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How does globalisation affect local production and knowledge systems? The surgical instrument cluster of Tuttlingen, Germany

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0. Abstract

The recent discussion of the winners and losers from globalisation has given prominence to regional development and industrial clusters in the global organisation of production and know-how. Tuttlingen, in southern Germany, is the recognised world leader in the global surgical instruments industry. However, price competition from emerging low-cost locations in South and South/East Asia and Eastern Europe, and rapid technological developments in medical engineering pose new challenges for the Tuttlingen cluster. In the past, institutional joint action was one of the pillars of the cluster's success, but there are doubts as to whether such institutions can face the new challenges. New public-private initiatives suggest a way forward, but it is too early to gauge their impact. In the past there were important examples of small and medium sized firms coming together in joint marketing, production, and research and development efforts. While they continue, local competition has become more intense, making inter-firm co-operation more difficult. Some firms do, however, co-operate with suppliers further down the value chain, particularly those in Pakistan and Malaysia. The new challenges are also leading to further differentiation, both amongst firms as well as between producers and traders within the cluster. The most radical forms of product and functional upgrading are being concentrated in the cluster's leading large firms. Innovation seems to be linked to close ties with end-users, the concentration of knowledge in medical engineering, and changes in surgical practices and health care delivery. Thus, the cluster while the 'big fish' in its own pond of surgical instruments, is having to come to terms with being a 'small fry' in the larger sea that constitutes the global health care sector.

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1 Introduction

The small town of Tuttlingen in Southern Germany has occupied an unrivalled position in the international surgical instruments industry. It now faces unrelenting price competition from producers in low wage countries and more exacting demands from increasingly powerful customers. Together, these factors are forcing prices down and quality up. Consequently, Tuttlingen firms have had to re-assess their position in the traditional surgical instrument industry. At the same time, additional pressures have arisen due to the emergence of new products, notably instruments for minimally invasive surgery and surgical implants. Furthermore, emerging technologies including biotechnology, robotics and micro-technology are transforming the classical art of surgery – at least in the major markets in North America, Europe and Japan. This paper examines if and how the cluster has responded to these challenges.

In the academic literature, there are several theoretical approaches that capture the success of regional economies. While some general patterns seem to be unquestioned, like the positive effects of external economies through agglomeration, there remain areas of debate. The literature on industrial clusters (PORTER 1990, 1998, ENRIGHT 1996) emphasises the stimulating effect of competition, whereas the industrial district approach leads us to look in particular at the potential gains from co-operation and the importance of knowledge spill-over and socio-economic features (e.g. BRUSCO 1990, BECATTINI 1991, PYKE & SENGENBERGER 1992, for a comparison,

see MARTIN & STUNLEY 1996). Tuttlingen is very much a cluster, but it is also part of a global value chain. In many ways it is the focal point within the global chain. What the paper analyses is how links at the cluster and chain level affect the ways in which Tuttlingen confronts the challenges it currently faces. These challenges relate to production (competition from cheaper labour producers) and knowledge (innovations and new technology, changes in health services in general and surgery in particular). These pressures underline that while Tuttlingen may be the big fish at the level of production within the boundaries of the surgical instrument value chain, within the framework of the wider medical engineering value chain it is a relatively small fry.

Consequently, this paper goes beyond local linkages and examines the linkages between producers and customers in different markets (Germany, US, and other markets). In the international literature, such forward ties have been analysed in studies on global value chains (e.g. GEREFFI, 1999). In accordance with that literature, this study on the surgical instrument sector finds that these linkages are changing. In some chains, changes in the organisation of the hospital sector are leading to a gradual power shift towards the customer. However, the chains do not (as yet) have the characteristics of Gereffi's buyer driven chains. This is mainly because Tuttlingen has retained the capacity to innovate. This capacity to innovate is of central concern to this paper.

In line with HUMPHREY & SCHMITZ (2000), the paper distinguishes between

different types of upgrading. It examines if, and how, internal and external linkages strengthen or undermine upgrading by local producers. This is a difficult undertaking because – contrary to the common image of European industrial districts – there is no unified community of producers. The Tuttlingen surgical instrument cluster is extremely heterogeneous, ranging from one-man enterprises to the local lead firm which employs about 2,000 people locally and over 6,000 worldwide. Section 2 illustrates that this unevenness is borne out in the production statistics. A feature not apparent in these statistics, and possibly more significant, however, is the fact that concentration in the knowledge system is significantly higher than in the production system. The paper clarifies these concepts in later sections, but it must be noted from the start that the financial and human resources for upgrading are distributed very unevenly in the cluster.

Despite the cluster's heterogeneity, there is mutual dependence and economies of agglomeration continue to be powerful. There are a number of questions that will affect whether or not this small town can retain its leading position in the global surgical instrument market: Can it cope with the challenges outlined above? What upgrading opportunities are available for firms through collective efficiency at the local level and through engagement in value chain ties? What is the scope for local upgrading strategies where producers operate in global value chains? Finally, in what ways may different types of value chain governance effect or influence upgrading strategies

at the local level? This paper provides evidence that many parts of the production chain are located within the Tuttlingen cluster of surgical instruments and, moreover, that different market channels increase external ties. Thus, both local cluster governance and global value chain governance occur simultaneously in Tuttlingen. Nevertheless, other parts of the value chain are located outside the cluster: wholesalers and large buyers, and constitute the link to end producers in many channels.

This leads us away from the cluster for the moment to consider the changing environment the cluster has to react to. Since health care service has taken an increasing share of the national income during the last decades, national health care systems in most countries are under increasing financial pressures. Efforts to save costs have had a big influence on health provisioning. In the German health-care sector, small single hospitals have joined together to form hospital associations in an effort to economise on costs (see: KNAPPE et al. 2000). In the United States, hospitals are one step ahead, uniting as “power-shopping” associations, in order to bulk buy at better rates.¹ This favours large suppliers who are able to use scale economies to supply instruments at lower prices. Another approach to saving costs is to support operation techniques that minimise a patient's stay in hospital, for example, through minimal invasive surgery. This leads to a further push in

1 In power shopping associations consumers – in this case hospitals – make joint purchases, thereby receiving a higher discount with larger orders.

research and development for new applications of this technology. A third consequence is a greater level of specialisation as hospitals become “centres of excellence”. This maximises the utilisation of specialised, sophisticated and expensive equipment.

At the same time, progress in surgery is fast and intense. This is mainly driven by cross-section of technologies like micro-electronic, bio-technological and new-materials research. Future surgical innovation is expected particularly in fields where different technologies interact, such as robotics in surgery, image regulated endoscopies, re-absorbable implants, tissue engineering, laser surgery and many others (see: GRÖNEMEYER 2000). While adding to existing technologies and techniques, these innovations force producers and traders to react. They force big firms to increase their knowledge bases, either through their own efforts or through external cooperation ties and acquisitions.

The findings of the paper are rooted in primary field-research, conducted during the Spring and Summer of 2000. A total of 64 interviews were carried out, including 18 qualitative interviews with institutions and key-informants. Thirty-five manufacturing firms and 11 trading firms were surveyed using a semi-standardised questionnaire. Additional information was obtained through the author’s participation in a consultancy study for the Steinbeis Foundation, as well as visits to the sector’s leading international trade-fair, “Medica”, at Düsseldorf in November 2000, and to

two firms in the former cluster of surgical instruments in Sheffield, UK.

Section 2 introduces the Tuttlingen cluster, presenting its main actors and explaining its specific features. Section 3 describes the material and knowledge flows within the cluster. The heterogeneity of the cluster and the complexity of distribution are introduced at length in order to clearly illustrate the structures both at the cluster level, as well as within the value chain. Section 4 examines whether joint action in the cluster promotes upgrading, whilst Section 5 poses the same question in relation to value chains. Drawing on the findings of the previous sections, Section 6 discusses the implications for the interaction of global chain governance with local cluster governance. Finally, Section 7 provides concluding remarks and considers further prospects for the cluster.

2 The Tuttlingen cluster of surgical instruments

This section introduces the Tuttlingen cluster, presents first the cluster’s roots and historical specificities. It then goes on to an overview of the cluster, introducing the cluster’s structure and main actors.

2.1 Historical development of the Tuttlingen cluster

The initial clustering of surgical instrument production was a result of specific locational factors that provided beneficial geographical resources, such as iron-ore and wood around Tuttlingen and transportation along the river Danube. These locational factors led to the growth of a craft-based industry at the

end of the 17th century, centred around the iron-work of the Duke of Württemberg.² The first product specialisation of these metal-based firms was in nail and knife forging. In the latter product Tuttlingen competed against Solingen in the Ruhr-area, Germany's most important centre of stainless steel products. In 1800, there were over 20 knife- and nail-forging firms, and 50 years later, at the beginning of the Industrial Revolution in Germany, there were over 100 firms (DOLD 1920). Three of these labelled themselves specifically as "firms for knife-forging and surgical instruments". The move from knives to surgical instruments came out of the superior performance of Solingen, forcing Tuttlingen to seek its own market niche. Gottfried Jetter who, in 1867, founded Tuttlingen's current leading firm in medical engineering, Aesculap, took the initial steps towards specialisation and introduced modern machines such as steam engines. In subsequent years, other firms followed, pooling know-how from all over Europe, especially Paris, which was then the world's leading centre of medical knowledge and surgical instruments. Soon after the beginning of the 20th Century the increasing number of instrument types led to further specialisation, enabling craftsmen to reduce the production time of each single instrument and obtain economies of scale.

The historical development of the cluster is reflected, albeit poorly, in official data. This distinguishes between industrial and craft firms within the

surgical instrument sector, and locates the sector as a sub sector of precision mechanics. Moreover, the census' administrative boundaries have changed several times within the last century. To trace the development of the cluster it is thus necessary to combine carefully several sources. The early development of the cluster is shown in table 1. It shows the number of surgical instrument firms, in both craft and industrial sectors, within the city of Tuttlingen. Census enumeration was discontinued due to the disruption of World War I and the economic depression in the 1920s. The first count for the county of Tuttlingen was in 1939 and identified 39 small firms employing 130 people (the city of Tuttlingen was not included).

In terms of employment and total production, industrial firms have played an important role in Tuttlingen ever since: "Most outstanding of all is the Corporation for precision mechanics (...), which formerly employed over 2,000 people. With 2,500 people, the [surgical instruments] industry of Tuttlingen [city] accounts for over two-thirds of total German production." (FORDERER 1949:242, translation G.H.). In the early years after World War II, the development of the sector in the county of Tuttlingen was estimated by HILZINGER (1956:43) using data of the surgical instruments manufacturers association (table 2). It shows a steady increase in firm numbers and employment. In 1955, the city of Tuttlingen housed a total of 149 firms employing 3013 persons (table 3). In the following years, the industry expanded steadily

2 The successor firm is still alive (Schwäbische Hüttenwerke)

both in terms of firm numbers and employment.

Table 1: Development of the sector in the city of Tuttlingen

year	industrial firms	craft firms
1901	3	77
1906	3	79
1911	4	80
1920	6	64
1928	8	108
1936	9	71
1948	8	66

Source: REINERT 1951: 69

Table 2: Development of craft firms in the Tuttlingen country

year	no. of firms	employment
1945	105	n.a.
1946	127	n.a.
1947	132	n.a.
1948	137	n.a.
1949	142	283
1950	154	284
1951	157	340
1952	162	555
1953	165	624

Source: HILZINGER 1956: 43

Table 3: surgical instruments: firms and employment in the city of Tuttlingen in 1955

	no. of firms	employment*
craft firms	126	326
industrial firms	23	2687
total	149	3013

* without firm owners

Source: Tuttlinger Blätter 1956: 182

The sector has historically been concentrated in Tuttlingen. In 1999, 87.5 % of all surgical instrument craft firms in Germany were located in Baden-Württemberg, almost all in Tuttlingen. As table 4 shows, in 1956, 84 % of the craft firms engaged in manufacturing surgical instruments in Baden-Württemberg were in the county of Tuttlingen. In 1995, this share had risen to 89.6 %. This concentration exemplifies the importance of clustering within the sector. Internationally, there is only one other cluster of note, in Sialkot, Pakistan. Clusters of surgical instrument manufacturing were formerly found in Nogent-sur-Marne in France, in Sheffield in England, and to a certain degree, in Solingen in Germany. All of these clusters are today, by and large, extinct with only a handful of firms surviving.

In addition, a large firm in Debrecen, Hungary, was set up to supply former socialist states of Eastern Europe, while there are an extensive array of medical engineering (including surgical instruments) firms to be found in Switzerland’s “Mittelland” and along the East Coast of the United States. Nevertheless, firms in these latter locations compete with Tuttlingen producers not in surgical instruments but in other segments of medical engineering.

