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Local clusters in global value chains: exploring dynamic linkages between Germany and Pakistan

Khalid Nadvi and Gerhard Halder*

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INSTITUTE OF DEVELOPMENT STUDIES
Brighton, Sussex BN1 9RE
ENGLAND

* Institute of Development Studies, University of Sussex, Brighton UK and Department of Geography, University of Stuttgart, Stuttgart, Germany respectively.

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Summary

Industrial clusters and global value chains command growing interest in regional studies. Yet, there is a paucity of empirical material on how clusters are linked into global value chains, and limited research on ties between clusters in the developed and developing world. This paper seeks to fill these gaps. Using the case of the global surgical instrument industry, it analyses connections and differences between the industry's leading production sites, namely small firm clusters in Tuttlingen, Germany and in Sialkot, Pakistan. In terms of knowledge, the two clusters mark the high and low technology ends of the industry. Yet, in terms of production, there are significant links between German and Pakistani firms. Moreover, quality upgrading, low-cost competition, and developments in medical technology raise new challenges for firms in both Pakistan and Germany. The paper draws on evidence from both clusters to assess the upgrading responses to these challenges. Cluster and value chain approaches are used to explore local and external linkages. The distinction between knowledge and production systems helps illustrate differentiation within each cluster, and underlines their diverging trajectories.

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1 Introduction

Since the 1990s, industrial clusters have generated much excitement amongst academics and policy makers. The view that competitiveness can be enhanced in geographically concentrated and sector-specialised clusters has found resonance amongst geographers (Markusen 1996; Scott 1996), economists (Krugman 1991; 1995) and business management specialists (Porter 1998). It has also inspired numerous case studies from both the developed and the developing world.¹ The allure of the approach lies in its promise for small-scale industry and the importance it attaches to *local* linkages. It shows that, with economies of agglomeration and local joint action, small and medium sized enterprises (SMEs) can compete alongside large firms, and in global markets (Schmitz 1995). Cluster-specific external economies include the presence of specialised labour, specialised suppliers, and knowledge spillovers. Economies of scale and scope arise where firms concentrate on particular processes and produce complex goods by interacting with each other. High levels of organisational flexibility within small clustered firms – often at the expense of workers and family members – can result in further cost advantages. Finally, local joint action, between firms and through local institutions, has the potential of enhancing the capacity of small firms, and raising the competitiveness of such cluster.

While enthusiasm with industrial clusters continues, researchers have come to recognise that such agglomerations are by no mean homogenous (Harrison 1994), nor do they follow a “natural” and sustained growth path (Belussi 1999; Whitford 2001). Internal heterogeneity, and the restructuring of large firms, has made competition sharper and reduced many of the advantages of clustered SMEs. Furthermore, in the wake of globalisation, there is growing awareness that external actors can play a critical role in shaping the growth path of clusters (Schmitz and Nadvi 1999). Amin and Thrift (1992) considered clusters as “nodes” within global networks. This paper reviews clusters from developed and developing countries as specific, but inter-linked, nodes. In order to unravel a dynamic perspective on these nodes, the paper distinguishes between the analysis of production systems, which encompass the production of goods to desired specifications, and that of knowledge system, which generate and manage changes in the production process or the organisation of production (Bell and Albu 1999: 1723).

It is widely acknowledged, that one strength of clusters lies in the rapid use, replication and circulation of knowledge (Nadvi 1999a). However, other authors have stressed, that cluster circulation, absorption and modification of already existing knowledge rarely changes the stock of knowledge in more than an incremental way (Humphrey and Schmitz 2000). As a consequence, for radical upgrading a combination of external and internal knowledge is often required (Bell and Albu 1999; Knorringa 1996).

Thus, an important aspect of the contemporary research agenda is the relationship between local clustered firms and global buyers (Schmitz and Knorringa 1999), especially where such linkages are not based on purely arms-length market-based transactions. The value chain approach provides a way forward in analysing such *external* linkages, combining global nodes (Gereffi 1994). It shows how the distinct

¹ See, for example, the collection in Pyke and Sengenberger (1992); and Nadvi and Schmitz (1999).

² Amin and Thrift (1992) also saw clustered industries as “nodes” in wider global networks.

functions involved in turning a raw material into a final product, from design, production to marketing, can be mapped onto the complex inter-relations that exist between local suppliers and their global buyers. The approach emphasises the role of governance, or conscious coordination, of distinct activities within the chain. The influence of actors in the chain can vary, affecting their ability to determine the parameters of production – including what is produced, how, when, and at what price (Humphrey and Schmitz 2001). Coordinating inter-firm relationships within (non arms-length) chains can involve network arrangements between relatively equal partners who share complementary skills and abilities; quasi-hierarchical ties in which one actor has disproportionately more power over other independent actors; or hierarchical vertical integration. The value chain approach, thus, highlights the significance of power in the chain, and the role of the lead firm in exercising it. This helps explain where and how value is added, and appropriated, along the chain. As Humphrey and Schmitz (2000) observe, the scope for local actors to promote strategies for upgrading and growth varies with the way the chain is governed.

With the exceptions of Knorringa (1996), and more recently Saxenian and Hsu (2001), there have been few attempts at examining relationships between clusters in a given value chain. In addition, comparative studies on clusters from the North and the South are rare (exceptions include Scott 1994 and Rabellotti 1997). We seek to fill these gaps. Using the case of the global surgical instrument industry, we analyse the similarities, differences and connections between the sector's leading clusters in Sialkot, Pakistan and in Tuttlingen, Germany. In terms of innovation, the two clusters mark the lower and higher (and quality) ends of the global industry. Yet, in terms of production, there are significant ties between technically advanced German firms and Pakistani producers.

The rise in quality requirements, the emergence of low-cost competition, and radical developments in health care delivery and medical technology raise new challenges for firms in both Pakistan and Germany. This paper examines the responses of the clusters and the implications for the relationships between them. To this end we draw on primary evidence from both clusters, including survey data collected in 2000 from 42 firms in Sialkot and 46 firms and traders in Tuttlingen. Interviews were also undertaken with key informants in both clusters, at the sector's leading annual trade fair – Medica in Düsseldorf, and with firms in Sheffield, UK. In this study, we use the concept of collective efficiency to assess the gains of clustering, while we use the value chain approach to explore links between firms and external actors, and ties between the two clusters.

The paper shows the differing positions of the Southern and Northern clusters in the global surgical instruments industry. Having outlined these differences, we bring in the connections between the two clusters. Both connections and differences change over time. Exploring the dynamic trajectories of differences and linkages between the two clusters requires an understanding of the nature of recent challenges in health care delivery. We identify three distinct sets of challenges. First, there is the challenge to reduce costs. This is, in part, an outcome of increasing demands on healthcare provisioning, changing demographic and disease profiles, and growing pressures on publicly-funded medical budgets. Hospitals are ever more concerned with reducing expenditure and enhancing efficiency (Knappe *et al.* 2000). This includes better control and maintenance of inventories of medical equipment and more competitive

sourcing of instruments. Hospitals have also sought to shift inventory costs and service functions down the chain to instrument suppliers. This requires surgical instrument suppliers to be more conscious of logistics, and of the value-added of service, maintenance and financing activities.

Second, global concerns with quality, safety, and health standards, at all stages of the health delivery system, have had a significant impact on the medical instruments sector. New disease patterns, such as HIV-AIDS and non-variant CJD, have enhanced the threat of contamination from used surgical instruments and led to a growth in demand for disposable instruments, often made with cheaper materials and thus significantly lower in price. At the same time, with the increasing globalisation of medical instrument production, regulators in leading markets (including the United States and the European Union) require products used in medical procedures to conform to international standards on quality assurance. This has consequences for the nature of inter-firm linkages further down the production chain.

Third, advances in bio-medical technologies have led to challenges for new product development. New techniques and equipment have radically altered the ways in which many surgical procedures are carried out (Grönemeyer 2000). Minimally invasive (or keyhole) surgery, using fibre-optics and laser technology, have meant that many operations can be done more quickly, more effectively, more safely, and more cheaply. Post-operative recovery time is reduced and patients suffer less. Such minimally invasive procedures demand new types of surgical instruments and endoscopes. Similarly, the marriage of electronics, computing and information technologies with surgery, such as the use of magnetic resonance scanners (MRS), has resulted in new types of advanced instruments, while enhancements in materials technologies have widened the range of artificial surgical implants.

Responding to these challenges requires upgrading. In line with Humphrey and Schmitz (2000), we distinguish between the following forms: product upgrading involves improvements in existing, and development of more sophisticated, products. Process upgrading emerges through improvements in the technologies used in production, or the ways in which production is organised. Functional upgrading arises from an enhancement, or change, in the activities that a firm undertakes and can involve developing new capabilities – such as design or distribution. Inter-sectoral upgrading appears when a firm uses capabilities developed in a particular activity to enter into a new sector. Thus, the adoption of global quality standards may require process and product upgrading. Developing minimal invasive instruments, or complex logistical and service-based activities, call for functional and product upgrading. Upgrading can demand new forms of knowledge.

This distinction between *knowledge flows* and *production flows* (taken from Bell and Albu 1999) – is central for explaining the nature of linkages between the two clusters, and their distinct trajectories. It provides an important organising principle to the paper. The different knowledge flows within and between the clusters and the chain, and the coordination of the division of labour in production require different types of relationships between firms. We seek to understand how the two clusters are linked, what forms of upgrading they are able to undertake in response to external challenges, and the implications for cluster growth. To this end, Section 2 outlines the global nature of the surgical instruments sector. Section 3 introduces the Sialkot and Tuttlingen clusters, and Section 4 shows the

distinct patterns of upgrading in the two clusters in the face of the new challenges. Section 5 focuses on the nature of material and knowledge flows across the two clusters that have brought about such upgrading. The paper concludes by considering the future trajectories of the two clusters.

2 The global surgical instruments industry – an overview

The scale of global trade in surgical instruments is difficult to accurately measure. According to UN trade data, world exports of medical instruments and appliances grew from US\$10.6 billion in 1991 to US\$21.7 billion in 1999 (UNCTAD 2001). Surgical instruments, however, are only one of many sub-sectors that fall under the umbrella of medical instruments and appliances. The latter include a wide range of products, from bedpans and hospital beds to various types of non-electronic diagnostic equipment. Key informants, and earlier estimations by Nadvi (1996), suggest the scale of the global hand held stainless steel surgical instruments industry to be roughly US\$650 million. This, however, excludes new types of instruments and medical devices, such as endoscopes or surgical implants.

In this section, we introduce the world market for surgical instruments, identify the main locations of production, and show how these various locations are linked with each other and the global market. This helps contextualise the subsequent discussion on the Tuttlingen and Sialkot clusters.

Historically, surgical instruments were manufactured in regions that traditionally forged and worked metals, particularly knives and subsequently stainless steel products. The range of distinct production tasks within the industry promoted a division of labour whereby small firms flourished and local clusters emerged. Thus, in the early twentieth century, centres of surgical instrument production were found in Sheffield in England, Nogent-sur-Marne in France, and Solingen and Tuttlingen in Germany. With the exception of Tuttlingen, these locations no longer survive as important centres for surgical instrument manufacture. Instead, the last quarter of the twentieth century has seen Pakistan emerge as a key producer of traditional surgical instruments. In addition, Malaysia, and more recently, Poland and Hungary have come forward as production sites, although not on the same scale as either Pakistan or Germany.

