technology, is fairly clear cut.

2.2.2 Innovation and Technological Diffusion

Bell and Pavitt [1993] argue that a more realistic view of the nature of technology and understanding of technological change requires the distinction between innovators and adopters to be rejected. To begin with, the *successful* adoption of technology involves more than merely the purchase of machinery and the learning of operating procedures [Dahlman & Westphal 1982]. It is not a case of simply plug-and-play[4]. In part, this is because of the tacit nature of much technological knowledge: making it difficult or very costly to effectively communicate the full range of skills and knowledge required to execute complex tasks. This means that firms cannot shift effortlessly along the production function [Lall 1992], nor operate any particular technique immediately at optimal efficiency. For firms in the South therefore, while technology "transfers" may be necessary, they are not sufficient. The effective adoption and mastery of a technology requires the acquisition of knowledge about a set of procedures, understanding of why the procedures work and skill in putting them to use.

According to Bell & Pavitt [1993] it also involves firm-level processes in which:

a) the basic features of a technology are adapted to meet the idiosyncratic needs of a specific situation, and,

b) a stream of further incremental modifications improve the technology and / or adapt it to changes in the inputs or products demanded by a competitive market.

Evidence from studies of large-scale industrial plants in North and South, indicates both phases of adaptation require complex and creative activities, and have the potential to generate significant improvements in production and economic gains [Hollander, 1965; Dahlman & Fonseca, 1987].

This suggests that innovation should be understood not as a distinct precursor to technical change in production, but rather as part of an integral process which takes place *within* the environment of the innovating firm. It is among other things, the process which involves matching technological

[4] I risk a rather loose use of this metaphor here in solidarity with the millions of PC hardware consumers who have learned only too well that adoption of technology is never an effortless process.

possibilities to market opportunities [Freeman 1982: 112]. Furthermore, the incremental innovations – adaptations, modifications and enhancements to products and processes – which occur within firms may be just as economically important as major investments in new machines or changes in products that originate outside the firm [Bienaymé 1986].

2.2.3 The Technological Effort of Learning

The kind of improvements in industrial performance mentioned above, are often interpreted as a natural consequence of doing production: the result of an automatic learning-by-doing process [Arrow 1962]. However, studies of infant industries in the South [e.g. Bell *et al.* 1982] demonstrate that learning does not occur spontaneously, and that performance can easily stagnate or decline over the long-run. Firms which do manage to master technology and initiate a process of *incremental innovation*, do so as a result of learning which is neither automatic nor effortless. Even minor innovation requires a spectrum of skills, knowledge and capacities for searching, selecting, assimilating and adapting techniques. Developing and maintaining these capabilities requires both a conscious effort by firms and the investment of significant resources.

However, while the pursuit of innovation is not effortless, its outcomes are intrinsically uncertain and unpredictable. This is particularly true for firms in the South which face an especially uncertain environment, and often have only limited access to, or capability to absorb, the latest research knowledge. Two things follow from this uncertainty. First, because of the cost and effort involved, firms must feel obliged to effect changes – either by competitive pressures, or because of technical problems (bottlenecks) within the firm. Second, because of the uncertainty, firms are more likely to concentrate their efforts in areas that are already familiar and thus less risky to them. Most of the time, for most firms, technological change is cumulative and incremental. This results in what Dosi [1988] calls firm-specific growth vectors.

Contrary to orthodox assumptions of homogeneity therefore, differences between firms play an essential part in determining the processes and direction of technological change. All firms have their own vectors and their own specific strengths and weaknesses - their own unique core capabilities - which are determined by historical events; by the attitudes and ambitions of the firm, and crucially by the searching and learning routines and resources that firms use and accumulate to effect technical change.

2.3 Technological Capabilities in the South

The idea that firms in the South also need technological capabilities is now widely accepted, and has spawned many empirical studies since the late 1970s. In her Ph.D. thesis on the acquisition of technological capabilities Romijn [1996:33] lists 29 major studies in the South. Some of these suggest significant capabilities have emerged, particularly in Latin America, Korea and India.

Interpreting and comparing studies of capability acquisition is not easy, in part because the resources firms accumulate are diverse and difficult to categorise. They comprise both human capabilities: skills, experience and knowledge vested in people, along with institutional resources: the internal procedures, routines and organisational structures of the firm, and the external linkages cemented with other firms and institutions. An easy trap to fall into, is to associate “technology” only with production activities, for example product design, manufacturing processes and the organisation of production. However, this ignores the importance of capabilities in other areas of supporting activity: in investment activities; in the procurement of capital goods; in raw materials supply, and in distribution of products [Lall 1992:167; Bell 1995:84].

One common approach is to distinguish three general types: production capabilities, investment capabilities and innovative capabilities [Lall 1992; Biggs *et al*. 1995; Romijn 1996]. *Production capabilities* involve those skills, knowledge and resources needed to use existing plant and processes efficiently to make established products. These capabilities enable firms to monitor raw materials inputs, schedule production, control output quality, maintain and replace machinery, and generally deal with day-to-day problems. *Investment capabilities* involve those skills, knowledge and resources which enable firms to expand workshop facilities, procure and install standard equipment; as well as to search for, evaluate and select technology and its sources for new production projects. Finally and crucially, *innovative and adaptive capabilities*[5] consist of the skills, knowledge and resources which enable firms to

[5] Biggs *et al.* [1995] called these “Learning Mechanisms”

Figure 2.1 Technological Capabilities of Small Producers
An illustrative framework derived and adapted from Lall [1992], and Bell and Pavitt [1993].

	Production Capacities	**Technological Capabilities**
Ability to do production activities such as:		
Investment Activities	Construct workshop facilities. Procure standard equipment.	Search for, evaluate and select technology and its sources for new production projects.
Process & Production Organisation	Do routine operation and maintenance. Improve efficiency of existing tasks.	Improve layout of workshops. Improve maintenance procedures. Adapt and improve production processes. Design organisational changes.
Product centred Activities	Replicate fixed specifications & designs. Do routine quality control.	Adapt products to changing market needs. Improve product quality. Design new products.
Ability to do supporting activities such as:		
Supply of Capital Goods	Replicate unchanging equipment and machinery. Replace original parts (capital stretching)	Copy new types of tools or machinery. Adapt existing designs and specifications. Design original tools & machinery.
Inputs Supply (Backward Linkages)	Procure available inputs from existing suppliers.	Search for and absorb new information about materials from suppliers and local institutions.
Customer Orientation (Forward Linkages)	Sell "given" products to existing and new customers	Search & absorb new information from customers and local institutions. Search for potential new markets, and identify ways into them.

assimilate, change and create technology via such activities as capital stretching, adapting processes and modifying products.

However, to give these three categories equal status is to miss an important distinguishing dimension. Lall touches on this when he points out that the process of developing capabilities occurs gradually and cumulatively. In general it leads from simple routine activities in which learning is based on experience, through more complex adaptive and duplicative activities requiring searching functions, to the most innovative activities based on more formalised research [Lall 1992]. This does not mean that all firms evolve technologically through the same steps: some functions may be bought in for example. However the basic core capabilities tend to expand sequentially as the firm extends and deepens its technological activities.

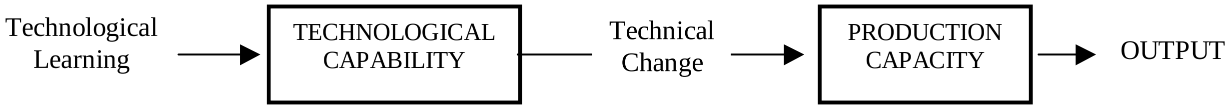
Building on Lall's insight, Bell and Pavitt [1993] introduce a general distinction between basic production capacities and dynamic technological capabilities. This distinction applies across the full range of firm activities and adds a new dimension to the taxonomy of capabilities. *Production capacities* are static attributes. Knowing a firm's production capacities gives a "snapshot" of the firm's ability to use existing production facilities, make standard investment decisions, expand established processes. *Technological capabilities* on the other hand are dynamic resources, which encompasses the skills, knowledge and routines involved in generating and managing technical change, whether they concern production activities, investment activities or relations with other firms.

The table in figure 2.1 above, illustrates the differences between the respective types of capabilities by showing the kinds of activities associated with each. The specific activities listed are only illustrative, but can be related to the hypothetical activities of a successful small manufacturing enterprise. This serves to highlight how the conceptual distinction between technological capabilities and production capacity is relevant for small firms.

Bell and Pavitt call the learning process involved in building the underlying dynamic resources "technological accumulation" [Bell & Pavitt 1993:164]. The relationship between these different terms and concepts is represented schematically below:

Figure 2.2 Technological Capabilities: Basic Concepts & Terms

(after Bell & Pavitt 1993)



	Resources Needed To Generate Change		**Resources Needed to Produce Goods**
The Acquisition of Technological Capabilities	Knowledge, Skills & Experience of change Institutional Resources Structures & Linkages	Incremental Adaptation & Improvements. Intro. Of New Machines	Fixed Capital Operating Skills & Know How Production Procedures

The process of technological learning so defined is thus clearly distinct from the process of technical change, even though the latter does also often involve learning (of techniques and operating skills for example). This distinction is not easy to grasp intuitively and I will need to return to it repeatedly during this dissertation. For now, a simple concrete example may help. A small firm is engaged in technological learning when it learns how to use the Internet to spot new developments in process technology that affect its products. The same firm is engaged in technical change when it learns how to operate a new machine that it has purchased.

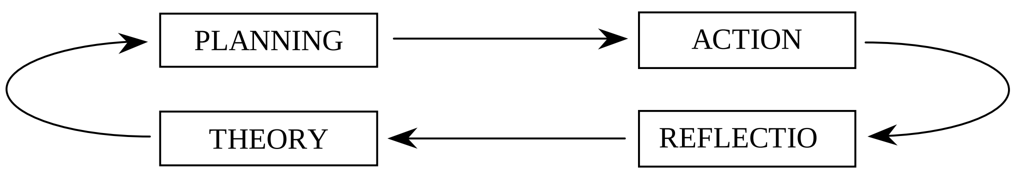
Using Bell & Pavitt's conceptual model it is easy to see how a firm with a fixed set of technological capabilities might generate a stream of improvements in production capacity over time. Such improvements may be important in enabling the firm to modify or scale-up production. A firm with no technological capabilities at all, would be rigidly unable to adapt to any changes in its environment, and would not survive long. However, the fact that a firm has a limited set of technological capabilities, and uses these to gradually improve production capacity, may not always be adequate either. In the long run, such a firm may not be able to change radically enough to bridge the discontinuities that occasionally arise in technical change, and may be out-competed by those that can. If this conceptual model reflects reality, then a most important task facing firms in the long run is technological learning: the acquisition and strengthening of their technological capabilities.

2.4 Acquisition of Technological Capabilities

2.4.1 Learning Cycles

In Figure 2.2 above the relationship between technological learning, technological capabilities, technical change and production capacity was shown, for simplicity, as a linear process: A leads to B leads to C. It is widely accepted however, that learning processes are best represented by cycles. Jambekar and Pelc [1996] for example, describe and compare four examples of learning cycles devised by Dewey, Deming, Kolb and Kofman. All these models share the idea that learning involves a moving back and forth between doing (action) and thinking (theory).

Figure 2.3 Archetypal Learning Cycle



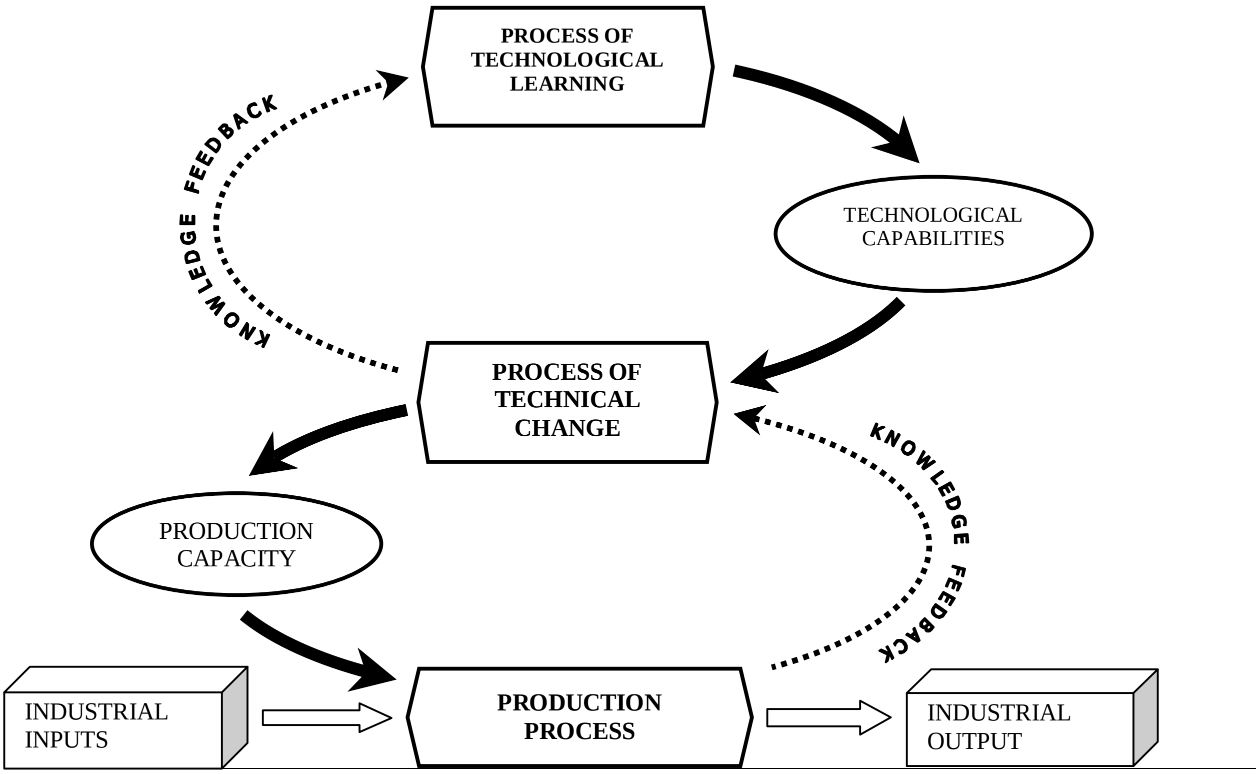
The argument is that when individuals learn they build theories (patterned conceptual representations of the environment) that provide coherence to a complex world of experience. These patterns of knowledge are then continuously tested in the realm of action. For learning to proceed however, it is essential that the learner reflects on (studies and analyses) the results of her action – using the knowledge gained to update and improve her theoretical understanding. In other words, learning requires at least some degree of systematic feedback.

By analogy, the same cyclical process can be applied to learning in organisations and firms. Organisations which monitor their own performance, analyse their strengths and weaknesses, plan strategically etc. are more likely to learn and improve than ones which are constantly in fire-fighting mode, reacting to external events.

2.4.2 Technological Learning Cycles

Combining this cyclical view of learning with the system of technological learning terms used by Bell and Pavitt above (figure 2.2) gives a model of two inter-locked learning cycles shown in figure 2.4. Note, the main flow line of Bell & Pavitt's model (the dark arrows) is now supplemented by learning feedback loops (dotted arrows).

