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Developing Company Technological Capabilities

Erik Arnold

Erik Arnold is a director of Technopolis Ltd, a technology policy and management consultancy based in Brighton.

Introduction

In OECD countries, innovation policy is becoming increasingly concerned with promoting the development of technological capabilities required for innovation in small and medium-sized companies (SMEs). These companies play a large role in OECD economies, yet are generally regarded as under performing. The technological capabilities they need are 'soft' as well as 'hard'. They relate to the creation and management of internal technological resources, external networking and the strategic management of technology and its relationship to business strategy.

This paper develops a taxonomy of these capabilities. It is based on a mixture of literature survey and our own evaluations and comparative studies of innovation policies. It offers an intellectual framework to decision makers wishing to review and improve policies for capability development.

Company capabilities are dynamic, growing as companies learn. They tend to increase with firm size and the possession of internal technological resources. Since firms themselves have differing levels of capability, public policy should differentiate between segments of the company population, offering an hierarchy of services to encourage and help companies learn new capabilities. Managing the coherence of the policy system and the transparency of the interface with SMEs are important policy functions.

The Place of SMEs in Industry Policy

Since the 1950s, there has been a movement away from separately-conceived science and industry policies and towards innovation policy. Governments have become increasingly reluctant to provide large-scale industrial subsidies, and have signed trade and other treaties (e.g GATT) which limit this type of activity. Instead, they turned to investing in technologies which could secure future industrial positions, notably in transport and electronics. Recently, these attempts to 'pick winners' have been complemented by more generic innovation policies, often aimed at smaller firms.

In science and technology policy, government intervention has historically focused on the innovation-creation process. This has been justified by arguments about market failure: the inability of market mechanisms to secure long-term, 'common good' improvements in science and technology.[1] However, there are other types of failure in markets and in firms' capabilities which impede the technology diffusion process by preventing entrepreneurs from taking rational technology decisions. These failures tend to be most acute for SMEs. Tackling these problems extends the policy sphere to include not only technology generation but also diffusion and companies' 'absorptive capacity' for technology.

Over the last decade, policy makers have increasingly accepted that it is "not the creation of technological leadership in itself that affords a nation its competitive advantage, but the rate and level of diffusion of the technology into economic use"[2].

- Technology development and diffusion are clearly of considerable potential economic importance, with diffusion offering particularly large benefits
- Technology diffusion involves far more than the simple introduction of new machinery into the firm. Additional measures, such as internal reorganisation of both production and management processes and upgrading of skills, may be essential to capturing economic value from investment in new technology
- Whereas it may not be necessary to produce technology to reap its benefits, diffusion is essential to maximise potential national economic returns. However, realising the benefits of diffusion may depend critically on broader social and institutional changes, which may, in fact, represent the most important obstacles of all[3].

Quite where adoption and adaptation of technology shade into incremental improvement and innovation is often hard to say, since "any act of adoption involves certain transformations and is an act of incremental innovation in itself."[4] Similar technological capabilities are required for each, so policies which promote 'absorptive capacity' are part of a continuum with policies to foster invention.

Despite their limitations, SMEs collectively play a major role in OECD economies. They make up the majority of firms, but the SME population is unstable: there are high rates of entry and exit. They have a very wide range of capabilities and performance. Some stay small because they deserve to. Others are potential motors of economic growth and move on to seize the commanding heights in their industries.