There are important similarities and distinctions between these locations. In each country, production is concentrated in specific locations. Both Sialkot and Tuttlingen have a similar background in metalworking. However, while Tuttlingen and Sialkot each have over 300 surgical instrument manufacturers, there are only a few firms in Poland, Malaysia and Hungary. There are also important distinctions in the types of instruments produced in these locations. Sialkot, Penang (Malaysia), Debrecen (Hungary) and Novy Tomyśl and Warsaw (Poland) primarily manufacture traditional, stainless steel hand-held instruments. Tuttlingen has diversified into a wider range of products with the manufacture of minimal invasive instruments, endoscopes, surgical appliances and surgical implants. Despite these distinctions, however, there are direct links between Tuttlingen and each of these locations. Firms in Pakistan undertake job processing and original equipment manufacture (OEM) production of instruments for Tuttlingen firms. Malaysian production is dominated by the wholly owned subsidiary of Tuttlingen's lead firm. Plants in Poland are either owned by, or closely tied to, Tuttlingen firms. In Hungary, there is

one large firm, which formerly supplied the Eastern bloc, and which now sells primarily through a large Tuttlingen-based trading firm that it has acquired.

Surgical instruments are used world-wide. The main markets, however, are in the United States, Western Europe and Japan. Not all the production centres trade directly with the leading markets. Malaysian production, for example, is 'routed' through the Tuttlingen lead firm. Similarly, Polish and Hungarian production to the US and the EU is also channelled through producers and traders in Tuttlingen. Pakistan is the exception. While some of its trade is with Tuttlingen, 65 per cent of its total surgical instruments exports are directly to the US market.

These trade and production linkages underline the global nature of the industry, and the role of Tuttlingen as one organising hub. They also point to the ways in which Tuttlingen and Sialkot dominate the industry. Sialkot exported US\$125 million of surgical instruments in 1997, giving it approximately one-fifth of the global market of traditional surgical instruments (Nadvi 1999a). Tuttlingen is significantly larger in terms of output value. Its total annual turnover in 1999 we estimate to be US\$610 million and includes both traditional and new instruments and medical devices.³ According to local informants, Tuttlingen has a 55 per cent share of the world market for surgical instruments (both traditional and new instruments). This highlights the relative scale of the two clusters. What distinguishes them further is that whereas Sialkot is largely confined to the relatively mature product sector, Tuttlingen has moved into higher value added product lines reflecting advances in medical technology. The next section examines the two clusters more closely.

3 The surgical instrument clusters of Sialkot and Tuttlingen

Detailed descriptions of the Pakistani and German surgical instrument clusters can be found elsewhere (see Nadvi 1999a; 1999b; for Sialkot; and Halder 2002 for Tuttlingen). Here we distil their key features. We compare the structure and composition of the two clusters, the nature of production and process organisation, the role of local institutions, and the distinct markets and distribution channels that they feed into. We assess the gains from agglomeration and local joint action in each cluster, and the ways in which both clusters are linked into global value chains. In particular, we tease out the linkages that exist between the two clusters. We begin with brief summaries of each cluster.

³ This is estimated by taking the actual turnover of all firms with over 20 employees in the medical engineering sector in Tuttlingen – producing instruments, endoscopes, implants and apparatus. Output of small firms (with less than 20 employees) is estimated by taking the average labour productivity in small firms (obtained from the survey of small firms) and the total employment in the small firm sector. Our figures match those reported by key informants in Tuttlingen, and are in line with estimates in Nadvi (1996). The data sources are the Statistisches Landesamt Baden-Württemberg (Vierteljährliche Produktionserhebung) and the Landesarbeitsamt Baden-Württemberg (on sectoral employment).

3.1 Sialkot

Surgical instrument manufacture constitutes a small, but wholly export-oriented, industry in Pakistan. At its core are some 350 manufacturing and exporting firms, the bulk located within Sialkot's urban boundaries. Most firms are small, family-run, units. There are, however, over 30 large firms employing 100 or more persons. Among these are joint venture units set up in collaboration with firms in Tuttlingen. Surrounding instrument manufacturers are a wide range of input suppliers, service providers and over 1,500 specialised sub-contractors. There are also a number of local state and private institutions. These include the sector's trade body and the local chamber of commerce, an industrial technology institute, a dry port facility, financial institutions, and the state-run export promotion body.

The cluster produces an extensive range of standard surgical instruments, relying heavily on labour intensive techniques. It does not manufacture the new minimal invasive instruments or surgical implants. It has, however, developed a strength in low quality and relatively cheap, but high volume, disposable clinical (or floor) instruments. It also produces higher quality, reusable, operation theatre instruments. Over 90 per cent of total exports are to the US and Western Europe. The US market accounts for the bulk of disposable exports, while theatre instruments are mainly for the EU market. Export growth has been high, roughly 10 per cent a year on average from the mid 1980s to the late 1990s. There are four distinct distribution channels through which local firms export. These include:

- foreign buyers (including Tuttlingen traders) who purchase complete instruments from Sialkot and supply wholesalers, retailers and end-users in specific markets;
- Tuttlingen producers who sub-contract all or part of particular instruments to Sialkot, or use Sialkoti firms as OEM suppliers;
- expatriate Pakistani traders who supply (usually lower quality) instruments in various markets, especially in the US; and
- foreign sales outlets (or subsidiaries) of Sialkot manufacturers.

The continued export success of local firms is tied to the externality gains of clustering. Extensive and well-developed local markets for inputs, services, and skilled labour ensure competitive prices and easy availability. The flow of sector-specific and technical information within the cluster generates important knowledge spillover gains for local firms. Widespread subcontracting provide economies of scope and scale, with savings on costs, skills and space. While important to all producers, agglomeration benefits are critical for small firms (Nadvi 1999a).

Despite intense, and often predatory, local competition, local joint action is a further factor in the cluster's competitiveness. While bilateral cooperation between local producers is rare, and strategic production and marketing information closely guarded by individual firms, cooperation through local private institutions has been critical at key moments in the cluster's development. For example, a public-private effort initiated by leading firms in the 1980s, in response to constraints in handling exports in the country's main port, led to the formation of the local dry port (Nadvi 1999a). In the mid-1990s, the trade

association successfully organised a cluster-wide response to pressures by US regulators to comply with global quality assurance standards (Nadvi 1999b). Joint action is also present in vertical ties. Firms have long-standing relations with subcontractors, involving extensive technical discussion on product quality and production organisation. Ties with buyers are especially significant. Firms often receive support from buyers on measures to improve product quality, and buyers are cited as the primary source for new ideas on product development. Such technical support is most pronounced where firms deal with buyers who are themselves surgical instrument producers, particularly from Tuttlingen. These linkages with Tuttlingen manufacturers involve extensive technical knowledge flows from Germany to Pakistan. Tuttlingen producers often provide Sialkoti suppliers with training (in Sialkot and in Tuttlingen), machinery, technical blueprints, and advice on process and quality upgrading. We turn now to Tuttlingen.

3.2 Tuttlingen

A century ago, Tuttlingen was known as a knife-forging town. Unable to compete against the Solingen cutlery cluster, the local industry turned to the specialised niche of surgical instruments. Since the early 1900s, the Tuttlingen surgical instrument sector has grown steadily, both in terms of firm numbers and employment levels, expanding beyond the confines of the city and into the surrounding county. Between 1955 and 1999, it grew from approximately 320 firms (3,800 employees) to 480 firms (6,200 employees) of which some 300 produce finished instruments and the remainder are subcontractors. There are also approximately 200 home-workers employed by the cluster's main firms. Over twenty local input suppliers and service firms are directly linked to the cluster, while a number of metal working firms in and around Tuttlingen supply turned metal and other parts. There are a further 76 specialist traders, with over 600 employees in 1999, who provide one link between producers and end markets. The size distribution of firms is more uneven than in Sialkot. Eight firms account for 64 per cent of total manufacturing employment in the sector, while the cluster's lead firm employs some 2,000 persons in Tuttlingen. Only 41 other firms employ more than 20 persons. At the other end of the scale, there are more than 200 "one-person" firms (Halder 2002).

The cluster has an estimated annual turnover of US\$610 million, of which roughly two-thirds is exported.⁴ The leading export markets are the US, the EU and Japan. The cluster's output includes traditional and new surgical instruments, endoscopes, surgical apparatus and implants. In terms of employment, surgical instruments production is the main activity with 30.5 per cent of total manufacturing employment within the medical technologies sector in Tuttlingen. However, nine of the ten largest firms in the cluster specialise in the new sectors of endoscopes, implants and surgical apparatus. In contrast, small firms employing less than 20 persons predominantly work in the instruments sub-sector. The cluster's lead firm, which produces instruments, implants and other surgical products, employs 32 per cent of the cluster's total manufacturing workforce. Firms whose primary specialisation is in endoscope

⁴ According to the Baden-Württemberg statistical office, firms with more than 20 employees in Tuttlingen's medical engineering sector exported 64 per cent of their turnover in 1999 (Statistisches Landesamt Baden-Württemberg 2000).

manufacture account for 20.6 per cent of total manufacturing employment, and those in implants and apparatus production engage 17 per cent of the workforce.⁵

The local Chamber of Commerce estimates that Tuttlingen accounts for 55 per cent of the world market of surgical instruments, producing between 15 to 20 million units of some 20,000 different instrument types annually. For many instruments, batch sizes are small, offering possibilities for high quality craft production. The production processes in standard surgical instrument manufacture are similar to those in Sialkot, although use of specialist technology is more common. Manufacture of surgical implants and endoscopes is technically more complex and less labour-intensive. Process subcontracting does take place, but only in instrument production and the practice is not as extensive as in Sialkot. Instead, many of Tuttlingen's small firms specialise in particular products, undertaking most process activities in-house.

Despite intense local rivalry, there are significant examples of joint action between firms. The most important of these are two associations of firms. The mainly medium and small sized firms within these two groups maintain joint marketing and distribution functions. Moreover, both groups have their own research and development staff, and well-recognised brand names. This allows them to compete alongside the cluster's lead firm. One of the two groups is now the cluster's second largest manufacturer of instruments and implants.

The wide range of instruments, along with small (often irregular) batch sizes, force traders and firms to maintain large and diversified stocks to meet changing demands. In addition to their own products, firms also purchase specialised instruments from other producers as part of their stock portfolio.

There are three leading distribution channels in the instruments sub-sector of the cluster. First, large Tuttlingen producers sell directly to end-users, often sourcing instruments from small local producers. Second, both small and larger producers sell to Tuttlingen-based traders. Third, local producers sell through external buyers. The latter is a traditional form of distribution for small Tuttlingen producers. External wholesalers and in particular large overseas buyers regularly visit the cluster to source products. Some maintain buying offices in Tuttlingen. However, the share of the different distribution channels varies according to different markets. Tuttlingen-based actors dominate the domestic German market. In contrast, external buyers exercise the greatest influence in the important US-market. Supply to other parts of the world is the strength of country-specialised traders, often Tuttlingen-based, who are familiar with the respective needs of each market. In the highly concentrated endoscopes and implants sub-sectors, most firms are large and market directly to end-users.

Institutions play an important role in the cluster, in particular the Chamber of Industry and Commerce and the Chamber of Crafts. They co-finance the BBT, the cluster's leading training institution and the sole body in Germany providing the necessary formal qualification in surgical instrument making. Moreover, they have been involved in occasional initiatives to promote the industry and moderate local joint action (Halder 2002). Two recent initiatives are a technical competence centre for the development

⁵ Based on data from the Tuttlingen labour force office and firm annual reports.

of minimal invasive instruments and a technology park. These bring together the Chambers, local government, university hospitals, and external research institutions. It is too early to judge the significance of these new ventures. Their aims are to strengthen the cluster's technical position in surgical instruments, and to diversify its product range by attracting new, innovative, firms from complementary fields of medical engineering.