2.2 Brief overview on the Tuttlingen cluster

The Tuttlingen cluster of medical engineering consists of a core of about 300 producers of all size, who manufacture complete medical devices, either as individual craftsmen or as industrial firms. Together, they achieve an annual

turnover of about Euro 1 billion. Within a wide production range, surgical in-

Figure 1 shows the product range of the Tuttlingen cluster.³ The cluster's

Table 4: Development of craft firms in surgical instruments

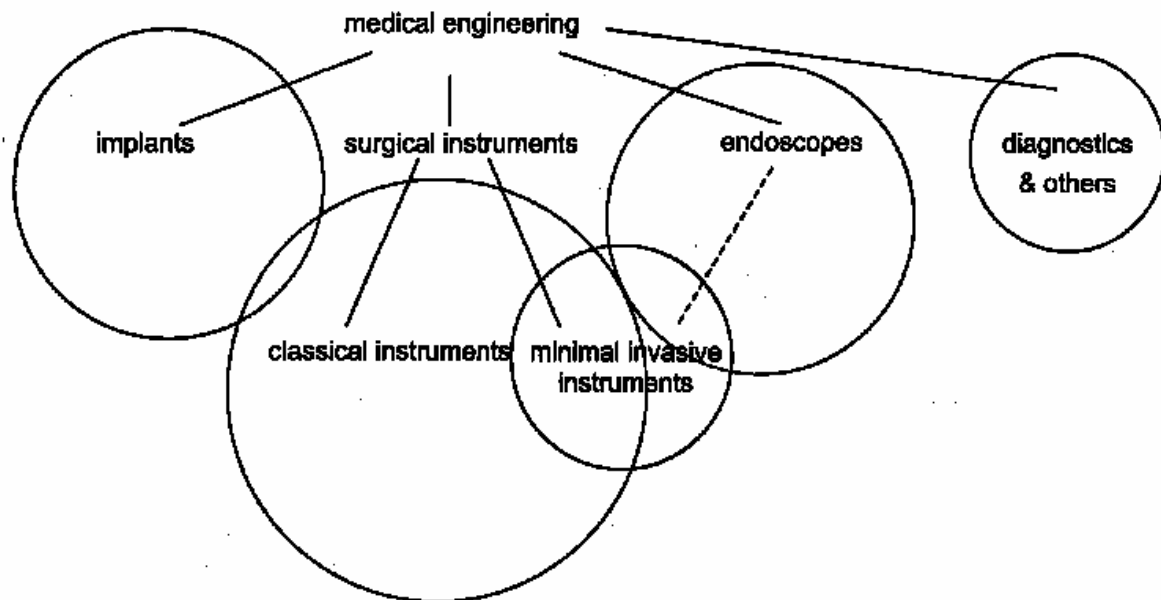
year	Baden-Württemberg			County of Tuttlingen		
	no. of firms	employees	turnover in Mio. Euro	no. of firms	employees	turnover in Mio. Euro
1949	125	441	1,17	n.a.	n.a.	n.a.
1956	175	1279	7,53	147	992	5,16
1967	193	1262	24,23	n.a.	n.a.	n.a.
1977	201	1826	80,12	n.a.	n.a.	n.a.
1995	307	3791	370,94	275	n.a.	326,89

Source: Statistisches Landesamt Baden-Württemberg: Handwerkszählung, different years

struments are by far the most popular products in medical engineering produced in the cluster. Besides classical surgical equipment, new minimally invasive instruments are also produced.

origin was in the production of surgical instruments. During the last decades, some of the larger firms have started to enter into other fields of medical engineering, requiring different technologies

Figure 1: Products of the cluster of medical engineering



Other products include various types of implants, as well as medical and electromedical apparatus, although these are limited to a few large firms.

and skills. Diagnostic instruments and endoscopes have required a move away from metal working, whereas the pro-

3 In figure 1, the size of the circles reflect an estimation of the scale of the distinct segments.

duction of implants has led to a higher stage of metal based production, using titanium and sophisticated alloys. For most small firms this shift has led to a growing local market for minimally invasive instruments, which in most

The producers in the cluster are surrounded by 200, often very small, process specialised sub-contracting firms. About 30 firms supply manufacturers with inputs, including two specialised die-making and forging firms. Two other

firm-size-class	0	1 to 19	20 to 99	100 & more	total
no. of firms	208	233	34	8	483
share of firms	43.1 %	48.2 %	7.0 %	1.7 %	100 %
no. of employees	0	1,065	1,157	4,001	6,223
share of employees	0 %	17.1 %	18.6 %	64.3 %	100 %
average firm-size	0	4.6	34.0	500.1	12.9

Source: Statistisches Landesamt Baden-Württemberg, Landesarbeitsamt Baden-Württemberg.

cases require similar technologies to that used to manufacture classical instruments.

While many firms producing classical instruments are also engaged in the production of minimally invasive instruments, the production of endoscopes as well as diagnostics equipment and implants are limited to larger firms in the cluster. Some larger firms engaged in the new segments (implants or endoscopes), however, are producing special instruments to handle with their main products in surgery.

The cluster's success during the last 20 years is linked to its ability to diversify and expand into segments beyond classical surgical instruments. Some firms have emerged as recognised success stories, becoming leading firms, both in terms of size as well as technological advancement, despite starting as small craft firms.

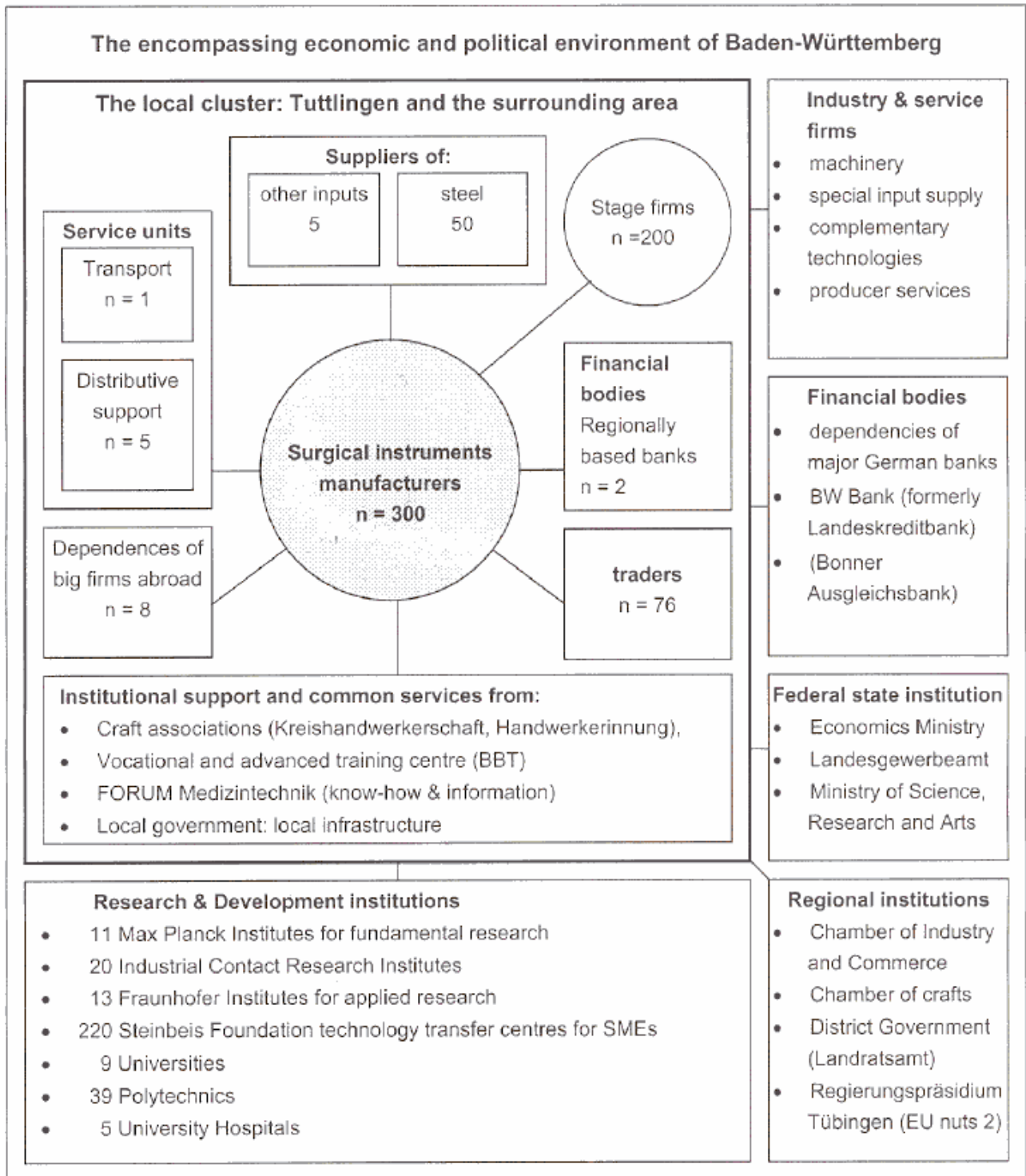
die-making firms are located at Solingen. A number of turning firms provide the cluster with semi-finished goods.⁴ A few specialised retailers offer other input supplies like machinery and industrial equipment for smaller producers. Suppliers of specialised machines, for example machine-tools, are not located within the cluster, but many are based near Tuttlingen. Finally, some 20 firms provide a range of producer services to the cluster, ranging from specialised software, to translation offices, logistics and transportation.

The size structure of the core manufacturing firms in medical engineering is shown in Table 5. Most firms in the cluster are very small. Over 90 % of firms employ less than 20 persons.⁵

4 These firms mainly work for other end-markets, especially the auto sector, but to avoid dips in business cycles also supply to other sectors like surgical instruments.

5 20 employees is the cut-off point in official German statistic for manufacturing firms.

Figure 3: Cluster map: Key elements of the Tuttlingen surgical instrument sector.



6 Within employment data of producing firms administrative and support staff is also included. Thus this data is sensitive to firm-size.

7 We will see in the following sections, that the underlying hub-and-spoke relations have changed within the last years.

much more significant than official statistics suggest, and are increasing every year.⁸

Of the range of private firms and public institutions, some emerge as main actors. The largest firm in terms of employment is *Aesculap*, which employs about 2,000 persons locally and over 6,000 worldwide. This firm is engaged in many fields of medical engineering. Its priorities are shifting away from surgical instruments into other segments, particularly implants. *Aesculap* itself is owned by an even larger German company, which, while located outside the cluster, is also engaged in the broader medical products industry. The next firm in size is *Karl Storz*, with a staff of nearly 1,000 employees. This firm specialises in endoscopes and is a worldwide technological leader. Besides these two large firms, there are two organisations, *Medicon* and *Gebrüder Martin*, which are made up of 25 mainly small producing firms with about 900 employees in total. Figure 2 provides a model of the production system of the Tuttlingen cluster of medical engineering. It estimates the structure and size of distinct sub-sectors and production steps. It shows how in-house production and subcontracting is inter-linked within the cluster.

Although the centre of medical engineering, the city of Tuttlingen is not the regional capital, either in terms of administration or population. Important institutions related to the cluster are not situated in Tuttlingen, but at the geographical border of the cluster, such as the Chamber of Industry and Commerce in Villingen-Schwenningen or the Chamber of Crafts in Konstanz (figure 3). The chambers provide market information and statistics to their members,

are engaged in vocational training and inform firms of the different technological development programmes at regional and interregional levels. Moreover, they provide a link with regional economic interests and act as an intermediary with actors at the federal state level as well as the regional level.⁹

At the local cluster level there are a number of key institutions. Associations of craftsmen play an important role in ensuring high quality advanced training with common rules and testing standards. The *FORUM Medizintechnik*, provides an institutionalised platform for technological learning through lectures on innovation, research and development, partly funded by local government. Finally, the local government provides infrastructural support, including site development. Since soft location factors are regarded as an important issue to attract highly educated employees, local government investment also contributes to the local economy.

The local government is currently involved in a major project to attract new technologies and skills to the cluster. The most important local institution is the BBT (*Berufliches Bildungszentrum Tuttlingen*), which provides basic and advanced training for metal workers. Since this is the only place in Germany to learn the profession of a *Chirurgiemechaniker* (mechanics in surgical instruments), it forms the pillar on which the cluster is built on. One of the main gaps in the cluster is the lack of research institutions. Nevertheless, the cluster benefits from the dense research landscape and variety of technical transfer institutions within Baden-Württemberg

as a whole. Baden-Württemberg has 11 Max Planck Institutes for fundamental research, 13 Fraunhofer Institutes for applied research, 20 Industrial Contact Research Institutes, 220 Steinbeis Foundation technology transfer centres for SMEs, 9 Universities and 39 Polytechnics (see: COOKE & MORGAN 1994:99, HEIDENREICH & KRAUSS 1998:229). The most important clinical research institutions for Tuttlingen are the surrounding University Hospitals in Freiburg, Tübingen and Ulm, which are all within 90 minutes drive of the cluster.

Of special importance are the polytechnic schools at Furtwangen, Konstanz and, again, Ulm. The latter houses the Institute for Applied Research in Medical Engineering (IAF), which is the only institute with a specific focus on the industry segment. Although the surrounding research landscape and technology transfer system is impressive, pure numbers do not imply effective delivery of technical advice (see: HEIDENREICH & KRAUSS, 1998:230). Most research institutions are small in size and focus on a particular technological field, and are thus unable to provide comprehensive consultancy services. Thus, they are passive actors, requiring “very precise demands on the part of the company. The ability to find innovative questions for the transfer centres is not something that can necessarily be taken for granted, especially among smaller (...) companies” (ibid: 230). As a result, technology transfer is only used by a limited group of companies, and effectively strengthens technically stronger firms.

A central feature that a cluster provides for local firms are external economies, and Tuttlingen is no exception. The gains of pooling the labour market, the emergence of specialist suppliers and technological and knowledge spill-over (often referred to as Marshallian external economies) remain important for the cluster’s success. The Tuttlingen cluster generates a number of external economies for its firms:

- *First*, traditional production knowledge in the manufacture of surgical instruments. This is formalised and embedded into the vocational training system of the BBT. This provides production knowledge and facilitates innovation in production technologies.
- *Second*, specialist suppliers in the fields of material inputs, software consultancy, material testing as well as translation offices and business consultancy are located in, or nearby, the cluster and are specialised to meet the cluster’s idiosyncratic needs.
- *Third*, the cluster of specialised small scale firms are able to deal with small batches to fulfil customer requirements. Neither large firms on their own nor dispersed production would have been able to deal with the variety of small batches required at uncertain times. Thus, clustering leads to economies of scale and scope.
- *Fourth* traders and distribution staff of larger firms have acquired market knowledge in particular national markets. On the other hand, their knowledge about the Tuttlingen production facilities, quality and produc-

tion specialities enables them to adjust orders to customer's requirements.

- *Fifth*, geographical closeness facilitates information flow about new processes, new products and markets. These flows of information and learning processes through exchange and interaction, both formal and informal, are largely unintended and often unreflected by the actors.
- *Sixth*, relevant local and regional institutions further support the economic base of the regional economy. As such, several initiatives have helped promote the cluster.
- *Seventh*, the Tuttlingen cluster has acquired a world-wide reputation for quality with firms from abroad seeking to enter into joint ventures or establishing plants at Tuttlingen.

These advantages of clustering lead to a reduction in transaction costs for individual firms and to external economies. The outcome of external economies is visible in the dense clustering of the surgical instrument sector. There are examples of firms that have relocated at Tuttlingen due to the geographical proximity to forward and backward linkages. This agglomeration effect has furthermore led to the re-location of a range of traders and wholesalers, even from abroad. The main strength of this unique labour market is its generation of spillovers. The passive gains of clustering (NADVI 1999, pp.1609) – the “Marshallian trinity” of labour market pooling, specialised suppliers and technological and knowledge spillovers (see: MARTIN & SUNLEY 1996) – can therefore be observed in Tuttlingen. To participate in active gains, joint action is required.