[1]Arrow, K., Economic Welfare and the Allocation of Resources for Invention,' in National Bureau of Economic Research, *The Rate and Direction of Inventive Activity: Economic and Social Factors*, Princeton University Press: Princeton, 1962
[2]Rothwell, R. and Zegfeld, W., *Reindustrialisation and Technology*, Essex: Longman, 1985

[3] Brainard, R., Leedman, C. and Lumbers, J., *Science and Technology Policy Outlook*, Paris: OECD, 1988
[4] *Technology and the Economy: The Key Relationships*, Paris: OECD, 1992, p48

Collectively, SMEs - especially those able to make technology central to their strategies - have higher growth rates than large firms.[5] Their importance is reinforced by the growing tendency of big companies to fragmentation through outsourcing, strategic partnerships and other types of networking. This fragmentation is increasingly enabled by Information Technology, as is the growing ability of SMEs and individuals to work in networks and to form 'virtual companies'. We may, therefore, be seeing a technologically-enabled shift in the structure of industry in which smaller economic units compete and cooperate based on their combined ability to exploit internal capabilities and to access external ones. Networking becomes an increasingly important capability in itself.

Innovation Characteristics of SMEs

SMEs' innovation characteristics are increasingly been explored. Thus, the Community Innovation Survey (CIS) includes a question about the obstacles that firms see to innovation. While the CIS includes all sizes of firm, the larger numbers of SMEs in the population means that CIS responses primarily indicate the views of these small companies. Responses from Irish[6] and Norwegian[7] companies are typical of the type of response obtained by the CIS and, indeed, other similar surveys.

The most important worry is money. It is easy to jump to the policy conclusion that, therefore, more finance should be available. Yet there are few symptoms of overall capital shortage in the economy, especially at today's low interest rates. The problem seems to be that lending SMEs money is **objectively** risky. SMEs have a high death rate. Their small scale and often underdeveloped business capabilities make it hard for them to do the kind of sophisticated research and business case development necessary in order to put a case to a financier. Technological risks and uncertainties may be hard to quantify and explain. SMEs also tend to have insufficient assets to back major loans or injections of equity

CIS respondents themselves regard innovation as expensive and risky. Many of the other obstacles identified relate to technology capabilities - with the most important being the company's internal capabilities ('innovation potential'). Several obstacles (such lack of information on markets and technologies) may relate more to inadequacies in companies' interfaces with the outside world than to a genuine deficiency in the environment.

The smallness of SMEs - their defining characteristic - is an important driver of capability. While there are many actors in the environment emitting 'signals' about technology and market opportunities, SMEs do not always have good 'receptors' for this information. SMEs tend to have relatively shaky economics and therefore to focus on short-term problems rather than long-term improvement opportunities. Managements tend to be small and multi-functional. Often, entrepreneurs run companies single-handed or take a disproportionate share of

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5 US DoCdata, cited in the *European Green Paper on Innovation*, Brussels: CEC, 1995; Arne Isaksen and Keith Smith, *Innovation Policies for SMEs in Norway: Analysis and Policy Options*, STEP Rapport 2/97, Oslo: STEP Group, 1997

6 Anne Fitzgerald and Marcus Breathnach, *Technological Innovation in Irish Manufacturing Industry*, Dublin: Forfás, 1994

7 Svein Olav Nås, Tore Sandven og Keith Smith, *Innovasjon og Ny Teknologi i Norsk Industri: En Oversikt*, STEP Rapport 4/94: Oslo, STEP Group, 1994

the key decisions, in addition to functioning as the general interface to the outside world. Creating a larger, 'professional' management is desirable, but until a certain size is reached it is difficult to create much division of labour or to develop specialised external interfaces.[8]

SMEs tend to undervalue professional advice, to be shocked at its price or to be unable to 'leverage' strategic advice or cost-reductions across a sufficient volume of sales. Such advice may also be seen to undermine management's authority. In many cases SMEs work within a small economic 'space'. This generally means working within a small geography, but it can also mean a tight linkage to a particular industrial sector or to the supply-chain of one or a small number of large companies. SMEs tend in the first instance to work in interpersonal networks defined at these geographic and sectoral levels.

SME capabilities seem to vary with size. There are important exceptions - especially among New Technology-Based Firms - but in general, companies' propensity to enter technology agreements,[9] network with other companies and to exploit the state-run innovation support infrastructure rises with company size up to about 200 employees then tails off a little.[10] This suggests that companies growing beyond 200 increasingly substitute internal capabilities for external relationships and support.