Table 3.1 Key similarities and differences between Sialkot and Tuttlingen clusters

Similarities	Sialkot	Tuttlingen
Historical roots	Late nineteenth century, although dating back to sword and dagger manufacturing in the seventeenth century.	Late nineteenth century, based on earlier knife forging industry.
Cluster-structure	350 final producers 1,500 process subcontractors >200 specialist suppliers	300 final producers 200 subcontractors 200 homeworkers > 20 specialist suppliers
Main Markets	US, EU	Germany, rest of EU, US
Local Institutions	Business Chambers and Trade Association Technology Centre Dry Port	Business Chambers Training Institute Competence Centre for new products and technologies (in planning)
Cluster-based advantages	Agglomeration Economies Joint Action gains	Agglomeration Economies Joint Action gains
Differences	Sialkot	Tuttlingen
Structure	SMEs dominate in terms of employment	8 large firms have 64% of total cluster employment
Scale – production	• US \$ 125 million	• US \$ 610 million
Scale – employment	• 30,000	• 6,000
Product Range	Theatre surgical instruments Disposable surgical instruments	Theatre surgical instruments Minimal Invasive instruments Endoscopes Surgical Implants Medical Apparatus and Devices
Main Distribution Channels	<ul style="list-style-type: none"> • Foreign buyers (traders) who source on OEM basis • Foreign producers (mainly from Tuttlingen) who source on OEM basis • Expatriate Pakistani traders • Foreign sales outlets of local firms 	<ul style="list-style-type: none"> • Foreign buyers who source on OEM and ODM basis • Local traders who source on OEM and ODM basis • Direct sales to end-users
Competitive Advantages	Cheap and Skilled labour	Knowledge-intensive skills and R&D Ties to end users Design and product development Brand identity
Key Challenges	Quality Assurance Standards	Low cost suppliers New products and medical technologies Changing needs of health care providers

3.3 Sialkot and Tuttlingen: similarities, differences and linkages

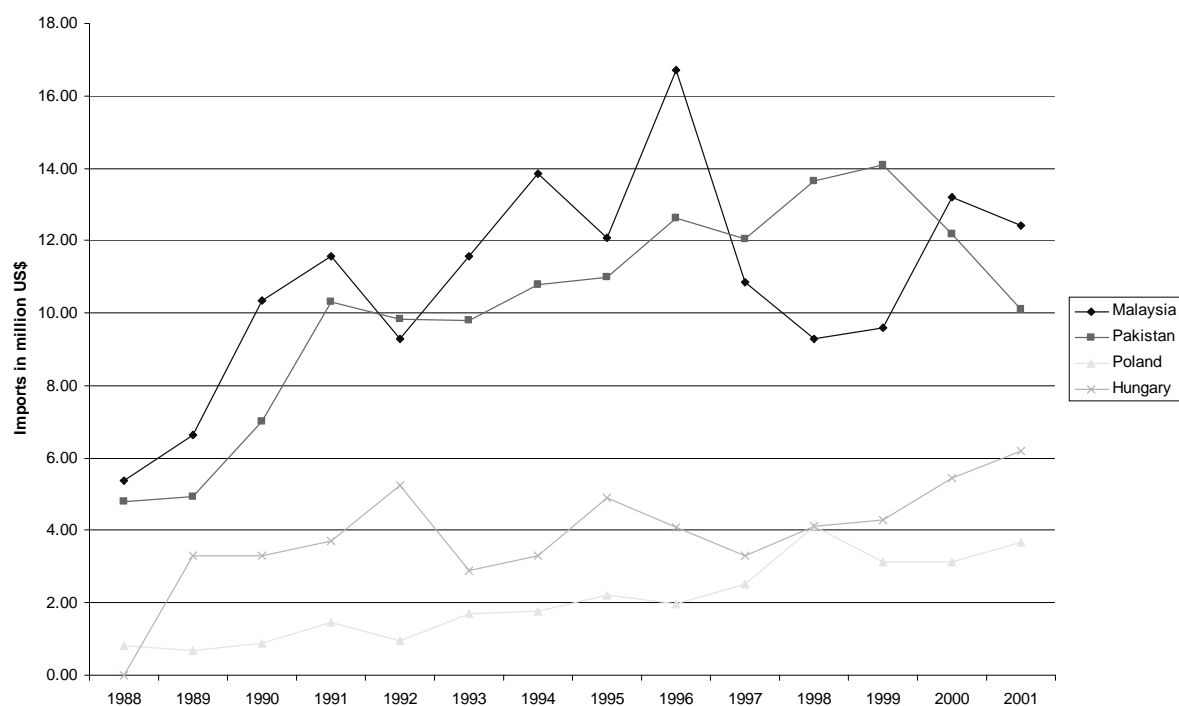
The Sialkot and Tuttlingen clusters share various common features, and have significant differences (see Table 3.1). They have similar histories, a similar structure with a preponderance of small firms, and similar kinds of private and public institutions. Firms in both clusters benefit from local clustering advantages, including the availability of skilled labour, specialised inputs and the flow of information and knowledge. Despite intense local competition, and mistrust, there are examples of local joint action in both clusters. Differences are equally stark. First, large firms are more dominant in Tuttlingen. Second, while geared to similar regional markets, the two clusters produce an increasingly differing range of products. Third, Sialkot employs roughly five times more people than Tuttlingen but sales are only one fifth. Although comparing labour productivity between the two clusters can be problematic given their divergent product range, it is instructive that the difference in labour productivity is as high as 24:1. Fourth, the comparative strengths of the two clusters diverge with Sialkot relying on cheap labour and Tuttlingen on knowledge and innovation. Finally, there are critical differences in the nature of global value chains that the two clusters are inserted into. In Sialkot, external actors, particularly from Tuttlingen, have a direct influence over production, whereas for Tuttlingen knowledge tie with end-users are critical.

Thus, the two clusters are closely inter-linked, through material flows and knowledge flows. The direct ties are, however, restricted to a handful of firms in Sialkot and to those producer and trader firms in Tuttlingen engaged primarily in the instruments sub-sector.

In 1972, Tuttlingen's lead firm became aware of Sialkot's prowess in instrument production. Realising the potential competition from Sialkot, it established its own plant in Malaysia, gaining from low wages and from the tax advantages of Penang's free trade zone. This initial move towards global sourcing was soon followed by the second largest instrument manufacturing group in Tuttlingen, which set up a joint venture plant in Sialkot in the early 1980s. Other Tuttlingen producers followed. In response to the problems of poor product quality, ties between Tuttlingen and Sialkot firms began with job processing. The former supplied the latter with the critical input, high quality stainless steel forgings. The Sialkot firms were responsible for the intermediate, and relatively labour intensive, tasks of grinding, filing and polishing. Semi-finished instruments were then returned to Tuttlingen for the final processes of further polishing, cleaning and packaging. In addition, there were significant flows of technical knowledge and equipment from Tuttlingen to Sialkot. Workers from Sialkot came to Tuttlingen for training, while technicians from Tuttlingen were sent to Sialkot for quality inspections and to improve production practices. With consistent improvement in metal forging in Sialkot during the 1980s and 1990s, there was a decline in levels of job processing undertaken on pre-forged German instruments by Sialkot firms but a rapid rise in OEM production by Sialkot for the Tuttlingen cluster. Exports of pre-forged instruments from Tuttlingen for job processing in Sialkot peaked at US\$3.40 million in 1993. By 2000, however, this had declined to US\$2.09 million. At the same time, there was a substantial increase in Tuttlingen imports

of instruments (both finished and job processed) from Sialkot, increasing from US\$6.24 million in 1990 to US\$27.53 million in 1999. (Statistisches Landesamt Baden-Württemberg 2001). These trends are shown below.⁶

Figure 3.1: Surgical instrument imports from various locations to the Tuttlingen cluster – Baden-Württemberg



Source: Statistisches Landesamt Baden-Württemberg 2001.
(Converted to US\$ using IMF *International Financial Statistics* 1999 and 2001)

But Sialkot, as we have mentioned earlier, is not the only supplier of instruments to the Tuttlingen cluster. In Malaysia, where Tuttlingen’s lead firm increasingly uses its integrated plant for the manufacture of traditional hand-held instruments (especially forceps and scissors), a similar pattern is observed. As shown above, imports into Tuttlingen from Malaysia, increasingly of finished instruments, rose in line with those from Sialkot. Moreover, after the fall of the “iron curtain”, Poland and Hungary emerged in the 1990s as suppliers of finished instruments to Tuttlingen, although not on the same scale as Sialkot or Malaysia.

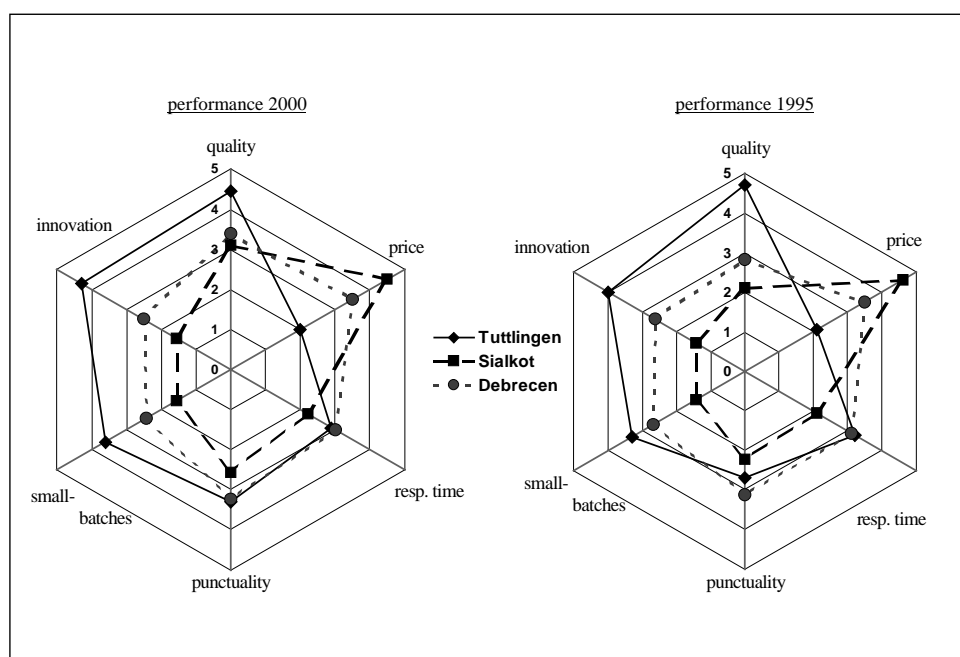
Figure 3.2 shows the views of Tuttlingen based traders on the standards of various production locations and how this has changed over time.⁷ Debrecen in Hungary enjoys significant labour-cost advantages over Tuttlingen, and is in relatively close reach to Tuttlingen. Moreover, other than price,

⁶ While the data in Figure 3.1 is at the country level, production of surgical instruments in each country is almost wholly concentrated in one location. For example, in Pakistan there is no manufacturing of instruments outside Sialkot, while Tuttlingen accounts for approximately 90 per cent of total firms, and employment, in the surgical instrument sub-sector in Baden-Württemberg.

⁷ Respondents were asked to evaluate suppliers according to various criteria on a numerical scale of 1 to 5, with 1 referring to the lowest level of satisfaction and 5 to the highest level of satisfaction.

Debrecen retains competitive advantages over Sialkot, in innovation, punctual delivery and response time. Sialkot continues to be seen as the most price competitive location and has improved over the past five years in product quality.

Figure 3.2: Tuttlingen traders' evaluation of various locations now and five years ago



Source: Authors' survey

In the last decade, there has been a substantial rise in the numbers of specialised traders in Tuttlingen. Many of the small traders were former instrument producers. Others are closely linked to existing manufacturers in the cluster. However, at least three of the five largest traders are either wholly or partially foreign owned. One has minority and one majority Pakistani shareholding, while the third is wholly owned by the Hungarian manufacturer. Barring the latter, all the leading traders source directly from Sialkot and Tuttlingen.