Figure 2.4 Technological Learning Cycles



In this model, the lower cycle represents the technical change process. At the very bottom, production capacity is used to convert material inputs into goods. A certain amount of production experience (knowledge feedback) may be derived from the production process, and used to augment a process of technical change whose outcomes are improvements in productive capacity. Note however that without the presence of technological capabilities to generate and manage technical change, the feedback from production experience is of limited value (just as industrial inputs are of little value without productive capacity). One particularly important technological capability in this context, is the ability to systematically gather information from one's own production experience (monitoring regimes) and use it to generate knowledge about underlying technological processes.

The upper cycle represents the true technological learning process. Technological capabilities are used to generate and manage a process of technical change whose product is production capacity. A certain amount of change experience (knowledge feedback) may be derived from the process of technical change, and used to augment the process of technological learning whose outcomes are improvements in technological capabilities.

This model will form the basis of this dissertation's investigation of the acquisition of technological capabilities in small firms in the South. I am especially interested to see whether certain forms of small-firm industrial organisation known as clusters are "…conducive to a process of sustained innovation particularly via the dynamics of technical learning…" as is sometimes suggested [Nadvi & Schmitz 1994:3]. In order to do this however, the basic bones of the schematic model above need to be given a little more flesh. The next section will begin to do this.

2.4.3 Knowledge Acquisition – an analytical model

There are a number of separate tasks involved in investigating the acquisition of technological capabilities. In principal, in any situation of technological learning, one would wish to know:

a) What stimulates or drives the learning process?

b) What internal knowledge feedback supports the learning process?

c) What external resources/inputs support the learning process? [Romijn 1996:122]

The *stimuli* or causes of technological learning in the sense intended here, are those external and internal pressures or ambitions that motivate a firm to increase its capabilities. One must be careful to distinguish between the commonplace stimuli to increase or improve productive capacity, and the distinctive stimuli which induce a firm to seek long-run improvements in its capacity to generate and manage technical change. The former may arise from short-term competitive pressures or changes in demand. The latter may stem from management strategies, awareness of long-run trends or even government policies.

The possibility of internal *knowledge feedback* has already been described in the learning cycle above. Systematic feedback from the process of engaging in production and distribution contributes to the process of technical change – for example: interaction with customers can provide information about desired modifications to products – which leads to improvements in production capacity. Feedback from the process of technical change - for example: from the experience of purchasing and installing new machinery – can contribute to a firm's capability to manage future investments.

The *external resources or inputs* which firms use to build capabilities include a variety of skills, knowledge, technical and financial services available from the labour market, from interactions with other firms and from supporting institutions. Again, one needs to distinguish between the external resources which contribute directly to processes of technical change – for example: technical advice and investment credit – and the external resources which support the acquisition of technological capabilities. The latter are not so simple to identify. Indeed the question of what external resources (if any) can facilitate technological learning in small firms is a key research problem. For now, knowledge derived from close and systematic links with research institutions may serve as an example, as may knowledge derived from links with other more innovative firms or consultants.

When these components are included in the model developed above, the result is a more comprehensive analytical model of what can be called the *knowledge acquisition system* of a firm, illustrated in figure 2.5 below. Illustrative examples of the stimuli, inputs and feedback relevant to each level of learning are shown in the accompanying table in figure 2.6.

Figure 2.5 Firm-level Knowledge Acquisition System

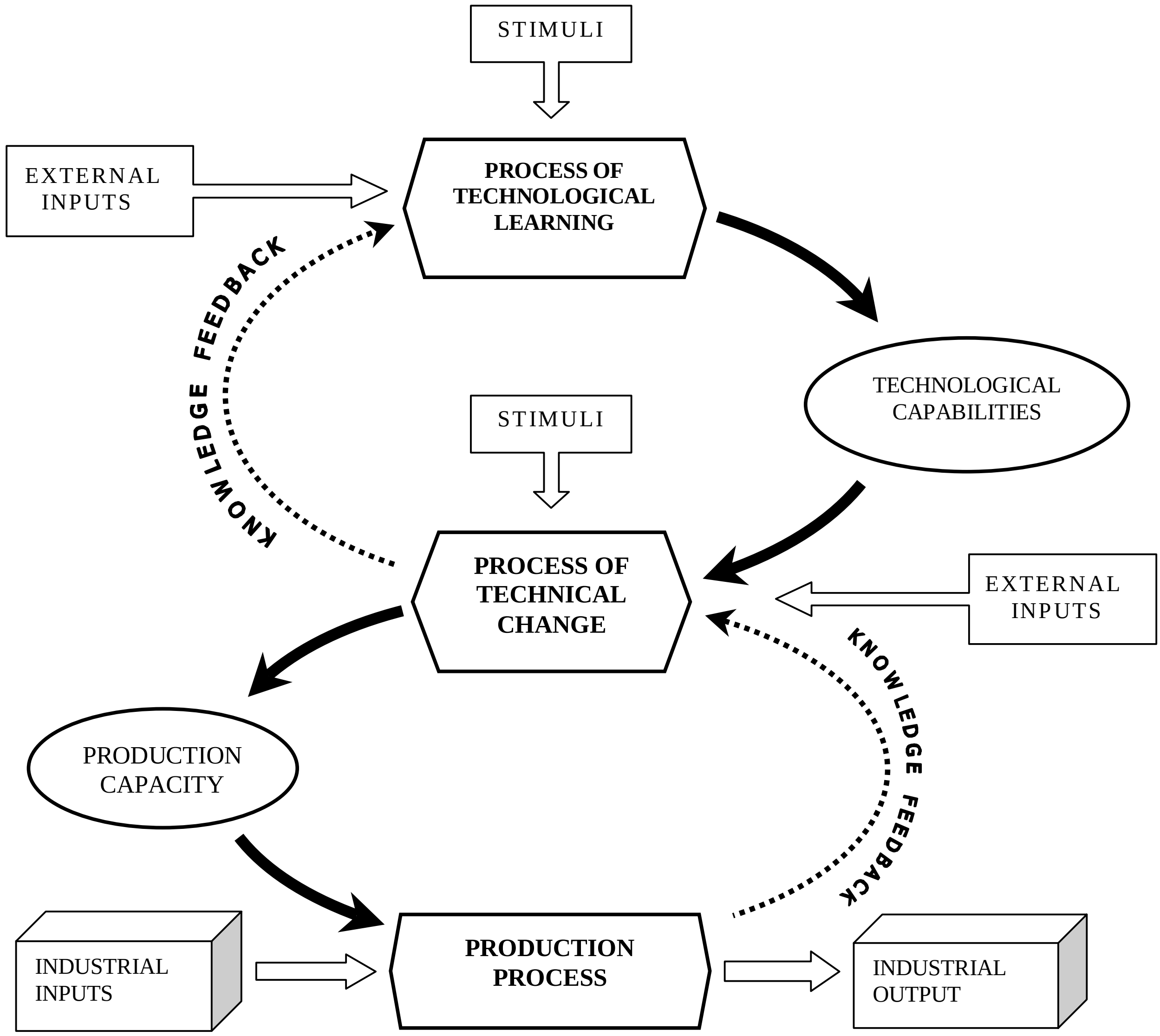


Figure 2.6 Illustrative Framework for Knowledge Acquisition System

	Process of Technical Change	**Process of Technological Learning**
STIMULI	Short-term changes in demand. Competitive threats & opportunities. Demonstration effects.	Government policy encouraging innovation. Culture & norms of social environment. Strategic awareness of economic trends.
KNOWLEDGE FEEDBACK	Skills & knowledge gained from experience of production. Interaction between producers & users	Skills & knowledge gained from investment projects. Insights gained from effecting improvements and modifications
EXTERNAL INPUTS	Training in Operating Skills Hiring Skilled Labour Technical Advice Services	Training in Strategic Planning, Design, Management of technology. Collaboration between research & industry Consultancy Services

Note: The stimuli to technical change may also act as stimuli to the process of technological learning, if the existing technological capabilities and flows of knowledge do not yield adequate technical change.

2.5 Summary

To recap, technology is best conceived of partly as something embodied in the machines and tools of production, and partly as something manifested in the techniques, skills and routines of those who create, adapt and use them. As a result, processes of technological change and innovation are not confined to firms at the leading edge of technology applications; they are necessarily present wherever firms are successfully adopting and mastering technology, even if the technology concerned is mature. At a time when competitiveness is increasingly based on innovation and improvement, firms which use technology need to be able to generate and manage technical change. Specifically, they need to have the technological capabilities to search for, select, assimilate and adapt technology in all its tangible and intangible forms.

The relationship between technological capabilities, processes of technical change, production capacities and the process of production itself have been conceptualised in an analytical model (Figure 2.5 above). In the next chapters, this model will be used to investigate the dynamic and innovative properties of a particular form of industrial organisation: the small-firm industrial cluster in developing countries.

Chapter 3
Industrial Clusters

3.1 Introduction

As the introductory chapter described, this dissertation is motivated in part by interest in small-firm industrial development in the South. Most of the research into small-scale industry and the so-called 'informal sector' in developing economies has been discouraging however. It describes small producers either as technologically subordinated to large-scale business or as marginalised in constricted economic spaces with little prospects for developing their human or technological resources [Schmitz 1982; Moser 1984].

Recently however, a growing body of literature suggests that in the right circumstances, clusters of predominantly small and medium-scale firms in the South demonstrate the ability to expand and be internationally competitive. In many cases the original inspiration behind these studies was the growth and success of small-firm industrial districts in Europe – particularly in Italy during the 1960s and 1970s [Becattini 1990]. However, examples of successful industrial clusters are also described in Asia and South America. Their success has been attributed (at least in part) to the innovative and dynamic characteristics of this form of industrial organisation [Brusco 1990; Nadvi & Schmitz 1994].

Given the importance of building and sustaining competitive advantages for firms, the claim that innovative capabilities lie in part behind industrial clusters' success, is inspiration enough for an investigation of technological learning in clusters. Later, in chapters 4 and 5, I will use the model developed in chapter 2 to analyse evidence for this in some empirical studies of clusters in developing economies. First, in this chapter I describe and define what is meant by "clustering" North and South in the literature, and attempt to distil out some of the analytical approaches used to explain how industrial clustering might generate a particularly dynamic or innovative potential.

Section 3.2 begins by describing the range of phenomena that fall under the label industrial clustering. A simple taxonomy will be developed in order to disaggregate the notion of industrial clusters and distinguish between examples more and less relevant to my focus on clusters in developing countries.

Section 3.3, continues by describing the historical origins of interest in "agglomerations" at the turn of the century, and to its more recent revival in the form of the Italian industrial districts model.

Section 3.4 describes and critiques three different theoretical approaches to analysing the structure and functioning of industrial clusters. In particular, the way in which these approaches deal with the dynamic and innovative characteristics of clusters is examined. Finally, these approaches are set against the evidence of one particular study from Italy and in section 3.5 some conclusions are drawn about the extent to which the existing literature on clusters deals with the question of innovative technological capabilities.

3.2 Defining Industrial Clusters

3.2.1 Sectoral Agglomerations

Industrial clustering broadly signifies any form of industrial organisation featuring a spatial concentration of numerous firms belonging to a similar industrial branch or *filière*[6] [Brusco 1992]. Often, the majority of firms in industrial clusters are small or medium-scale operations, although this does not mean that large firms can be ignored. Indeed, in some clusters large firms, although few in number, may have a very significant role [Humphrey 1995:157; Schmitz 1993:137]

The clustering concept implies much more than a simple physical agglomeration of homogeneous firms operating independently of course. Firms in industrial clusters tend to specialise in carrying out particular processes or stages in the production and distribution channel. For example, in a furniture-making cluster, some firms may process and supply the rough timber, others may saw and plane the timber to standard dimensions, the next may carry out the detailed joinery and assembly of furniture, while a different group of firms may be responsible for surface finishing and final marketing. This

[6] The concept of a *filière* can best be understood as a channel of production and distribution, incorporating all the economic and technically interrelated operations, which feed goods directly or indirectly toward a similar end market.

vertical disintegration of production, may well be complemented by *horizontal specialisation*. Thus, among the timber suppliers may be firms which specialise in making panel-board or plywood; and among the joinery firms may be those dedicated to making just tables or just beds. In addition to this horizontal and vertical specialisation, one may also find heterogeneous other firms providing inputs and services which contribute to the cluster's operation as a whole: financial services, trading agents, tool-makers and suppliers.

Consequently, firms in clusters are almost by definition enmeshed in more or less complex networks of inter-firm relationships. The degree of firm-level specialisation and density of inter-firm relations found in any particular industrial cluster represent a general quality which we can call the cluster's "depth". This depth is closely related to the existence of increasing returns to scale [Schmitz 1997] and other positive localisation benefits for the firms involved. In other word, directly or indirectly, it appears to generate competitive advantages and economic benefits for the firms involved – enabling in some cases, small firms to overcome the disadvantages associated with their modest scale of operations.

3.2.2 Taxonomy of Clusters

Empirically, the label of industrial clustering could legitimately be applied to a very broad and motley range of industries around the world. At one end of the spectrum might be artisanal *jua kali*[7] metalworkers in certain industrial zones of Nairobi, Kenya [King 1996]; at the other extreme, the producers of high-tech integrated circuits in Silicon Valley, California [Saxenian 1985]. In between, or perhaps along other dimensions undefined, can be found such diverse clusters as machine tool-makers in Peru, footwear manufacturers in Mexico; rattan furniture exporters in Indonesia, garment makers in Denmark and engineering companies in Baden-Württemberg, Germany [Nadvi & Schmitz 1994].

Given the wide variety of clusters, it is necessary to circumscribe the range of industrial phenomena which are relevant to this study. Three examples of simple taxonomies of industrial clusters follow:

First, Amin [1994:52] makes a strong case for distinguishing at least three types of cluster.

a. Craft-based, artisanal or traditional-sector industrial clusters engaged in the manufacture of footwear, garment-making, furniture, metalworking. The successful cases in this category illustrate the salience of co-operation, product specialisation and informal social and institutional arrangements.

b. High-tech complexes (such as Silicon valley). These demonstrate the need for huge R&D budgets, vast reserves of venture capital and excellence in technology-intensive products.

c. Clusters based on the presence of large-firms (such as the engineering sector in Baden-Württemberg) show up the importance of regional institutional support via high-quality training, education, R&D and communications infrastructure.

Second, a distinction between two types of industrial cluster is drawn on different lines by Pedersen [1997]. He distinguishes between *diversified industrial clusters* and *subcontractor clusters*. The former are based on vertical specialisation of individual enterprises and vertical diversity of the cluster as a whole. Competitive gains tend to be derived from enterprise collaboration both within and outside the cluster. The latter are based on a narrow vertical *and* horizontal specialisation, in which most of the enterprises are dependent on and linked as subcontractors to one or more large-scale enterprises. Competitive gains tend to be based on reduced transaction costs from dealing with a large enterprise. However the large enterprise(s) may also appropriate most of the benefits.

Third, the relationship between clusters and their markets forms another important criteria for disaggregation. Humphrey [1995:157] distinguishes different prospects for clusters using Gereffi's concept of 'commodity chains'. *Producer-driven* commodity chains are characteristic of capital- and technology-intensive industries. Production in these chains is dominated by large-scale manufacturers who co-ordinate backward and forward linkages: organising supply chains and defining the final product. *Buyer-driven* commodity chains on the other hand are characteristic of labour-intensive consumer goods industries. In this case large retailers, marketers and trading companies play the main role in setting up decentralised production networks. Humphrey's point is that the development of any cluster will depend on its position within and interaction with other elements in the commodity chain, just as much as on its internal structure and relationships.