Technological Capabilities

Following Schumpeter, economists tend to describe innovation as "a new combination of the factors of production". This can involve using results of scientific or technological research, but it can also involve much more mundane things such as laying out machines on the factory floor in a better order, changing product packaging or copying ideas from a producer in a distant market in order to create a local advantage. A key observation, however, is that innovation is fundamentally an economic process in which technology may play a greater or a lesser role: it involves a great deal more than creating and selling 'black boxes'.

Perhaps surprisingly, in order to define 'technology' in a way which is relevant to industrial and economic development, the most useful place to go is probably the Oxford English Dictionary (OED), which defines technology as "the scientific study of the practical or industrial arts". There is a great deal of content packed into this short definition

- "Arts" here means the production of artifacts - not only 'works of art' but products more generally.[11] "Arts" involves an holistic view, where design is part of **production**
- Technology involves **knowledge** about

8 See Erkko Autio's systematisation of growth stages in 'Supporting the consolidation and internationalisation of SMEs - The systemic perspective,' in Osmo Kuusi (ed), *Innovation Systems and Competitiveness*, Helsinki: Taloustieto Oy, 1996

9 R Ratti and M Baggi, 'Analyse stratégique et spatiale des accords de coopération entre les entreprises du secteur industriel,' '*Revue d'économie régionale et urbaine*' No 3/4, pp 464-478

10 Technopolis Ltd and PERA, *The Technological Infrastructure which Supports Industry*, confidential report to the UK Department of Trade and Industry, 1994; Erik Arnold et al, *The Technology Transfer and Partnership Programme: An Evaluation*, Dublin: Forfás (Forthcoming, 1997)

11 In the UK, this old definition of 'arts' is frozen in the name of the Royal Society of Arts - which is more concerned with defining and measuring the skills needed for economic production than with painting or sculpture

doing practical things, especially producing things

- The definition does not distinguish between engineering and **managerial** aspects. The modern discipline of management is, historically, an off-shoot of engineering.[12] Many would argue that this fragmentation was a mistake.[13] The revolution in production engineering and management which has introduced 'Japanese' methods and 'soft technologies' such as continuous improvement and lean production can be interpreted as reintegrating the engineering and managerial aspects of technology
- Technological knowledge is built up using scientific methods. It is described in books, tested by experiment and can make deliberate (sometimes rapid) progress by doing work in places which are located **away from the production process**.[14] This distinguishes it from craft knowledge, which is defined and communicated through skills and which tends to evolve together with production
- Because it is a scientific study, technology involves **codification**: writing down knowledge in a systematic way. (In fact, the OED also lists an older definition of technology as "a discourse or treatise on an art or

  Uncodified knowledge remains important in production. Technological progress involves a battle to try to codify knowledge which today is tacit, in order to study and improve it
- Codification means that a crucial feature of technological production, compared with craft production, is that its principles can more easily be communicated or **transferred**. Craft skills move 'vertically' from master to apprentice. Technological knowledge spreads 'horizontally' between technologists
- Codification also implies that people who work with technology must be **educated**. The idea of a skilled but illiterate craftsman is familiar from both history and anthropology. The idea of an illiterate technologist is self-contradictory

This broad definition of 'technology' as something soft as well as hard, and as including important aspects of management and organisation, guides the scope of the company capabilities and the policies we have considered.

The innovation literature contains many observations about **aspects** of technological capability and a smaller number of discussions about how these develop but almost no attempts to provide an overall view. We need this overview both to ensure that our description of technological capability is reasonably comprehensive and in order to understand companies' technological capabilities as **systems**, where individual components are related to each other.