There are three important distinctions to note in the nature of ties between Tuttlingen and Penang on the one hand, and Sialkot on the other. First, the range of producers and traders who have either direct or indirect ties to Sialkot is large. It includes large firms as well as small producers unable to compete against Sialkot. In contrast, ties with Malaysia are restricted to the cluster's lead firm, and to one other large firm that has a local subsidiary in Penang. Second, Pakistani capital has established a significant trading foothold in Tuttlingen. Third, these patterns suggest very different forms of governance relations. Whereas ties between Tuttlingen and Penang are clearly hierarchical, those between Sialkot producers and Tuttlingen buyers range from arms length to quasi hierarchical.

This section provided a sketch of the two main clusters in the global surgical instruments industry. It shows how the clusters increasingly differ in their product ranges. Whereas Sialkot has improved its

competitiveness in traditional instruments, Tuttlingen firms are moving from mature products to new types of instruments. For Tuttlingen, product upgrading is driven by pull, the development of new medical technologies, and push factors, competition from low waged suppliers, not least Sialkot. The next section shows how the two clusters differ in their responses to new challenges and analyses how linkages within and between the two clusters change.

4 Upgrading in the Sialkot and Tuttlingen clusters

As we have seen, the global surgical instruments industry faces three distinct, yet inter-related, challenges: first, the challenge to reduce costs; second, the challenge of international standards, especially on quality assurance; third, the challenge of new product development arising from advances in medical technology. All three challenges have implications for production and for knowledge systems, and call for distinct forms of process (improvements in production practices), product (improvements to existing products and development of new product lines), and/or functional (conducting functions that were previously not undertaken by the firm) upgrading. This can lead to the repositioning of firms, and clusters, within global value chains. As Humphrey and Schmitz (2000) have noted, the potential for upgrading is related to the nature of local governance within the cluster, and global governance within the value chain.

The subsequent discussion is structured around the three distinct challenges and seeks to unravel the pattern of upgrading in the two clusters. We review upgrading at the level of individual firms, at the level of the cluster and of the value chain. We also explore how distinct forms of upgrading are tied to linkages within the cluster, and to interaction within the global value chain.

4.1 Cost challenges and upgrading

Cost pressures are both supply and demand driven. In the area of traditional surgical instruments, there has been a sustained entry of lower cost producers. The Tuttlingen cluster has had to confront competition from Sialkot, while intense local competition within Sialkot has systematically lowered product prices. In addition to cost pressures from below, there are demands from buyers and end-users to lower costs. As medical budgets come under increasing strain, health care providers are under greater pressure to be cost-efficient in health care delivery.

There are various responses at the firm level to these pressures. In terms of process upgrading, firms in Tuttlingen have introduced new, productivity-enhancing, machinery. This includes various CNC machine tools used for a range of processes, including grinding and milling, laser-cut welding and die-making. Moreover, many firms have adopted an advanced production flow. Process upgrading is reflected in superior outcome: of 23 firms sampled that reported upgrading processes, 19 also stated that they had increased turnover in the last five years. Most of the 30 large Sialkot firms have also acquired NC and CNC machine tools, as well as improved forging, heat treatment and die-making equipment. This has raised product quality in Sialkot as standards of forging and metal hardness rose. One sign of this has been the reported decline in average reject rates, from 7 per cent to under 3 per cent for the sample as a whole,

and to around 1 per cent for large firms. These improvements are not restricted to large firms alone. Specialist forging sub-contractors have acquired NC-die machines and hammer forges, while higher quality vacuum furnaces for heat treatment are now used by all of the cluster's specialist heat treatment service providers. Thus, process technology benefits are availed by smaller firms through their use of specialist subcontractors.

Another response to cost pressures has been to squeeze labour. In Tuttlingen, there are qualitative signs of greater self-exploitation by individual craft-based units through increased working hours. There is also greater reliance, primarily by small firms, on specialist local sub-contractors for labour intensive processes such as polishing. Of the firms interviewed in Tuttlingen, 17 increased local outsourcing in the past five years, compared with only three that brought production steps in-house.⁸ Similar patterns are seen in Sialkot. Reliance on sub-contractors is high, especially for small and medium sized firms; working conditions are often poor, especially in small sub-contracting units.

A more significant response by Tuttlingen firms to costs pressures from low waged competitors is to outsource production to Sialkot and other low cost locations. As shown above, this accounts for a significant volume of trade between the two clusters, and for links between Tuttlingen and other locations. This practice began with job processing, whereby Sialkot firms undertook specific, labour-intensive, tasks. There is now a move from job processing to increasing OEM production by Sialkot suppliers and by foreign subsidiary plants of Tuttlingen firms. This has different implications for firms in the two clusters. As a number of mature product lines move from the Tuttlingen cluster to Sialkot, and other locations, firms in Tuttlingen have sought to upgrade into new product lines, as well as move into trading. Thus, the Tuttlingen cluster's lead firm now relies solely on its subsidiary plant in Malaysia for production of standard surgical instruments, which up to the late 1970s were primarily produced in Tuttlingen. Similar responses can be observed in other Tuttlingen firms that now rely on Sialkot and Eastern Europe for the manufacture of standard instruments.

The growth of trading has been a key feature in Tuttlingen in the past decade. A number of former producers have completely shifted to trading while others have increased their trading activities. Most traders, either directly or indirectly, source instruments from OEM suppliers in Sialkot. This move towards trading points to one form of functional upgrading. It also reflects the competitiveness of Sialkot manufacturers in the mature instruments sector.

These changes in Tuttlingen, open up new opportunities for Sialkot producers, to enter into product ranges that were formerly the preserve of Tuttlingen firms. There is evidence of Sialkot firms producing more complex instruments, including Tungsten-carbide (TC) tipped instruments used in vascular surgery and laryngoscopes which require some electrical and optical functions. Tuttlingen producers and traders also report investing in ties with Sialkot producers. This includes building long term relationships, transferring machinery to Sialkot, undertaking inspections of production facilities in Sialkot and providing

⁸ This finding has to be treated cautiously, business cycles appear to have a big influence on the levels of subcontracting.

training and technical advice to Sialkot suppliers. The most developed form of such investment in Sialkot is the joint venture plant of the second largest Tuttlingen instrument producer.

Earlier research in Sialkot confirms such practices, with local respondents reporting German buyers undertaking annual inspections, and sending skilled technicians to raise metallurgical capabilities (Nadvi 1999a). This is also borne out by our surveys undertaken in 2000 in both clusters. Of the sub-sample of 38 producers and traders mainly engaged in the surgical instruments sector in Tuttlingen, ten directly sourced from OEM suppliers in Sialkot. Of these, eight claimed to have been the main actors responsible in raising product quality of their Sialkot suppliers. Small firms regularly reported visiting Sialkot to instruct local suppliers on quality improvements, while large firms had invited Sialkot workers to Tuttlingen for further training. Similarly, of the 42 producers interviewed in Sialkot, fifteen stated that their main buyer was in Tuttlingen. Of these, seven were large producers. Ten firms reported that their main Tuttlingen buyer was also engaged in production, and six claimed that their major source of new know-how came from their Tuttlingen buyer.

We have so far concentrated on the upgrading responses to cost pressures from below. Pressures to reduce costs coming from buyers and health care providers sometimes take distinct forms. Halder (2002) reports the growing practice of hospitals making joint purchases of instruments in order to reduce unit purchase prices. The development of minimally invasive procedures have also reduced post-operative costs and increased surgical turnover (Grönemeyer 2000). This has forced instrument manufacturers to undertake process and product upgrading. Changes in hospital practices, driven by cost pressures, have also led to forms of functional upgrading by instrument suppliers. Some large European hospitals are seeking to transfer instruments inventory costs to their suppliers, and to encourage leasing, as opposed to outright purchase, of complex instruments. These developments are changing the nature of functions undertaken by leading producers in Tuttlingen.

The cluster's lead firm is at the forefront of functional upgrading in response to demands from hospital buyers. It has developed a capacity in the area of services, focusing on the tracking, sterilisation, maintenance and repair of surgical instruments and apparatus held by individual hospitals. It has acquired a technical capability to track instrument usage through a joint venture arrangement with a foreign partner. Through its merger with a large German (but not Tuttlingen-based) medical products supplier, the lead firm can now provide buyers with the complete complement of instruments and medical products required by hospitals. This enhanced capacity has meant that the lead firm is able to supply full operation kits. By improving its logistics capabilities, it can now supply complete operation kits to hospitals within Germany on a next day delivery basis. Key informants suggest that leasing – at least of sophisticated and infrequently used – instrument kits will grow in importance in the near future. These developments transform the functional capabilities of the lead firm. In addition to being a producer of surgical instruments and implants, it is in the process of becoming a complex service provider to the health care sector. It can be expected, that alongside this development, economic rents (Kaplinsky 1998) will shift subsequently from production to trade and services.

4.2 Quality assurance and upgrading

Since the early 1990s the medical products sector in most Western countries has had to comply with international standards on quality assurance. The US Food and Drugs Administration (FDA) requires all medical instruments suppliers in the US to conform to its good manufacturing practices (GMP) standards on quality assurance. Similarly, the EU directive (93/42/EEC) requires all producers of medical devices to meet international quality assurance standards (such as ISO 9000 or EN 46000). These regulatory demands emerge from public concerns, often linked with litigation, to raise quality standards in areas that directly effect the health, safety, and lives of patients and medical professionals. Improving accountability and traceability to ensure that recognised quality procedures are adequately followed at each and every stage of production, reduces the vulnerability of buyers to failures by their suppliers.

Adopting quality management standards requires detailed documentation of procedures for internal and external audits, training of personnel, and constant monitoring of quality performance measures. Implementing such standards can imply changes in production organisation and management practices. It can also have implications for the relationships that producers have with their suppliers. Furthermore, standards can have a differential impact. Small firms often lack the knowledge and resources required for such process and management upgrading, and the costs incurred in implementing standards and undertaking external audits can be prohibitive.

Compliance with international quality assurance standards in both the Tuttlingen and Sialkot clusters is extensive. ISO 9000 standards were widely adopted in Tuttlingen in the early 1990s. Local cluster institutions attempted to facilitate this process through critical know-how and joint auditing. In practice, most firms achieved compliance with the assistance of market-based consultants and auditors. ISO 9000 is no longer considered a challenge for Tuttlingen, although it remains an important concern for some of its lower-waged suppliers.

In the mid 1990s, firms from the Sialkot cluster were excluded from the US market for failing to comply with US' GMP standards, and were under growing pressures to attain ISO 9000 certification for the EU market. This forced local producers to improve quality management procedures, or risk losing markets. The response was rapid. By 2000 well over two-thirds of Sialkot's producers had attained either the GMP or ISO 9000 standard, or both. This is a remarkable achievement given the poor base of management expertise in the cluster, and the low levels of literacy of much of the local labour force. Compliance was directly facilitated by local joint action and, to a lesser extent, local firms' ties with external buyers.

The cluster's leading trade body organised a collective response to the US quality assurance "shock" by providing technical information and hiring a foreign technical consultant, paid in part by local firms, to train producers and improve their quality management procedures. Within a period of two years, some 200 local firms were compliant with the US standards (Nadvi 1999b). The know-how acquired from this process helped local firms to later meet ISO 9000 standards. In addition to local joint action, value chain ties were also significant at least in the case of GMP standards. Buyers were reported as an important

source of technical information, and in some cases of material and technical support. Cooperation with buyers also emerged as the statistically most significant factor associated with firm growth (ibid.).