This could influence future upgrading of the participant firms.

3 Production, distribution and upgrading in the cluster

This section details the production and knowledge system of the Tuttlingen surgical instrument cluster. It shows how, traditionally, instrument manufacturing was a craft activity, involving a huge range of different types of instruments and small batch production. Moreover, this section introduces the concept that differences in the knowledge system can be a critical resource for upgrading. The section is divided into three subsections: *product differentiation and the production system* and the *distribution system*, are about material flows and particularities in production and distribution, the *knowledge system* is concerned with knowledge flows.

3.1 Product differentiation and the production system

To understand the production system, it is necessary to first look at the specific facets of the manufactured products, and then consider their implications for the production system. Surgical instruments were developed from a rudimentary knowledge of surgery at the end of the 19th century. Starting from a few types of instruments they have increased in number along with the knowledge of medicine and surgery. It is estimated that over 30,000 instrument types are currently produced in Tuttlingen.¹⁰ The large variety of instruments is due to two key factors.

First, with the constant refinement of medical knowledge, there is an increasing number of operation techniques. Surgeons often seek to improve procedures by refining their medical equipment. Often there are incremental improvements, from changes to the instruments' form to functional adjustments. Since the art is so heavily dependant on the surgeons, there is little resistance to a surgeon's insistence on an adjustment in the development of new specialist instrument that promise better results.

Second, new surgical methods do not necessarily substitute existing techniques. In many cases, traditional techniques are used under special circumstances.¹¹ Moreover, according to different surgery traditions, the equipment varies between different national markets. These factors, combined with varying financial capabilities of customers in different countries explain the huge and increasing range of instruments being produced at Tuttlingen.

As a result, there are a number of market niches in which firms can specialise, either producing a single product or a small range of products. The Chamber of Industry and Commerce estimates that there is an annual production of about 15 to 20 Million single instruments and about 30,000 types of surgical instruments in the county of Tuttlingen. This would mean an average batch of 500 to 660 pieces of a single instrument per year. This explains much of the persistence of small craft firms, for it is difficult for industrial firms to deal with such small batches and uncertain demand.

In the cluster we find both product specialisation as well as process specialisation regardless of firm-size. To start with, a craft firm in Germany is only allowed to engage special skilled persons, called *Meister* (instructor). This rule seeks to ensure the best level of product quality. *Meisters* are proud of their skills and try, whenever possible, to produce an "individual" product which includes as many production steps as possible. For this reason, most craft firms are highly specialised in a small range of products. Nevertheless, single production steps are often outsourced. These are either capital-intensive processes, like heat treatment or laser-working, or labour intensive processes, like polishing.

A widespread practice for large firms is to use both in-house capacities as well as outsourcing to deal with unsteady demand. Of the firms visited that mainly produced surgical instruments, 87 % outsourced some production steps to other firms. These included all of the larger firms¹² (20 employees and more) interviewed. Usually subcontractors work for several firms but irrespective of this, production ties are generally long-standing. The subcontractors visited had ties with their three main buyers that had lasted over 15 years, on average. Although changing supplier, or buyer, is not the rule in the production system, there are shifts in volume according to changing demand for orders. More than 51 % of the production firms interviewed had increased outsourcing in the last five years, mostly due to growing orders. On the other hand, most firms stated that even in recessions they

would, where possible, outsource a guaranteed minimum level of work to subcontractors as a safeguard, because the survival of contractors was crucial to the producers' performance during boom-times. Small suppliers, who felt relative safety under these circumstances, confirmed such patriarchal behaviour. Nevertheless, the general loyalty of larger firms has declined in recent years, especially in relation to home-working, which is an old, but dying characteristic of the local supply chain in Tuttlingen. At the beginning of the 20th century, DOLD (1920) wrote, that workers at Tuttlingen often preferred to produce at home instead of at the firm, although good workers were allowed to do so. Those home-workers produced only for one single firm, which provided them with input materials, whereas the equipment belonged to the individuals. While this practice still exists, it is declining. The two largest firms, Aesculap and Karl Storz, have reduced home-working dramatically in order to gain internal flexibility in the use of workforce. They have asked most home-workers either to return to the factory or to leave. Another reason for the decline in homeworking is the steady leakage of capacities, as many home-workers became independent producers over the years, competing against their former employers.

Subcontracting also varies according to product segments. Firms engaged in endoscopy/minimally invasive surgery and especially in the implant sector have fewer subcontracting ties, although they also tend to be bigger in size. This is rooted mainly in technological con-

straints, the higher requirements in product regulations (mark III products according to the European CE-standard), and the higher degree of automation. Furthermore, in the case of implants, customers' traceability and punctuality requirements lead to direct control of production processes.

Surgical instruments are usually produced in three distinct steps (for more detail, see NADVI 1996). The initial steps include forging and related processes. Metal turning can also be counted as part of this step. The second step includes the main process of metal working, like milling, fitting, filing and grinding, up to heat treatment. It could be asserted that all the steps that ensure the basic function of the instrument are included at this stage. The final processes include surface-treatment, polishing, labelling, cleaning and inspection. The division into three main phases of production is important, especially in understanding how production is being restructured in the wake of globalisation.

Input suppliers in Tuttlingen undertake the initial steps, the few exceptions being made by large firms. Surgical instrument manufacturing firms at Tuttlingen usually begin work at step two - that is, drawing on forged materials or turned steel. In addition to traditional equipment new, sophisticated machines are common in the cluster. This is only partly an issue of firm-size: all larger firms use CNC-machines, as do many of the small firms (although others work in a more traditional way). Having the experience of many years, product quality of the latter is not usually far behind the former, but there is a difference in

production speed. Although a few of the larger firms also work with robots, a high level of automation is not the norm, especially as batches are small and different manual skills often lead to better results. According to key-informants, experience is such an important factor for product quality that even the market leader was forced to re-employ some old workers after their retirement. Younger scissors-makers were, at that time, not able to attain the required quality. As a rule, it is said that an instrument maker in Tuttlingen requires ten years post-apprenticeship experience to be recognised as a skilled instrument maker. For the highest level of skill it takes many years of experience.

Subcontracting ties with firms abroad are playing an increasingly important role. In the early 1970s, production was transferred for the first time to developing countries to benefit from lower factor costs. The lead firm established a manufacturing facility in Malaysia. Other large firms at Tuttlingen followed, starting production ties particularly with Sialkot in Pakistan (see: NADVI 1996). The last decade has led to a new step for two reasons. First, the entrance to the market of Hungary and Poland after 1989 led to new prospects for firms, as cheaper labour was now available within a 10 hour car drive of Tuttlingen. Second, small Tuttlingen firms also started subcontracting ties with foreign locations (mainly Sialkot and Debrecen in Hungary).¹³ The usual way has been to start job processing,¹⁴ particularly with Sialkot firms. This means that products are outsourced for

the labour intensive medium steps of production. To ensure quality, the products are brought back to the Tuttlingen cluster for the final steps (job processing).

As a result, new types of firms have appeared in Tuttlingen. Besides the classical producers and traders, as discussed earlier, the traditional trading system led to a third type of firm, the producer who also trades. During the last decade, a fourth type, the trader who also produces, has appeared. This last type has specialised in job processing with firms in low-wage countries. The firms are usually owned by multi-skilled people who are able to combine production knowledge with market knowledge developed through previous employment by larger firms in Tuttlingen. Although many of them are called traders, they also have either direct or indirect production capacities to ensure acceptable product quality. These linkages with lower waged production sites have led to a steady shift of production away from Tuttlingen.

3.2 The distribution systems

The distribution structure of surgical instruments is even more complicated than the production system. This section describes the cluster's distribution structure, we will also return to this in Section 5 in the context of production chains.

The total world market for medical engineering products in 1998 was estimated to be about US\$ 113 billion (F&O 1999). The US accounted for about 47 % of this. After the US market, markets in Europe as well as Japan were the next largest. Other than these three major

markets, 20 % of exports are divided across many single markets, of which the newly industrialised countries in South-East Asia as well as Brazil are most significant. In principle, there are three modes of distribution for production firms. These are integrated with the three main markets (Table 6).

Large US-firms are the most important buyers for small and medium sized firms in Tuttlingen. These health-care giants¹⁵ are usually involved in most segments of medical engineering, both in production as well as in sourcing products from all over the world. Firms in the Tuttlingen surgical instrument cluster usually act as OEM-manufacturer, producing complete instruments ready for sale, with the exception only of labelling. Tuttlingen’s leading firms are also trying to get better access to the US market through alliances with US retailers. A few of the large Tuttlingen firms also have subsidiaries in the USA, most of them engaged in marketing, but some also engaged in production.

The European market is mainly occupied by a few brand-name firms, especially Aesculap and Medicon (particularly in the German market) and

Gebr. Martin (particularly in some European markets). Wholesalers located outside the cluster still play a central role in the European market. The strength of the wholesalers is explained by their huge, well-skilled staff that provides service and advice. This is an important feature for hospitals and surgeons who do not have an overview of the full range of products available.

The German market only accepts high-quality re-usable goods and has been, until now, generally willing to pay higher prices for the perceived safety of brand-name products. This practice has been challenged in recent years through changes in the health-care system, particularly through moves to save costs (as seen in most industrialised countries). Tuttlingen trading firms fight for a share in “external” markets and are generally specialised in one or several national markets (in Africa, Latin America, the Middle East and the Far East). Firm owners are often former employees of larger firms in Tuttlingen, specialised in one or a few countries, who use their contacts and market knowledge to become independent. The successful sale of surgical instruments to most other

Table 6: Importance of market channels for manufacturers

The number of signs reflects the importance of market channels.

distribution by	large firms			small firms		
	Euro pean market	US-market	other markets	Euro pean market	US-market	oth er markets
own distribution	+++	++	+	o	o	o
wholesalers and traders	+	++	+++	+++	++	++ +
other producers as intermediaries*	o	o	+	++	+++	+

* producers in their respective domestic markets

source: own investigations

parts of the world requires market knowledge and an understanding of specific cultural particularities and requirements.

In addition to distribution to specific countries, traders in Tuttlingen fulfil another important function in the cluster. Not all instruments are available at all times. On the demand-side, this leads to cyclical and episodic phenomena. New product lines experience an initial boom, and consequently face a sharp fall in consumption after market saturation (as in the MIC-field in the early 1990s) and/or a return to traditional operation techniques, which are eventually proven to be better than some over-hyped novelties. Additionally, national decisions about how to regulate health-care systems can significantly influence market demand. For example, the surgical instrument industry of Sialkot collapsed in 1994 due to regulatory changes in the US market (see: NADVI 1999, pp.1606).

On the production side, an expected minimum batch of 10,000 pieces per type of instrument is necessary to cover the costs of die-making in Germany. Die-ownership, patent protection of dies and availability of instruments according to market expectations (average batch size of 500-650 pieces per year compared with the required 10,000 pieces to start die-making) are constraining factors for producers. This can be exemplified by a statement of a surveyed trading firms: "If there is a big project, such as a new hospital to establish, I can get 70% of the products easily, but have a costly and frustrating time with the rest" (I 36).¹⁶

One of the features of Tuttlingen is that distribution is divided into three distinct systems. The first is a distribution system, organised in the usual way from producer to traders, via wholesalers, to customers. In the case of larger producing firms, the chain may be shorter. The second distribution system, which might, at the cluster level, be called the traditional one, is for buyers (wholesalers, large foreign firms, etc.) who travel directly to Tuttlingen in order to source directly from the small and medium-sized firms. This kind of distribution was portrayed by DOLD (1920) as common practice for many years. A third distribution channel is for small firms to sell directly to larger firms in the cluster, who themselves either sell on to wholesalers or directly to end-customers. The Tuttlingen producers are usually engaged in all three systems simultaneously, although the third system has declined significantly in importance (see Sections 5 and 6). Of the producers visited, only 3 stated that their main buyer is another producer (without a larger distribution department). 14 producers stated that their main buyers are traders and wholesalers, of these 11 firms have their own brand. A further 15 firms stated that their main buyers are directly engaged at all levels: from production, distribution and branding, to maintaining R & D facilities. Although far from providing precise quantitative data, these findings can, nevertheless, be seen as an indication of the significance of the three distribution systems.

In Tuttlingen, trading has seen the most impressive growth in all fields of firm activity according to interviews

with key-informants and firms. This is also borne out in official statistics. Whereas 76 traders were counted in 1999 with a staff of 640 employees, this was an increase of 27 % in firm number and 36 % in employment since 1993. Additionally, a number of interviewed firms report a shift towards trade and other non-production activities in recent years.

Figure 4 provides a model of the distribution system of the Tuttlingen cluster of medical engineering. It estimates the structure and size of distinct distribution systems and distribution channels according to the different markets (European market, US market, other markets). It shows how different production systems are linked with different end-markets. It also exemplifies the complexity of the distribution system. To fulfil large orders, producers and traders can purchase potentially from any other firm, which produces a special product or holds a stock of it (fuzzy exchange of products).