12 see David Noble, *America by Design: Science Technology and the Rise of Corporate Capitalism*, New York: Alfred Knopf, 1977; republished Oxford University Press, 1979

13 RH Hayes and WJ Abernathy, "Managing Our Way to Economic Decline," *Harvard Business Review*, July-August 1980, pp159-175

14 Adam Smith grasped the importance of this fact very clearly when he described how technical progress was enabled by "philosophers or men of speculation whose trade it is not to do anything but to observe everything; and who, upon that account, are often capable of combining together the powers of the most distant and dissimilar objects" *The Wealth of Nations*, 1776; reprinted, Harmondsworth: Penguin, 1974, p115

Two exceptions are Howells[15] and Dodgson and Bessant.[16] **Exhibit 1** shows how they respectively characterise technological capability. Both recognise that the ability to use and develop technology is deeply embedded in the 'soft' factors which surround the hardware, consistent with the broad definition of 'technology' which we use in this paper. Howells' description is static. His concern is to show the interdependence of tangible and intangible assets in underpinning firms' competitiveness, making the distinction between these two kinds of assets central to his model and treating tacit knowledge as a particularly special category of intangible assets.

Bessant and Dodgson's approach is dynamic. They define their terms as

- **Resources** All the assets in the firm which enable firms to operate, including tangible and intangible assets, skills, knowledge, organisation, links with other firms
- **Innovative Capabilities** Features of firms and their management which enable them to **define** and **develop** competences to create competitive advantage
- **Competences** That focused combination of resources which enables firms to differentiate themselves from their competitors

These three elements interact through learning: namely, a purposive search for competitive advantage.

If our analysis of technological capability is to be consistent with the current neo-Schumpeterian or evolutionary view of the firm, it needs to involve this combination of resources and intelligence

> Capability is much more than ... individual assets. If it were not, the firm would be no more than a bundle of bilateral contracts between owner and employee, and rent could not exceed the differences between current and next-best use value. One thing this tells us is that the organisation must possess a memory, or a tradition of practice, so that losses in personnel can be matched with new employees who can be trained in the firm's routines.[17]

The need for a memory drives progressive companies to accumulate tacit knowledge, to identify its components and to try to codify it as intellectual capital. This happens in many companies through, for example, engineering and re-engineering, computer systems development and the articulation of processes and company standards. Creating intellectual capital - technology in the older sense of "a discourse or treatise on an art" - in this way is intended to improve the firm's effectiveness. But it also tends to lock the company into specific products, markets and technological trajectories, promoting 'path-dependency'. The problems can in principle be reduced if the corporate memory can forget as well as learn.[18]

Modern, evolutionary economics thus sees the firm as a searching, learning mechanism. It survives and improves by continually reinventing itself. It consists of

15 Jeremy Howells, 'Tacit knowledge and technology transfer,' in Gustavo Fahrenkrog and Patries Boekholt (eds) *Public Policies to Support Technology Transfer*, EIMS Report No 8, Luxembourg: European Commission, 1994, p3

16 Mark Dodgson and John Bessant, *Effective Innovation Policy: A New Approach*, London: Thomson, 1996, p12

17 J Stan Metcalfe and N de Liso, 'Innovation, Capabilities and Knowledge: The Epistemic Connection,' University of Manchester (mimeo) 1995

18 Björn Johnson, 'Institutional Learning' in Bengt-Åke Lundvall, *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, London: Pinter, 1992

a pool of assets, including both physical assets and intangible ones such as capabilities, and intelligence, which learns from the environment and modifies the resources (**Exhibit 2**). Each of these elements can be broken down much further. An important attribute of the firm's 'memory' is that it comprises a mixture of knowledge (tacit as well as codified) and of the **configuration** of assets: namely, organisation, characteristics of the capital stock, relationships, and so on.

In **Exhibit 3**, we set out a simple way to think about technological capabilities which captures both this need for a corporate memory and the need to connect it with the market. It shows three kinds of capabilities: internal; external; and strategic. These are interlinked and interdependent.