Thanks to the earlier experience with the GMP standards, widespread adoption of ISO 9000 standards in the Sialkot cluster (now held by over 170 firms) came with little or no support from local institutions or external buyers. Extensive knowledge spillovers on quality management practices and the increasing presence of specialised consultants and auditors facilitated the rapid adoption of the standards. Nevertheless, while most markets demand certification, the vast majority of sampled firms state that their buyers are more concerned with price, quality, and delivery reliability.

The key messages from the experience with quality assurance standards in Sialkot are, first, that Sialkot can deliver traditional instruments to the required global quality standard, although there remain concerns as to whether the imposition of quality standards actually brings about an improvement in product quality. Second, widespread certification has resulted in looser ties with customers and increased competition among Sialkot producers. Small firms are particularly squeezed. Third, low prices have deepened the division of labour between Sialkot and Tuttlingen in the field of traditional instruments.

4.3 New product development and upgrading

The medical engineering sector is not only one of the most technically sophisticated industries, it is also one with a significant outlay on research and development. According to Anderton and Schultz (1999: 16f), R&D in medical engineering accounts for an average of 10 per cent of sales, ranging from 5 per cent in the precision engineering branch of medical equipment production to 20 per cent in the field of diagnostics.

In the last two decades, new technology has resulted in radical changes in the field of surgery. During the 1980s the development of endoscopes provided surgeons with a clear view of the abdominal cavity without resort to major trauma surgery. This advance allowed new operating techniques using specialised instruments. Such instruments could be inserted into the body cavity through small incisions, and came to be known as key-hole or minimally invasive surgery (MIS). MIS reduced hospital costs for patients, through quicker operations, often requiring local as opposed to general anaesthetics, and involving shorter post-operative recovery time. The use of this technique began initially with gall bladder operations. During the 1990s, minimally invasive surgical procedures proliferated to include various types of obstetrics and gynaecological, abdominal, thoracic and head and neck surgery. The range of minimal invasive instruments expanded to cater to the needs of new operations. Recently, research has begun in developing multi-purpose instruments, that allow surgeons to carry out a mix of functions and thus further reduce operating time. There have been further developments in this technology, such as the use of lasers and electro-medical scissors as cutting instruments, and advances in micro-surgery.

Another area where surgical treatment has advanced is through the development of surgical implants, including hip and knee joints, heart valves and other body parts. Implants are complex products, they must not only mimic the function of the body part they replace, they need also to be of materials that are durable and that are not rejected by the human body. New advances in bio-medical engineering,

re-absorbable implants, robotics, and tele-surgery (that allow surgeons to conduct operations remotely using robotic technology and instruments) are likely to further alter conventional surgical practices.

These technical advances have significant implications for the Tuttlingen and Sialkot clusters. MIS instruments are produced using similar technologies to those required for mature instruments, but call for enhanced skills. Large firms were initially at the forefront of this development in Tuttlingen. They began manufacturing MIS instruments in the mid-1980s. From the early 1990s, production of MIS instruments spread widely amongst small and medium sized firms in the cluster. Of the 29 medium sized instrument manufacturers (employing between 20 and 50 persons) in Tuttlingen today, 15 produce MIS instruments, while four firms are partly engaged in other fields of advanced medical engineering. In contrast, only a few of the larger firms in Sialkot are in a position to enter into production of even the technically less complex types of MIS instruments.

Tuttlingen has also seen the rapid development of the endoscope sub-sector, with one of the leading global endoscope manufacturer in the cluster. This firm began life in the 1960s as a classical surgical instrument producer. Another large, and technically advanced, endoscope producer in Tuttlingen is a leading OEM supplier to international buyers. Initially a producer of metal and glass syringes, this firm entered endoscope production by acquiring a firm engaged at the early stages of the development of endoscopic technologies.

The manufacture of endoscope, implants and apparatus now accounts for approximately half of total medical engineering employment in Tuttlingen. Tuttlingen's ten largest firms are all specialised in one or other of these new product lines. At the same time, many of the cluster's small firms have specialised in minimal invasive instruments, while some have begun to produce less complex surgical implants. These new products point to the substantial product upgrading that has taken place in Tuttlingen in recent years.

Such upgrading is an outcome of the research and development activities of individual firms, as well as technical benefits that have emerged through local cluster linkages and through chain ties. The development of endoscopes and implants has often required more technical as opposed to medical knowledge. Computer aided design, materials technology and advanced engineering techniques have been used. In contrast, development of many of the new minimal invasive surgical instruments have required close contact with surgeons to acquire a better understanding of the functional needs of such instruments.⁹ Thus firms in the instruments field that have been engaged in developing new minimal invasive instruments, have had to invest in ties with direct end-users, surgeons. While this has also been important for technological advances in surgical implants and endoscopes, advances in these fields have often required close ties with knowledge-intensive institutions and firms in other advanced technical sectors. Thus, for example, in the development of endoscopes, leading producers in Tuttlingen have had to engage with technical leaders in microscopic lighting, optical lenses and video camera technology. One

⁹ Close cooperation between manufacturers and surgeons has also been important in the development of other sub-sectors in medical equipment (see Lawson and Lorenz 1999: 313).

large Tuttlingen-based endoscope producer acquired a specialised German optical lens manufacturer to enhance its technical core competence.

Firms developing new products need to work with their customers, especially hospitals. Detailed and lengthy clinical trials and adequate testing of new implants are required before they can be licensed for use. This calls for close collaboration with hospitals and surgeons. While such trials are often standardised in nature, there needs to be close dialogue and feedback between surgeons and producers in order to perfect implants.

While developments in new product technologies have required significant forward linkages, there has been no pressure to enhance backward linkages in the value chains. None of the leading producers of endoscopes and surgical implants, with the exception of the cluster's lead firm, have direct production ties with either the Sialkot cluster or with other low waged production locations. In fact, one leading apparatus manufacturer which sourced instruments from Sialkot, sold its traditional instrument division five years ago as it no longer saw this as its area of core competence.

Local cluster linkages have had a limited role in promoting upgrading around the new products in Tuttlingen. The local business Chamber, through the Forum Medizintechnik, organises lectures on medical and technological innovations that have a bearing on the cluster. In addition, the Chambers undertake initiatives to promote upgrading by the cluster's smaller firms. This includes providing such firms with direct contacts to surgeons and informing them on developments in trade laws and medical practices. The BBT training institute has the technologies and machine tools used in many of Tuttlingen's factories, including the new laser welding machines and CNC machine tools. It trains workers to produce all kinds of instruments including MIS instruments. While not specifically geared to training on implants and endoscopes, many of metalworking skills imparted by the BBT are transferable to the new product sectors.

An important new cluster initiative, aimed at enhancing the ability of local firms on the area of minimal invasive instruments is the Competence Centre. While it is too early to assess the impact of the centre on the cluster, a point to note is that only the medium and large firms have the technical capabilities to actually engage with the Centre. Collectively, the various cluster initiatives tend to be geared to process and not product upgrading. Nevertheless, it is apparent that local linkages have not been important for developing new products. Once new products are developed, however, local linkages do matter especially for smaller firms who seek to copy or modify these products.

The findings from Tuttlingen support the argument that competitive pressures are especially acute for (a) small firms and (b) for firms in the field of classical surgical instrument. Of the 21 small firms interviewed in Tuttlingen, 17 were mainly producing classical surgical instruments. Of the 14 medium to large firms, eight are engaged mainly in the advanced fields. Amongst the small firms 13 expect turnover to decline in the next five years, while all medium to large firms expect an increase in turnover.

4.4 Summary – challenges and upgrading responses

The surgical instruments industry faces inter-connected challenges. The two clusters have responded by upgrading in different ways. The first challenge is the relentless price competition. The Tuttlingen cluster responded by using labour saving equipment (process upgrading); moving out of labour-intensive processes and mature products to new, technically more sophisticated, instruments (product upgrading); and concentrating on sourcing from cheaper OEM suppliers of classical instruments and on distribution and service activities (functional upgrading). Firms in Sialkot improved production organisation (process upgrading) and raised product quality (product upgrading). Intense local price competition leads, however, to the fact that many firms in Sialkot continue to pay low wages and accept decreasing profit margins.

The second challenge centred on the implementation of quality assurance standards. Tuttlingen responded in the early 1990s by complying with ISO standards and strengthening brand identity (process and functional upgrading). Quality assurance is now only a problem when sourcing from outside Tuttlingen. This challenge has been especially acute for Sialkot. Compliance with international quality assurance standards is now widespread due to significant process upgrading within the cluster. In part, this was brought about through local linkages, and in part through links with buyers, especially in Tuttlingen. But, compliance has led to looser ties between Sialkot manufacturers and their buyers.

The third challenge is associated with the development of new products. The development of minimal invasive instruments, endoscopes, implants and surgical apparatus, has opened new production frontiers for Tuttlingen's firms. Product upgrading has been widespread, and 26 out of 35 interviewed producers have been able to innovate or to improve their products at least incrementally. The cluster's leading firms made major investments in design and new product development. This was facilitated by their links with end-users, and with firms specialising in complementary technologies. Nevertheless, there is a clear differentiation. The cluster's large firms concentrate on endoscopes and implants, leaving production of minimal invasive instruments to medium and small firms in Tuttlingen. This differentiation points to the distinct knowledge requirements of these product groups, and to knowledge flows within the cluster. The Sialkot cluster, however, lacking either the technical capabilities to manufacture the new products or access to end users, has been unable to respond to this challenge. These differences between production and knowledge flows, have important implications for the trajectories of the two clusters. The next section explores this further.

5 Knowledge flows and production flows

As argued in this paper, the global surgical instruments industry has been transformed in the past two decades by challenges from low cost suppliers in the developing world, demands from final markets to comply with global quality assurance norms, and advances in medical and surgical technologies. This has implications for how production and innovation are organised and where they are located. The industry has become increasingly differentiated. This differentiation has occurred within, and between the clusters. This section examines in more detail how knowledge flows, while connecting the two clusters, lead to distinct patterns of product specialisation

Clearly, knowledge and production systems are closely inter-related. This is a central theme in much of the innovation and learning literature (see Lall 1992; Camagni 1991; Bell and Pavitt 1993; Storper 1993; Maskell and Malmberg 1999). Lundvall (1988), for example, stressed the learning potential of user-producer interactions. Stewart and Ghani (1991) observed how knowledge spillovers arising from firm agglomerations accelerated technical learning. Audretsch and Feldman (1996) took this further, arguing that innovation patterns in clusters are associated with product life cycles.

However, as Bell and Albu (1999) note, knowledge systems need to be distinguished from production systems. The latter refers to those processes that link labour, machinery, inputs and product designs that result in the manufacture and delivery of goods. In contrast, a knowledge system is dynamic. It consists of knowledge stocks (held within firms and individuals), knowledge flows (that take place within firms, between firms, within clusters, and along the value chain), and the 'organisational systems involved in generating and managing changes in the products, processes or organisations of production' (Bell and Albu 1999: 1723). Bell and Albu (1999) make a further distinction between the ability to apply and reproduce existing knowledge (what they refer to as knowledge-using capabilities), and the ability to innovate, adapt and absorb new knowledge (knowledge-changing capabilities).

As we show in the case of the global surgical instruments industry, distinguishing between knowledge and production systems helps illustrate the differentiation within and between the two clusters, and outlines their distinct dynamic trajectories.

We show how knowledge and production flows at the level of the firm, the cluster, and the chain are differentiated between the mature product sector and the new product sector. The mature products sector consists of classical hand-held stainless steel surgical instruments. Many of these are technically complex products, and their manufacture requires skills in metalworking, metallurgy and materials. Most of these skills are held by craft-based artisans in both Tuttlingen and Sialkot. The new products sector requires the marriage of traditional metalworking skills with new skills and capabilities in optical technologies, in non-metal materials technologies, especially ceramics and plastics, and in electronics. This implies different forms of knowledge from that required to produce traditional instruments. In the latter case, knowledge flows are internal to the cluster and to the production chain and in the context of traditional clusters, heavily reliant on tacit knowledge of the particular workforce. In contrast, knowledge flows in the new products sector go beyond the cluster and the production chain, to include ties with end users in the value

chains and with suppliers of specialist services and complementary technologies. As this new knowledge is tacit for the period of invention, it may be codified easily afterwards.