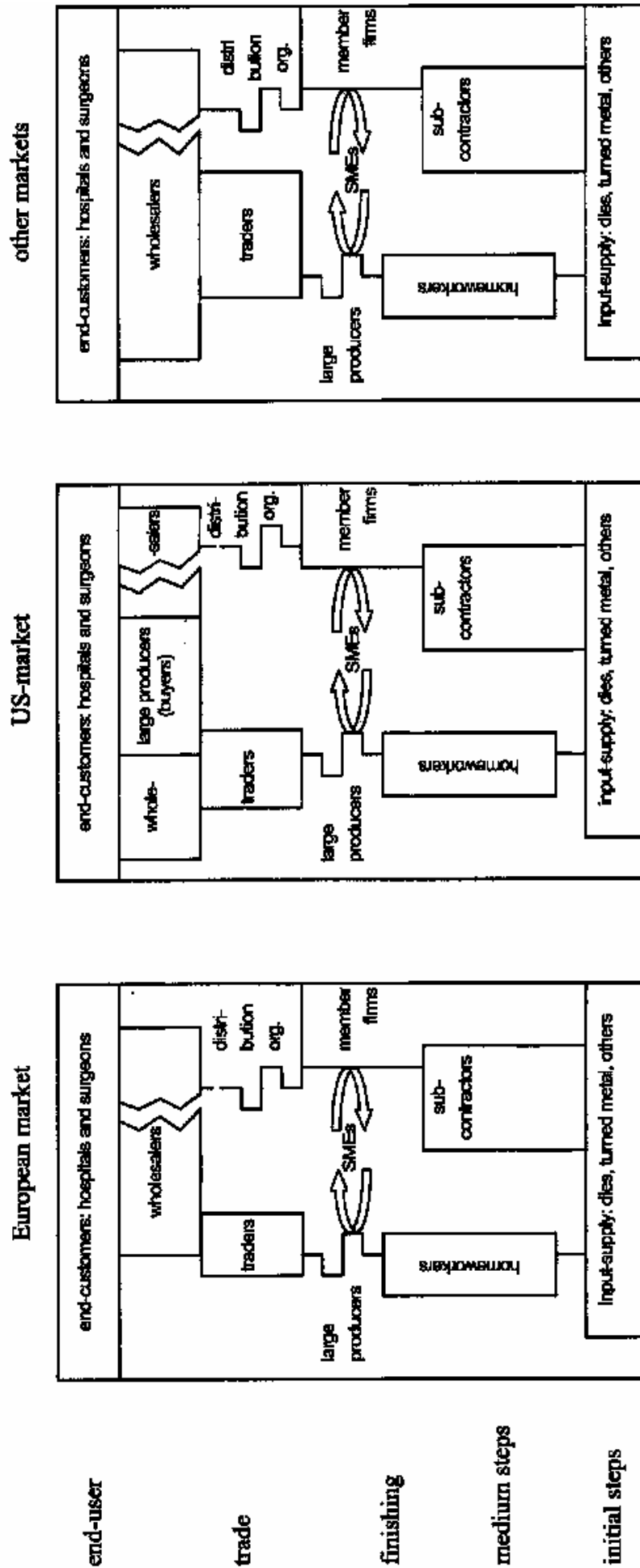
3.3 The knowledge system

In their article on technological dynamism in industrial clusters, BELL & ALBU (1999) emphasise the need to distinguish between production and knowledge systems. As “the production system can be understood to encompass the product design, materials, machines, labour inputs, and transaction linkages involved in production”, the knowledge system “encompasses those flows of knowledge and organisational systems involved in generating and managing changes in the products, processes and organization of production” (BELL &

ALBU 1999:1723). Later they distinguish between *knowledge-using* and *knowledge-changing* elements and *open* and *closed* knowledge systems. Knowledge-using elements refer to the work involved in maintaining (or even expanding) given modes of production, like the training of workers in established conventions, the imitation of production techniques etc. This usage of knowledge-using thus includes incremental efforts in product and process upgrading. This is in accordance with the observation “that upgrading – while important – rarely changes knowledge in more than an incremental way” (HUMPHREY & SCHMITZ 2000:20) at the cluster level.¹⁷ This section is directly concerned with knowledge changing elements and will investigate how knowledge is changed in the context of cluster. This will be done both for product and process upgrading.¹⁸

The decentralised system of technology transfer in Germany and especially in Baden-Württemberg promotes process innovation and its diffusion (HUCKE & WOLLMANN 1989). For process-upgrading at Tuttlingen, many resources are therefore available both within and outside the cluster. Sophisticated machinery and technical consultancy services are easy to access, and new methods diffuse quickly. Moreover, a high quality labour market distributes process know-how, although there are often shortages of labour in boom-times. However, this is pertinent to the general development of technological know-how in Germany and does not reveal any special features specific to Tuttlingen.

Figure 4: Market channels of the Tuttlingen surgical instrument cluster



fuzzy exchange of products

In the surgical instrument sector, for both radical and incremental product-upgrading, direct contact with customers is vital. This is important for developing instruments for new applications as well as improving existing instruments. Consequently, access to customers is a prerequisite for successful innovation. Customer requests may lead to design modifications, or to the creation of entirely new products. An example of the latter can be seen in the miniaturisation of instruments. A significant majority of adjustments, however, are incremental. Technologically, these improvements are mostly limited to the field of metal working and often include the use of sophisticated materials such as titanium, and a range of alloys.

In contrast, knowledge-changing capacities require the management of innovation processes and the search for, selection and adoption or assimilation of new product or process technology (BELL & ALBU 1999). If we consider firm-size, this radical upgrading in terms of completely new products, for example through engagement in the production of instruments for new operating techniques, is limited to larger firms which have the capacity to be engaged in steady product development. Not more than 40 firms are estimated to have such capabilities in Tuttlingen. Even within these 40 firms, innovation capacity is very uneven. It is expected that only a handful of firms, or groups of firms, are engaged in research in a knowledge changing way. Again, the hub-and-spoke structure is crucial, but this time it divides firms even more sharply.

The lead firm in Tuttlingen employs more than 200 employees worldwide in R & D, and annually develops 500 to 600 new products. To emphasise the stark differences in size within the cluster, we see that the lead firm's R & D department is almost as large as the third largest firm's total staff. As the second largest firm in the cluster is engaged mainly in the technologically advanced field of endoscopes, it is expected to have a similar research capacity, even though the firm is smaller in size than the lead firm. To draw a conclusion, the difference between the two lead firms and the cluster's spoke is even higher in the field of knowledge than it is in the field of production.

To emphasise the third distinction, BELL & ALBU (1999: 1726) have proposed, "open" versus "closed" knowledge systems, which act in different directions. Firms attract external knowledge which is then distributed by "gatekeepers", such as large firms or technological support firms. The latter are mainly engaged in a specifically focused field of knowledge. Large firms might therefore provide access to a broader and more systematic view of research outside this narrow domain. This, however, requires a commonality of interest between the lead firm and the cluster. In Section 6, the openness or closeness of the knowledge system is discussed in more depth. This explores the interaction of cluster dynamics with those of the value chain. The next sections however illustrate that, for small firms, knowledge may derive from several sources. Critical knowledge may be acquired through joint action with other firms

within the cluster, or through ties with external partners. Hence, the importance of joint action for industrial upgrading, in relation to the value-chain as well as through cluster-activities, needs to be interrogated.

4 Does local joint action promote upgrading?

One of the main objectives of this paper is to examine the roles of local versus global linkages in the generation of new knowledge. This section is concerned specifically with local linkages, in particular with the role of local joint action in upgrading. Cluster theory developed in the course of the 1990s attaches a great deal of importance to joint action (see for e.g. BRUSCO 1992, SEMLINGER 1995). This includes joint action amongst private actors, and between public agencies and private enterprises and organisations. At this point it is important to assert that upgrading requires substantial investment (HUMPHREY & SCHMITZ 2000). At the local level, the resources for upgrading can come either from individual large local firms, joint private initiatives or public-private initiatives. These three sources are not mutually exclusive. On the contrary, we have seen that successful clusters have often managed to combine these sources (see for the case of many Italian districts during 1980: BELUSSI 1999). This section is therefore driven by the following questions: What upgrading opportunities are opened through collective efficiency at the local level in Tuttlingen? What types of upgrading do joint actions address? What efforts are made for joint action and upgrading at the local level? To what

degree does joint action take place in the Tuttlingen cluster?

Most producers in Tuttlingen recognise their individual strengths and weakness. Much of the weakness originates from typical problems of small-scale industries. These include: a small non-production staff, a dependence on buyers, and a narrow technological knowledge base which is limited to metal-based technologies. Joint action might be a way to reduce these disadvantages. However, joint action as a form of cooperation between actors requires trust, “defined as the experience-based expectation of co-operative and benevolent behaviour” (SEMLINGER 1995:274) or at least mechanisms to avoid opportunistic behaviour, when trust is absent. In conversations (interviews), both positive and negative examples were discussed, although the latter prevails. Nevertheless, despite these collective failures some remarkable successes have occurred, emerging from a socially constructed weak background for collaboration, which shall be introduced first.

4.1 The weak ground for co-operation: historically seized and socially constructed mistrust

This sub-section seeks to examine the weak socio-economic ground for joint action in the cluster. Given the intensity of local competition, it underlines how difficult joint action is to achieve.

Being asked about partnership, cooperation and collective forms of problem solving, most actors in Tuttlingen, both private and public, stated spontaneous somewhat like “you won’t find that

in Tuttlingen". Competition is high, and trust is a joke. While peeling away the ostensible discourse in attempting to understand the lack of inter-firm cooperation and joint action, it is necessary to consider the roots of the cluster, which trace back to the beginning of the 20th century. At that time, instrument manufacturing in Tuttlingen was in many ways similar to what ALTENBURG and MEYER-STAMER (1999: 1695f) call a survival cluster. The manufacturing of instruments in Tuttlingen was already widespread, but product differentiation was not highly developed. Specialisation was low, and most firms produced roughly the same products as their respective competitors. Buyers were thus able to go from house to house, bartering prices down. The situation was so desperate for the craftsmen that the government of Württemberg was forced to set minimum prices for instruments on two occasions in order to avoid hunger-riots. Additionally, as specialisation was low, and technical knowledge not differentiated within the cluster, firms and buyers would actively search for or request information to enable either imitation of new products or generation of product improvements.

The lack of patenting or protection of design is a big issue in the cluster, which provides often "innovation for free" for copying firms. This problem is also one of the main tensions in the relations between small firms and large firms. There are three reasons (which operate both together and in isolation) as to why many innovations are not protected by patents: production consists of small batches, the firms are small and

improvements are incremental. Thus firms often seek to avoid costly patenting procedures. Additionally, large firms suffer from the departure of skilled workers, who leave to start an independent firm when a specific patent is running out, or where patent protection is missing. In turn, small firms lament the copying of their improvements by large firms. This steady leakage of earnings – and even more crucially – of know-how and skilled workers is a basic source of potential confrontation between small and large firms even now. In fact, the mutual mistrust between large firms and small firms prevented the success of the most ambitious initiative started by the head of the regional government at the end of the 1980s.

Both oral history and social practice in Tuttlingen have influenced Tuttlingen's workers and firm owners' acculturation, as the stories of past times heard from grandparents or even parents are still remembered. Tuttlingen fieldwork participants told many anecdotes that gave an impression of the level of mistrust within the cluster. While this seems odd to an outsider, the narrative about local mistrust is clearly more than a myth when it is told seriously and frequently by interviewees. The following response gives some idea of this: "There are five instrument manufacturing firms right here in this street. Each of us has its own vacuum heat treatment unit, which we use once or perhaps twice a week. If we worked together, we could save over a hundred thousand dollars per year. But no one does, and we refuse to do so either" (I 10). The story was told proudly, providing a clear demonstration

of how embedded the limits of private joint action are in the cluster. A consequence of this behaviour is the isolation of small independent firms, as illustrated by a firm owner's statement: "If I have a problem, I really don't know who I should turn to" (I 12).¹⁹

Discussion about agency or behaviour of firms implies also a discussion about agency or behaviour of members of firms as socially embedded individuals. There are indications, however, that previously such ties did not play a role. Family members were excluded, and older people at Tuttlingen still avoid discussing the firm as a result of this past culture. Some of the long-established manufacturers have stated that they might have reluctantly helped one or "maximum two" colleagues, under the understanding of a reciprocal exchange of information, if they had a limited problem, but there has been no resulting long-term collaboration from these interactions. The legacy of previous circumstances is, however, fading. The personal relationships between firm owners and the relational ties of extended families, which permeate the firms' fabric, nowadays leads to a degree of collaboration and problem-solving. In contrast to the last generation's reticence, the younger generation, especially within larger firms, often adopts a more modern and open style: "The younger management team know each other very well - both from schooldays and from our vocational training - "so we talk to each other a great deal. We even discuss (...) issues our bosses should not hear!" (I 38).

4.2 Examples of joint action through private initiatives

Despite local mistrust, some efforts have been made, both in the past and at present, to overcome rivalry and mistrust. While a promising way to reduce rivalry has arisen during the 1990s, the most successful joint action at private level, associations of independent firms, have their roots in history and have proved to be successful for many years.

a) interaction in reaction to earlier crisis: the Medicon and Martin example – consequences for upgrading

Despite sharp competition between firms, there are a few remarkable examples of collaboration linking small single producers together in a way that they are able to compete in markets even against the lead firm. The two associations, Gebrüder Martin and Medicon, bring together a number of independent firms who market their products jointly. Both trace their histories back to times of difficulty, when new challenges forced firms to find new ways to compete. This has been so, when at war times or post war crisis large markets were lost, or inflation in the domestic market has forced firms to search for markets abroad. Thus, these associations were formed when firms faced the choice of unit and survive or die. Nevertheless, as the associations have been successful, they have kept their organisational form even when the crisis receded.

Gebrüder Martin was founded in 1923 by seven producers as a consequence of the post-war crisis. Including the producers, Martin today employs about 650 staff locally. The size distribu-

tion of the member firms is uneven and ranges from over 200 to under 20 employees. The group together produces over 12,000 different types of products, with about 70 % of production exported. The *Medicon e.G.*, founded in 1941 by six firms, consists currently of 18 craft firms with about 350 employees. Together the group produces over 20,000 different products. The firm structure is unequal within the group, including one-person firms as well as larger firms which employ up to 40 employees.

In both cases, *Medicon* and *Martin*, production arrangements have been negotiated internally within the group, so that each product is produced exclusively by one member firm. As a result, the member firms have achieved the core objectives of their collaborative efforts: economies of scale, specialisation and decreasing competition. An other advantage has arisen over time: Both *Medicon* and *Martin* are recognised brand names, which are leading to positive effects at market (see: KAPLINSKY 1998). Because of their joint size, both groups are able to offer a full-size program for hospitals.²⁰ This is important in cases, when customers require a full range of instruments, e.g. if a new hospital has to be established. An other advantage for member firms is their enhanced innovative capacity, thanks to the steady contact their marketing departments retain with surgeons and their development departments and laboratories.

Nevertheless, such co-operation is far from being conflict-free. The inequality between the firms within the group has resulted in differing levels of development over time. In both cases,

strong members often try to bypass rules for their own benefits. Group strategies as well as the distribution of earnings have led to disagreements. In one case, this has resulted in the exit of the most powerful member firm from one group. The search for a successor firm to keep the group alive in the early 1990s is an indicator to show the importance of the associations for the member firms. In contrast, the firm that exited while still growing and successful, has not been able to reach fully the predicted superior performance on their own.