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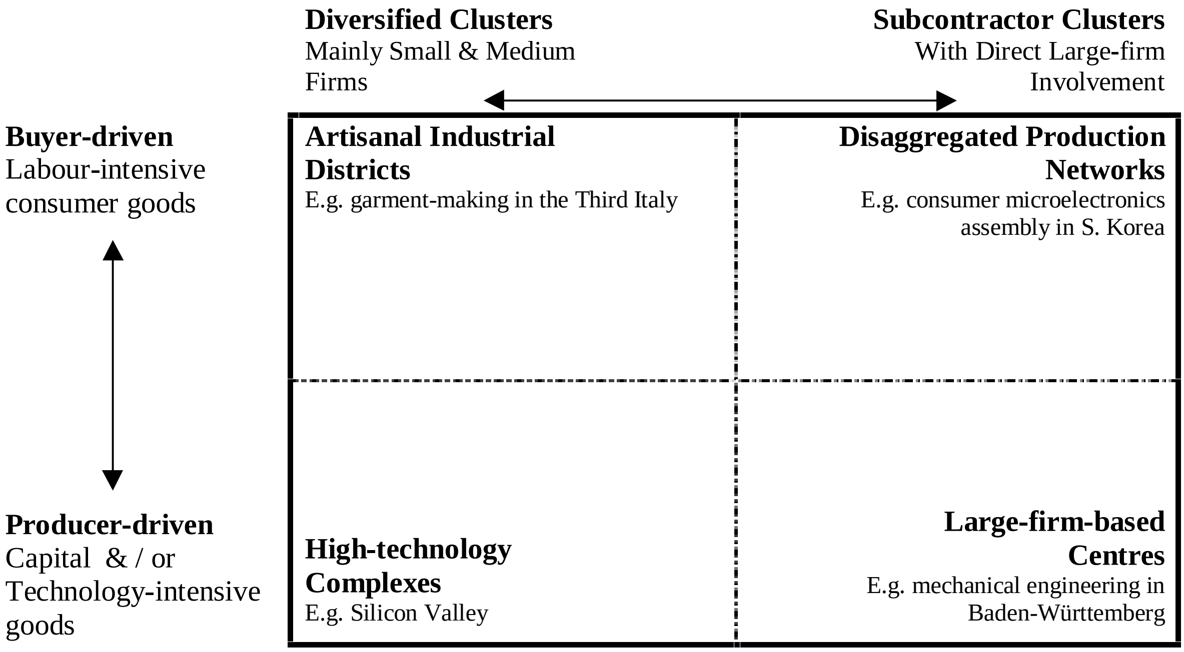
[7] *Jua Kali* (literally "hot sun" in Kiswahili) refers to self-employed artisans working outdoors in makeshift workshops for lack of covered premises.

These three authors illustrate some of the variety of perspectives that can be adopted in categorising industrial clusters. Alternative dimensions could be historical or social criteria for example, or the nature of production processes being undertaken. Holding onto the distinctions used by Humphrey and Pedersen however, we can produce the simple two-dimensional schema shown in figure 3.1 (into which Amin's categories also fit rather conveniently).

Figure 3.1 Taxonomy of Industrial Clusters



This new taxonomy is useful for identifying which empirical experiences are most likely to be relevant to the South, if two general assumptions are accepted. First, developing economies are better endowed with labour than capital or technology resources and their industries or prospective industries tend to be part of buyer-driven commodity chains. Second, industrial development that draws on local resources and does not require the presence of large-scale international firms or international capital may be particularly important for the South. On this basis the most relevant cluster experiences will be those that fall in the top-left quadrant of the matrix in figure 3.1. In other words, the main empirical focus of our research will be industrial clusters which are engaged in labour-intensive artisanal or traditional craft-based industrial production and which are *not* dominated by large firms in control of hierarchies of production. Given that processes of technological learning in clusters form the main topic of this dissertation, it is worth noting at this early stage that it is precisely those clusters in the top-left quadrant which appear to have least access to external knowledge inputs. They are neither well integrated with sources of academic research, nor tied into the knowledge-generating systems of large firms.

In Chapter 4 the possible sources of innovative capability in industrial clusters of the top-left quadrant, will be explored with reference to analytical model developed in Chapter 2. For now, this chapter continues with a review of the existing literature and its explanation of the dynamic gains that appear to derive from clustering particularly for small firms in traditional artisan manufacturing.

3.3 Dynamic Clusters and the Italian Industrial District Model

Recent interest in clusters was largely inspired by the growth of clothing, footwear, ceramics and furniture sectors in Emilia-Romagna, Tuscany and other regions of the Third Italy during the 1960s and 1970s [Brusco 1990]. Becattini [1990], who first defined the industrial district (ID) as a socio-territorial entity, related the economic performance of the district to its social and historical attributes. The stylised ID comprises firms of all sizes roughly divisible into three categories. Firstly, firms that manufacture and deliver the final finished products. It is particularly characteristic of Industrial Districts that this group includes an unusually high proportion of small firms. Secondly, "stage" firms that carry out one or more

of the production phases, either as subcontractors or as vertically disintegrated agents in the production chain. Thirdly, heterogeneous other firms that provide inputs and services which contribute to the district operation as a whole. In general, size is not a strong indicator of the role played by a particular company in the manufacturing process [Brusco 1990; 1992].
According to the protagonists[8] of the ID model, the attributes which distinguish the industrial district and account for its success, are:

- *Vertical disintegration of production at the firm-level.*
  High degree of specialisation and deep divisions of labour between firms made possible by a dense network of forward and backward linkages between the different categories of firms mentioned above. These linkages are based on both market transactions and also non-market exchanges of goods, information, services and people.

- *Co-operative competition.*
  This reflects the ability of firms to engage in intense rivalry when competing within a particular market for a specific input or productive phase, but also to forge informal co-operative alliances across vertical and horizontal divisions when necessary for common advantage.

- *Socio-cultural identity (social milieu).*
  The benefits which derive from the highly fluid interplay of competitive and co-operative relationships between firms are only possible because of a special social climate involving a sense of cultural identity and a shared set of social norms, values and attitudes. This facilitates trust between firms by providing a strong tradition of contractual conventions, behavioural rules and socially imposed sanctions against opportunistic behaviour.

- *Support from private institutions, active self-help organisations and consortia.*
  The linkages, co-operation and trust which are characteristic of the Industrial District find expression in the specific phenomena of active self-help organisations. These take many forms, of varying degrees of formality, from trade associations and sales consortia to political lobbies to collectively sponsored technical training schools.

- *Support from public institutions and local government.*
  Finally, local government support for the Industrial District is important, and may itself be both a cause and a result of effective local self-help organisation. One important form of support is the centre for real services – providing services such as marketing and technological information to groups of firms [Murray 1996:164]

In the literature on clusters in the South, the ID model is not always regarded as particularly useful. One common criticism is that it is not strictly speaking an analytical model, but a set of stylised facts [Rabellotti 1995a]. It thus does not distinguish what is essential from what is incidental. For example it is not clear whether local government support is a necessary condition for the district's success, or whether it is the result of the influence and self-confidence generated by success. Another criticism is that it tends to take the local area in isolation, obscuring the importance of external linkages, for example the role of export traders in global markets [Schmitz 1995b].
Neither of these criticisms get to the heart of the question about dynamic capabilities. By focusing on an idealised "end-state", the model is essentially static, and distracts attention from the question of how industry moves from the present, to where it would like to be in the future [Humphrey 1995]. Do industrial districts have the capabilities needed to sustain competitive advantages over long periods, and if so how do they develop them? Many of the Italian cases which inspired the ID model have undergone subsequent changes, even economic depression, since their heyday [Schmitz 1995b]. While this is not a sign of failure, the interesting question is whether they have the (adaptive & innovative) capacity to respond to crisis – an issue that the model hardly begins to address.

3.4 Dynamic Advantages of Clustering: some theoretical approaches

The claim for dynamic advantages to clustering has to be based on more than a stylised model of a European experience. It is necessary to have analytical arguments that explain the dynamic competitive

[8] Two comprehensive collections of the arguments for Industrial Districts as a model for industrial reorganisation are found in Pyke & Sengenberger's books [1990; 1992].

advantages, and which can be tested more generally with clusters of various depth and in various stages of development. In this next section several different approaches are considered.

3.4.1 Collective Efficiency

One principal approach is summed up in Schmitz's simple concept of "collective efficiency". This term describes the combined advantages firms experience as a result of external economies and gains from joint action [1995b; 1997].

External economies arise where market-priced transactions do not fully incorporate all the benefits or costs associated with transactions. The most obvious examples are benefits which arise from the easy access which firms in clusters enjoy to:

- specialised local suppliers of inputs and services
- a local mobile pool of labour with highly relevant skills and knowledge
- a local *industrial atmosphere* in which relevant technological know-how and ideas are "in the air", and readily available to all.

Conventionally external economies are regarded as a source of "inefficiency" rather than benefits. For example, the rapid diffusion of technological knowledge which is said to be characteristic of industrial clusters could be expected to cause under-investment in technology [Stewart & Ghani 1991]. Although clusters do seem to be weak at radical innovation, pervasive incremental technical and organisational changes often seem to be their strength, it is claimed. Even the most innovative enterprises appear to gain more from being in the cluster than they lose through their technologically-porous walls [Schmitz 1997:16].

External economies are only one part of the picture. Much of the recent literature has also emphasises the gains that arise as a result of consciously pursued *joint action* [Brusco 1990; Pedersen *et al*. 1994; Schmitz 1995b; 1997]. These gains are generated through co-operative and collaborative relations between firms in a variety of institutional forms. The most common form of collaboration occurs bilaterally between individual firms – for example, the horizontal sharing of specialist capital equipment by competing firms, or vertical collaboration on product improvement between producer and user or seller.

More importantly, in well-developed clusters there may be multilateral institutions ranging from trade associations and sales consortia to political lobbies. Examples of collectively inspired action may include: opening up new markets through trade fairs; improving local infrastructure, and organising technical training. Even if many firms, particularly the smallest, are unable to actively join in these types of collaborative ventures, the fact that there are others amongst them who lead in pushing forward the clusters' technological or marketing frontiers can be very significant [Nadvi 1996:40]

Nevertheless, except for the possible role of collaborative institutions in facilitating knowledge-generation, the notion of collective efficiency does not offer much insight into dynamic processes of knowledge-acquisition in clusters. The benefits of collective efficiency are essentially static advantages to do with the efficient use of existing resources.

3.4.2 Trust, the Social Milieu and Transaction Costs

The concept of the social milieu has already been raised in the Industrial District model to describe socio-cultural aspects, including such attitudes and traditions as the local work ethos, shared values and questions of identity [Brusco 1990]. Common cultural, psychological and sometimes political backgrounds are credited with generating "synergy effects". One example would be an entrepreneurial and innovative local social atmosphere which encourages, even demands, a mixture of competitive spirit and social responsibility from the working population.

Synergy effects are closely related to issues of trust in various forms. The social milieu is also thought to be particularly important in reducing or moderating different types of uncertainty faced by small firms [Humphrey & Schmitz 1996a]. These effects can be modelled systematically using a transaction costs approach.

Transaction costs are the inefficiencies that arise at the interface of activities in the production and distribution process. For example, they include the costs of planning, managing and contracting tasks; of monitoring activities and outputs, and of insuring against losses due to corruption and opportunism [Williamson 1975]. Firms in industrial clusters can be assumed to have transactional costs advantages. In comparison to small isolated producers, clustering firms gain from reductions in communications, transport and distribution costs. More interesting is the possibility that clustering small firms gain competitive advantage over large integrated firms by somehow avoiding the normal trade-off between costs of internal and external governance. Thus while on the one hand they eliminate the costs involved in maintaining internal bureaucracies etc., they do not incur, on the other hand, the normal costs associated with the uncertainty and risk of anonymous market transactions.

One example of this is seen in contracting. In many cases firms in clusters engage in multiple sophisticated transactions involving complex components, goods and services; and they do so without the expense of formal contractual arrangements. Instead they rely on mutual trust and social institutions, such as: traditional conventions which prescribe the quality and form of goods; behavioural rules which govern financial transactions, and socially imposed sanctions against opportunistic behaviour.

Clustering can also be understood to perform other functions which reduce the uncertainty that would otherwise increase the transaction costs of small firms. [Camagni 1991:130] Two examples of these functions are:

- *Collective information-gathering and screening.*
  Informal exchange of information and demonstration effects of successful decisions can create a collective information-gathering and screening function in clusters. The screening function can also help overcome the difficulties small firms often have in inspecting and monitoring the quality and hidden characteristics of inputs, components and technical equipment.

- *Signalling*
  Successful clusters can develop quite a "reputation". The signals this gives to the market can function as both cooperative advertising, and a form of quality certification. This reduces the uncertainty and hence transaction costs of buying from the cluster.

However, in this context the transaction costs approach is still essentially static – it only addresses issues of allocative efficiency and organisational structure. It does not begin to explain, for example, why industrial clusters might develop the technological capabilities needed to sustain competitive advantages over long periods.

3.4.3 Analyses of Enterprise Networks

We have already seen that the interactions between firms in an industrial cluster include co-operative and strategic alliances which are not pure market transactions, nor are they governed by the authority of internal organisation. Rather, the firms display the characteristics of a "social network", which has its own special economic properties. In her econometric study of the Ghanaian manufacturing sector, Barr [1997] found that networks are significant in explaining the differences in productivity between enterprises. Her results were also consistent with the hypothesis that networks facilitate flows of knowledge between enterprises, and that networking can transform the decreasing returns faced by isolated entrepreneurs into constant or increasing returns to scale [Barr 1997].

Networking among firms is not an homogenous phenomenon however. In fact, Barr makes the important point of distinguishing two types of network: morality networks and innovation networks. The former mitigates against opportunistic behaviour and other forms of uncertainty by supporting systems of reputation and community enforcement. The latter act as conduits for knowledge. Although, morality networks may evolve into innovation networks once there is a sufficient presence of formal institutions and generalised morality[9], the optimal structures of the two are quite different. The size of morality networks needs to be tightly controlled if they are to be effective; whereas size is not important for innovation networks, but configuration is [Barr 1996:244].

Network approaches have also been developed recently which stress the role networks play in facilitating firms' strategic goals, which may include controlling the direction of technical change. A basic assumption is that the individual firm is dependent on resources controlled by other firms, and therefore seeks access to these through its position in the web of network relationships [Johanson & Mattsson 1987; Knorringa & Weijland 1993]. Roberto Camagni [1991] suggests two forms of group relationship:

[9] Barr cites Aoki [1988] on the Meiji period of Japanese history when the government successfully broke down barriers of distrust between kinship and village groups, without removing the network of relationships or the tendency of Japanese people to form small group allegiances.

co-operation networks and local innovative milieux. The distinction is similar to that made by Barr above. *Co-operation networks* are characterised by explicit negotiated relationships in an open, often global, setting. It is typical of high-tech complexes of firms using new communications technology to create a "spaceless" economic environment. *Local innovative milieux*[10] on the other hand, are associated with the territorially-bound clusters, where relationships are often informal or implicit. In practice, the two concepts are deeply linked and complementary. An important reason for this, and a useful insight, is that local innovative milieux require inputs of external energy (external linkages) if they are not to die an entropic death [ibid.:140].

