AS ADVANCED COUNTRIES and geographical regions such as the United States and the European Union evolve into knowledge societies, the ability to generate, use, diffuse, and absorb new knowledge is increasingly viewed as critical for economic success. Consequently, conventional wisdom regards high-tech, research-intensive, and science-based industries as the key drivers of future economic prosperity. The policy conclusion is that high-cost industrialised countries should concentrate their efforts on promoting these industries. So-called low- and medium-tech (LMT) manufacturing industries, by contrast, are deemed to offer very limited prospects for future growth, and as a result they receive less explicit policy attention and support.

THE POWER OF THE PRACTICAL

LOW-TECH’S NEGLECTED STRENGTH

Hartmut Hirsch-Kreinsen

The contribution of low-tech manufacturers to innovation is poorly understood.

LENGTH: 11 min (2630 words)
Sectors with an R&D intensity below this threshold, such as appliance manufacturing, the food industry, and the paper, publishing and print industry are regarded as low-medium-tech. These industries can also be termed mature and non-research-intensive because they are well advanced in their life cycles.

**The Statistical Basis of this Perspective is the Internationally Accepted R&D Intensity Indicator, Developed by the OECD in the 1960s, Which Measures the Ratio of R&D Expenditure to Company Turnover or to the Output Value of an Entire Sector.**

The significance of LMT manufacturing in advanced economies can be explained by their surprisingly high and specific innovative capability, and their relevance with regard to the innovation ability of the economy as a whole...

The significance of LMT manufacturing in advanced economies can be explained by their surprisingly high and specific innovative capability, and their relevance with regard to the innovation ability of the economy as a whole – something that is generally overlooked in the scientific, as well as in the public, debate. Thus the question arises: what are the features of low-tech innovations?

**Typical LMT Innovation Strategies**

To answer this question one must first define what the term “innovation” means. The economist Joseph Schumpeter conceived it as any activity that includes the development and successful marketing of new products, the introduction of new production technologies and services, and the technical and non-technical reorganisation of processes. Based on this definition, and on the main findings of LMT research – in particular, research conducted in the EU and in Germany over the past decade – various innovation strategies of LMT companies can be regarded as typical for the sector (see Table 1).

The first innovation strategy is characterised by the continuous further development of given products, and can be referred to as step-by-step product development. Typically, it concerns enterprises that manufacture products for relatively stable market segments – for example, for special applications in the automotive industry. This strategy is typical for manufacturing sectors with mature technologies and products such as fabricated metal products. Not only are the markets well defined, but the products are also well-established, and often standardised; production technology remains unchanged for longer periods, and is at best gradually adapted to changed product requirements. In such sectors the processes have a high degree of efficiency, and price is a major factor in competition.

The second strategy involves innovation that is primarily directed at securing and improving the marketing situation of an enterprise. This holds good for the fashion-oriented design of products, and can be referred to as marketing-oriented innovation. Typically, it concerns enterprises that manufacture products for relatively stable market segments – for example, for special applications in the automotive industry. This strategy is typical for manufacturing sectors with mature technologies and products such as fabricated metal products. Not only are the markets well defined, but the products are also well-established, and often standardised; production technology remains unchanged for longer periods, and is at best gradually adapted to changed product requirements. In such sectors the processes have a high degree of efficiency, and price is a major factor in competition.
the functional and technical upgrading of products, rapid responses to changing customer wishes, the exploitation of market niches, skilful branding strategies, and the expansion of product-related service activities. Unlike the first strategy, enterprises pursuing this strategy belong to a relatively broad range of industrial subsectors, ranging from textile and clothing industries geared to anticipate fashion cycles to office furniture manufacturers that at very short notice accept orders for novel products from large retailers. This can be referred to as a customer-oriented strategy.

A third type is primarily directed at the technical and organisational structures of the production process and is used by companies that employ advanced, capital-intensive process technologies, often with a high degree of automation. Examples include sheet-forming companies, firms manufacturing plastic parts, mechanic components or parts made of aluminium, paper manufacturers and firms involved in food processing. Furthermore, under these technical and organisational conditions, the safeguarding and constant improvement of the product quality is seemingly achieved as a by-product.