5.1 Knowledge and production flows in mature instruments sector

There are over 20,000 different types of surgical instruments that come within what we describe as the “mature” product sector. Many of these instruments were originally developed some fifty or more years ago. While most have been refined, incrementally improved, or adapted for particular markets, the bulk of these instruments are relatively standardised. Technical specifications are well known, and product blue prints widely available. The manufacture of such instruments requires various metallurgical, chemical and metal working skills. This includes knowledge of making appropriate steels, of making dies, and of forging, grinding, milling and filing of metals to high levels of precision. Some of these processes can be easily mechanised. Others rely heavily on skilled manual labour and incorporate the tacit knowledge of craft workers. Such knowledge is concentrated in the Tuttlingen and Sialkot clusters. It can also, as the experience from Malaysia indicates, be fostered by external actors in locations that have no earlier metalworking history. Thus, tacit knowledge in this sector can, as the Malaysian example suggests, be codified.

Historically, innovation in surgical instruments was concentrated in the West, especially in Tuttlingen. Mature instruments were originally designed through the collaborative efforts of surgeons, as end-users, and instrument manufacturers. Tuttlingen boasts long-standing links with leading surgeons, and can be seen as an example of successful user-producer interaction. While the majority of mature instruments are now well known products, for both manufacturers and end-users, incremental innovations and improvements continue. Again, this usually requires interaction between surgeons and producers.

What is apparent is the ways in which production flows in the manufacture of mature surgical instruments have transformed the industrial map of the global surgical instruments industry. While Tuttlingen continues to hold a quality advantage, as well as critical commercial benefits of reputable brand-names, the extent of production of such instruments has been declining within the cluster since the 1970s. Less than half the total employment in the cluster is currently engaged in producing mature products. Instead, many of Tuttlingen firms have turned to OEM suppliers in Sialkot, and to a lesser extent in other locations, to furnish it with such instruments. Tuttlingen firms provide distant suppliers with instrument designs and specifications, sometimes inputs and materials as well. There is also a clear flow of technical knowledge, aimed at process upgrading and involving machinery and advice on production organisation, from Tuttlingen to Sialkot. A similar pattern is seen with the cluster’s lead firm and its subsidiary in Penang.

However, the flow of technical knowledge is costly, time consuming and unpredictable in its outcome. One concern is the very tacit nature of knowledge in surgical instrument production. This can be observed by a statement heard frequently during the fieldwork in both Tuttlingen and Sialkot: ‘To be a good instrument manufacturer, you need at least ten years experience’. Despite the three years of formal training required in Tuttlingen to adopt the formal qualification of the profession, one can see that in both

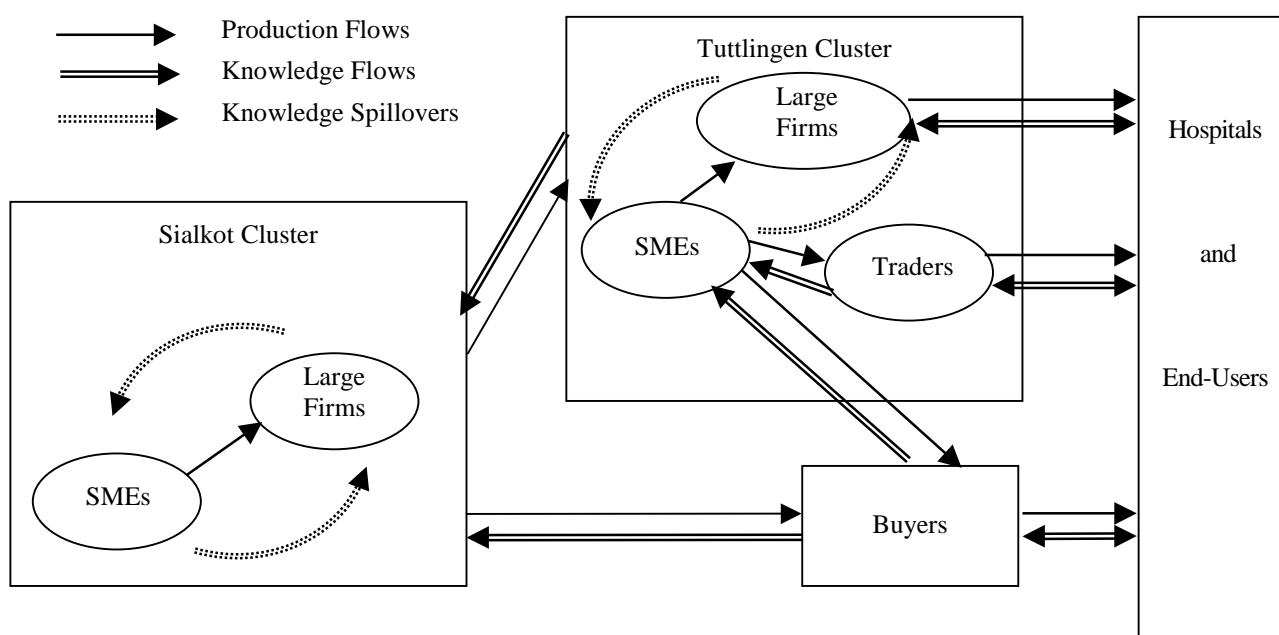
clusters knowledge is very much bound in with the levels of experience of individual workers. Yet, in Penang Tuttlingen's lead firm has managed to offset the absence of a local knowledge base in metal-working by mechanising key processes, and by investing in a thirty year period of constant knowledge transfer. A similar pattern of long-term knowledge flows is also seen between Tuttlingen and Sialkot. Thus, in both Sialkot and Penang, as mentioned earlier, the development has gone through different steps starting with job processing to OEM-production. Key informants have stated, that the lead firm has managed to upgrade its facility in Penang in a way that it is able to produce at the required quality of advanced markets in Europe or North America. In contrast, Tuttlingen firms state that they still have to inspect, and often partly rework products, acquired on an OEM basis from Sialkot to make them acceptable for quality-driven markets. This difference may be an outcome of different governance and ownership patterns, leading to different degrees of investment in partners abroad.

This has implications for the Sialkot cluster. There is a pattern of differentiation. Firms that act as OEM suppliers in Sialkot are mainly large or medium sized units. Small firms, with some notable exceptions, usually lack the requisite capability to produce the volume, the required quality and meet the delivery schedules imposed by buyers in Tuttlingen. Small firms are thus often restricted to lower quality, and lower value products that are distributed through production channels dominated by Pakistani traders abroad. In contrast, large and medium sized firms have grown, in scale and in technical ability. The degree of job processing is declining as sales of finished and semi-finished instruments increases. And the range and quality of instruments produced by such firms in the cluster has expanded. Some of the technically more able firms have also begun to specialise in more complex product lines, such as laryngoscopes. Moreover, along with the advances in product quality observed in Sialkot in recent years, Sialkoti firms have acquired a strong position in the expanding and high volume field of disposable instruments, a sub-sector where price competition is key.

For Sialkot's firms, operating in the cluster continues to generate important agglomeration economies. Some forms of institutional collaboration are also important, as was seen with collective response to the challenge posed by international quality standards. Yet, acquiring technical know-how and learning is increasingly determined by forward linkages with external actors. For many smaller firms, the flow of information within the cluster facilitates the process of technical learning, as skilled workers and sub-contractors move from factory to factory. Nevertheless, the concentration of new knowledge in the hands of the larger producers suggests a process of further differentiation within the cluster. Some large firms, including the largest firm in the Sialkot cluster, have sought to enhance their role as OEM suppliers to German and other foreign buyers, by developing their own brands. While original brand manufacture (OBM) is relatively limited, in the area of disposable instruments and in some of the more common, volume-based, clinical surgical instruments, this offers a potential growth path for Sialkot's larger producers. It also implies that some of Sialkot's technically more competent producers can eventually enter the field of minimal invasive instruments. There is little to suggest, however, that firms in Sialkot could move to own design manufacture. Not only do the cluster's leading producers lack internal design capabilities, they also have no direct knowledge links with end users, either in Pakistan or abroad.

As we have mentioned earlier, the manufacture of MIS instruments require the same set of skills, albeit at a higher level of precision, as producing classical instruments. There is, therefore, no reason to doubt that the production of such instruments, initially through job processing and subsequently on an OEM-basis, could be transferred to Sialkot, or by Tuttlingen's lead firm to its subsidiary in Penang.

Figure 5.1 Knowledge and production ties between Sialkot and Tuttlingen in the mature products sector



As we have seen in the mature products sector, the knowledge system in Sialkot is largely tied to existing knowledge stocks of local artisans, and knowledge flows from Tuttlingen producers. Such knowledge flows closely follow material and products flows, but the knowledge flows are uni-directional, from Tuttlingen to Sialkot, and are found in existing and well established channels that links Sialkot producers as OEM suppliers to Tuttlingen's firms. Such knowledge flows essentially enhance, what Bell and Albu (1999) term, knowledge-using capabilities. Acquiring know-how on adopting quality assurance procedures in production processes, and incorporating new technologies in manufacture, has helped local producers in Sialkot to produce mature instruments more efficiently and meet quality assurance demands. It has not, however, led to the development of knowledge-changing abilities within the cluster. Nevertheless, the Sialkot cluster was able to upgrade within the existing knowledge system. Cluster gains mattered, especially in terms of knowledge spillovers. Yet, as Maskell and Malmberg (1999: 177) would put it, Sialkot's firms by imitating the skills that Tuttlingen had earlier acquired in the mature products sector, were in effect 'spending time and effort in learning yesterday's ways and skills'. But this is not inconsequential. By raising its competence in production of mature instruments, Sialkot has applied immense pressure on Tuttlingen. The response to this pressure has been uneven. Small firms in Tuttlingen have largely followed a

“re-active” strategy, resulting in a shift towards trading activities, as well as a decline in the production (and employment) in mature instruments. Large firms, however, have adopted a “pro-active” response. Engaging suppliers in low cost locations, and enhancing their knowledge changing capabilities in order to move into the new products sector.

5.2 Knowledge and production flows in the new products sector

The new products sector includes the expanding range of minimal invasive instruments, endoscopes and surgical implants. In the following discussion, the technological conditions for the development and manufacture of these products are outlined, and their implications for, first the production and knowledge system, and second, for value chain relations and cluster ties, considered.

Each of these product ranges require awareness of metal working skills. However, these complex products link metalworking knowledge with complementary technologies. Thus, the production of endoscopes requires knowledge of optical lens, electrical, especially miniaturised image-enhancing lights, and video technologies. The manufacture of surgical implants calls for knowledge of materials technology, especially ceramics, plastics, metal alloys and titanium, and specialised surface treatments. It also relies heavily on sophisticated machine tools. Even the manufacture of minimal invasive instruments, which is primarily based on existing metal-based and metal-working knowledge, calls for enhanced skills in miniaturisation, and for some instruments, awareness of ceramic and plastics technologies. The more advanced minimal invasive products often involve an interface with sophisticated electrical measurement apparatus that help surgeons better visualise and control the instruments’ functions.

Access to such knowledge requires ties to technical skills that lie outside the Tuttlingen cluster. Thus, Tuttlingen’s endoscope producers have either acquired, or entered into collaborative joint venture agreements with specialised firms in the field of optical lenses from outside the cluster. Some of the firms that have been acquired were previously suppliers. By bringing these firms in-house, as it were, endoscope manufacturers successfully internalised the new specialist technologies. In the case of surgical implants, some firms strengthened backward linkages with specialist machine-tools suppliers, thereby enhancing their capabilities in the complex manufacturing procedures required for sophisticated implants.