One virtue Camagni claims for his approach is that it deals with dynamic capabilities. He highlights the importance of mechanisms in the innovative milieux which a) facilitate collective learning processes and b) reduce dynamic forms of uncertainty. However, by dynamic, he is referring to a strategic dimension of firm behaviour; for example: a firm's ability to control the outcomes of complex interactions with other actors in the milieu [*ibid.*:127]. Aside from the recognition that local milieux require inputs of external "energy", there is little discussion of the resources or capabilities involved in sustaining innovative technological change or knowledge-acquisition.

3.4.4 Theory of Flexible Specialisation

The analytical approach most frequently associated with clustering is the theory of flexible specialisation (FS) [Schmitz 1993; Pedersen *et al*. 1994]. FS theory posits that industrial organisation is experiencing a paradigmatic shift from "inflexible" Fordist mass-production to a more flexible mode involving increasing disintegration and specialisation at the firm-level. As consumer markets fragment and demand more differentiated products, and as new technology provides the means to inject such variety into production[11], so the basis of competition is shifting from "price" alone, to characteristics such as high product quality and reliability, the ability to deliver promptly and in small batches [Piore & Sabel 1984].

Flexible specialisation creates challenges and opportunities for both large-scale and small-scale producers according to its protagonists. Large firms need to decentralise internally, move to cellular layouts, trim inventories and create more co-operative relations with their suppliers and sub-contractors [Womack *et al*. 1990; Hoffman & Kaplinsky 1988]. Small firms need to capitalise on their ability to meet small order sizes and short delivery schedules by intensifying specialisation in the context of strong inter-firm networks. Hence the relevance to industrial clusters.

According to FS, important markets are getting smaller and / or more volatile. Firms competing in these markets have two basic options: the "high road" or the "low road" [Pyke & Sengenberger 1992]. The *high road* involves investing in the flexibility to shift production between different products quickly and cheaply by having skilled workforces and multipurpose machines. In this way, the firm creates stability for itself by being highly adaptable. The *low road* involves relying on low-cost, short-term labour and minimal capital investment. The firm grows and shrinks by hiring and firing workers in response to its widely fluctuating order book. It is claimed that pursuit of the high road was and is the basis for growth and competitive success in Italy's industrial clusters. This is a testable hypothesis at least. Examples of clusters featuring strong investment in human capital, multipurpose machines and well-developed networks can be compared to those characterised by low-wages, insecure employment and transient sweat-shops. Such research is ongoing, for example by Rabellotti [1995b; 1997].

It must be noted that systemic adoption of the new strategies and management techniques required for FS makes heavy demands on organisational and management capabilities that are often very scarce in the South [Kaplinsky 1995]. The successful adoption of new "flexible" technologies in particular calls for technological capabilities which are often greater than in traditional neo-Fordist systems. FS theory in itself is therefore no substitute for an analysis of technological learning processes.

In summary, flexible specialisation offers a coherent set of arguments for the potential advantages of industrial clustering for small firms. These derive from the collective capability – given the right kind of inter-relations – to be very responsive to an increasingly differentiated and changing market. Nevertheless, FS theories have little to say about the processes by which dynamic gains are achieved. Continuous improvement in products and processes is seen to flow from a change in management

[10] The concept is similar to the social milieux of the ID model, but claims to be different in emphasising the role of the milieu as a generator of innovative behaviours, as well as a reducer of uncertainty.

[11] Programmable technology and numerically-controlled machines for example, enable even very small firms to "stock" designs for thousands of components that can be turned out cheaply in small numbers on demand.

practice and production organisation, without too much analysis of the nature of technological and organisational change, or the resources that generate it.

3.4.5 Evidence from Veneto

In contrast to the analyses reviewed above there is one empirical study from Italy which does examine innovative capabilities in industrial districts in great detail, although it is rarely cited in the literature on industrial districts. This is Belussi's study of industrial innovation and firm development in Veneto [Belussi 1992]. Using a sample of more than 100 firms, she explored the factors determining industrial organisation, and related this to innovative capabilities and firm size.

Belussi disaggregated the firms in the Veneto sample using a modified form of Pavitt's [1984] taxonomy based on differences in the sources of innovation[12]. As predicted by Pavitt, she found that small-firm industrial organisation was indeed characteristic of the "traditional manufacturers" class of firms, which operate in sectors most relevant to clusters in the South. Belussi also found that innovation generation capability was clearly influenced by the setting of each firm within its taxonomical group. The "traditional manufacturers" sector had a very low propensity towards truly inventive activity. Furthermore, among the small firm sector, competitiveness based on low labour costs was widespread [Belussi 1992:322]. This suggests that perceptions of the Italian clusters as having followed the high-road to success are biased by the performance of certain innovative sub-sectors, which are neither representative of the traditional manufacturers, nor necessarily involve predominantly small-firms. Belussi acknowledges that in the context of intense market segmentation, product variability is a decisive factor behind the development of competitive industry based on small-firm networks [*ibid.*:324], but gives little support in other ways to the flexible specialisation theory. In explaining the strong presence of small firms in Veneto she emphasises two key factors: entrepreneurship originating from skilled manual workers & the positive influence of local policies directed towards providing a cohesive and protected environment for newly created firms. She concludes that the relatively decentralised industrial structure in Veneto is the outcome of a very high process of firm creation during the 1970s related to particular social and cultural conditions [*ibid.*:326] but questions whether this provides any special advantages vis-à-vis innovative capabilities.

[12] Pavitt [1984] analysed industrial sectors according to the sources of innovation: finding regularities within groups of firms characterised as a) science-based (high-tech), b) scale-intensive (mass-production & process industry), c) specialised suppliers and d) traditional manufacturers (supplier-dominated).

3.5 Summary and Conclusions

The aggregation of small firms engaged in related activities (forming a *filière*) into industrial clusters is a phenomenon found in both industrialised and developing economies. There is plenty of evidence, going back a century or more, to suggest that clustering generates static advantages for the participating agents. More interesting and more controversial, is the claim that industrial clusters are conducive to innovative change and sustainable growth. If this is true, an understanding of the mechanisms and features that make some clusters successful would be valuable for the promotion of small-firm industrial development in the South.

This chapter has sought to present an overview of some eclectic analytical approaches used to explain industrial clusters' performance in the literature. All of these approaches represent at least one step forward from a neo-classical atomistic analysis based on individual firms. In different ways they recognise the importance of inter-firm relationships or networks based on more than anonymous price mechanisms. The firms in clusters are seen to be strategic agents with varying capabilities to influence their external environment.

Nevertheless, none of the analytical approaches described goes as far as examining the capabilities which firms in clusters may or may not have to influence their technological environment. In that sense, technology is still treated in the cluster literature as an exogenous factor. This seems to be a major limitation, given the importance ascribed to innovation and the management of technical change in contemporary literature on competitiveness, as described in chapter 2. In the remaining part of this dissertation, the analytical model of technological learning in firms that was developed in chapter 2 will be used to critically review evidence from some empirical studies of clusters in developing economies.

Chapter 4
Technological Learning in Clusters – A Framework for Analysis

4.1 Introduction

In chapter 2, I presented a schematic model of a "knowledge acquisition system" which is derived from analysis of technological learning processes in individual firms (figure 2.5). In this chapter I shape this abstract model to provide a simple framework for analysing learning in clusters of firms.

To begin with, I describe how most empirical research on the acquisition of technological capabilities in the South has neglected smaller firms. This neglect might be justified. Small firms in the South rarely demonstrate the kind of dynamic performance improvements which are associated with technological learning, and they may lack incentives to engage in capability building [Romijn 1996:36]. However, while this may be true for small firms acting in isolation, it does not necessarily hold for clusters of firms acting in collaborative ways.

In section 4.3, I consider the implications of this conjecture. Perhaps the phenomenon of industrial clustering somehow generates the mechanisms and incentives which permit smaller firms, collectively, to accumulate technological capabilities. Might this be part of the explanation for the claimed innovativeness and dynamism of some clusters? This discussion leads to a justification for the remaining part of the dissertation in which I explore the application of technological learning concepts to the experience of firms organised in industrial clusters.

However, the model was conceived in relation to a single firm, and the concepts of external inputs and knowledge feedback at the firm-level cannot be transferred unambiguously to the inter-firm context of clusters. In order to use the model of knowledge-acquisition systems with clusters of firms, some modifications are necessary as described in section 4.4.

4.2 Technological Capabilities and Small Firms

The empirical basis for the knowledge acquisition system described in chapter 2, is research on the accumulation of technological capabilities by writers such as Dahlman & Westphal [1982], Lall [1992] and Bell & Pavitt [1993]. These authors, like most others in the capabilities literature, based their research on large modern-sector firms. Romijn [1996:27] reviewed 29 major capabilities studies carried out in the South during the 1980s, and found that "the great majority of firms studied have been large, very large, even gigantic, especially by local standards…". One suggested explanation for this neglect of small firms is that although many authors see technological learning in small firms as desirable, they do not believe that it actually occurs, because they assume small firms in the South lack the incentives or the potential for building capabilities [*ibid.*:35].

4.2.1 Switching the Focus from Large to Small Firms

How realistic is this assumption? Or in other words, what empirical support is there to suggest the knowledge acquisition system of chapter 2, is relevant to small firms in the South? Romijn [1996] provides at least a partial answer. She found 26 studies in the small enterprise development and informal sector literature that referred in some way to the acquisition of capabilities, and from these extracted implicit indicators of capabilities increasing over time [Romijn 1996:77]. The three most commonly found indicators, identified in more than 50% of the studies, were:

- Increasing range and complexity of output over time (92%)
- Development of internal design skills (73%)
- Introduction of new, more advanced machinery (54%)

She also extracted evidence from these studies for three general mechanisms by which small firms learn technologically. These learning mechanisms compare quite closely with the knowledge acqusition system (figure 2.5).

Internal technological activity:

Romiijn refers by this to the trial and error efforts of firms to learn from the repair, maintenance and reconditioning of equipment [*ibid.*:102]. This mechanism can be related to the concept of *knowledge feedback* derived from the internal efforts and experience of the firm. The more effort a firm makes to systematically learn from observation, reverse engineering and practical experimentation the greater the knowledge fed back into building its capabilities.

Information search or communication:
This refers to the acquisition of new information from outside the firm. This mechanism can be compared with the concept of *external inputs* to the knowledge acquisition system. Acquisition may occur passively via general interaction with the outside world, or actively as a result of systematic search efforts [*ibid.*:104]. The latter is correlated with successful capability building in some studies [e.g. Girvan & Marcelle 1990].

Direct human capital formation:
Here Romiijn refers to formal and informal training and education, which widens the channels through which information can be obtained and makes internal efforts more efficient [Romijn 1996:106]. This mechanism could be considered as the direct augmentation of *capabilities*. Alternatively it may be useful to distinguish between training which involves imparting existing knowledge that already lies within the firm's ambit (a form of knowledge feedback), and training that involves instilling knowledge or skills that are new to the firm (an external input).

4.2.2 Limited Evidence of Technological Capabilities in Small Firms

Having drawn on Romijn's careful reviews of the capabilities literature as support for the knowledge-acquisition system, I now have to criticise her analysis! For although she brings a welcome focus on small firms, she does not strictly distinguish between the (lower) learning cycle involved in increasing production capacity and the (upper) learning cycle involved in deepening technological capabilities. Hence as seen from the indicators above for example, her concept of technological learning encompasses both the introduction of new machinery (lower cycle), and the development of internal design skills (upper cycle). The former strictly speaking only indicates an increase in production capacity, whereas the latter can be taken to indicate an increase in the capability for generating future technical change (in products).

A failure to make clear this subtle but important distinction may lead to misinterpretation of the value of technological capabilities to small firms. Suppose a study reveals evidence of increasing production capabilities in a firm, or group of firms, but also finds a failure to adapt or expand beyond a certain stage: an inability to compete in liberalised markets for example. This is what Aftab and Rahim [1989] found in their study of agricultural tubewell manufacturers in Pakistan. This small-scale sector grew very fast in the 1960s and early 1970s in response to a surge in demand from farmers. However, "after successful initial expansion from the level of household units and artisan shops into small-scale engineering enterprises, and diversification into a product demanding definite improvements in production methods, these firms confronted insuperable barriers to further growth and technical upgrading."[Aftab & Rahim 1989:492] In fact after 1974 when the market conditions changed, the sector declined as rapidly as it had grown. An uncritical observer might have concluded that "technology" was not an important factor in competitive success in this case. Aftab & Rahim however identify the barrier as being the limited capacity of the owner-entrepreneur to "absorb and attract through the market, skills and resources needed to adopt the necessary technical and managerial improvements." [*ibid.*] In other words, while these tubewell manufacturers had dramatically expanded their production capacities over several years, they had not managed to deepen their technological capabilities sufficiently to enable them to manage a sudden change in the market.

One of the problems for the small firm, as Romijn points out, is that it does not make sense to build up specialised capabilities across a broad range of tasks. Instead, it is more efficient to concentrate on "acquiring choice capability, simple repair and maintenance capability and product-design capability, and to rely on specialised suppliers and repairers of machinery and equipment to supply the major installation and breakdown services and substantial process adaptations." [Romijn 1996:55] Clearly there are some interesting parallels between this line of reasoning and the discussion about the benefits of in industrial clusters in chapter 3. For it suggests that the major limitation of being an individual small firm lies not necessarily in scale but in being isolated.

4.3 Technological Learning in Clusters

One of the important insights of the growing clusters literature, is that to understand industrial economic performance and behaviour it is often necessary to shift the frame of reference from the individual firm to the collective cluster or network of firms. However, as described in chapter 3, this kind of shift has not yet been achieved satisfactorily in relation to understanding technological learning and innovative behaviour.

What does it mean to talk about technological learning at the cluster-level? As discussed in section 3.3 and 3.4, well-developed clusters are not homogenous entities: they include small firms, larger firms, suppliers of specialised services, traders, supporting institutions. Does such a heterogeneous network of inter-linked agents have the potential to collectively accumulate technological capabilities? Can the interaction of different agents in a cluster in effect mimic the functions of a large innovative company (albeit without the formal hierarchy)? If so, this might imply that one aspect of the "collective efficiency" of clustering is indeed a truly dynamic potential for deepening the capability to generate and manage technical change.

To properly address this question is a major empirical project, which is beyond the limited scope of this Masters dissertation. My objective at this stage is therefore more modest. In chapter 5, I review five empirical studies taken from the literature on industrial clusters in the South for evidence of technological learning. I use the model of knowledge-acquisition described earlier, to critically analyse the authors' approach and their interpretation of the evidence which they collected. The five studies were chosen because they are all recent, accessible studies which focus on empirical research a doctoral level.

1. Khalid Nadvi's [1996] dissertation on small firm industrial districts in Pakistan
2. Meenu Tewari's [1996] dissertation on metal-working industry in Ludhiana, India
3. Roberta Rabellotti's [1995] dissertation on the footwear industry in Mexico
4. Pamela Cawthorne's [1993; 1995] studies of the cotton knitwear industry in Tiruppur, India
5. Henry Sandee's [1995] dissertation on roof-tile manufacturing in Java, Indonesia

4.4 Knowledge Acquisition at the Cluster-level

In chapter 2, I describe two key elements of the firm-level knowledge acquisition system as being "knowledge feedback" and "external inputs". The first represents a flow of knowledge generated as a result of internal activities within the firm – an endogenous process; the second represents a flow of knowledge generated by externally-orientated activities such as searching and absorbing information from outside the firm – an exogenous process. It was also emphasised that both flows of knowledge can occur on two distinct levels: as part of the learning cycle which results in increases in production capacity, and as part of the learning cycle which results in increases in technological capabilities (figure 2.5). I have already discussed shifting the concept of capabilities from the individual firm to the collective cluster-level. In order to transfer the whole model of knowledge acquisition to the cluster-level, it is also necessary to redefine what is meant by these endogenous and exogenous processes.