The strategic level provides the intelligence or control mechanism which allows the firm to manage its capabilities and exploit them via the market. This meta-level involves the entrepreneur in deliberately stepping outside the accustomed circular flow of daily economic life, trying to understand what knowledge makes the business succeed and using this knowledge about knowledge to increase performance. In modern industrial practice, the strategic function does not have a monopoly of learning, but ensures that it takes place at all levels of the firm, for example through Continuous Improvement groups. Intelligence is thus **distributed**, rather than belonging solely to an 'heroic' Schumpeterian entrepreneur.

The second category has to do with the **internal** capabilities of the firm: its management's ability to

- Identify and invest in the right physical infrastructure to meet the competitive requirements of the firm
- Analyse its situation, identify and put in place the needed skills
- Organise appropriately, and have the vision to understand when organisation needs to change

The third group of capabilities is **external** - or, more precisely, concerned with managing the relationship between the firm and the outside resources which it needs. These are largely the issues addressed by the current discussions of 'networking' in the innovation literature. If contemporary writers are correct that networking is central to the innovation process, then the ability to network must itself be a crucial capability. This means: making use of external knowledge; using partners to access complementary assets; and managing the producer/user relations which have consistently been identified in the innovation literature as key to innovative success.

Different firms possess these capabilities in differing amounts. **Exhibit 4** shows a simple hypothesis about a useful way to segment companies according to their level of **research and engineering** capability. It is far from perfect, and needs to be complemented with other hierarchies (for example, in formal business management) which may be even harder to measure but which nonetheless are likely to explain differing levels of overall technological capability.

Our segmentation suggests that there are four reasonably distinct levels in the development of firms' engineering and research capabilities. At the bottom level, there is no meaningful capability and there will tend to be a presumption that none is needed. At the next level up, the 'minimum capability' level, the firm acquires at least one person able to speak the language of technology, to monitor and understand the significance of technological changes happening outside the firm. These bottom two levels of firm rarely have much contact with universities. They do not share a common language or interest with them. The professors are likely to be interested in things which are longer-term than they can consider.

In OECD countries, many larger firms belong to the third level of 'technological competents', where there is enough capability to do fairly serious development work and where there tends to be a specialised innovation or development function. The highest level firms - 'research performers' - are of two types. Some correspond to the ideal of the very large company with capabilities in research as well as development and the strength and vision to work for the long term as well as the immediate future. Others are new, technology-based firms such as university or other research spinoffs, many of which exist primarily to do research and will be absorbed by larger companies if their work is successful. These highest-level firms' research departments communicate easily with universities. Third-level firms often have difficulties in doing so.

Policy to Promote Learning

Successive generations of 'innovation models' have characterised innovation as increasingly complex and bound up with socioeconomic factors such as market linkage and match with the available infrastructure[19].

Taking a fifty-year perspective, the government-funded Research and Technological Development (RTD) systems in Europe are generally in a state of being refined, tuned and rationalised after the great post-war expansion. Changes in the RTD system have been accompanied by changes in innovation theory. Whether theory drives policy or the other way round is not always clear.

The startling achievements of physics during the Second World War had made clear the immense power of science, reinforcing belief in science as a force for social change. The 1950s and 1960s saw significant efforts in many countries to build up their university systems and, often, dedicated research institutions. There were many reasons for this, including an increasingly democratic view of education as well as a belief that this growth would hasten economic reconstruction and development. But in economic terms, underlying these efforts was the now-traditional 'linear' view of the innovation process as being essentially 'pushed' by science. The policy implication of the linear model is simple: if you want more innovation (and therefore economic development), you fund more science. During the 1950s, the technology-push model of innovation dominated. Then, thanks to the empirical work of those such as Carter and Williams,[20] Schmookler[21] and Myers and Marquis,[22] more emphasis came to be placed on the role of the marketplace in innovation. This led to market-pull or need-pull models of the innovation process.