The foundation of similar associations or cooperatives have been tried several times in the cluster history (REINERT 1951: 62). Examples of failed initiatives have been the approach of the “Vereinigte Chirurgiemechaniker Tuttlingen“ in the 1920s, the “Chirurgie-Union e.G.mbH”²¹ prior to World War II, and the “Vereinigung der Hersteller Chirurgischer Instrumente (VHC)” post World War II.²² Of the surveyed independent producers, two told of their own experience with co-operations linking a few firms together in a synergy creating way. Both examples failed due to perceived opportunistic behaviour of members. Thus, the positive example of *Medicon* and *Gebrüder Martin* is not sufficient to overcome mistrust and opportunistic behaviour as long as business for most firms runs well.

b) rudimentary examples for joint action at the firm-level

Further examples of joint action at inter-firm level are worth mentioning. Twelve years ago, the ACIG, a private organisation, was established as a forum which

offered a meeting point and guide for specialised purchasers related to the traditional trading system. In offices of 400 m², about 100 firms currently participate in a permanent instruments exhibition and contribute to a printed annual guide to give buyers an impression of the product range of small firms. In addition, twenty small firms have been offered the opportunity to participate, at low costs, in the MEDICA, the world's leading trade-fair on medical engineering. As a result of co-operation through ACIG, a programme ("cracker-barrel") has been established to enable firms to meet regularly and discuss news and problems. This forum currently attracts about 20 member firms regularly. Since some traders are also members, discussion does not refer to functional upgrading. Nevertheless, ACIG is an remarkable step in overcoming small firms isolation, given the "atmosphere" mentioned above. As the ACIG fulfils obvious needs for the cluster and its success is noticed, there has been growing participation over the years. It should be made clear, however, that its aim and outcome is not comparable with the Medicon or Martin example.

Some other efforts have been made to overcome limitations of the individual small firms' constraints at a collective basis. Those efforts have led to several problem centred initiatives, most of them conducted as a co-operation between public and private actors.

4.3 Joint action established by public or public-private initiatives

In this section, initiatives to promote the cluster are introduced and their outcome briefly discussed. Most initiatives are limited in size and scope, and formal institutions are essential in mediating such joint action in order to overcome competition and mistrust. As shown in the cluster-map, a range of public and private institutions are concerned with the medical engineering cluster. Those institutions provide regular services for their clients, but are also engaged in special initiatives to promote the cluster in order to either solve problems or prevent them. As medical engineering is a key industry for the region, they are engaged in improving this sector in a variety of ways. One of the key constraints for many small firms is their lack of own distribution and marketing channels and, related to that, low levels of direct producer-customer contact that could help induce innovation. Since the mid 1980s, several efforts have been undertaken to reduce this weakness. Some other ways to promote the cluster have been tried, with different outcome, as shown below.

a) BBT – building the local knowledge base by training

The *Berufliches Bildungszentrum Tuttlingen* (BBT) is the centre of basic and advanced training for metal industries. Founded jointly by the Chamber of Industry and Commerce and the Chamber of Crafts, the BBT has offered theoretical and practical courses since 1977. Although the BBT concentrates on various different sectors, special impor-

tance is given to the surgical instrument sector. The training to become *Chirurgie-Mechaniker* - the main qualification for a surgical instruments manufacturer - is offered nowhere else in Germany.²³ The *Chirurgie-Mechaniker* training is integrated into the German *dual vocational system*. This involves a one year theoretical and practical course at the BBT, followed by a two and a half years of training with dual instruction in theory at public vocational schools and practical training within enterprises. Skilled workers may continue their training to become a *Chirurgiemechaniker Meister* (supervisor/instructor), which is offered by the BBT and is a pre-requisite to manage a surgical instrument craft firm in Germany. Moreover, the BBT offers modules that companies often cannot provide, such as training on all kinds of mechanical or electronic machines, on computer systems and software as well as basic business management. A staff of 20 teachers and 80 specialised external lecturers offer a wide programme of courses.

b) *Forum Medizin-Technik* – Transferring knowledge on innovation

Established in 1990, the *Forum Medizintechnik* aims to provide professional development for firms in several fields. It is a joint programme, which includes the Chamber of Industry and Commerce, the Chamber of Crafts, the *Landesinnung Chirurgie-Mechanik Baden-Württemberg*, the BBT and the *REFA-Bezirksverband*. Additional funding is contributed by the state government of Baden-Württemberg. Information is provided on medicine, medical engineering, production technology as well as

business economics, legal issues and business management issues. Thematic topics are drawn from general information rather than an attempt to provide solutions to recent problems and challenges of the cluster. The *Forum Medizintechnik* struggled initially due to low levels of firm participation but is now well developed. Initial difficulties in coordination and development emerged from the wide differentiation in the cluster regarding firm-size and technological know-how. The most significant reason for initial reluctance to participate reflects high levels of local competition (VOLKERT 1992, pp. 61). This was revealed during the fieldwork by key-informants and firms. Discussion within the Forum being limited by the reluctance of participants to reveal in public meetings their firm's actual or perceived weakness or difficulty. It is worth noticing, that the government of Baden-Württemberg was willing to pay a substantial fund to establish a research and marketing institute for the Tuttlingen medical engineering sector at the end of the 1980s. The project stopped after both the small and large firms lamented the opportunistic behaviour of each other and refused to join the initiative. The much less ambitious *Forum Medizintechnik* was subsequently established in the wake of these plans.

c) Initiatives on promotion and diversification of craft firms

- Firms in other metal-based branches in Germany are often engaged in more than one field to enable survival during cyclical crises. One concern for small firms in the Tuttlingen cluster is the absence of a

second product range to diversify into. Due to this limitation, the Chamber of Crafts began an initiative to promote diversification. In collaboration with the *Landesgewerbeamt Stuttgart* and the *Department for Product & Industry Design of the School of Arts, Stuttgart*, small firms and specialist designers actively searched for new products in other fields. Twenty firms initially expressed an interest. Out of these, nine firms have developed partnerships to explore new products. In terms of its innovative results, the project was a success, producing some remarkable new products (e.g. a phono-arm for record players ensuring high quality performance). However, the project has failed on economic grounds, as small firms were unable to produce at higher volume and at acceptable prices. Here, the difference between industry and craft firms is obvious.

- Another initiative is a one-day trade fair, *Products Seeking Producers*, based in Spaichingen. This is partly funded by the Federal state and organised in collaboration with the *Steinbeis-Technology-Transfer Centre Infothek* of Villingen-Schwenningen. The fair exhibits new products, prototypes and other products in the field of medical engineering and precision mechanics, as well as multimedia products that are linked to the health-care sector. Its objective is to link new product inventions with producing firms and traders to enable distribution. Founded in 1997, the initiative is now an institution, and is running in its fifth successive year. Additionally, key informants revealed that it is a useful public relations exercise, which generates inspiration and admiration from its visitors.
- In order to overcome innovation gaps of small craft-firms, the Chamber of Crafts has arranged several visits to University hospitals for firm employees. Viewing surgical operations first-hand enables personnel to see instruments in action and generate ideas for new functional or ergonomic adjustments. Surgeons and producers may then be brought into direct contact later on, enabling the communication of further needs and possibilities for instrument's manufacturing. Surgeons are often too busy to engage in feedback with small firms, so this is a unique chance for firms to gain vital information. Although mainly focused on incremental product upgrading, this process is of considerable importance for such firms.
- The latest limited initiative has been related to research on the sterilisation of instruments. The aim was to develop knowledge and capability in making complex instruments safely re-usable after due and proper sterilisation. The approach was to improve the reputation of all instruments by testing the most complicated and sensitive product lines. The intention was to reduce the burden of proof in the case of legal claims, especially in the US-market, arising from post-operative complications. In that case, about 20 firms, craft firms as well as industrial firms, research institutions and specialised external suppliers engaged in the production of sterilisation apparatus contributed to the study. This joint action was limited to this specific purpose (exoneration from legal liability through the inves-

tigation of sterilisation safety issues) and was terminated after its successful conclusion.

d) The role of public institutions on standards compliance

At the beginning of the 1990s, the Chamber of Crafts started to prepare firms for imminent compliance with the ISO 9000 standard. At the beginning of this process, small firms refused to engage with this issue due to cost and time constraints. This changed as buyers requested compliance as a precondition for further trade. The BBT and *Forum Medizintechnik* provided assistance and links to professional guidance. Moreover, the Chamber of Crafts and the Chamber of Industry and Commerce started a consultancy firm in public-private-partnership to offer the knowledge required to meet ISO 9000 at firm level. Despite this, most firms have undergone the certification process alone or with the assistance of external professional consultant services (79 % of firms stated these services to be “very important”). In contrast, firms view the relevant public institutions (Chambers) as an unimportant part of the process of compliance (90 %). Know-how about this process has been derived from the literature on certification and, in the case of subsidiaries, from the parent firm. As key informants stated, cluster firms often prefer to get consultancy services from outside, for example to introduce “independent” firms or institutions who have not been involved in the cluster before.

What can be learned from this experience? It seems that the Chambers did play an initial role in informing the small

firms in the sector about ISO 9000, and also offered solutions that firms adapted with the help of consultant firms. However, the joint venture between the Chambers and a certifying firm was not as successful as initially anticipated. This may have been because Tuttlingen firms preferred assistance from external, rather than cluster-based, service firms which may have also been engaged in serving competitors.

4.4 New initiatives to meet future challenges

Actors in Tuttlingen are noticing further challenges to the sector, from above and below. There is increasing competition from low-wage producers who cut into the traditional product lines in mature surgical instruments. The speed of innovations taking place in several technological fields, which have the power to change health care and surgical practices. In order to accelerate innovation, new initiatives have started within the cluster to help push it forward.

a) The competence-centre – joint action for future success

In 1999, Germany’s Ministry of Research and Education began an initiative to promote eight centres of competence (*Kompetenzzentren*) in specific fields of medical engineering in order to accelerate innovation. In response to the initiative, the Chamber of Industry and Commerce, the University Hospital of Tübingen and a host of other private and public partners successfully submitted a bid (against 56 other regions across Germany) to develop a “Competence and Technique Centre for Minimally Inva-

sive Surgery for Tübingen-Tuttlingen MITT". The proposal was submitted to a fund which will spend Euro 3,7 million over the next five years in order to stimulate and accelerate basic research prior to competition. Part of the fund's remit is to establish a structure to facilitate joint projects (*Verbundprojekte*) between research institutions and firms in basic research. Additionally, a central aim is to ensure the sustainability of the Competence-Centre after the five-year funding ends. To this end, any existing resources and competences in this field will be incorporated into a central network (BMBF 2000). Moreover, the establishment of specific co-operation conditions will reduce small firm disadvantages. A special feature is that the MITT is forming a network consisting of a University Hospital, two polytechnic schools and seven materials and processing-orientated research institutes, based at the Universities of Stuttgart and Karlsruhe. This is expected to make a considerable contribution to the sector, which suffers from the absence of a specifically dedicated research unit. Thematic issues on the agenda of MITT are

- the visualisation of minimally invasive surgery (MIS) through the future development and integration of ultrasonic and magnetic resonance systems,
- the development of agile MIS systems,
- miniaturisation of MIS systems for new applications (e.g. endoscopes in neurologist surgery),
- multi-functionality and systems-integration.

As mentioned in Section Two, only 40 firms are expected to be able to contribute substantially to the MITT-initiative with their own knowledge-intensive innovation capabilities. Other firms are not expected to have the necessary resources (knowledge, capital, staff) to engage more deeply in research. Joint action might open up some possibilities, but this would require a great 'leap of faith'.

b) Technology park "Take off": Attracting new firms in complementary technological fields

The second new initiative for the cluster is the new Technology park, "Take off", at Neuhausen (south of Tuttlingen), where the "Competence Centre" will open its offices. "Take off" is located at a former German army airbase that was converted in the early 1990s after the military cut-backs that followed the fall of the "iron curtain". The project will mainly focus on start-up firms in the medical technology sector. Additionally, the restraints on Tuttlingen's industry enlargement, such as the Danube Valley's topographical limitations, will be overcome by allowing firms to relocate. "Take off's" agenda is to build an innovative environment based on three pillars: first, the provision of services at "house seven" including testing laboratories for common use; second, an academy to link medical research with production, through a lecture series; and third, to provide a venture capital fund for start-up firms. It is expected that the project will attract firms within technologically complementary fields, giving the historically metal-based industry a diversifying push.

The main actors behind “Take-off” are the city of Tuttlingen and the city of Neuhausen ob Eck, on whose land the former airfield is situated. Further support is expected from the government of Baden-Württemberg and the local credit institutes. To ensure the success of the two projects, they need to be interlinked, which requires the integration and synergy of all actors. To some extent, however, governance problems have already appeared, since one main actor sought to establish the Competence Centre office at the BBT in order to strengthen its existing institution. Since both initiatives have only just begun, their future success is uncertain. It depends on the participation and co-operation of both the firms and the project administrations. Without the firms’ participation and once public promotion runs out, both the “Competence Centre” as well as “take off” could easily burn out rather than flourish. Although 18 firms have joined the initial proposal for the “Competence Centre”, there has been a limited reaction from a high proportion of firms so far. Of critical importance is the question of whether or not the leading local firms will join: their strategies involve vertical as well as horizontal linkages with actors outside the cluster and would therefore be expected to make positive gains for the regional industry as a whole. Local linkages with other actors in the cluster play merely a complementary role and are important for their production system, but not for their knowledge system.

4.5 The significance of local joint action to promote upgrading

As discussed above, despite intense local competition, joint action does take place in Tuttlingen, although under special conditions. First, the grounds for joint action has to affect all firms in a similar way, and the costs of individual reaction to problem-solving has to be prohibitive.²⁴ Second, there is a need for public institutions to mediate joint action in order to overcome local rivalry in Tuttlingen.