4.4.1 Technological Capabilities in Clusters

The nature of technological capabilities and production capacities of firms, and the activities associated with them, were described in section 2.3. In order to transfer these concepts to the cluster-level it is necessary to show that the cluster's capabilities as a whole are enhanced by the interaction of individual firms, drawing on specialised services, knowledge and skills within the cluster as and when required. In the case of production capacities the evidence for this is not difficult to spot. For example, the presence of specialist lathe-turners within a metal-working cluster could be taken as evidence that the production capacity of all the firms who use their services is enhanced. Even more so, if the relationship between manufacturers and specialist contractors have been nurtured in a climate of mutual trust and obligation created by a common social milieu.

In the case of technological capabilities, the evidence has to be sought a little more judiciously. One would need to be clear that the specialist services or other resources (such as institutional support) were contributing to a deepening of the cluster's capabilities in its entirety. It is not enough to show that clustering levels the playing field, enabling some firms to catch up technologically with their neighbours. It has to be shown that at least some of the firms are able to generate or manage technical changes that are entirely new to the cluster. For example, the presence of a technology institution that is effective at developing and disseminating new knowledge and skills within the cluster about how to manage product or process change, could be taken as evidence of technological capabilities in the cluster. Murray [1996] describes such an institution: CITER in Carpi, Italy.

4.4.2 Endogenous Knowledge Feedback within Clusters

As discussed earlier (in sections 2.4.3 & 4.2.1) knowledge feedback in an individual firm refers to internal activities of observation, experimentation and analysis which contribute to increasing capabilities. At the cluster level, endogenous feedback can occur as a result of interaction between firms, the flow of information and the movement of skilled labour. However, in order to claim this as a mechanism for learning at the cluster-level it is necessary to show that the cluster as a whole gains new knowledge. It is not enough to simply show that firms more easily acquire skills and knowledge that already exist within the cluster. Evidence is needed that at least some firms develop knowledge or skills that are entirely new to the cluster, by learning from their own and other firms' experiences.

As before, it is also necessary to distinguish between endogenous knowledge feedback that contributes to the increase in production capacity, and that which contributes to technological capabilities proper. Insights gained from observation of or even collaborative participation in other firms' production processes, via subcontracting relationships for example, may generate improvements in production capacity. However, feedback into the technological learning process requires insights gained from observing or participating in technical change processes of other firms. For example, the circulation of teams which specialise in helping firms to implement changes in machinery and process layout (see Tewari [1996]) may contribute to technological learning in the entire cluster.

4.4.3 Exogenous Knowledge Inputs into Clusters

Transferring the notion of firm-level external knowledge inputs to the level of clusters is not conceptually difficult. Knowledge inputs exogenous to the cluster may come from foreign buyers, technological institutions, universities, capital goods suppliers, trade journals etc. just as with individual firms. The only issue is where one draws the inevitably vague boundary of the cluster. A local technical institute created or financed out of the collaborative efforts of local firms and local government, might be considered to be a socially-embedded part of the cluster. However, a similar institution implanted from outside, by a development agency or national government, might be thought of as an external agency. In either case, an important function of the institution will be to filter and channel relevant information into the cluster.

As above, it is still necessary to distinguish between exogenous inputs that contribute to the increase in production capacity, and those which contribute to technological capabilities proper. As a result of interaction with external buyers for example, information may be obtained which enables firms in the cluster to improve their products by upgrading quality control methods in production. This is a case of improving production capacity. However, if the buyers were, for example, to teach the manufacturers in a cluster how to use market information to design new products, that would be improving technological capability.

Figure 4.1 Illustrative Framework of Technological Learning in Clusters

Learning Cycle:	**Technical Change**	**Technological Learning**
Capabilities Generated:	Production Capacities	Technological Capabilities
Endogenous Mechanism: Knowledge Feedback	**Endogenously generated knowledge from:** Collaboration in production User – producer interaction Mobility of skilled labour	**Endogenously generated knowledge from:** Collaboration in installing or adapting machines & tools Collaboration in trials & experimentation on shop-floor
Exogenous Mechanism: Knowledge Inputs	**Exogenously generated knowledge from:** External customers' feedback Technical advice services Trade information services	**Exogenously generated knowledge from:** Training in technology management e.g. quality control Development of local R&D institutions

Chapter 5
Analyses of Technological Learning in Cluster Case Studies

5.1 Introduction

This chapter critically reviews five case studies of industrial clusters from the analytical perspective of the knowledge acquisition system described in chapter 4. This approach will be called the "technological learning perspective" for brevity.

In each case that follows, the industrial cluster (or clusters) which was the subject of empirical research is briefly described. The methodology and analytical approach of the researcher is then examined, in particular to see how they addressed issues of technical change and innovation. Following this an attempt is made to extract, summarise and interpret the relevant evidence presented in their study along the analytical lines suggested by the technological learning perspective. Evidence of technological capabilities and mechanisms of knowledge-acquisition are identified. Finally, some conclusions are drawn about the various authors' approaches to dealing with technological issues in their studies.

5.2 Surgical Instrument Manufacture in Sialkot, Pakistan

Khalid Nadvi's [1996] D.Phil. thesis sets out to explore and compare the economic basis of competitiveness in a specialised metal-working industrial cluster in the province of Punjab, Pakistan. His focus is on the inter-relation between the economics of clustering, the influence of local social identities and international competitiveness.

5.2.1 Description of the Clusters

The city of Sialkot is home to a very successful cluster of firms who manufacture and export stainless-steel surgical instruments. Some 350 producer firms form the core of the cluster; but these are linked to more than 1500 ancillary service providers and sub-contractors ("stage firms"). More than seventy per cent of the producers are small – defined as having less than 20 employees[13]. The Sialkot cluster serves a niche market on a global scale. It supplies 50% of the world market for low-quality "clinical" instruments (mainly to the USA), and 10-15% for high-quality "surgical" instruments (mainly to the EU). Apart from two slack periods during the late 1970s and late 1980s, Sialkot's output and export earnings grew consistently at more than 10% p.a. during the past three decades [*ibid.*:Chapter 3].

Despite the high earnings and export success of Sialkot's instrument-making cluster, the industry's wages are low, employment standards and working conditions are extremely poor. Sialkot thus does not follow the "high road" (see 3.4.4), and "concerns are beginning to gather regarding the sustainability of the cluster's competitiveness"[*ibid.*:74]. The concerns came to a dramatic head in 1994 when the USA Food & Drug Administration embargoed Sialkot's instruments until manufacturers complied with Good Manufacturing Practice (GMP) standards[14]. The way that the cluster as a whole set about tackling the crisis this caused provides an interesting point of contact between Nadvi's thesis and the technological learning perspective.

5.2.2 Methodology and Analysis

Nadvi's methodology was both quantitative and qualitative. A questionnaire-based sample survey of 57 firms in the cluster, was supplemented by detailed case-studies of six firms. His interpretation of results is explicitly related to the concept of "collective efficiency" (section 3.4.1). Nadvi emphasises *passive* gains arising from the external economies of agglomeration, and *active* gains which only derive from conscious joint action between and among firms. In line with this perspective, Nadvi's enquiry focuses on how local social identities influence production behaviour and determine the effectiveness of joint action.

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[13] If sub-contractors are included the proportion of small units rises to over 90% [*ibid.*:61].

[14] GMP standards are a form of precursor to international quality assurance certifications such as ISO 9000. They specify quality control procedures, monitoring and tracing of products through all the production processes, and thus create particular problems for highly disintegrated production systems.

Collaboration is understood to touch on technological issues, but the investigation and the discussion of this aspect are conceptually limited. The key questions related to innovation in his main survey tool were:

a) What new technologies and equipment have you started using in the last five years?
b) Generally, where do technical innovations come from?
c) In the past 5 years have you changed the way production is organised and controlled?
d) What are your sources of information for process innovation?
e) Where do your ideas for new product designs come from? [*ibid.*:Appendix 2]

Such questions could constitute a useful starting point for an investigation of technological learning, however the results are not tabulated and only figure in passing in the discussion. Despite this rather cursory treatment of technological issues, Nadvi seems confident that there is a causal link between joint action and technical change. One of his main conclusions is that:

> "The benefits (of collaboration) are most obvious in the way in which quality standards rise and production organisation improves, especially in the more critical stages of production" [Nadvi 1996:131].

From the technological learning perspective, this has to be interpreted as implying a relationship between collaborative joint action by firms and the acquisition of technological capabilities. Is it possible to extract evidence from his study which supports this claim?

5.2.3 Evidence of Technological Capabilities

According to Nadvi's survey, 60% of the firms in Sialkot reported major improvements in their product quality standards in the previous five years.

> "Growth in output and capacity in recent years… has been matched by increasing use of new technologies, greater mechanisation and evidence of individual firms moving up the value-added chain, producing instruments which were formally beyond their technical capacity." [Nadvi 1996:132]

However the evidence is not presented clearly in the thesis and more significantly, there is no discussion of the capabilities that generate these technical changes. Nadvi's own view (expressed in a more recent paper) is that:

> "In an industry reliant on traditional knowledge and metalworking expertise, the adoption of new technologies has been relatively simple in that the logic of new equipment can be easily understood… Local producers dismantle equipment and rebuild it." [Nadvi 1997:6]

This simple identification of technology with machines should be familiar from the discussion in section 2.2.1. From this standpoint, the technological learning perspective is irrelevant: Sialkot's manufacturers already have all the technological capabilities they require to grow by buying or copying new technology. However, it is noteworthy that Sialkot's technological capabilities clearly were not adequate when change required the introduction of new production methods which Nadvi distinguishes as "soft technologies". The 1994 crisis over compliance with GMP standards meant introducing:

> "…ways of doing [that] often go against production practices that have developed locally over decades and that underlie the sector's traditional knowledge base. This is a more arduous process of change than adopting "hard" technologies." [*ibid.*]

In fact, in order to cope with the GMP crisis, Sialkot's manufacturers had to bring in external technological capabilities (see below).

5.2.4 Evidence of Endogenous Learning Feedback

Protagonists of "collective efficiency" often make the general claim that joint action promotes learning and technical improvements. Nadvi for example writes:

> "…purposeful information sharing and technical exchanges entailed in user-producer dialogue within vertical production chains found in a cluster can accelerate the process of learning and innovation…" [1996:17].

However Nadvi's own evidence about firms learning from each others' technical change experiences in Sialkot is deeply ambiguous. On the one hand, interviewees claim that they learn from each other's experiences via informal networks. For example: "friendly and co-operative" ties with sub-contractors facilitate improvements in quality control and production organisation; and "ideas about new technologies, processes and ways of doing permeate factory walls", or again: "…most producers willingly exchange production related ideas… with other local actors." [*ibid.*:120] On the other hand, information about technical change often seems to be specifically excluded from the realm of inter-firm collaboration. Nadvi notes that:

> "…there are no indications that ties with sub-contractors help [small firms] innovate. In fact, where [small firms] had moved up the value-added ladder, technical advances often led to the internalisation of key processes in order to… limit the leakage of valuable technical know-how." [*ibid.*:111/2]

No doubt, reality is paradoxical. Firms may strive to maintain secrecy over their proprietary knowledge, but to some extent they fail in this objective, so that an "industrial atmosphere" (section 3.4.1) does also permeate the cluster. However, from the technological learning perspective, Nadvi's analysis is vague because it conflates two distinct processes. One is the spread of existing technological knowledge in the cluster from one firm to another. On its own this is not indicative of innovation or dynamism, although it may contribute to static collective efficiency in the short-run. The other process is the generation of new insights and knowledge as a result of constructive feedback from the cluster's collective experience. This constructive feedback depends not just on the presence of linkages and information flow, but crucially on the type and quality of information being exchanged.

5.2.5 Evidence of Exogenous Learning Inputs

In contrast to the ambivalent evidence of the technological value of collaboration *within* the cluster, Nadvi is emphatic about the technological gains from linkages with buyers outside the cluster, particularly foreign producers. "Ties with foreign buyers are often considered as being closer and technically more collaborative than those producers have with other firms in Sialkot."[*ibid.*:116] There is evidence here not just of exogenous inputs to the *technical change process* (technical information, specifications, quality feedback), but of substantial help to firms in building their technological capabilities: "German producers sent out metallurgical engineers for periods of up to three months to train the Sialkot partner-firm on quality control and production engineering."[*ibid.*:117] All this, and a comparison between Sialkot and a neighbouring non-exporting cluster in Gujrat, leads Nadvi to conclude that technical development and innovation are mainly driven by external linkages. This conclusion contrasts significantly with the general implication that it is collective efficiency effects which accelerate the process of learning and innovation in clusters.

Apart from buyers, an important identified source of exogenous knowledge inputs into the cluster is the Metal Industries Development Centre (MIDC) providing a range of advisory and technical support services. It is widely used (88% of respondents in the previous year), and "…has played an important role in introducing and popularising the use of certain new technologies which raise productivity and improve the quality of surgical instruments…" [*ibid.*:132], for example: hammer forging and vacuum heat treatment.

However, the most dramatic evidence of the value of exogenous knowledge inputs is the contract won by US consultants (MQS) to advise and train 200 core firms to achieve GMP certification. Lobbying by the manufacturers trade association (SIMA) persuaded the regional government to finance this. The outcome of this intervention, in terms of the aggregate export performance recovery has been positive [Nadvi 1997:8].

5.2.6 Discussion

Nadvi's thesis provides a comprehensive and detailed study of inter-firm linkages and collaboration in a demonstrably successful industrial cluster. He shows how various forms of collective efficiency contribute to the static competitiveness of Sialkot's surgical instrument industry. It is also clear that Nadvi does regards innovation and technical change as relevant to competitiveness. For example, in comparing the demands of outward and inward-orientated markets, Nadvi reasons that the former is associated with a more acute need to "raise quality, innovate and be flexible", particularly in the activities that are strategically important to the cluster's overall competitive position [*ibid.*:181]. In theory at least, he connects these two issues: "Co-operation in production *has the potential* to raise efficiency, accelerate technical learning, and strengthen the cluster's ability to face exogenous shocks." [*ibid.*:105, my italics]. However his own evidence gives little support to this happening in practice. Rather, it is the external linkages and sources of technological knowledge which are important to the cluster.

From the technological learning perspective, the key question is whether clustering generates the dynamic capabilities necessary to sustain the competitiveness of an efficient production system. Nadvi's meticulous research focuses on the capacity to produce efficiently, but does not extend to a systematic investigation of the capabilities to innovate, adapt and change. For this reason, it is not possible to say whether Sialkot's industry is truly dynamic and innovative.

On the limited evidence available, it appears that the cluster in Sialkot is significantly less endowed with technological capabilities than might be expected for an industry operating in sophisticated international markets. So far it has offset this weakness by relying on its foreign buyers and at a moment of crisis, by collectively buying-in technological capabilities in the form of external consultants MQS. It will be interesting to see if this is a viable strategy in the long run. The poor performance of MIDC, the fact that the MQS intervention was needed, and the long delay in responding to the quality problems which provoked the FDA action in the first place, all suggest that cluster is actually quite weak at innovation and change. According to his latest information [1997], the input by MQS is improving the quality of production capacity right through the vertical production chain. However, it also seems to be diminishing the depth of inter-firm linkages and encouraging internalisation of production [Nadvi 1997:16]. These changes thus threaten to undermine the very social cohesion among producers which Nadvi is offering as the basis of collective efficiency.