In the late 1970s, Mowery and Rosenberg[23] largely laid the intellectual

19 Rothwell, R., Successful Industrial Innovation: Critical Factors for the 1990s,' *R&D Management*, 3, p 221-239, 1992

20 Carter, C. and Williams, B., *Industry and Technical Progress*, Oxford University Press, 1957

21 Schmookler, J., *Invention and economic growth*, Harvard University press, 1966

22 Myers, S. and Marquis, D.G., *Successful Industrial Innovation*, National Science Foundation, 1969

23 Mowery, D.C. and Rosenberg, N., 'The Influence of Market Demand upon Innovation: A

argument to rest by stressing the importance of **coupling** between science, technology and the marketplace. Their coupling model constituted a more or less sequential process linking science with the marketplace (via engineering, technological development, manufacturing, marketing and sales), but with the addition of a number of feed-back loops and variations over time in the primacy of 'push' and 'pull' mechanisms.

Rothwell[24] has charted this succession of innovation models into the 1990s. His fourth and fifth generation models are essentially increasingly complex refinements of the third generation 'coupling' model. The upshot of these evolutions in innovation theory seems to be a need for greater humility: there is a great deal about the innovation process that we do not know, or know partially but cannot generalise. The policy implication and practice resulting is to retreat from simplistic solutions and to create a wide range of instruments to promote individual capabilities (**Exhibit 5**). There is not a single, simple lever that policymakers can pull in order to improve capabilities and performance at a stroke. The heterogeneity of firms, too, militates against such a simple policy approach. Policymakers must continue to struggle to **segment** firms into groups with generically similar needs. However, the design of policy delivery systems needs also to take account of the uniqueness of firms as individuals. Some state support infrastructures are (in our view, rightly) taking an approach of diagnosing needs at the level of individual companies as part of their approach to developing companies and capabilities.

Critical Review of Some Recent Empirical Studies', *Research Policy*, April 1978

[24] Rothwell, R., Successful Industrial Innovation: Critical Factors for the 1990s,' *R&D Management*, 3, p 221-239, 1992.

The need for such a diagnostic approach is built into the 'learning paradox' associated with capabilities. Those with limited capabilities also have limited ability to identify their own problems and opportunities. If it is to help, the state needs to be **proactive** with those who cannot yet decide what to do for the best. Despite the attractions of 'hands-off' policies which do not involve the state in making firm-level decisions ('picking winners'), it is therefore difficult to imagine many effective 'hands-off' measures to improve capabilities (especially among weaker firms). This means that progress in policy depends not only on finding the right economic levers but on closer engagement with firms and technological practice.

Generally, quite a number of actors and programmes share the task of developing technology capabilities. However, the support system needs to operate as an effective whole. **Exhibit 6** illustrates how such programmes can relate together into a developmental staircase, even if the services need not map onto the staircase in a one-to-one manner.

It is important that individual programmes operate in conjunction with the other parts of the support system to

- Obtain cost synergies, especially in needs diagnosis
- Enable cross-referrals to and from other parts of the system
- Enable an holistic approach by the system to company development
- Avoid fragmentation and build the scale necessary to provide high-quality, specialist capabilities.

A complete capability development system would tend to have services capable of moving firms some considerable distance up the capability staircase. At the top of the staircase, research-performing firms will be well integrated into global sources of science and technology. There is not a necessity for local or regional actors to meet their needs - though it may nonetheless be helpful, for example in influencing company decisions about where to locate R&D.