The aim of public institutions in promoting the cluster can be summed up as “creating the preconditions for competitiveness and success”. This includes training of workers, access to modern technologies and, more limited in scope, different kinds of information (e.g. markets, laws and regulations). In this respect, the various initiatives are successful and can be seen as one pillar on which the cluster is built. Joint action has been successful in terms of enabling firms to upgrade their processes (although focusing less on product improvement). This is mainly a result of the forms of learning passed on through the efforts of the BBT or the *Forum Medizintechnik*. Second in line of importance has been problem-specific joint action initiated by other actors, which have had differing levels of success. All initiatives and measures related to actual technical improvement or those concerning technical norms – which can be used for product upgrading – have some degree of success.

From the individual firm’s perspective, the combination of the typical

limitations faced by the small firms, with over-arching regional mistrust, prevents deepening engagement in private joint action. Thus the main constraint is the lack of private joint action, particularly the unwillingness of private firms to engage in co-operation to overcome the limitations of their small scale. But is this too ambitious? Competition always both enables and limits further success. PORTER (1990) regards competition as a key to innovation, and strong competition in clusters as a motor to push the cluster ahead. We know from various studies, that local competition can be intense (for the instrument sector: see NADVI 1999). To gauge the degree of competition at Tuttlingen, we have to look at an example of successful joint action overcoming local rivalry in a cluster right next to Tuttlingen. The *Heuberg* area around Gosheim, 20 kilometres from Tuttlingen, houses a cluster of about 400 metal turning firms. As the products are more or less standard, the fear grew at the beginning of the 1990s that this industry might be lost as a result of increasing globalisation. Nevertheless, the cluster managed to establish a Steinbeis Transfer Centre for Quality Management offering quality management, material testing services, vocational training and mediating measures for further co-operation (SEMLINGER 1995: 278ff). The main difference compared with the Tuttlingen case are that a private firm initiated the process, assisted by local institutions including an association of private firms founded to promote this initiative. This private institution grew from 40 to 160 member firms within a few years. Although this process was not conflict free (see in more

detail SEMLINGER 1995), the basic firm behaviour seems to be quite different from what we find at Tuttlingen.

It is worth noticing that the cluster of Tuttlingen has been very successful up to now, *despite* the absence of trust within the firms. Moreover, at certain points in history, for some firms it was able to overcome mistrust and form successive associations which enabled their members to compete even against the cluster's lead firms. The question arises, under what conditions does such close co-operation emerge? Here it is important to notice, that all, both successful and failed, co-operative initiatives that aim to form associations, (like *Medicon* or *Martin*), were established in times of difficulty for the cluster as a whole. Thus, one can argue, where extreme external pressure is lacking, local competition prevails hindering proactive solutions that could offer synergy effects for all. Thus, the question arises whether joint action to promote the cluster is sufficient to withstand future challenges. These challenges are in the areas of new technological opportunities on the one hand and price pressure on the other. Additional innovation efforts are required in the face of the limited ability to decrease costs in the craft-based sector without exploiting the workforce.²⁵ The current initiatives of the competence centre and "Take off" might be a way forward, but their success would require greater participation by private firms than has been seen in the cluster up to now.

5 Does co-operation in value chain ties promote upgrading?

The significance of value-chain linkages for upgrading has been emphasised in several studies (e.g. NADVI 1996, SCHMITZ & KNORRINGA 1999, GEREFFI 1999). It has recently been asserted that the prospects for upgrading through engagement in value chains is distinctly differentiated, since different types of chains have different outcomes (HUMPHREY & SCHMITZ 2000). Section three has shown how value chains in Tuttlingen's surgical instruments cluster feed into the general structure. In this section several other questions are asked: What upgrading prospects arise from the cluster's internal and external ties? How are i) different value chains and ii) different segments of the value chain governed? Are different chains governed in different ways? What kind of information and/or know how is transmitted within the chain? In which ways does this promote upgrading? What types of upgrading are promoted by co-operation in the value chain? These questions will be answered mainly by drawing upon interviews with key informants and – to a lesser extent – deductive conclusions from the work of HUMPHREY & SCHMITZ (2000). I look first at value chain ties in production. I then turn to value chain ties relating to the knowledge and innovation nexus, focussing on the three distinct distribution systems in the cluster. Then, the role of buyer concentration in value chains and its impact on functional upgrading is discussed, before ending with a discussion of the findings.

5.1 Upgrading in value chains

In recent publications, the concept of the value chain is transferred from a descriptive, heuristic, to an analytical tool whose elements consists of *dynamic rents*, *governance structure* and *systemic efficiency* (KAPLINSKY 2000, see GEREFFI 1999). This paper refers mainly to governance structures to estimate the upgrading prospects of chain members. The chain members' interactions reflect the co-ordination of distinct economic activities. In this field of research, several attempts have been made to capture the relationships and hybrid forms "between" hierarchy and market (e.g.: WILLIAMSON 1979, SYDOW 1992). The term governance is defined as co-ordination of economic activities through non-market relationships. With regard to value chain studies, HUMPHREY & SCHMITZ (2000) distinguish between hybrid forms by introducing i) the "quasi hierarchy" concept to describe asymmetrical vertical chain relations, and ii) the "network" concept to describe horizontal relations that appear even within the value chain, when power and influence are balanced by complementary know-how or resources. Thus, related to quasi-hierarchy is (a minimum of) independent decision-making power in contrast to hierarchy, where direct ownership excludes bargaining power. The fourth case, "arm's-length market relations" describes market transactions that keep a distance between two economic actors, where mutual learning is limited to market signals. These distinct types of co-ordination of economic activities can be used as categories to describe different governance patterns of value chains. In

order to identify the governance pattern in the Tuttlingen cluster, several indicators are used in Table 7. In the following discussion we will see that there is a distinction between relations and governance in ties both within the *produc-*

5.2 Value chain ties in the production system

By far the most pervasive form of forward-linking chain governance are arm's length market relations, regardless of whether it is in relation to buyers, trad-

Table 7: Indicators of governance in value chains

Indicators	Chain Governance
<ul style="list-style-type: none"> • No collaboration in product definition (standard product or product definition is established by the supplier) • Product requirements easily met by the supplier • Producer's Reputation implies a low risk for the buyer 	Arm's length market relations
<ul style="list-style-type: none"> • Co-operation between more or less 'equals': Joint product definition. • Complementary competences and innovation capacities on both sides. 	Network
<ul style="list-style-type: none"> • Buyer has high degree of control over supplier and defines the product. • Buyer incurs losses from suppliers' performance failures. • Doubts about the competence of the supplier. Buyers invest in specific suppliers and seek to tie them to their chain. 	Quasi-hierarchy
<ul style="list-style-type: none"> • Buyer takes direct ownership of the operations. • The buyer carries out product definition, which may involve proprietary technology. • Quality is used as a brand attribute of the buyer. 	Hierarchy

Source: HUMPHREY & SCHMITZ 2000: 16 (table 4), own adaptation.

tion-distribution context and ties within the *knowledge-innovation* context. KNORRINGA (1999) for the Indian footwear-sector and TEWARI (1999) for the Indian woollen knitwear industry showed that different types of governance can co-exist within the same sector and that firms can be engaged in different chains at the same time.

In this case, the same actors assume different positions depending on whether a transaction is geared towards daily business or towards innovation and upgrading.

ers, wholesalers or large producers. In the field of surgical instruments, the value chain deals with the production of mature goods and even small producers have a reputation for high quality instruments, making them relatively reliable and low risk partners. Moreover, most types of products are made by several producers, which offers a choice for buyers to keep prices down. In fact, many firms stated that it has been impossible to raise prices since the mid of 1990s, despite increased production costs. The daily business of traders and buyers, collecting products by visiting producers - or just sending an order message in the case of regular ties -

show that this form of governance prevails in daily business.

Backward-linkages to subcontractors are somewhat different. We need to distinguish between backward linkages with local suppliers, and those with foreign suppliers. In Tuttlingen, there are subcontractors with good reputations, where normal market relations can exist. Indeed, there are also relations in which doubts about quality lead to quasi-hierarchical governance, with regular instructions on specification and final inspection by the producer.²⁶ There are examples both from producers and subcontractors. One producer reported reducing subcontracting, as the costs of instructing and controlling some of his subcontractors remained high. Subcontractors complained about the meticulous inspections undertaken by their customers, and increasing reject rates arising from higher quality demands.

In the case of subcontracting ties with low-wage countries, quasi-hierarchical relations are much more common. Up until now, producing firms in Eastern Europe and particularly in Pakistan have not been able to produce goods that easily meet required standards. As a consequence, Tuttlingen firms have substantially assisted these firms. All of the interviewed firms that had a considerable share of products²⁷ originating from those countries claimed to have provided substantial aid to their subcontractors (10 firms including traders). Eight (out of ten) claimed to be mostly responsible for the increase in quality of Sialkot products. This aid consists of production know-how, machines, input supplies and training of

workers. While small firms send staff for regular visits to Sialkot to instruct workers and maintain quality, larger firms have also invited Sialkot workers for a stay at Tuttlingen for instruction. The firms stated that it would not be easy to change subcontractors because of the investment or effort they have spent either directly (through capital) or in an indirect way (through time and/or know-how) to raise the subcontractors product quality and process performance. Rapid changes of subcontractors would also affect the ability to meet purchase orders of their buyers punctuality and the required level and product quality. In these cases, the upgrading efforts through forward-linked firms may have an influence on power relations and negotiation positions. Backward-linkages to subcontractors in low wage countries are governed differently compared with most Tuttlingen subcontractors, at least partly because of quality deficits. Tuttlingen firms maintain a high degree of control by quasi-hierarchical chains or share direct ownership by joint ventures. The uni-directional knowledge flow as well as bi-lateral material and product flows are lead to quasi-hierarchical relations between Tuttlingen firms and their subcontractors in Pakistan and Hungary.

Although there are some differences in chain governance regarding the production system, in the case of the knowledge system they are even higher.

5.3 Value chain ties in the knowledge and innovation system

In Section 3, three distinct distribution systems for the Tuttlingen cluster of

surgical instruments were introduced. In the following section, their implication for the knowledge system is examined. Table 8 provides characteristics of the

Tuttlingen's larger players are by no means limited to the region or even the region of Baden-Württemberg. They maintain R & D contacts on a German-

Table 8: Distribution systems in the Tuttlingen surgical instrument sector

Distribution system	Specifics regarding information and knowledge flows.
1. Small producer-large producer-customer	<ul style="list-style-type: none"> • market information through short chains • direct marketing neither necessary nor possible
2. Any producer-trader-wholesaler-customer	<ul style="list-style-type: none"> • market information through long chains • direct marketing necessary to find new customers
3. Any producer-buyer (= large external producer)-customer	<ul style="list-style-type: none"> • contact with end customer through short chains • little marketing necessary, for buyer visits producer regularly

distribution systems with regard to information and knowledge system.²⁸

Innovation in the field of surgical instruments has historically required close interaction between surgeons and manufacturers. In the case of Tuttlingen, this is exemplified by the various visits of the famous Professor Sauerbruch in the early 20th century, who travelled from Switzerland to Tuttlingen to improve instruments and develop new ideas. As previously mentioned, larger firms still have direct contact with surgeons.

These firms are not only engaged in inventing new instruments, but also in developing new operation techniques, including new instruments, implants, and other equipment. Therefore, besides pure technological knowledge, they need doctors and surgeons among their staff to interact with external specialists and to evaluate internal progress. The research and development contacts of the

wide and even world-wide basis. To establish these contacts, steady observation of the innovations made externally are necessary. This requires participation at conventions and symposiums to keep abreast of new trajectories, methods and techniques. With this in mind, it is easy to see how this world has been closed to smaller firms.

a. small producer – large producer – customer

Up until the 1970s, a “network of mutual commitment” characterised relations between the lead firm and small producers, who produced instruments as OEM-suppliers for the former (FINKE 1998: 80). The second firm in size acted in a similar way (I 26). As a result, many SMEs were integrated to the production system of the large firms, in a way MARKUSEN (1996) characterised as hub and spoke. Moreover, the small firms were integrated into the lead firm's knowledge system through regular meet-

ings. Product improvement and modifications of instruments were jointly developed, according to market needs perceived by the lead firms. As a result, many small firms were also integrated into the lead firm's knowledge system. However, on being merged with a large external company, the lead firm changed its strategy. In addition to its plants abroad, the firm is increasing its production capacity in Tuttlingen, in order to be able to produce all articles itself (see: FINKE 1998). This is conveyed in the firm's marketing phrase that it has "all it needs to operate". This has led to increased competition in production, as the market leader enters into direct competition with its former subcontractors (ibid). Another consequence is that subcontractors have been forced to open new distribution channels as well as new innovation channels, as ties with the lead firm have broken down or at least diminished.²⁹ According to FINKE (1998), the former "network of mutual commitment" has disappeared. In a similar way, the second largest firm in Tuttlingen has lowered its number of subcontractors and reduced contact with subcontractors to market transactions, which necessarily excludes knowledge flows (I 26, I 15). Nevertheless, although these large firms have reduced relations to small firms, and arm's length relations now prevail, large cluster-based firms remain an important distribution channel for small producers.

b. producer-trader-wholesaler-customer

Since ties with large firms have become weaker, traders have developed an important role in mediating between end-

customers and producers.³⁰ Through these actors, knowledge gaps concerning product improvement and partly concerning new products can be closed. Traders maintain contacts with nearly all major national markets. Through traders information about new products, or specific adaptations and improvements in national markets may be transferred to small Tuttlingen producers. On the other hand, as the chain increases in length, information takes longer to disperse and it is therefore subject to distortion. Additionally, the direction of information flows are often uni-directional, so interaction is not very common because information mainly moves upwards through the value-chain. These limitations are a result of the care traders take to avoid bringing producers into direct contact with their customers,³¹ but also reflect the communication problems that lie between surgeons and traders, and surgeons and small producers. Nevertheless, traders and other buyers are often the main source of knowledge leading to product innovation for the small producers today.

c. producer-buyer-customer

For small producers, the traditional trading system in Tuttlingen, where buyers order products directly, is still of considerable importance. Under such circumstances, buyers fall into both categories: wholesalers and large foreign producers. The activity of wholesalers in the knowledge system is largely limited to incremental improvements according to the proposals or requirements of end-customers. Large foreign producers that use Tuttlingen firms as OEM-suppliers

provide greater knowledge input. In such instances, ties become co-operative when new products are being developed. The forward linked firms either provide direct knowledge by inserting their own specialists into the process, or act as mediators between end-customers and the OEM-producer. In some cases, large overseas-based producers have bought Tuttlingen firms outright. This was happening with a few larger Tuttlingen producers in the implant sector. Their production line was of strategic importance to their buyers to be able to make a contingent offer to end-customers. In this case, the production knowledge of the Tuttlingen firms was crucial for the decision to “buy” instead of “make”. In the meantime, vertical integration has led to hierarchical ties with their buyers and their knowledge is interlinked. Thus, further product upgrading derives from the interaction of the subsidiary with the mother firm, either through direct contact or through mediation. In such cases, the focus of R & D has shifted from the Tuttlingen plant to the main location outside the cluster. Moreover, ties with other Tuttlingen firms have been reduced to a minimum.³² As they are no longer actively linked to the cluster, these cases are reminiscent of firm relations described in MARKUSEN’S (1996) satellite-platform model.