5.3 Metal-working Industry in Ludhiana, India

Meenu Tewari's [1996] D.Phil. thesis sets out to investigate the basis for the achievements of small-firm industry in the Indian state of Punjab, and in particular Ludhiana district, whose "…firms are noted for their dynamism, and incorporation into national and export markets"[*ibid.*:26].

5.3.1 Description of the Cluster

Compared to other industrialised states in India, Punjab has very few large-scale firms, but this is offset by the proliferation of small firms[15] which "exercise significant command over national markets in the sectors in which [they] specialise" [*ibid.* 12]: machine-tools, auto-parts, bicycles, sewing machines, agricultural implements and woollen hosiery. Small firms have dominated industrial employment in the Punjab for decades. They continue to account for some 80% of jobs – a proportion that shows no sign of declining, although small firms' share of output is. Strikingly, small firms also maintained a 60 – 70 % share of Punjab's exports, which grew at a rate of 23% p.a. during the 1980s [*ibid.*:29].[16]

Ludhiana is the hub of Punjab's industrial base. With a population of 2.4 million (0.3% of India) Ludhiana produces 95% of India's woollen hosiery; 85% of its sewing machine parts; 60% of its bicycles and their parts, and accounts for over half of Punjab's exports. According to Tewari, small firms are the backbone of Ludhiana's regional economy, even in sectors which tend to be characterised by large and integrated firms in other parts of India. They have also proved remarkable vibrant and resilient in the face of several political and economic shocks to the region since Indian independence.

5.3.2 Methodology and Analysis

Tewari argues that the pattern of industrial growth in the Ludhiana cluster can be understood by referring to four elements:

1. The historical and present day role of the state government in shaping the region's industrial trajectory.
2. Demand-induced growth produced by "fortuitous" events in the industrial history of the region.
3. The particular social relationship encompassing skilled workers and owners of small firms.
4. The skilled regional labour market with its diverse but complementary paths of technical skill acquisition.

The main part of her thesis is taken up with an analysis of the social and economic history of the local industrial base. She describes the creation of an entrepreneurial class of urban artisans; and various economic stimuli to industry caused by irrigation programmes, defence procurement and import-substitution policies during nearly a century of development. In contemporary times, state investment in road, rail, water and power infrastructure have been an important advantage. However, Tewari concludes that the key reason for Ludhiana's growth and success is the innovative adaptability of her small firms, which "…learned to deal with downturns, conflicts and adversity,"[*ibid.*:263]. She relates to the fourth issue above, of technical skill acquisition, which is the focus of her empirical research.

The empirical research is based on interviews with 117 firms in Ludhiana. Unfortunately, the thesis suffers throughout from a lack of comparative data, and a failure to quantify the interview findings or put them in a methodological context. At times this reduces the evidence to a string of anecdotes. Nevertheless, the qualitative findings are revealing of both the workings of Ludhiana's industrial organisation, and the thinking that underlies the study.

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[15] Small firms in India are defined by their level of fixed capital investment. The limit in 1992 was 6 million Rps (~ $ 250,000). Fiscal and regulatory incentives encourage firms to remain within these limits, so that vertical integration of production is discouraged [Cawthorne 1993:47]. Owners expand instead by establishing new units. According to Tewari "most" owners had 3 or 4 units.

[16] According to the Economic Survey of Punjab, large firms' share of output grew rapidly to exceed that of small firms in the last two decades: 23% in 1970; 48% in 1980, and 64% in 1990 [Tewari 1996:23, footnote]. Industrial output in the Punjab grew at 7% p.a. between 1970 and 1990, but when this figure is disaggregated, the performance of small firms (<4% p.a.) is not so impressive. Output per small firm unit in Punjab is actually slightly lower than the national average in India [*ibid.*:18, Table 1.3]. The contrast between these figures and the export / employment figures is not discussed by Tewari, but suggests a dichotomy between a few strong small firm exporters and a very large number of others whose position must be increasingly precarious.

5.3.3 Evidence of Technological Capabilities

There are frequent references in Tewari's interviews to the diverse and differentiated skills of Ludhiana's workers, including their ability to "understand, copy and manipulate machinery". If this evidence is taken at face-value, not only does it appear that metal-working skills and productive capacities are well-developed in the district, but so too are the technological capabilities to modify and adapt machinery and processes. The kind of adaptations undertaken mainly involve cost-cutting process improvements and low-cost replication of imported machinery. This "allows small firms to upgrade their production processes at a pace and cost that most small firms not located in an environment of such industrial depth can hardly afford." [*ibid.*:174]

Tewari does provide one small but useful comparative study, of differences between Ludhiana and Howrah, Calcutta. Howrah is a metal-working industrial area also based on small-firms but which declined steadily during the 1950s-60s, just as Ludhiana was growing [*ibid.*:198]. She blames Howrah's decline on the comparative inability of its firms and skilled workers to reconfigure technical skills and develop new markets when its traditional source of demand – the railways industry in Bengal – diminished. Ludhiana's firms, on the other hand, are "constantly seeking modifications, different ways of performing specialised operations… new, cheaper or customised ways of doing things…"[*ibid.*:200]. From the technological learning perspective this sounds like a good description of technological capabilities in action.

The skills, knowledge and resources underlying these capabilities are vested in the experienced technician-mechanic *(mistry)* and the small-firm owner (who has usually worked as a *mistry* himself, before setting up his own workshop). In addition, Tewari emphasises certain roving groups – *reconditioning teams* – comprising highly skilled and experienced workers who sell their services from place to place [*ibid.*:176]. These highly-paid teams are expert in reconditioning machines, but also at assisting firms to select, adapt and modify equipment. They form the chief link between small firms and the "technology market" and are "important conduits for the spread of technological information among the region's firms of all sizes"[*ibid.*]. As a result, lower capital start-up costs also form an important advantage for firms in Ludhiana.

There does seem to be qualitative evidence therefore, for some level of technological capabilities in the areas of investment activities, process & production organisation and supply of capital goods (see Section 2.3.1, Figure 2.1). Less attention is paid to capabilities in the other type of activities described in that section. From the technological learning perspective the test of dynamism is whether Ludhiana as a cluster, has the ability to sustain the competitiveness of its production system over the long-run in an increasingly open environment. As discussed in section 4.4, the best indication of this to look for, is the presence of effective knowledge-acquisition mechanisms.

5.3.4 Evidence of Endogenous Learning Feedback

Great emphasis is placed by Tewari on the vocational training / skill acquisition systems (formal & informal) which account for the rapid and effective diffusion of skills and knowledge through the cluster's workforce. For socio-historical reasons, practical training is highly valued in Punjab and the state-run vocational industrial training institutes (ITI's) have a much higher reputation than elsewhere in India. The staff frequently themselves own or are involved with producer firms. They also moonlight as technical consultants and let graduate owners use the institution's facilities after-hours.

For many owners, the ITI's do not merely provide vocational skills, but also play an important role in helping them form professional social networks. Classmates form a close personal cohort which later maintains an important function as a cheap and trustworthy source of technical information and advice. From a technological learning perspective the vocational training system in Ludhiana therefore qualifies as a feedback mechanism in *both* cycles of the knowledge-acquisition system.

The particular social context is a factor too. According to Tewari's interviewees, there is little social divide between skilled workers and small-firm owners in Ludhiana. Among other things, this facilitates feedback between producers and users. For example, machine-makers get information about their customer's needs and views from the operators and repair mechanics who both use and service their products. Tewari sets great store by this network of feedback givers - firms, contractors, labour teams, distributors and intermediate goods producers - that provide advice and customised help to each other [*ibid.*:270]. The technical orientation of owners also drives firms to constantly seek modifications and improvements to machines and processes. Many of the owners clearly enjoy tinkering in their tool shops [*ibid.*:247]. Tewari implies that cumulatively this is the basis for systematic learning in the region.

But does this mean that firms which successfully achieve a significant upgrading of their productive capacity, volunteer their new knowledge to their potential rivals? Not directly of course: "…there was a lot of hiding of proprietary technology or modifications from competitors…" [*ibid.*:230]. However, according to Tewari the dense inter-linking above facilitates the flow of both explicit and tacit knowledge so that individual firms' technical change experiences are rapidly widely shared. This analysis is very similar to that put forward by Nadvi [1996] above (section 5.2.4), and shares the same weakness. The phenomenon of skill and knowledge diffusion among the cluster's firms is conflated with the possibility that the cluster as a whole deepens its technological knowledge base as a result of collaboration.

In any case, like Nadvi, Tewari realises that it is not possible for the cluster to sustain innovation only on the basis of endogenous incremental change. At some point external knowledge is required ("to turn outward" as Tewari puts it).

5.3.5 Evidence of Exogenous Learning Inputs

In contrast to the emphasis on endogenous mechanisms, external resources come in for only incidental treatment in Tewari's study. Passing references are made to a "government-run heat-treatment & finishing centre", an R&D institute called the Central Tool Room (run with German funding), a Bicycle R&D Centre (run by UNDP), a Small Industries Services Institute and the Punjab Agricultural University. Unfortunately, the role of these institutions and what services they actually provide are not explored at all.

A more emphasised source of exogenous knowledge is via direct contacts between the owners and outside customers and distributors. These relationships apparently provide ample feedback on the quality requirements and technical standards of products [*ibid.*:234-8]. New techniques or processes are also glimpsed on visits to factories outside the region, and imitated on return.

5.3.6 Discussion

Tewari's study does suggest that the particular structure of production in Ludhiana (based on small firm clustering) has evolved mechanisms for technological learning. There is evidence of at least a moderate level of technological capabilities among at least some actors in the region. Also, mechanisms are shown to exist for the technical changes these actors generate to become rapidly diffused through the cluster. Clustering thus helps explain how industry in Ludhiana efficiently replicates *existing* skills, knowledge and capabilities very widely.

However, the question of how new knowledge and skills for managing technical change are acquired, of how the cluster's technological capabilities are extended and deepened, is not properly explored.

5.4 Footwear Manufacturing in Leon & Guadalajara, Mexico

Roberta Rabellotti's (1995b) D.Phil. thesis sets out to analyse the economic effects arising or not arising from clustering, and in particular from the linkages existing among economic agents within clusters. For my purposes the relevant empirical subjects of her investigation are two clusters of footwear firms in Mexico. Unlike the other cluster studies reviewed in this chapter, these clusters are not presented as dynamic or innovative. Instead, a comparison is sought between the reality of these clusters and the idealised industrial district model (see section 3.3).

5.4.1 Description of the Clusters

The leather and footwear industry in Mexico employs approximately 140,000 people and accounts for 2 – 3% of GDP[17]. More than half of the entire sector is concentrated in the vicinity of Leon, and nearly a quarter in Guadalajara (22%). Unlike other important sectors in Mexico, the leather and footwear industry is overwhelmingly locally owned.

Leon is dominated by the footwear industry: it generates 70% of the city's GDP and 40% of its employment. Footwear manufacturers employ 70,000 people, mostly in small or medium sized firms[18].

Guadalajara is home to several industries traditionally characterised by small firm organisation.

Footwear manufacturing employs 25,000. However, the statistical picture in Guadalajara is skewed by

[17] Official statistics are unreliable and probably underestimate informal unregistered production.

[18] 49% of employment (& 42% of value-added) is with small firms with less than 100 employees. A further 26% (33%) is with medium-sized firms with less than 250 employees [Rabellotti 1995b:129].

the presence of one giant vertically integrated firm employing 10,000 people. This firm interacts little with the rest of the cluster and is unfortunately not part of Rabellotti's study.

For many years, the footwear market in Mexico was completely protected by import-quotas and cushioned by excess domestic demand. In 1988, this ISI policy was reversed overnight, with dramatic consequences: imports surged ten-fold, many firms closed. By 1991 import tariffs re-imposed at 35% had stemmed the decline. International competition continues to grow however, and Mexican firms must adapt if they are to survive and grow [*ibid.*:119]. Traditionally, the Mexican clusters lacked the kind of intense inter-firm linkages and collaboration that characterise the Italian districts. In the wake of trade liberalisation however, the Italian industrial district model is one which the Mexican entrepreneurs are trying to emulate [*ibid.*:120].

5.4.2 Methodology and Analysis

Rabellotti's methodology was both quantitative and qualitative. A structured questionnaire-based sample survey of 101 firms in the four clusters, was supplemented by network case studies of nine firms, which examined inter-firm linkages specifically. A key objective was to compare the results with the stylised model of the Industrial District, described in section 3.3. Rabellotti stands out among researchers of "clustering effects" for emphasising a distinction between static effects – that impact on the level of productivity of the system; and dynamic effects – that impact on the system's capability to grow and innovate [*ibid.*:166].

For the most part, her investigation focuses on collaborative linkages between firms, their suppliers & buyers. Some of the effects which co-operation generate can be defined as "dynamic" in her view because "they represent an important contribution to the system's capability of innovation and growth"[*ibid.*:169] An example of a dynamic linkage in Rabellotti's terms, would be a consortia of exporting firms that aimed at discovering new markets, as opposed to merely collaborating to sell in existing markets. Some dynamic effects detected in the Mexican clusters included demonstration effects on attitude and motivation (inspired by proximity of rivals and competitors); and collective learning induced by inter-firm mobility of skilled labour [*ibid.*:170]. However in general Rabellotti found dynamic effects to be rare in the Mexican clusters because of a general lack of horizontal disintegration, process specialisation or vertical collaboration.

Strangely, given her emphasis on dynamic effects, the technological dimension features even less significantly in Rabellotti's survey tool than in does in Nadvi's [1996] above. The most incisive questions asked in the questionnaire were:

a) Over the past 5 years, has the standard of your equipment improved?

b) Over the past 5 years, has the quality of your products improved?

c) Generally, where do technical innovations come from?

d) What are your sources of information for process innovation

[Rabellotti 1995:249, Appendix 1]

Furthermore, the findings are tabulated very summarily [*ibid.*:98/99, Tables 6.9 – 6.11] and warrant only about 600 words of discussion. This discussion confines itself mainly to recounting how little innovation takes place; but adds the suggestion that

> "the lack of a domestic industry specialised in the production of machinery for the shoe sector is probably the main drawback to increasing technological co-operation and introducing innovations." [ibid.:144]

This sounds rather like another version of the "technology equals machines" paradigm again (see section 2.2.1). The neglect of technological issues which this perspective generates is particularly striking in this case, given the technological challenges which the footwear industry faces (see below). Rabellotti does not appear to consider the possibility that the innovation constraints might lie with the footwear manufacturers' limited capability to manage technical change, and that the lack of a domestic capital goods industry supplying the sector might be a symptom of this, rather than a cause.