In addition to links with firms from outside the Tuttlingen cluster, ties with end-users are important in the development of some of the new products. Design innovation in minimal invasive instruments requires close interaction with surgeons. As with the development of classical instruments, surgeons help firms specify the functional requirements of instruments. In addition, firms in the new products sector increasingly draw on specialised technical public and private research institutes from outside the Tuttlingen cluster.

These developments outline how, for firms engaged in the manufacture of the technically more advanced new products, ties external to the cluster gain importance. These ties either involve forward linkages within the value chain, such as the relationship with key surgeons in the production of MIS instruments, or backward linkages, as with machine tools producers in the implants sub-sector. They also underline the fact that as firms move from the mature products sector to new products, they also enter

into new technical paradigms, involving new kinds of technical partners and competitors. Thus, for example, an important competitor for Tuttlingen's endoscope producers is Olympus, a firm famous for cameras which has diversified into the medical technologies sector and is a leading global producer of flexible, fibre-optic, endoscopes.

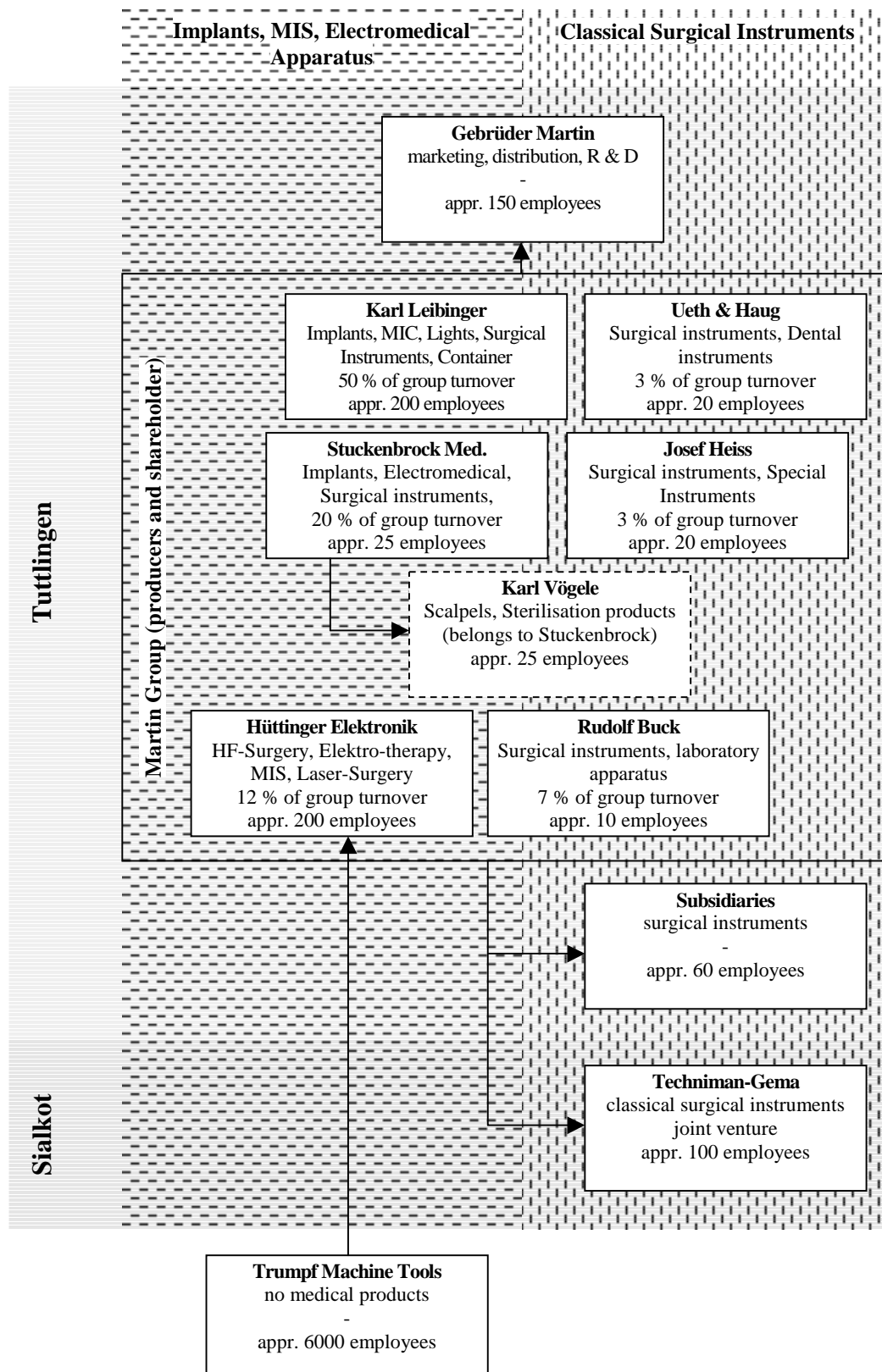
This would suggest that in the development of the new products sector, local, cluster-based, knowledge ties are not of strategic importance. Local linkages, however matter for production flows and some knowledge flows. Take production flows. As many of the large firms move into the new products sectors, most continue to supply a range of instruments, including minimal invasive instruments and also classical instruments. To do so, they source from small OEM suppliers in Tuttlingen. Thus, for example, the cluster's lead firm has for some time relied on local OEM suppliers of specific instruments, although there are signs that this reliance is now decreasing. Both groups of associated firms in Tuttlingen continue to turn to local OEM suppliers. The leading firms in the endoscope sector also rely on local suppliers to ensure that they can offer the full range of products under their name. Thus, cluster-based economies of scope, arising through local production linkages remain important to large firms.

Similarly, local knowledge have not become unimportant. At the very basic level, the cluster offers new products manufacturers a pool of skilled and technically able labour. This skill base, reinforced through local institutions such as the BBT, has both tacit knowledge and a thorough technical understanding of the industry. This makes it relatively easier, and quicker, for such labour to absorb the new know-how and technologies for developing the new products. Furthermore, the flow of technical knowledge within the cluster, through for example the movement of workers from firm to firm, raises the capabilities of many of the cluster's smaller producers. Thus, such firms acquire the capacity to eventually develop into OEM suppliers to the cluster's technical leaders. Moreover, skilled workers with the cluster's leading firms often leave to set up their own enterprises. These small spin-offs, while lacking the capability to develop new products, can copy and modify some of the new instruments at great speed. Such patterns of knowledge diffusion within the cluster stress the continuing importance of external economies in Tuttlingen's new products sector.

Some of these links at the level of production and knowledge within the cluster, and between the Tuttlingen cluster and the Sialkot cluster, are captured in Figure 5.2 on one of the leading firm associations in Tuttlingen. It shows that the larger firms in the group have become implant manufacturers. Recently, they have strengthened ties with a major machine tools producer which has bought shares of the group. These ties are particularly significant for knowledge flows, given the significance of the machine tools sector to the manufacture of surgical implants. At the same time, the group has a wholly owned firm in Tuttlingen that supplies MIS instruments as well as more complicated classical instruments, and a joint venture unit in Sialkot that is largely responsible for the production of classical instruments. The group is thus able to market, under its well-recognised brand name, a wide range of products, including a full complement of all necessary surgical instruments to hospitals. It is also able to enhance its growing strength in the surgical implants sector through its direct links with the machine tools producer. Thus, in terms of employment, the group as a whole is the second largest surgical instrument manufacturer as well

as the second largest implant producer in Tuttlingen. There are various forms of knowledge flows and governance ties within the group. The Sialkoti joint venture obtains process knowledge from the group, and is governed through quasi-hierarchical arrangements. The ties with Tuttlingen, and other non cluster-based German, firms in the group are largely network-based relations.

Figure 5.2 Tuttlingen firm group and its production network

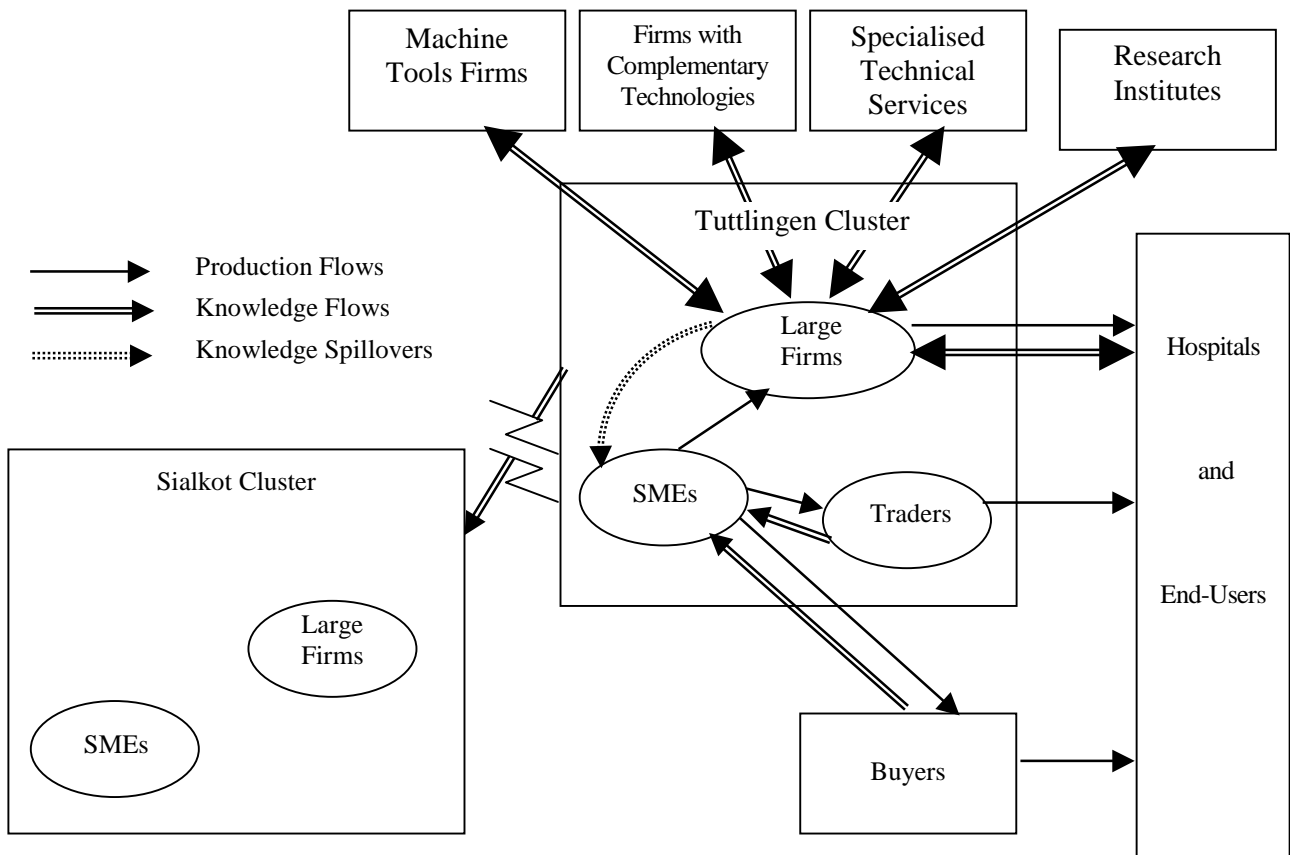


What is apparent is that the nature of product and knowledge flows reflects the differentiation within the Tuttlingen cluster. It is primarily the large and medium sized firms that have entered the endoscopes, implants and surgical apparatus sectors. Large firms – regardless of their primary product focus – have their own R&D staff. Small firms, alongside many of their larger counterparts, tend to be restricted to the instruments sector although many now also produce minimal invasive instruments. A number of the small firms also act as OEM suppliers to large firms in the cluster, while some small firms have branched out into the area of specialised surgical implants. Most small firms, however, do not have the capacity to develop radical new products, and lack resources and R&D functions (Halder 2002).