A good innovation support infrastructure would have the following services available:

- **Proactive mentoring** Someone in the infrastructure is needed who has a brief to guide firms - especially those with limited technological capabilities - in identifying their needs and finding ways to satisfy them.
- **Basic, general-purpose capability development services** To raise SMEs' competences, not only in technology but also in the basics of business, there need to be sources of practical help and training close at hand. Issues such as Quality, simple manufacturing strategy and use of IT are generic, yet these are areas where many SMEs need help. Some of these services are useful to firms at the 'Low-tech SME' stage in development; all have relevance to the 'Minimum Capability' stage, and provide an important basis for moving firms up the capabilities staircase.
- **Sector- or technology-specific capability development services** may not be more sophisticated than those considered under 2 above. However, for reasons of scale, they are certainly more difficult to deliver across the generality of the economy unless target firms are present in 'clusters' - especially where the sectors they address are relatively narrow.
- **Technological development services** such as contract R&D can be bought by almost any firm with money to spend. However, adequately specifying and making good use of them requires a fair degree of internal capability. By the time a firms climbs to this point on the staircase, the questions are no longer about creating a level of internal technological capability but about making best use of it.
- **R&D services** include collective R&D, research information and services to link companies with capabilities in universities and research institutes. These presuppose quite high levels of technological capability on the part of users. Most SMEs are not in a position even to have a conversation with university or research institute researchers, so users of this type of service are quite special.

Broadly, state financing will tend to be needed most in the services lower down this hierarchy. As companies' capabilities grow, and become increasingly 'rational' (in the economic sense), services should be provided on more of a market basis.

Both because there is a need for the support system to have this developmental structure and because of the complexity of current systems, it is important to have an 'intelligent interface' between the bulk of the system and its clients - especially those with weaker capabilities. The behavioural characteristics of SMEs have several implications for the type of support infrastructure needed, the way this should be delivered and how the interface to the system should work.

- SMEs have limited time and ability to absorb information coming from outside. Programmes' and actors' sales messages need to be short, to be right first time and to be convincing.
- SMEs learn only slowly about the support infrastructure. They tend to stick with known, well-established

supports and mechanisms, moving beyond these only when under stress. Policy makers must therefore be cautious and gradualist in changing both the structure of the support system and the interfaces to it. Change requires learning, and SMEs have little time for this. In practice, it is possible to change the **contents** of support programmes over time while leaving the 'user interface' stable.

- The comparative importance of interpersonal networks and the small 'space' - geographic or sectoral - inhabited by SMEs makes local diagnosis and delivery of support services important and reinforces the need for interpersonal contact. An alternative mechanism is to use regionally-based advisors who visit firms in their area, identifying needs and and 'signposting' sources of help and advice. A key success factor for this type of interface is that it it is **personal**. Another requirement is that the advisor has some level of diagnostic capability.
- Because SMEs' horizons are short and their anxiety about risk is considerable, the promoters and deliverers of infrastructural support need to deliver **demonstrable** solutions and need continuously to be able to prove their competence and relevance.

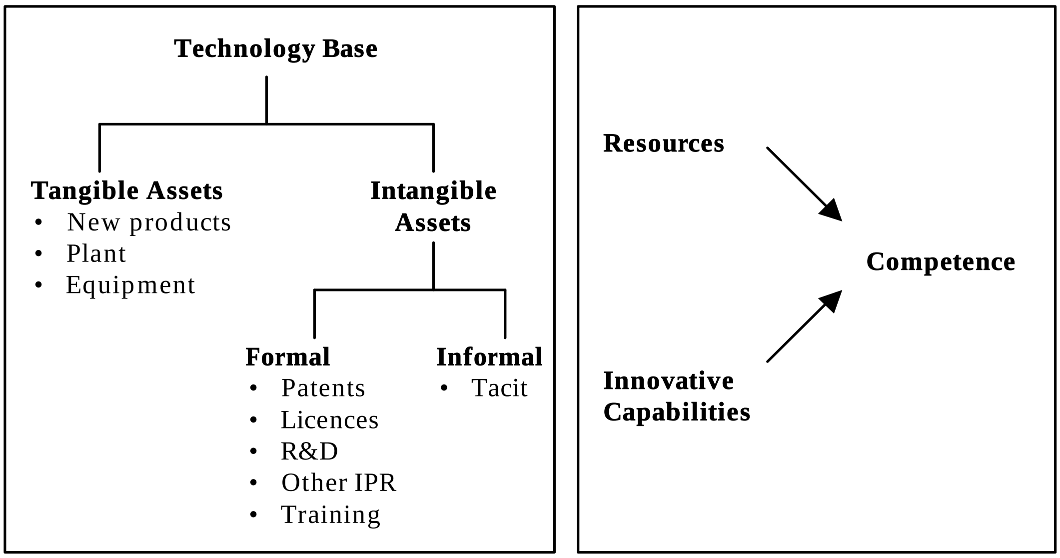
Most support systems are trying to tackle this problem of transparency by creating dedicated interface functions which combine diagnosis or 'proactive mentoring' of firms with a role as 'signposts' to where individual SMEs should go in order to satisfy their needs.