5.4.3 Evidence of Technological Capabilities

The small-firm footwear industry in Mexico uses labour-intensive, artisanal techniques, and has had little investment or innovation over the years. Levels of technological co-operation and innovation are very low. Rabellotti found that in the previous five years only 20% of firms had worked with "technology suppliers" to develop some process innovations, and only 12% had adapted machines in some way

internally. The picture was even more static among small firms: 80% had made no or very few technical changes.
Rabellotti's explanation for this technological stagnancy again focuses on the machines, rather than the people. Until recently automation in the global footwear industry has been confined to the large mass-production firms. Of the Mexican firms, only 10% are described as automated and 44% partially automated. The main application of machines is for leather stitching and embroidery, rather than core processes such as cutting and lasting. However there are far-reaching developments underway, particularly in CAD & CIM systems[19]. These have major implications for competition by smaller firms; creating opportunities for improving quality, reducing viable batch size and shortening delivery schedules.
Nevertheless, CAD adoption is very slow in both the Italian and Mexican footwear clusters, a fact which Rabellotti does relate in part to lack of awareness on the part of entrepreneurs and the difficulty of re-training traditionally-skilled shoe-modelists [*ibid.*:75]. From the technological learning perspective, it is worthwhile examining whether the obvious lack of technological dynamism in these particular clusters is matched by an absence of knowledge-acquisition mechanisms.

5.4.4 Evidence of Endogenous Learning Feedback

Rabellotti indicates some circulation of information takes place among groups of firms linked by family or friendship ties. However, in general information feedback is limited and secrecy is paramount. For example: " shoe entrepreneurs interviewed in the network case studies said that they do not usually allow other entrepreneurs (even) to visit their plants" [*ibid.*:143]. In the questionnaire survey only 28% of entrepreneurs cited other local shoe firms as sources of information for innovation.
The only other significant form of endogenous knowledge feedback implied by her evidence is the 20% of firms who described co-operating with suppliers of technology to develop a process innovation [*ibid.*:141]. Cluster studies often suggest that collective learning takes place as a result of the high mobility of skilled labour between firms. Rabellotti's survey instrument found no significant evidence of this happening in the Mexican cases[20].

5.4.5 Evidence of Exogenous Learning Inputs

Both Leon and Guadalajara have institutions for research and technological assistance (CIATEG in Leon; ITC in Guadalajara). Among other things these are described as providing training and seminars aimed at introducing quality control techniques, production planning systems and other organisational and managerial innovations [*ibid.*:157/8]. Strangely however, neither are cited as sources of technical innovations in the questionnaire survey[21]. It is not clear if this is because the institutions are not actually effective, or because Rabellotti is making some unspecified distinction between different forms of innovation.
The source of innovation that is most cited by firms is an exogenous one. 58% of firms cite specialised trade fairs and exhibitions as a source of information for process innovation [*ibid.*:143]. However, unlike the Asian clusters that Nadvi [1996] and Tewari [1996] studied, Rabellotti does not find linkages with external buyers played any significant technological role in the Mexican cases. This is explained in terms of the inward-orientated nature of the footwear industry prior to recent trade liberalisation. It is also suggestive that clustering *per se* is not the key issue.

5.4.6 Discussion

In comparing the industrial district model (see section 3.3) to the reality of clusters in Mexico, Rabellotti found "considerable differences concerning the intensity and quality of collective effects between the real situations studied and the ideal-type district." One conclusion she draws concerns the need to move from

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[19] Developments in Computer Aided Design (CAD) greatly reduce the skill and labour involved in translating shoe designs into the numerous graded sizes of lasts, stencils and components required to make a full range of shoe sizes. Computer Integrated Manufacturing (CIM) involves the direct transfer of CAD data into cutting and stitching machines on the production floor.

[20] One possible suggested response to "sources of information" in survey question 9.3, was "workers previously employed in other firms". The number of checks to this response was insufficient to warrant including them in the results in Table 6.9, p 142.

[21] "Technology institutions" was not offered as a suggested response to question 9.3, although it may have been included as a response under "Other".

a static viewpoint to a dynamic approach that explains changes over time [*ibid.*:228]. This point is emphasised particularly in relation to the changes occurring as a result of the new competition from the international market.

From the technological learning perspective, a major element of any such dynamic approach would be concerned with the cluster's capability to manage the opportunities and threats of technical change. Unfortunately this particular issue is neglected in both the empirical research and Rabellotti's discussion of her findings.

5.5 Garment Industry in Tiruppur, India

Pamela Cawthorne's [1993; 1995] study[22] set out to describe and explain the pattern of expansion and success in the cotton knitwear industry of Tiruppur, India. She relates the growth of firms of all sizes in Tiruppur to advantages derived from clustering and dense inter-firm networks. However she also notes that the Tiruppur cluster has kept closely to the "low road" (section 3.4.4) with low wages and poor working conditions unchanged by expansion.

5.5.1 Description of the Clusters

Tiruppur lies in the middle of Tamil Nadu's cotton belt in southern India; and is home to thousands of small-scale firms and larger factories involved in ginning, spinning, weaving, dyeing and assembling cotton garments. Historically, knitting is a recent industrial development in Tiruppur: the first knitting machine was brought in 1940. However, in the past two decades the cotton knitwear industry has exploded, with both employment and exports soaring in response to a massive increase in demand for this type of garment. Tiruppur accounts for between 26 – 60% of India's cotton knitwear exports [1995:55, endnote 2]. Employment in small production units[23] rose 600% between 1975 – 1985. Cawthorne notes that the knitwear cluster is made up of a good number of large and medium-sized firms as well as the myriad small-scale units. "The cluster has become highly differentiated and contains firms of quite different capabilities producing for quite distinct markets"[*ibid.*:50]. The larger firms account for a "considerable proportion of total turnover in the industry"[*ibid.*:45] and while a few of these started small, many began with relatively large amounts of capital investment. The rapid expansion of the cluster has accentuated these differences, with the size of firm being roughly correlated with the distance to its markets. Small firms make simple garments of various qualities for the local markets. Medium-sized firms sell in other Indian states or sub-contract for the largest firms, which increasingly make high quality garments for export.

5.5.2 Methodology and Analysis

Cawthorne researched detailed case-histories of 25 sample firms in the cluster. Like the other cluster studies described above, she focused on the way in which firms used "job-work" (a form of sub-contracting) to control crucial stages of the production process. Unlike the three studies above, she also took a particular interest in "labour process" within the firms.

Analysis of labour process is essentially Marxian, and involves asking questions about "the way in which workers (sellers of labour power) are organised for production, and the things that capitalists (buyers of labour and owners of equipment) do to achieve this organisation." [1993:60] Tiruppur's knitwear industry turns out to revolve around labour-intensive piece-rate working practices, in which productivity increases have been achieved by "sweating" labour. "Labour is cheap for employers in the sense that wages are both a low percentage of total costs of production and a low percentage of the value of output" [1995:54]. The disintegration of production among small units, job-work subcontracting etc. enables employers to avoid the problems "inherent in large workforces"[1993:58]

However, Cawthorne does not relate the recent rapid expansion of the cluster primarily to either the flexibility and low-cost of labour, nor the disintegrated, horizontally linked structures of production. "Tiruppur was an industrial cluster for a long time before it was a dynamic, expansionary, industrial cluster and the change was almost purely a function of export success."[1995:54] Thus little support is

[22] The papers (a journal article and a book chapter) used in this section are both based on research for Cawthorne's earlier Ph.D. dissertation [Milton Keynes, Open University, 1990], which I did not have access to.

[23] As described in the Ludhiana case above, the particular regulatory environment in India encourages firms to expand by establishing separate units of production. Often many small separate units are owned by a single firm, which distorts the statistical picture [Cawthorne 1993:54]

provided here for the idea that "collective efficiency" underlies the success of industrial clusters. Rather, it is the merchants and brokers specialising in export goods, and working out of wealthy urban centres such as Bombay who stimulated expansion [*ibid.*:50].

Meanwhile, technological issues are very explicitly not a factor in Tiruppur's success, in Cawthorne's view. However it is not clear on what evidence she bases this view, since her treatment of technical change is cursory, as shall be seen below.

5.5.3 Evidence of Technological Capabilities

According to Cawthorne, "there is relatively little technological change or improvement in the industry as a whole" in Tiruppur. Knitting machines "have remained basically unchanged for forty years"[*ibid.*:49]. Admittedly "some improvements were made in the 1970s to upgrade circular knitting machines and produce better quality fabric, using better quality yarn. SITRA (South Indian Textile Research Association) in conjunction with UNDP assisted with these projects" [*ibid.*:49, endnote] However, she also notes that SITRA's efforts to improve management techniques and expose firms to more sophisticated technologies tends to ignore the fact that "[m]arkets provide the impetus to upgrade production" [*ibid.*:51].

Cawthorne may well be right in this (see Nadvi [1996] above for example, on the technological importance of market linkages), but it is left unclear whether she found that production was being upgraded in Tiruppur or not. Furthermore, from the technological learning perspective, Cawthorne identifies the stimuli to technical change, but ignores any discussion of the capabilities or learning mechanisms that enable changes to occur.

5.5.4 Evidence of Endogenous and Exogenous Learning Mechanisms

The only opinion Cawthorne offers regarding internal collaboration within the Tiruppur knitwear cluster is that due to the "relatively little technological change or improvement in the industry as a whole, there is little advantage in pooling technological expertise" [1995:49].

At another point, describing products for the Indian market, she finds that:

> "…the quality of such garments has improved beyond recognition over a 10-year period, and that trend has continued. Both the impetus and the means for this trend arose out of contacts with international agents…" [ibid.:46].

This sentence is one of the few references in the whole paper to the fact that technological improvements might require a means (i.e. knowledge and capabilities) as well as an impetus.

Meanwhile the apparent contradiction between "little technological change" on the one hand, and product improvements "beyond recognition", on the other is surely symptomatic once again of a viewpoint that sees technology only as machines (section 2.2.1).

5.5.5 The SITRA Institution

Cawthorne has very little time for SITRA, as can be seen from the quote above, which is almost the only reference to this institution. It is interesting to compare Cawthorne's study therefore with Ganguly [1996] who examined SITRA's technological role in Tiruppur, largely on the basis of the institution's own documentation.

Ganguly believes that there is a fairly close association between the export performance of Tiruppur and the technological support received from SITRA. Certainly the institution appears to be valued by some firms: in 1995, it earned a much greater share of its income from consultancy services (over 50%) than any other industrial research organisation in India [Ganguly 1996:65]. Membership also increased 77% between 1980 and 1991.

According to its own annual reports, SITRA has been instrumental in introducing various product developments; in adapting machines and instruments for local use, and in providing training programmes to Tiruppur's textile firms. In other words, it acts as bridge between the cluster and external sources of technology. Many to these developments it introduced, have led to extensive changes in local mills and factories, particularly of the larger exporting firms. A significant focus of SITRA's work has been on process control and improvements to fabric and yarn quality. These are vital requirements for sustaining exports in the face of international competition and meeting the impending need to comply with international production standards, such as ISO 9000.

5.5.6 Discussion

As Cawthorne points out, Tiruppur's knitwear industry is an example of a relatively successful Third World industrial cluster. In the past 10-15 years it has experienced what she calls "dynamic expansion"[1995:54]. If dynamic expansion is different from just plain ordinary expansion, the distinction is not explained. However, it does not relate to technological change or improvement in the industry, since in her view these have not occurred [*ibid.*:49].

Although Tiruppur manifests many of the qualities associated with the archetypal industrial cluster (see section 3.4.1), these are a necessary but not sufficient explanation of its success: "it is not clustering *per se* which makes for industrial success, but clustering in a propitious macroeconomic context."[*ibid.*:54] The important propitious context in this case as far as Cawthorne is concerned, was a boom in demand for knitted cotton garments at the same time that Tiruppur "successfully entered export markets". This is a helpful but hardly conclusive explanation. One has to ask how Tiruppur entered these markets, and why the export merchants came, and kept coming back over the years, to Tiruppur in preference to many other textile centres in India, or elsewhere? Might it not have been something to do with technical changes which brought steady improvements in the quality of products?

While it might be naïve to take SITRA's self-assessment of its own role simply at face value; it must be foolish to ignore it entirely. The failure to make any systematic analysis of SITRA's role demonstrates the larger failure to grasp the importance of technical change and its origins. Thus Cawthorne misses a significant component of Tiruppur's success by dismissing the impact of technological changes (whether induced by SITRA or otherwise) in the cluster.

5.6 Roof Tile Manufacture in Central Java, Indonesia

Henry Sandee's [1995] doctoral thesis sets out to explore processes of technical change in mini-clusters of clay roof-tile manufacturers in Java, Indonesia. The research is different from the previous four case studies above in two important ways. First, he is interested very explicitly in technical change and particular the way in which an "innovation" spreads. Second, the study is longitudinal, comparing changes over a six year period.

5.6.1 Description of the Clusters

There are some 350 villages spread throughout Central Java which specialise in making clay roof tiles. Tile-makers naturally tend to cluster around their principal resource – sites of clay extraction [Sandee 1995:56]. Most production is organised as a seasonal household activity using very traditional *open-fire* technology, but these techniques can also be upgraded by using a wood-fired kiln to produce stronger tiles. This requires more costly inputs, including hired labour, but the resulting tiles can be sold to urban consumers. On the basis of this *kiln* technology, some villages have built up a year-round industry generating substantial employment and income. Karanggeneng is an example.

In 1987, 123 (11%) of Karanggeneng households were engaged in tile-making, using the kiln technology [*ibid.*:100]. The cluster was known for the quality of its product, and benefited from nearby urban markets and good roads which attracted traders from around the district. Since 1987, producers in Karanggeneng began adopting a different technique: the handpress[24]. Pressed tiles are lighter, stronger and more consistent in shape. They sell for nearly twice the price of traditional kiln-fired tiles and have a growing market with urban middle class consumers.

With the kiln technology, production usually involved 5 – 10 workers and there were limited economic returns to expanding the scale of production [*ibid.*:55]. Producers who secured large orders therefore contracted out surplus work, and the oldest, most successful producers established networks of other producers who work for them. However, in other respects, inter-firm linkages were underdeveloped [*ibid.*:62].

With the handpress technology however a new factor came into play. The major technical change lay not with the handpress itself but with a new process for preparing the clay, requiring a diesel-powered mixer. This "technological indivisibility" costs more than most individual producers can afford, and optimally serves up to seven handpresses at a time. Therefore, "[a]doption of the press technology required new forms of collaboration among tile producers, since joint action is a prerequisite for tackling the new technology"[*ibid.*:110]. Adopting the novel technology required not merely a learning of new technical skills, but a change in the social organisation of production. How this happened is the focus of Sandee's dissertation.

5.6.2 Methodology and Analysis

By 1993, half the producers in Karanggeneng had adopted the handpress technology. Sandee therefore had a laboratory for exploring the causes of, and constraints on, technical change in a small cluster. In 1987 he interviewed a representative "panel" of 34 producers in the cluster. This was followed up in 1990 by a survey of producers who had adopted the handpress up to that point, and in 1993 a census of all producers was taken. In addition he conducted comparative studies in three other tile clusters: one which uses traditional open-fire technology and is in decline; two others which had successfully adopted the handpress technology before 1990.

Sandee views technological change in terms of technological, financial and market gaps. Adoption of the handpress innovation happened in Karanggeneng when these gaps were closed through collaboration by "pioneers" - the individual entrepreneurs who first introduced the handpress and mixer in the cluster and encouraged others, the "adopters", to use the new techniques. In this way, Sandee treats innovation as an object: a "new technology package"[*ibid.*:133] that was brought to the cluster by the pioneers, and which caused the traditional networks of production to be upgraded. Thus he embraces precisely that division between innovation and diffusion that Bell & Pavitt [1993] reject (see section 2.2.2). The handpress technology is treated as a given set of machines and operating procedures that are simply incorporated unchanged into production.

[24] The handpress technology is not a new innovation in Indonesia: it has been used in other parts of the country since at least the late 1970s. However it was novel to the district to which Karanggeneng belongs.