**Table 1: Low-Tech Innovation Strategies**

<table>
<thead>
<tr>
<th>Primary subject area</th>
<th>Step-by-step</th>
<th>Customer-oriented</th>
<th>Process specialisation</th>
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</thead>
<tbody>
<tr>
<td><strong>Examples</strong></td>
<td>Incremental product development</td>
<td>Improving the market position; creating new market segments</td>
<td>Introduction and utilisation of advanced process technologies</td>
</tr>
<tr>
<td>Animal management, (Gallagher), refrigeration (Temperzone)</td>
<td>Furniture manufacturing (Formway Design)</td>
<td>Fruit processing (Mr Apple partnering with Compac Sorting Equipment)</td>
<td></td>
</tr>
<tr>
<td><strong>Main conditions</strong></td>
<td>Companies with relatively stable market segments and efficient processes</td>
<td>A broad range of companies with turbulent market conditions</td>
<td>Companies with highly automated and integrated manufacturing processes</td>
</tr>
</tbody>
</table>

**The Relevance of “Architectural” Innovations**

In terms of their priorities and objectives, these innovation strategies cannot at first be fundamentally distinguished from those found in industrial sectors with markedly higher R&D. However, if one looks at innovation focus, their special characteristics can be demonstrated. Following up on the critique of incremental versus radical innovations by MIT researcher Rebecca Henderson and Harvard University’s Kim Clark, the strategies outlined above can be inserted into a broad spectrum of innovation modes, ranging from incremental innovation to architectural innovation. Both have in common the use of given technological core concepts and knowledge assets and their further development within the existing framework – for example, the step-by-step product development employed by standard manufacturers. The term architectural innovation, on the other hand, denotes the recombination of existing components to obtain a new product design or technical and organisational structure, without leaving the well-established technological development path. An example is the customer-oriented strategy which combines almost unchanged product components and units to a new product, thus meeting special customer requirements while opening up new market segments. Market-orientation based on architectural innovation is a promising strategy for LMT companies in advanced economies which enables them to stabilise and improve their competitiveness, especially against low-cost competitors in international markets.

**The Specific Knowledge Base of LMT Innovations**

Knowledge is a key resource for innovation. However, in terms of LMT innovation, a distinction should be made between in-house and external knowledge bases and their corresponding information sources.

LMT firms drawing on in-house knowledge undertake very limited R&D, and formalised processes of knowledge generation play an insignificant role. Instead, innovation activities proceed by means of pragmatic doing and using. Hence, the knowledge that is relevant for these enterprises can be regarded as being practical and application-oriented. Unlike scientifically and theoretically generated knowledge which orients itself on criteria such as theoretical relevance and universality, practical knowledge is generated in the application contexts of new technologies. It obeys validity criteria such as practicability, functionality, efficiency, and failure-free use of a given technology. These types of knowledge, however, are difficult to distinguish. To simplify matters: theoretical and scientific knowledge in enterprises – for example, in the form of systematically acquired engineering knowledge – primarily can be assigned to research, development and construction processes, while practical knowledge accrues in the context of ongoing operating processes. “Practical knowledge” stands for a complex bundle of different knowledge elements. It comprises both explicit, codified, and formalised elements, such as design drawing and requirement specifications.
for new products, and implicit elements, such as accumulated experience and well-established, proven, and tested routines for solving technical problems.

The relevance of this type of knowledge can be exemplified by referring to the strategy of process specialisation: the enterprises considered here make use of engineering knowledge that is incorporated and codified in their production facilities and operating instructions, although specifications and ongoing intervention and adaptation measures are necessary. An indispensable precondition is the available knowledge on the shop floor (for example, knowledge of the shortcomings of the production technologies already in use). Process innovations generally occur in the context of ongoing operative processes, and may be initiated and conducted by those who are responsible for ongoing functions, such as engineers, technicians, master craftsmen, and even workers.

However, the company’s external knowledge base plays an even more crucial role for LMT innovations. This is largely because LMT companies can compensate for limited R&D resources by simply adapting externally generated knowledge, and LMT studies show that customer input plays a large role in product innovations. But, not surprisingly, information and knowledge from suppliers are of greater importance to LMT businesses due to the significance for them of process innovations. In line with the seminal work on sectoral patterns of technical change, in 1984, by University of Sussex researcher Keith Pavitt, many LMT firms can be characterised as supplier dominated. Their innovative capability is largely based on the ability to adopt externally developed components for process technologies or new products – an ability that is also referred to as embodied knowledge – and to adapt it to their own requirements. Finally, scientifically generated, codified knowledge, such as that originating in research institutions, consulting firms and trade fairs, also plays a role in the innovation ability of LMT companies.