In general, new products and, more frequently, adaptations of products appear which necessitate a closer collaboration than market relations permit. Ties in these cases become co-operative for specific projects because Tuttlingen firms are able to provide a high degree of competence in production, and, most

importantly, are able to implement new product ideas, a feature firms located elsewhere often lack.³³ Moreover, even small Tuttlingen firms are able to add their own ideas due to their long experience with materials and designs. This change of governance, from arm’s length relation to co-operation, is reversed however once the product has been invented and the individual project is concluded. For small firms, the development of new products merely punctuates daily production, and arm’s-length market relations dominate.

5.4 Functional upgrading in value chains and buyer concentration

As mentioned above, forward ties within the value chain play a central role in product upgrading. Access to surgeons and hospitals is key for both incremental and radical innovation in this field. The latter especially requires close co-operation with surgeons because it is often related to new operation techniques.³⁴ In this sense, product upgrading is also interlinked with marketing, for surgeons promote new techniques in scientific literature and through lectures at conventions. Furthermore encouraging scholarly practise at University hospitals has similar effects. The following subsection thus examines, what prospects for functional upgrading are emerging from interaction within value-chain ties.

Since functional upgrading is aimed at repositioning a given firm at a higher level of the value chain, forward (and possibly also backward) linkages are affected. If a buyer sees a backward-linked firm’s tasks as one of its own key-

competences, it will see the impending threat to its competence through a functional upgrade and thus make an attempt to impede it. On the basis of their study on the shoe sector of the Sinos-Valley in Brazil, SCHMITZ & KNORRINGA (1999:19) stated that “buyers helping their producers with this kind of upgrading risk making themselves redundant” (ibid). This may lead to a breakdown of business ties. Producers who wish to upgrade functionally are faced with high risks if they are reliant on a few buyers who account for a high share of turnover. The risk also increases if the producer is dependant on a buyer’s knowledge or information. SCHMITZ (1999:1648) considers buyer concentration to be a key to understanding whether functional upgrading occurs or not. In the following part of this paper, buyer concentration and the persistence of producer-buyer relations shall be examined.

a. Functional upgrading of small firms

This sub-section deals with prospects for functional upgrading of small Tuttlingen producers. To estimate buyer concentration, producers have been asked about the share of their turnover which is depending on their three main buyers. Excluding firms with over 100 employees, the three main buyers of the producers interviewed account for an average of 65.5 % of firm turnover. Compared with 66.2 % five years ago, buyer concentration has remained at a high level. Ties of small and medium sized producers with their main buyers last over 15 years on average. Within that period, producers have been able to increase

their average number of buyers by 16 % on average. In general, the degree of buyer concentration decreases with increasing firm-size. Nevertheless, on this findings, ties between producers and buyers in Tuttlingen can be considered to be very strong. This finding accords with the revelation by nearly all the interviewed small producers that it is difficult to find new buyers – a result, of course, of the strong ties which have a lock-in effect.

Under such conditions, functional upgrading is not easy for small producers. Nevertheless, of the sampled firms, two have made attempts at functional upgrading. The first, a skilled *Meister* who produced three different kinds of surgical instruments with a few employees, tried to move into trading activities with one of his products. This led the biggest buyer to break overall contact with the firm which in turn almost had to close. The only way forward was a radical shift in products. The owner was able to concurrently produce and also improve an instrument within another segment (micro-surgery), and has found new buyers for this product. But he no longer considers trading his products: “If this happened to you once, you wouldn’t do it again”. The other example is that of a small manufacturer, which recently began to build ties with an overseas medium-sized producer. He had been asked to establish a dependence, within Tuttlingen, on the external firm. For this reason, he has begun trading in the same market-segment as his main buyer. As this is a recent development, it is too early to assess its impact, although the

firm states that it expects to lose this buyer.

As indicated through interviews with firms and key informants, functional upgrading of small producers is rare. Additional constraints include the nature of the craftsmen as *Meister* of the profession. The long tradition of surgical instruments manufacturing must be considered with reference to its specific requirements for highly skilled manual producers. There exists a strong degree of self-restraint in the knowledge that their strengths are based on the shop-floor: "I am a craftsman. I don't want to sit in the office for hours and hours. I prefer to work with my hands. I don't want my firm to grow because then I will be bound to the office." (I 17).

If there is a kind of functional upgrading of small firms at Tuttlingen as such, it derives from the traditional trading system, where buyers and wholesalers from abroad tend to change practice. Recently, they have tended to make bigger purchase orders. This is far from single-sourcing, but combines some similar products to reduce the complexity. However, this leads to the need for small producing firms to buy from other small producers in order to fulfil requirements for larger consignments. Although some producing firms can survive on the earnings derived from trading activity when (own produced) instruments prices are low, this trading activity is limited in volume and not reproducible outside the chain. For that reason, I might call this practice passive trading to distinguish it from active trading in the market. It offers small producers a profit incentive, for buyers

are not necessarily noticing the trading activity undertaken by the producer.³⁵

b. Functional upgrading of large firms

In this sub-section the prospects for functional upgrading for large firms are examined. It is driven by the question, how future challenges might be met by large firms, being pushed by restructuring of health care services and pulled by innovations in the medical field.

As introduced in section one, price pressures and cost saving efforts of hospitals and surgeons at the one side, and fast technological innovation on the other side, are forcing large firms to react. First, there are new opportunities of size, while expanding globally. At the same time, scale economies are gaining new importance in the light of increasing competition according to the restructuring of public health care in major markets. Second, the direction of the fast technical change requires systems integration in so far alien fields of a particular firm. Third, new rents may be developed under the new conditions mentioned above (see: KAPLINSKY 1998).

As a result, we have seen many mergers and acquisitions in the medical field in recent years.³⁶ But there are also reactions at the level of the individual firm. One reaction of large producers has been to enlarge services for end-customers. There are examples of large firms who are providing full instrument services to hospitals, including sterilisation, repair and replacement of instruments. The service involves a computerised tracking system that enables close monitoring of each individual instrument (e.g. age, frequency of usage, state). This

leads to an optimal usage of instruments and lowers costs for the hospital. According to conversations with key informants, there are signs that, in near future, hospitals may rent, or lease, instruments from producers instead of buying them. In this development, large US-firms are prime movers. Large Tuttlingen firms are seeing themselves as being forced into this direction.³⁷

The offer of full supply to hospitals requires, apart from anything else, a substantial investment in logistics. With this prospect, gaining access to end-customers might be more difficult for other firms. Large producers are thus seeking to expand, in order to reduce costs, and increase purchasing and bargaining power and will become more concentrated. As a consequence, the new fields of activity of large producers have to be seen as functional upgrading, increasingly bypassing wholesalers and traders. Given the state of stagnating markets, any estimated growth of large producers will lead to competition for markets, and to further concentration at the end of the value chains.

In the case of Tuttlingen, the lead firm also undertakes upgrading efforts in the aforementioned way. As a result of being bought by an even larger company external to the cluster it offers a complementary product range that includes a full package programme of instruments for hospitals, and includes servicing, maintenance and logistics. A special feature in Tuttlingen is a conference facility developed by the lead firm, called the Aesculapium, where medical conferences and congresses take place, presenting new operation techniques and

new equipment.³⁸ Here, again, the difference between the market leader and the cluster of small firms becomes evident. Other larger firms are hot on the tail of the lead firm, restructuring production and making efforts in innovation, but they are unable to upgrade functionally in the same way. Well aware of this, some of Tuttlingen's large firms have decided to rest at the current position of a technological advanced OEM supplier. In this respect, the ability to constantly upgrade product is key for future success.

5.5 The significance of co-operation in value chain to promote upgrading

Section five aimed to answer the question, whether different forms of upgrading are promoted by value chain ties and its links with governance patterns. It can be asserted from the analysis in this section that the production system and the knowledge system perpetuate, and necessitate, different forms of governance within the same value chains. In relation to product upgrading, arm's-length market relations in the production system evolve into co-operation. In this field, upgrading is supported through value chain linkages, especially through forward linkages to surgeons. Regarding small producers, upgrading in most cases is mediated through traders, wholesalers and large external producers. In the case of external traders and wholesalers, ties with small firms at Tuttlingen were built up because of their production performance in relation to process knowledge and thus considered a precondition. Functional upgrading through value chain engagement in Tuttlingen is

largely hindered through buyer concentration. Nevertheless, a certain kind of upgrading is common through a buyer's shift to content purchasing. I refer to this as a passive trading system or as "trading on demand" to distinguish it from active trading in the market, which requires specific know-how and resources and which affects ties with forward-linked firms.

During the Tuttlingen survey, there were limited indications that value chain contacts led to process upgrading. As a result of relatively short chains in production, many of the forward linkages lack specific know-how in processes (traders and wholesalers). Such cases, where producers buy from other producers it is because they have specialised on the manufacturing of particular instruments, maintaining specialised process knowledge.³⁹ So contrary to the findings in relation to product upgrading, process upgrading through the value chain is rather exceptional at Tuttlingen. This is in line with a buyer's paradigmatic statement in another research context: "At the end of the day we cannot own their problems and they cannot own ours but we share problems" (citation of a buyer in SCHMITZ & KNORRINGA 1999: 19). This is the main reason why process upgrading plays – in contrast to product upgrading – almost no role within forward ties of Tuttlingen is producers.

Producers in low-wage locations, particularly Sialkot have made big advances in product quality - as commented on by all interviewed traders who are engaged in Sialkot. This is the result of the engagement of Tuttlingen firms as well as from increasing experi-

ence. This increase in quality poses a challenge to Tuttlingen for low wages complement increasing quality, although it will take more time to become directly comparable in quality. Nevertheless, the price-quality ratio has changed.

The ability to innovate in this situation will thus be a key factor for the future success of the Tuttlingen cluster. During field research, firms were asked about their upgrading success, along with changes in turnover. Of the interviewed firms, 23 (out of 33) had developed new products in the last five years. Of these, 20 firms had also raised turnover in the same time. Of those who were not able to develop new products (10 firms), only three had been able to increase turnover, while three had suffered a decline. Future expectations reiterate this development: While all firms producing in the minimally-invasive or implant field expect further increases of turnover, only 11 out of 23 firms on the "classical" instrument-producing firms side expect such increases. These findings are sensitive to product segments within medical engineering. All (six) firms whose main products are implants and four out of six firms engaged in minimally-invasive instruments or endoscopes experienced an increase in turnover. In the field of "classical" surgical instruments, only 14 out of 22 have been able to increase turnover. In conclusion, firms mainly producing classical surgical instruments tend to be less innovative than those engaged in the other segments like minimal invasive instruments or implants.⁴⁰

As a result, the innovativeness of cluster firms is clear. Yet, at the same time, most product upgrading has involved minor improvements (21 out of 33), and only five of the interviewed firms claimed to have made big improvements in this field. All of these were either engaged in segments other than instruments, or are larger firms. It is not easy for small producers to make the shift to radical product upgrading in higher value segments. This is particularly true for the implant sector, where advanced materials are used and intense clinical testing has to take place prior to obtaining permission to enter the market. Capital is therefore required, in addition to know-how in order to survive and to innovate. Thus, there is a marked shift from labour intensive to capital intensive production. Nevertheless, some of the small firms are trying to enter this field by, for example, specialising in a single product.

The most impressive upgrading has been done by large firms. In the field of production, large firms increasingly concentrate themselves on rent rich products like implants and minimal invasive surgery (instruments and endoscopes), while passing their mature classical equipment away to their plants or joint ventures in Sialkot, Malaysia, Poland, Hungary or Mexico. The lead firm for example, employs about 2,000 people at Tuttlingen, and a further 4,000 in Poland, Malaysia and Spain, most of them engaged in production. The plants abroad have been grown steadily both in number and employment in the last 20 years, while in Tuttlingen employment has only grown minimally. It would be

interesting to explore why the lead firm decided to ignore Sialkot and build new plants in regions without an existing surgical instruments cluster. This is particularly significant as it is the only firm that has managed to supply ready-made products at best quality from its plants abroad.⁴¹

Further business developments in Tuttlingen will be in the value-added segments of medical engineering, such as implants and minimal invasive surgery. This requires resources and an increase in knowledge. Thus, the high road of technological improvement is limited to larger firms, or associations of small firms, which have capital as well as technological know-how to maintain a steady programme of research and development. The lead firm in Tuttlingen, for example, states in its annual reports that 25 % of their products were developed less than three years ago. The firm is engaged in many segments, maintaining joint ventures with external leading firms in complementary technologies. A new unit is currently being built for implants, called the *benchmark factory*, which will lead to a 25 % reduction in production costs.⁴² Additionally, European logistics will be co-ordinated from Tuttlingen. Logistics are of special importance in the implant field, where short delivery times are required. Moreover, the lead firm has improved its services to become a full supplier for end-customers. That means that it will offer full content contracts including the sterilisation, repair and replacement of instruments and an “all it needs to operate” approach (firm slogan). As a result, it is predicted that end-customers will

eventually lease, instead of purchase, instruments and medical equipment while outsourcing the complete facility management to service firms, in which large producers may have influence through direct ownership or chain governance. The question arises, what will be the position of a cluster consisting mainly of small firms in the future? To consider this, in section six the upgrading prospects of both chain and cluster are combined.

6 The local cluster in the global value chain

This section first gives a view on the upgrading prospects mentioned in the earlier sections. It then asks, how global and local governance interact: Does engagement in value chain ties undermine firm's engagement in cluster activities? Or, alternatively, do linkages in value chain ties enhance cluster-wide efforts in upgrading? Which upgrading prospects are deriving from engagement in value chains and which from engagement in joint action at cluster level? In which are both interacting? The first subsection seeks to provide a synthetic view of upgrading prospects, whereas the second subsection seeks to unravel the interaction of local and non-local linkages.