By analysing the characteristics of "adopters" and non-adopters, Sandee is able to demonstrate the importance of inter-firm linkages and social networks in determining which producers adopted the new technology. In Karanggeneng, women producers' exclusion from networks of information and sources of credit was particularly important in explaining their total absence from the "adopters" group. The advantages of being part of a cluster in this case are amply illustrated.

From the technological learning perspective however, Sandee's dissertation is sparse. There is no discussion of whether the handpress technology was modified or adapted in any way by the producers, either initially or during use. Nor does the way in which producers individually managed the technical change attract any attention. They simply learned by doing. The only hint of a more dynamic view comes in a statement that technical assistance is needed "not… when press equipment is first installed, but… when the producers want to standardize and improve the quality of output."[1995:118] In other words, it seems successful adoption required at least some technological effort (see section 2.2.3).

5.6.3 Evidence of Technological Capabilities

In Sandee's terms, technological capabilities are the knowledge, skills and other resources needed to close technological gaps. These concern only the pioneers, since the adopters' role is seen as technologically passive. He finds that the pioneers are usually mobile young men with practical experience, access to information and linked to specific networks involving wealthy families firmly rooted in the cluster's economy.

For example, the man who pioneered handpress technology in Karanggeneng was able to organise producers to collectively visit other districts and persuade them to consider the new technology. He established a new system of production organisation to accommodate the changes required by clay mixers. He negotiated the purchase of his own machinery, installed it and later became a supplier of handpresses to his own growing network of adopters. He also managed the marketing of the new tiles for several years while the local traders were disinterested. From the technological learning perspective this individual brought a whole range of capabilities to the cluster.

What is not so clear from the study however is whether after six years of "innovation adoption", the cluster as a whole has deepened its collective technological capabilities, and increased its ability to create or manage further technical change. What evidence is there for technological learning mechanisms?

5.6.4 Evidence of Endogenous Learning Feedback

Sandee describes in some detail the way in which knowledge and skills required to adopt the handpress technology spread through Karanggeneng. He explains how the impetus for this came from economic interests of the pioneers themselves, and how clustering facilitated the process.

From the technological learning perspective however, there is no evidence in Sandee's study of constructive feedback leading to technological learning in the cluster. Aside from the actual installation of the machines, there is almost no discussion of what producers collectively learned during and from the process of change. The possibility that the producers may upgrade not only their productive capacities, but also their own resources for future technical change is therefore not addressed.

5.6.5 Evidence of Exogenous Learning Inputs

In Karanggeneng the process of handpress adoption was driven by pioneer producers.

In the other two handpress-using clusters which Sandee studied, the impetus came from buyers and also from the suppliers of the handpress and mixer equipment. External factors were very important: for example tile merchants were instrumental in purchasing mixers and then leasing them to the producers. Sandee interprets this as an example of buyers closing the technological gap [*ibid.*:142], but this is just equating technology with machines again. The interesting technological question is how the clusters acquired the skills and knowledge to adopt. According to Sandee, this happens through the external experience of the pioneers: usually young men who have travelled and worked elsewhere. In the early stages in Karanggeneng, institutional support also had a role: the local government helped finance study tours to other handpress-using clusters [*ibid.*:110].

Subsequently, there is no discussion of ongoing technological inputs to a learning process in the clusters. Linkages with external buyers obviously exist, but whether these generate any technological information is not described.

5.6.6 Discussion

In terms of exploring technological learning in clusters, Sandee's thesis has a head-start on all the other studies reviewed here, in that he was able to look at a cluster over six years, and he focussed explicitly on technical change as one of the dimensions of clusters' development. As a result he is able to demonstrate that clustering facilitates technological upgrading in a situation where due to technological indivisibilities successful adoption requires collaborative joint action by several actors [*ibid.*:179].

However, Sandee's approach offers little insight into whether the process of "innovation adoption" he describes leads to the tile clusters deepening their technological resources. He is concerned only with the closing of one particular technological gap, rather than the deeper question of how producers accumulate the capabilities they need to close future and larger gaps, so that in the long run they sustain their competitive position. Clustering may assist small firms to do this, but the evidence is not provided in this study.

5.7 Summary and Conclusions

Four of the five studies reviewed in this chapter concern industrial clusters which the authors characterise in one way or another as "dynamic". However the appellation is given without any precise sense of its meaning, other than as a synonym for "growing bigger" perhaps. Only Rabellotti it seems, recognises and highlights the important difference between increasing "productivity of the system" and increasing "the system's capability to grow and innovate" [Rabellotti 1995].

On close examination one finds that almost no attempt is made in any of these studies to match the hypothetically dynamic quality of the clusters with a thorough analysis of technological change. This is demonstrated particularly well by the limited space given in Nadvi's and Rabellotti's otherwise detailed studies to technological issues. Only Sandee's thesis explicitly focuses in any depth on processes of technical change, but even this study fails to explore the clusters' capabilities for generating change or their technological learning mechanisms. No study can focus on all the relevant issues of course. Rightly or wrongly, Rabellotti and Cawthorne seem to regard technology as a relatively minor factor, and thus avoid it. I have suggested, by referring to other sources, that this must be a significant oversight. However, in the case-study by Nadvi, the failure to adopt a more dynamic approach to technological change seems to be at odds with specific references to the importance of innovation and adaptation for sustaining competitiveness.

These weaknesses in the studies may be related to the authors' conception of technology itself. In four of the five studies (the exception in Tewari's) technical change is dealt with as a process that happens fairly spontaneously and effortlessly, as soon as the impetus (from foreign buyers for example) and opportunity are present. In Sandee's terms, there are merely various gaps which have to be closed, and then the process just happens. Technology is treated simply as machines or packages that get introduced when the conditions are right. There is little sense that clusters might need to build up particular change-generating skills or resources over time in order to enable technical change to happen.

The possibility of learning processes occurring endogenously within clusters is only really raised by Nadvi and Tewari. However, common to all the studies is a confusion between the process of knowledge spreading or being replicated across a cluster, and the quite distinct dynamic process in which interaction within the cluster leads to new knowledge being generated. This confusion may help explain the ambiguity of evidence about the level and quality of knowledge flow within the clusters. Given that firms try to appropriate their most valuable information, one has to wonder how technologically important are the information flows which go on informally and socially within clusters? Certainly, they may contribute to knowledge replication, but whether they contribute to dynamic, innovative capabilities and new knowledge generation is not at all clear.

All of the authors, with the possible exception of Tewari, regard the clusters' external relationships with traders and buyers as crucial to success. Cawthorne sees them as paramount. These external linkages are seen as providing the *impetus* for technical change to occur. In fact, external links were the only identified sources of almost all the important technical changes described. However, it is only Nadvi who investigates how these external relationships actually assist an industrial cluster to develop the *means* to effect technical change. The other authors seem to believe that, assuming financial means and marketing opportunities, the impetus to technical changes which external contacts bring is sufficient of itself to generate innovative and dynamic performance. Consequently, the important presence of other institutions channelling external technological knowledge and skills into the clusters is noted in three of the studies (Tewari, Rabellotti and Cawthorne) but their role is not seriously addressed.

In summary, the five studies of clusters reviewed in this chapter offer only very occasional glimmers of support for the theory that clustering is an inherently dynamic form of industrial organisation. However, the investigation and analysis of this issue overall is weak. None of these studies has seriously looked for evidence about the technological basis for the long-term dynamism of the clusters. If technology-related issues are important, as I have suggested in chapter 2, and which some evidence in these studies confirms, then any conclusions about the dynamic effects of clustering drawn from these studies are bound to be misleading.

Chapter 6
Discussion and Conclusions

6.1 Introduction

It is natural that a form of industrial organisation which, in at least some cases, brings international status to predominantly small labour-intensive producers, attracts interest from anyone concerned with industrial development in the South. The phenomena of industrial clusters appear to be a hopeful signpost in the search for industrial models that address the needs of the economically marginalised in developing countries. Nevertheless, the relative economic success of a few individual industrial clusters is unremarkable and generates few policy implications, unless it can be shown that clustering *per se* creates dynamic benefits which can sustain rising competitiveness over the long-run: a prerequisite for international competitiveness.

In many cases, this "dynamism" is just what is claimed for industrial clusters by the protagonists of this research field. It is argued, more or less explicitly, that industrial clusters have inherent characteristics which raise their potential for sustaining improvements and innovation. I have sought to investigate the basis for these claims within the protagonists' own empirical literature on industrial clusters.

In chapter 3, a brief review of the analytical approaches adopted in the literature on industrial clusters in the North, revealed that in general this literature has very little to say about how these production systems achieve long-term sustainability and innovativeness. The one study [Belussi 1992] which does address the issue, casts some doubt on the claims altogether. In order to carry out my own investigation, I therefore needed to design an analytical tool appropriate to the task. Fortunately, questions about innovation and sustainable competitiveness have been addressed in other contexts. The literature about the acquisition of technological capabilities in the South provided a number of concepts which as described in chapter 2, I shaped to my enquiry in the form of an abstract system of knowledge-acquisition (fig. 2.5). In chapter 4, I then related the system's abstract components to real activities and processes going on in industrial clusters, to achieve an analytical framework (fig. 4.1).

6.2 Technological Learning and Innovation in Clusters

In chapter 5, this analytical framework was used to critically review five recent doctoral studies of industrial clusters in the South. The questions driving this exercise were:

3. How well does the research on industrial clusters in the South explain the long-term sustainability of the production systems it investigates?
4. What does the research on industrial clusters have to say about the technological capabilities of clusters, or about other factors behind the processes of technical change which they experience?

My conclusions fall into two categories: one set relates to the approaches used in the research to generate evidence; the other set is derived from the evidence itself.

6.2.1 Conclusions about the Research Methods used in the Case Studies

Analytically, the literature on industrial clusters is distinguished from earlier research on small-scale firms and the informal sector in developing countries by a shift in the frame of reference from the level of the individual firm to the level of collective and interactive processes between economic agents in the cluster. This brings into play a variety of potential economic and technological effects which are overlooked by focusing on individual firms. Nevertheless, by the criteria developed in chapter 4, the studies failed to demonstrate either that chosen clusters had significant technological capabilities, or that there were particularly dynamic technological learning processes underway.

Two points need to be highlighted here. The first is that the mere fact of expansion is sometimes treated as an indication of dynamism. Even if it brings dramatic economic success in the short-term, expansion does not demonstrate that an industry has or will in future develop the capabilities to respond to long-run changes in its operating environment. This rather simple first point is acknowledged in some of the research on clusters. Among the studies I have reviewed, Rabellotti [1995] makes it in her thesis. Schmitz, in his research on the Sinos Valley shoe-making cluster, has also recently focused on the cluster's capacity to manage crisis and change [Schmitz 1995a].

However, the second point is that even where a more dynamic approach has been brought into the literature on industrial clusters in the South, it has not been explicitly applied to exploring issues of *technological* change. Technology still tends to be treated as an input: the 'machine' or the 'package' which simply slips into its place in the production system as and when required. The need for specific resources or capabilities to generate and manage technical change efficiently tends to be ignored. Thus, for example, emphasis is given to the important role that clustering plays in attracting external agents with knowledge about how markets are evolving. However, little analysis goes into if and how industrial clusters acquire the resources, skills and knowledge needed to effect changes in the production system in response to this kind of information. Even less consideration is given to the long-term implications of having a production system that may be responsive to change or crisis, but lacks the capability to anticipate or strategically direct technological changes.

6.2.2 Conclusions derived from the Evidence in the Case Studies

On the basis of the five case-studies, it is not possible to draw the conclusion that the phenomenon of industrial clustering generates no technological learning benefits at all, but evidence is very restricted. Some signs of existing technological capabilities and potential learning mechanisms are evident in the studies: ranging from the endogenous example of "reconditioning teams" in Tewari's study (section 5.3), to the exogenous example of foreign buyers' technological support in Nadvi's study (section 5.2). The overall impression obtained from these studies is of rather limited dynamic attributes, although one cannot exclude the possibility that more technologically-orientated research focus would have revealed more evidence of technological learning, in at least some of the clusters.

Interestingly, the most important technological changes identified in the case-studies almost all seem to have their origins in external sources of knowledge. The role that external, often foreign, buyers play in this is evident. However, there is also less well advertised evidence that technologically-orientated institutions can play a crucial role, both in effectively disseminating knowledge within the clusters and by acting as a bridge to the external world. It is not at all clear whether clustering *per se* has any influence on the effectiveness of these institutions.

6.3 Some Implications

If one was to draw on the explicit emphases and conclusions presented in these cluster studies, it might lead to the implication that there is little need to do anything about technological change and long-term sustainability in industrial clusters. One might even claim that technology will take care of itself, in the environment created by joint action.

I have demonstrated that this rather technologically-deterministic, *laissez faire* perspective is at least partly a product of inadequate investigation of technological change processes in the research on industrial clusters. If one does not set out to ask the questions about technology and long-term sustainability of production systems, then one does not reveal the opportunities for practical action.

For example it would be interesting to know what it was about the MIDC institution (section 5.2.5) that led it to be so ineffective in heading off the crisis over the quality of stainless steel in Sialkot's products. Conversely, what enabled SITRA in Tiruppur (section 5.5.5) to apparently play a much more important role in that cluster's process of technical change?

A more detailed investigation of the knowledge-acquisition mechanisms behind Ludhiana's 'reconditioning teams' (section 5.3.3), might reveal something about practical ways in which the region can become more outwardly orientated.

6.4 Future Research Directions

It has not been my intention in this dissertation to imply that technological change factors are sufficient to explain industrial performance in any production system. Clearly questions of organisation, finance and marketing are also important. However, the technological dimension is both a necessary and an often misunderstood component.

Future research on industrial clusters in the South would benefit not only from "…moving from a static to a dynamic approach, comparing trajectories and stages of development instead of snap-shots at a given point of time…" [Rabellotti 1995:229], but also from including a realistically dynamic model of technical change processes in the analysis. How can this be achieved?

First, it is necessary to find ways of separately measuring the resources described in the knowledge-acquisition model: production capacity and technological capabilities. Although she did not fully distinguish between two sets, Romijn [1996] has led the way in devising quantitative indexes for such aspects as the manufacturing complexity of products – one indicator of production capacity. Many other aspects: forms of knowledge and skills, probably defy direct measurement, but proxies may be conceived with a little imagination. In general, the capability to generate and manage particular changes can only measured by studying change outcomes in the production system over time. Thus longitudinal studies are essential.

Second, some attempt must be made to explore the relative value to firms of the various endogenous and exogenous knowledge flows which have been described as the mechanisms of technological learning. This type of enquiry is probably not capable of producing quantifiable results, but qualitative evidence about the functioning of these mechanisms could provide the basis for comparing the strengths and weaknesses of different clusters' knowledge acquisition systems. It will be important to distinguish between the mechanisms that serve to disseminate knowledge within a cluster, and those that actually lead to the acquisition of knowledge that is new to the cluster. This entails identifying the particular firms or other economic agents in the cluster which are in the front-line of knowledge acquisition, and focussing on their external and internal linkages and resources.

Institutions which play a technological role in clusters, such as training schools, research centres and providers of technical assistance in various forms will need to studied in greater detail. By distinguishing between those inputs which contribute to improvements in production capacity, and those that enhance the technological capabilities of the cluster, it may be possible to assess their technological role more accurately. Ultimately, this may help to identify weaknesses in knowledge-acquisition systems of particular clusters, and opportunities for strengthening them through institutional development.

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