**SME-SHAPED KNOWLEDGE MANAGEMENT**

How firms use internally and externally available knowledge – that is, how they organise the innovation process – is of decisive importance for their innovative capabilities. Because of the dominance of small and medium-sized enterprises in LMT sectors, the innovation processes are strongly shaped by the structures and the resource and capacity limitations of these companies. They have limited capital and know-how, and the degree of management professionalisation is often

low. Furthermore, due to limited R&D capacities, their technological capabilities are rudimentary. Instead, innovation processes occur at a practice-oriented level and are generated by a small group of management representatives and technical experts. Therefore, as empirical findings show, the innovation courses and practices in LMT companies are characterised by a low degree of formalisation. This can be seen, for example, in the use of innovation-oriented incentive schemes, the integration of innovation-related performance figures into target agreements, selective qualification measures, and the existence of innovation-promoting forms of work organisation - such as innovation circles, teamwork and temporary project teams.

Also, cooperative relationships with external partners are often influenced by this pattern of SME-shaped knowledge management as these businesses prefer informal, personnel-based relationships. Indeed, informal cooperation practices are often a precondition for LMT firms identifying the largely unarticulated, tacit, and unreliable knowledge of their customers.
Low-tech manufacturing offers greater prospects for employment and economic growth in mature manufacturing sectors. The economic landscape of knowledge-based countries in the first years of the 21st century does not appear to be undergoing a wholesale structural replacement of "old" sectors with "new" ones. In fact, this process is evolving as a restructuring of existing sectoral and technological systems. It is not dominated by industrial activities for which competitive advantage, capability formation, and economic change are generated by front-line technological knowledge, but rather by what are often wrongly termed low- and medium-tech industries. And it is characterised by a specific combination and continuous re-combination of high- and low-tech.

LMT industries can play a decisive innovation role because the involvement of low-tech companies and products is frequently a core precondition both for the innovativeness of value chains and for the design, fabrication, and use of a range of high-tech products. As Paul Robertson and Keith Smith of the University of Tasmania convincingly show through their research into the processes of technological change in advanced economies, the relationships between high-tech and non-high-tech sectors are highly symbiotic, and the well-being of high-tech firms and industries depends heavily on their ability to sell their output to other sectors in developed economies. The use of advanced machinery and the transfer of knowledge is important for both product and process innovations in LMT firms, but these transfer processes are not unidirectional; relevant innovation impulses also travel in the reverse direction—from low-tech to high-tech. As Robertson and Smith state, these impulses result from the simple, but often overlooked, economic fact that profits from the sale of new technologies are vital for the amortisation and continuation of R&D investments by research-intensive enterprises. Furthermore, additional impulses arise from the specification of new technology application requirements. These impulses often influence the development of new technologies if the requirements of individual users coincide with those of many other users, thus broadening the application field for complex products. One can therefore speak of a high level of technological complementarity between LMT and high-tech industries that is central to the industrial innovative capabilities of an entire economy.

**Innovation Models**

To sum up, the research findings on low-tech innovations prove convincingly that the linear model of innovation with its dominant focus on high-tech, which is widely adhered to in the public debate, reflects industrial innovation only inadequately (see figure 1).

The essence of this model is the assumption that research and development activities are the starting point for any kind of innovation, and that scientifically-generated knowledge triggers the development of new technologies. This model regards research and development as fundamental and necessary innovation steps, which functionally and temporally precede the industrial process. It assumes that there is a clearly structured course of action, during which the knowledge of basic research is transferred, specified and utilised step-by-step, via applied research, and is finally employed in the form of concrete technologies in a certain implementation context. Following this model, an effective innovation policy must focus on R&D in order to encourage industrial innovations. It is then merely necessary to ensure that the new knowledge asserts itself to the point of concrete development projects and fields application by promoting appropriate transfer measures.

However, industrial innovations are seldom based on scientific knowledge. The relationship may even be inverted – that is, with technology itself creating the foundation for scientific knowledge. Furthermore, technological innovations are very often initiated by practical problems in the production process and, more importantly, by market and application demands. This has been shown by innovation research over many years—for example in the chain-linked model of innovation described by Stanford University researchers Stephen Kline and Nathan Rosenberg in 1986. An innovation model referred to as the recursion model of innovation (see figure 2) may therefore be a more useful guide to understanding the processes of technological innovation, and in particular the innovation patterns of LMT firms.

**Key Take-outs**

- Low-tech manufacturing offers greater prospects for employment and economic growth in advanced economies than current policy acknowledges.
- The disproportionate support for high-tech, research-intensive industries fails to take account of the high and specific innovation capability of low-tech firms.
- Innovation does not necessarily begin with R&D activities centred on scientific knowledge, but may be driven by problems in the production process, or by market demands.