6.1 Upgrading prospects in the cluster and value chain context

For specific groups of firms, Table 9 provides a comparable view of the advantages and disadvantages of the cluster's engagement in value chain ties. The table measures, according to the discussions of the preceding sections, the

particular upgrading prospects that engagement in both the cluster and value chain provides. While the contrast is made between large producers and small producers, in most cases medium sized producers have to varying degrees characteristics of both. It is similar in the case of the associations, Medicon and Martin, where member firms are still responsible for processes, while product upgrading and functional upgrading are interlinked with the group. Traders are only considered in respect to functional upgrading. If they have their own production units, their process and product upgrading capabilities are akin to those of small firms.

Small firms are able to enter into process upgrading through cluster externalities (i.e. the labour market) and, in particular, through joint action promoted by institutions. In contrast, cluster externalities are less important for large producers, whilst attracting external knowledge is crucial. In this area, value chain ties play virtually no role. Process upgrading in Germany instead plays a large role in national industrial policy, which is intended "to build up a precondition for competitiveness and success".

The roles of cluster gains and value-chain gains seem to be inverted in relation to product upgrading. Joint action regarding product upgrading has so far had only limited results at the cluster level. Nevertheless, an important advantage of the cluster concerning product upgrading is the imitation of products, stimulated by cluster-bound information flows.

Engagement in the value chain, however, plays a major role in product upgrading. Access to end-customers, made possible by intermediaries further up the value chain, is crucial. Again,

Contrary to the variety of possibilities mentioned in Table 9, functional upgrading is limited to a few examples. Besides the past work of associations, for example, in achieving functional

Table 9: Upgrading in the Tuttlingen cluster of surgical instruments and medical engineering

	process upgrading through:	product upgrading through:	functional upgrading through:
small producers	<ol style="list-style-type: none"> 1. <i>cluster externalities</i> 2. <i>joint action (direct or indirect activity of institutions)</i> 	<ol style="list-style-type: none"> 1. <u>other producers as buyers (former system, extinct)</u> 2. <u>buyers (lasting traditional system)</u> 3. <u>traders (new trading system)</u> 4. <u>joint action (associations: <i>Medicon, Martin</i>)</u> 5. <u>joint action (limited result)</u> 	<ol style="list-style-type: none"> 1. <u>partly through traditional system: passive trading</u> 2. <u>assistance from firms outside the cluster</u> 3. <u>own efforts (virtually not existent)</u> 4. <u>joint action (associations: <i>examples of the past, some recent examples failed for network failure reasons</i>)</u> 5. <u>passive functional upgrading through enlargement of the production chain</u>
large producers	<ol style="list-style-type: none"> 1. external knowledge 2. <i>cluster externalities (lower importance)</i> 	<ol style="list-style-type: none"> 1. own resources 2. <u>direct contact with end-customers</u> 3. direct contact with research institutes outside the cluster 	<ol style="list-style-type: none"> 1. own resources: extending own activities 2. strategic alliances, mergers & acquisitions 3. <u>passive functional upgrading through enlargement of the production chain</u>
medium sized firms	mix of small and large producers capabilities and strategies		
traders			<u>Passive functional upgrading through enlargement of the production chain</u>

italic: upgrading through cluster gains;

underlined: upgrading through chain gains

large firms are not necessarily included in this assessment, for their scope and strength enables them to innovate in certain segments, whilst direct contact with customers and specialists facilitates product upgrading in others. It is too early to judge the most ambitious joint action approaches, the “competence centre” and the “Take-off” technology and firm founding park. However, if they succeed, it will change the role of cluster-bound joint action significantly.

upgrading through joint action, classical network failures have resulted in the failure of more recent efforts. Once again, we find that large firms are in a different position, as they are able to upgrade functionally. The resources required for this derive from their own strengths (capital, know-how) as well as from those of their partners, which are built up or maintained (co-operation, strategic alliances, acquisition, mergers) over time.

Both producers and traders are able to functionally upgrade through the enlargement of the production chain. They are able to build up ties with sub-contractors – particularly those in locations with low wages – further down the chain. In the case of Tuttlingen producers (and traders) which have maintained high production capability this has proved to be the case, at least concerning mature standard instruments. While the initial and final production steps are carried out in Tuttlingen further, the medium steps are transferred to low wage locations, thus the chain increases in length. Of importance in this case is not only, that sourcing locations have shifted, but that this shift is accompanied by a change in chain governance from arm's length market relations to quasi-hierarchy. Hence, the governance shift itself might be seen as a kind of upgrading, for the different influence of a particular firm over an other part of the chain may strengthen its competitiveness.

6.2 The interaction of global and local linkages

This sub-section is driven by the question, whether changes in value chain ties affect local governance. It builds on the findings from the previous sections. As seen in Tuttlingen, spending resources in ties with external specialists may viewed as more efficient by lead firms than engaging in cluster joint action. Thus the following questions arise: What benefits do large firms obtain from being in Tuttlingen? In what kinds of value chain activities are such firms concentrating their efforts? Does this lead to a passive behaviour by such firms concerning

cluster activities? And, finally, under what conditions is this the case?

We have seen in the sections above that, in several fields, cluster governance and value chain governance interact. This is so when firms extend their activities with chain members (vertical) at the expense of (horizontal) cluster activities. It also occurs where activities within the chain are undermining the cluster. This is particularly so when

- small producers' efforts in functional upgrading are hindered by forward-linked firms
- both producers and traders establish subcontracting ties with firms abroad
- large firms in the cluster are upgrading functionally and favour ties with external specialists
- large external firms buy technological lead firms of the cluster.

In the first case, tensions between producers and their buyers have long been present in Tuttlingen. This seems to be a typical problem of a multi-functional cluster, housing several steps of the production chain at the same time. In a dynamic sense, cluster governance is unaffected, as this is not related to cluster activity or to local joint action.

We have seen above, that products which were formerly sourced from Tuttlingen suppliers by larger firms are nowadays increasingly sourced from low wage suppliers, or the firms' own plants abroad. Here, the activity of particular firms cut into other firms' wealth, pushing them forward to innovate or fail - increasing the competition game. As long as outsourcing firms do not rely solely on such trading rents, but try to

innovate simultaneously in other segments in Tuttlingen, this chain activity would not weaken the cluster as a whole, nor would it necessarily affect their efforts at joint action at a cluster level. Nevertheless there are signs, that many firms are relying on trade rents.

In the field of innovation, the lead firms maintain ties with external specialists, both private firms and public research institutions. This is, on the one hand, due to the lack of advanced public R & D institutes in Tuttlingen. On the other hand, it is due to the new opportunities emerging from different new technologies, which were developed in different locations outside the cluster. As a result, it is important to note how important actors of the cluster are increasing their ties with external actors. This is by no means a negative sign for the cluster. Radical innovations in Tuttlingen have always come from outside. Nevertheless, there are differences in terms of the circulation of knowledge, as well as the ability to adapt and to improve external knowledge. In contrast to the past, complexity of knowledge has increased dramatically, which inhibits most cluster firms from participating in this process. This is especially true of new knowledge changing elements, which are exclusive by virtue of their complexity and interaction with other technological knowledge. Thus, knowledge will not circulate within the cluster at the speed it has in the past, and knowledge systems will become more closed (see: BELL & ALBU 1999).

A similar effect for the cluster occurs, when important firms within the cluster are bought by large external

competitors. Such firms usually have to shut their R & D activities outside the cluster. In these cases, while the production unit stays in the cluster, the firm's interests in the cluster are reduced to passive externalities. As a result, value chain ties are pursued at the expense of cluster activities.

This outcome leads to a general consideration of the inter-linkages between cluster advantages and the advantages promised by interaction in value-chain ties. This consideration lies in the dynamic of technological change, which is discontinuous over time, and the upgrading prospects that derive from this. Where radical technological innovation is limited, the fast assimilation of incremental innovation is the key to competitiveness for producers. One of the main features of clusters is the fast flow of knowledge. It leads to a rapid spread of innovations, but usually of an incremental nature. Thus, cluster firms may gain competitiveness by joining cluster initiatives. However, in times of radical innovation, value chain ties to external specialists may be more promising. As resources are limited, cluster activities of firms may decline at the expense of activities in value chains. This may partly explain the success of the Italian industrial districts during and after their difficult years in the 1990s. In the case of the medical engineering cluster of Tuttlingen, new technologies relating to robotics, micro-systems technology, bio-technology, optics, and advanced materials are pushing large Tuttlingen firms towards external partners.

An other argument leads to the initial and main strength of the Tuttlingen cluster, the production of high quality hand held surgical instruments. This has its roots in the high quality of the training system and in the tacit knowledge of the workers. As low-cost competitors increasingly cut into this area, and cost pressures lead to declining rents, large firms diversified their product range to advanced products, in collaboration with research facilities external to the cluster. Thus, the main competitive advantage of Tuttlingen is fading, as shown by the decreasing importance placed on the cluster by large firms. This is proven by Aesculap's decision on where to establish its new *Benchmark Factory* for implants.⁴³

The fact that firms may regard efforts in value chain ties as more efficient than joint action at the cluster level may lead to a conflict of interest, whether to support cluster activities or not. More crucial for cluster governance would be a second step, changing the passive behaviour to active opposition. This may be the case, if direct competitors for lead firms are to be found locally. Thus lead firms would not wish to help their competitors through joint action. This seemed to be the case, when the planned research and marketing institute in Tuttlingen was stopped by the lead firms. It might also be the destiny of the Competence Centre. From the Tuttlingen example, it is obvious that joint action occurs when there is a common self-protective reaction, unifying or otherwise, to external changes or pressures. This occurred when *Martin* and *Medicon* were founded and when the sterilisation of instruments

became an issue of joint action. If this were upheld by other studies, a sudden death of clusters facing new challenges would not be the consequence, but, rather, a creeping death resulting from the insidious effects of increasing heterogeneity and deterioration through a lack of common interests.

7 Concluding remarks

This section takes stock of the paper's findings, and provides additional remarks and questions. The previous sections have shown the range and internal heterogeneity of the Tuttlingen cluster as well as its historical development in surgical instrument manufacturing. Having experienced some economically outstanding decades, recent challenges to the Tuttlingen cluster necessitate major changes to sustain the cluster's competitive edge. As we have seen in Section 4, joint action at the local level plays a crucial role, particularly in building the cluster's knowledge base through vocational and advanced training. Since co-operation between private firms is limited, institutions are important in promoting and mediating joint action. This is a necessary undertaking, for private actors often mistrust each other. Nevertheless, it is worth mentioning, that two private associations, *Medicon* and *Martin*, allow some small producers to compete even with the cluster's lead firms.

Regarding upgrading, local joint action in Tuttlingen promotes in particular process upgrading by distributing technical knowledge through training and special lectures. Inducing product upgrading is usually not the central aim of

such activities. In contrast, joint action through value chains leads to product upgrading. Here, process upgrading emerges as the exception. For all firms, co-operation with end-users is the main source of product innovation. Moreover, a solid reputation, effective advertising and the catchment of future customers can be obtained by linking famous surgeons to product development initiatives and technique-promotion at university hospitals. However, only the larger firms, with the resources and the reputation to attract famous surgeons, are able to develop in this way. Small-scale firms are mainly dependent on their buyers as mediators for information. This leads, first, to inconvenient and sometimes distorted and delayed information flows; and, second, to incremental improvement rather than radical innovation. Functional upgrading is not common at Tuttlingen, for ties are strong and stable over time. The value chain, therefore, enables neither upgrading nor joint action at local cluster level. There are, however, three examples of successful functional upgrading. Firstly, where outside assistance occurs. For example, a large firm entering into a joint venture with an upgrading firm. Secondly, in the two cases of the trade associations, which emerged from joint action of the past. And thirdly, in the case of the lead firm, which was not driven by chain frictions in the same way because of the strength of its own resources.

The Tuttlingen cluster was able to diversify its product range from classical surgical instruments to implants, endoscopes and minimally invasive instruments, as well as some electro-medical

products. These segments are taking different trajectories. While the new fields are primarily driven by radical innovations, the classical segment of handhold surgical instruments are much more price driven, with competitive pressures increasing in recent years. Large Tuttlingen firms have built plants abroad, to gain from cheap labour costs. Other Tuttlingen firms have established production ties with producers abroad. Those ties are governed in a quasi-hierarchical way and offer a way to push price pressures further down the chain. This practice has recently been adopted by traders, who have become the most important actors in transferring know-how to other locations. As a consequence of price pressures, rents are shifting increasingly from production to trade, logistics and services in general; and from the manufacturing of surgical instruments to advanced products like implants and endoscopes in particular. Thus, the instrument manufacturing sector in Tuttlingen is declining, while other segments are growing. Within this development, the tacit knowledge of surgical instrument manufacturers will decline in importance, and the location factor specific to Tuttlingen will fade.

As the majority of the cluster's firms consist of small instrument manufacturers, this finding is of considerable importance. If the cluster's small firms are unable to adopt new skills and technologies, they might be undercut by low wage competitors in the long run. It is unclear whether this would affect large firms, for cluster advantages may fade with this development. On the other hand, emancipation of large producers

from the declining instrument field, may also lead to the view that the consequences of such decline for large firms would be of minor importance. Although small firms account for many incremental innovations, the high share of employees in large firms would suggest that big losses of small firms would not have a strong effect on Tuttlingen's economy as a whole.

Entering new fields means competing against new locations and firms, and in the larger sea of medical engineering, Tuttlingen is but a small fry. Thus, the main challenge for the cluster can be seen in the assimilation and internalisation of external knowledge, to combine it with passive and active cluster advantages. The cluster still contains innovative SMEs, a reputation for high quality products and highly skilled workers.

A promising way to strengthen the cluster might be the new initiatives, the competence centre and the business founding park, aimed at promoting innovation in Tuttlingen. It would be of decisive importance for the cluster whether firms join with substantial effort or not. Nevertheless, with the shift from surgical instruments to other products, the 'big fish' in the surgical instruments pond may need to choose different trajectories to swim in the large sea of health care delivery.

8 Literature

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