This disparity in the knowledge nexus of large and small firms becomes even more apparent in terms of the flow of specialist medical knowledge. Some large firms, such as Aesculap, the lead firm, employ specialised staff, including those with medical and surgical training, who are able to dialogue with end-users, read the appropriate technical journals and attend important surgical conferences and symposiums. It is not enough to have links with end-users. To be effective, such ties with surgeons requires these firm to be able to speak the technical language of surgeons, to understand the nuances within the surgical field and to have the power to convene meetings of surgeons. One key advantage of the lead firm in this area is that it has a medical conference unit on its Tuttlingen production site. This allows it to bring together leading surgeons from Germany and abroad, to listen to their deliberations, to engage them in discussions on product development, and not least to use this facility as an effective marketing tool. Small firms not only lack such facility, they do not speak the same language.

So where does this leave the cluster? As Figure 5.3 below shows, production and knowledge linkages arising from the new products, recognise cluster linkages especially at the level of production, but also emphasise the importance of knowledge linkages outside the cluster, and further up the value chain. Whereas knowledge flows within the cluster are essentially based on knowledge-using abilities (training of labour through the BBT, knowledge spillovers between local firms that accelerate the dissemination of manufacturing of new products within the cluster), knowledge flows that link cluster-based actors to firms and institutions outside of Tuttlingen enhance knowledge-changing capabilities. These distinct types of knowledge flows also underline how differentiation within Tuttlingen, as in Sialkot, is enhanced. Large firms have the technical knowledge base to make the qualitative leap to reach the technical frontiers in the development of many of the new product sub-sectors. As they do so, they also come into technical contact, and competition, outside the cluster with a wider range of actors in the medical engineering field. The smaller firms, however, have managed to make incremental improvements. Some have succeeded in becoming OEM suppliers to the large local producers, while a few spin-offs from large units have carved out specialist niches in the new products sector, copying developments learnt from working in large firms. Many small firms continue to sell directly through local traders and foreign buyers. However, pressures from lower cost competitors has forced a number of Tuttlingen's small producers to concentrate on trading.

Figure 5.3 Knowledge and production ties in the new products sector



5.3 Summary

This section sought to show how the distinct knowledge and production flows help explain changing ties within and between the cluster of Sialkot and the cluster of Tuttlingen. While local linkages remain important, it is apparent, both in Sialkot and Tuttlingen, that external ties matter more and more. Furthermore, the distinction between knowledge-using and knowledge changing capabilities helps distinguish patterns of radical and incremental upgrading within and between the two clusters, and the types of knowledge flows within and outside of the two clusters. In neither cluster do we see cluster-based knowledge flows as resulting in knowledge-changing abilities. Nevertheless, in both Sialkot and Tuttlingen knowledge flows that enhance knowledge-using abilities remain central to improving competitiveness. Finally, it is clear that these developments add to the on-going process of differentiation in both clusters, between small and large firms, between producers and traders, and between technical leaders and followers.

The distinct patterns of knowledge flows observed in the two clusters point to distinct cluster trajectories. These trajectories, as we have argued, are closely associated with the distinct nature of product life cycles. Sialkot is engaged in a strategy of enhancing its market share of the mature products sector. This requires upgrading, but based on enhancing knowledge-using abilities. In order to do this, it has relied on local cluster-based knowledge ties, and more importantly on external value-chain based knowledge ties. It is unable, however, to make the move to the new products sector. It lacks external

channels through which the requisite knowledge to enter this sector could be acquired, and the knowledge base to absorb this knowledge even if it could access it. It is only through further upgrading in the mature products sector, and through greater investment in knowledge-using abilities, will the Sialkot cluster be in a position to develop an ability to enter what is currently seen as new products. Tuttlingen's trajectory has two dimensions to it, one based on its reputational advantage which allows it to act as the trading hub in the mature products sector, and the other in its enhanced abilities in adopting knowledge-changing capacities through ties with external actors. As Nooteboom (1999: 132) has argued there is a trade-off between effectively exploiting existing knowledge and the ability to invest in new knowledge. This is apparent in Tuttlingen, with small firms focusing on the former, and large firms on the latter. Nevertheless, for the cluster as a whole, continued success rests on an agenda that incorporates both the development of new knowledge flows that leads to new products, as well as product flows, within the cluster and with lower cost locations, that enhance its ability to efficiently market mature products.

6 Conclusion

This paper began with the premise that while there is a substantial literature on industrial clusters (see Nadvi and Schmitz 1999) and on value chains (see the IDS Bulletin of 2001), there is less understanding of how industrial clusters feed into global value chains. In particular, there is limited comparative analysis of clusters from the North and the South, how they are linked, and how their position in the value chain differs. The paper set out to fill these gaps. Using the case of the surgical instrument sector, it explored the connections and differences between the sector's two leading production clusters, one in Germany and the other in Pakistan. It further considered how contemporary global challenges impacted on the linkages between the two clusters, and the ability of each cluster to upgrade. It used the framework of value chain analysis to investigate how upgrading leads to differing types of relationships between firms within each cluster, as well as between the two clusters. And, it used distinctions developed in the recent literature on knowledge systems to understand how and why the two clusters occupy complementary but increasingly different roles in the global surgical instrument industry.

This study takes the literature forward in several ways. First, the paper provides comparative evidence on clusters engaged in the same sector from the developed and developing world, outlining their differences and similarities. Together, the Sialkot and Tuttlingen clusters account for over 75 per cent of global manufacture of hand-held stainless steel surgical instruments. The two clusters share important similarities, in terms of their structure and with respect to collective efficiency gains, including cluster-specific agglomeration economies and joint action between firms and through local institutions. There are important differences as well, in terms of their relative scale of employment and sales, and in terms of their product ranges. The latter has become increasingly critical.

Second, while Amin and Thrift (1992) point to clusters as nodes in global networks, this paper provides empirical evidence on how such nodes are linked. In differentiating between these nodes, it shows how the developing country cluster concentrates on mature products whereas the developed

country cluster is focused on the development and production of new products. While the two clusters used to compete with each other in many product lines, the relationship has become more complementary as the range of products made by each cluster increasingly diverges. More than that, the two clusters have developed close ties with each other. From initially undertaking job processing functions, Sialkot has grown into an important location for original equipment manufacture for Tuttlingen producers and traders. Improvements in product quality and production capabilities has also helped firms in the Sialkot cluster export independently to quality driven markets in the US, Japan and the EC. Tuttlingen's producers have played a key part in channelling technical advice, equipment and know-how to Sialkoti partners. At the same time, the increasing price and quality competitiveness of the Sialkot cluster has led to many Tuttlingen's producers moving away from production to trading activities, and to sourcing more heavily from Sialkot. Finally, there are signs that Pakistani capital has established an important presence within the Tuttlingen cluster as key traders.

Since the Tuttlingen cluster marks the organisational hub of large parts of the production as well as of the distribution and the knowledge system in the sector, structural features have clear implications regarding upgrading and industrial policy. While the production capacity of the Sialkot cluster constantly evolves, partly due to knowledge flows from Tuttlingen, there is no indication that the division of labour between the clusters changes. And it seems that the distribution of gains confirms Kaplinsky's (1998) proposition. This is an outcome of the quasi-hierarchical chains between firms in both clusters. As Humphrey and Schmitz (2000: 23) suggested, in these cases knowledge flows remain at the sphere of production and avoid functional upgrading. Thus, by showing the linkages between the clusters, we outline their competitive edge as well as their constraints.

Third, by focusing on the responses to common challenges faced by the two clusters, the paper provides a dynamic perspective on the nature of inter, intra, and *extra*-cluster linkages as well as on differentiation within and between the two clusters. The new challenges facing the surgical instruments sector come primarily from competition from below, advances in medical technology and surgical procedures, and international production standards. To date, Sialkot has particularly been confronted by the latter of these challenges, whereas the first two challenges are most acutely felt in Tuttlingen.

The response to these challenges has meant that the Sialkot and Tuttlingen clusters have become more sharply distinguished in terms of their main product lines. This points to distinct forms of product and knowledge flows between, and within, the two clusters.

For Sialkot, process upgrading to meet quality assurance standards was initially brought about through local cluster linkages, and through knowledge intensive ties with external buyers in their value chains. Ties with Tuttlingen were especially significant in facilitating the flow of technical know-how to the cluster, both on implementing quality standards as well as in improving traditional, or mature, instruments. Upgrading in Sialkot was significant, but it was linked to enhancing the cluster's knowledge using abilities. This required both local and external knowledge flows.

Unlike Sialkot, Tuttlingen has seen radical product upgrading in recent years as the cluster's leading firms have moved their focus to new types of medical instruments. While this has required local linkages,

especially through the supply of skilled trained labour by the BBT, it has put a greater emphasis on external linkages. Innovation in MIS and surgical implants has required direct dialogue with surgeons and hospitals. Similarly, development of endoscopes has required firms to build links with firms specialised in complementary technologies, especially optical and electrical engineering. Finally, the implants sector requires close interaction with machine tools manufacturers and with specialists in ceramics, plastics and other materials technologies. It is possible to distinguish between local knowledge linkages, focussing on knowledge-using abilities, and external knowledge linkages, concentrating on improving the cluster's knowledge-changing abilities.

The capacity of Tuttlingen's firms to undertake new product development is also linked to their wider regional location. As part of the regional economy of Baden-Württemberg, Tuttlingen's leading firms can draw on the capabilities of the other knowledge intensive sectors. This includes machine tools producers (such as in nearby Gosheim), leading medical engineering firms (such as Maquet in Rasstadt, Richard Wolf in Knittlingen and Rösch near Stuttgart), advanced suppliers like Karl Zeiss in Oberkochen, leading technical research institutions, and key research-oriented medical facilities. In contrast, the Sialkot cluster operates in a relative vacuum, with little or no technical links to the local light engineering and metal products sector, or the wider regional economy of the Punjab or even to Pakistan's major hospitals.

A further dimension of upgrading in Tuttlingen is functional in nature. At present this is restricted to the cluster's lead firm. It nevertheless points to an important aspect of the growth trajectory of the cluster. Changes in the health care management systems are putting instrument suppliers under greater pressure to enhance the range of functions they offer their clients. It is not enough to supply instruments. Firms increasingly need to provide various services, from maintenance, repair and instrument sterilisation to instrument control and tracking systems. Moreover, as hospitals push inventory costs down the supply chain, suppliers need to invest in holding a wider and diverse range of medical products and providing sophisticated logistics and chain management. This can be beyond the scope of all but the larger firms. The pattern of mergers in the medical products and medical engineering sectors (such as between BBraun and Aesculap; or between Smith & Nephew and Baidersdorf) point to the importance of economies of scale and scope. These arise from size and the range of products that the larger enterprise can offer. The growing concentration in the wider global medical engineering industry thus has serious implications for the ability of local firms and clusters to access knowledge flows, and upgrade. This would suggest that external linkages, especially ties with the larger medical products firms, may gain in significance over local linkages.

Thus, external and internal linkages both matter for understanding the competitive strengths and weaknesses of the two clusters. And they matter for the design of local/regional industrial policy. Such policy cannot just focus on the clusters as an entity in isolation, but needs to recognise the critical importance of linkages to the other cluster. That other cluster, which used to be a rival can now become a strategic partner. Moreover, linkages external to both clusters, yet internal to the value chain, are likely to gain prominence in the future development of the two clusters, and in defining their competitiveness strategies.

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