Conclusions

Companies create and protect competitive positions using a wide range of technological capabilities: strategic; internal; and external. These capabilities are not just narrowly 'technical' but include important 'soft' and managerial aspects. Individual firms' capabilities change over time in response to competitive requirements, and tend to develop as companies grow. Technological capabilities seem partly to be driven by the possession of engineering and scientific personnel. SME capabilities are often limited, in part because of the limited opportunities for division of labour and specialisation in small economic units.

Since not only the creation of new technology but - especially - its diffusion and adoption is key to economic development, policy needs to consider the broad range of technological capabilities needed to handle the various parts of the innovation process. The complexity of the innovation system means actions are typically multi-point. The resulting support systems themselves tend to become complex. They need an overall design which helps users learn to climb a staircase of capabilities, reducing dependence on state finance as capabilities grow. They need a proactive interface linking the system with the needs of the less capable firms in the economy.

Exhibit 1 Approaches to Technology Capability



Howells, 1994 Dodgson and Bessant, 1996

Exhibit 2 Evolutionary Model of the Firm

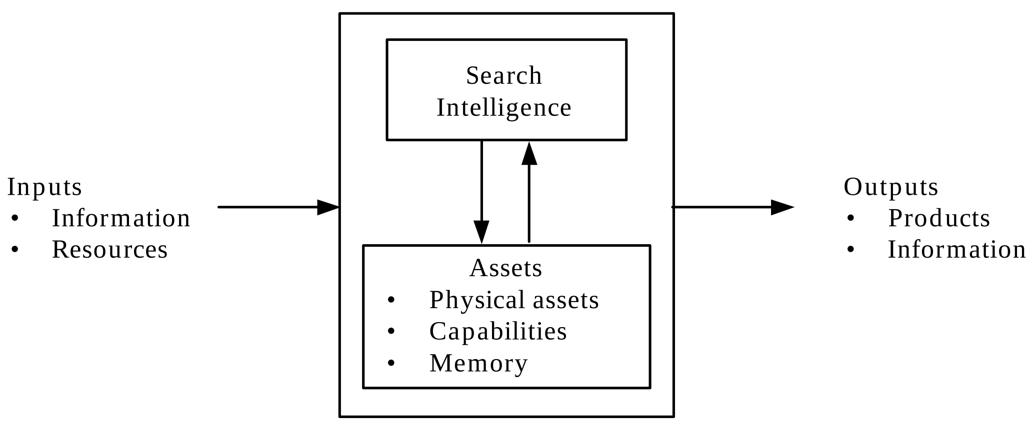


Exhibit 3 Key Elements of Technological Capability

Strategic Capabilities

- Search for market opportunities
- Understand and manage the fit between the firm’s capabilities and market needs

Internal Capabilities

Manage tangible technology base

- Products
- R&D facilities
- Appropriate plant and equipment

Develop and manage appropriate intangible resources

- Codified intellectual capital
- Qualification and skills profile adapted to the needs of the firm
- Tacit knowledge

Create needed organisation

- Technology management capabilities
- Change-management capabilities
- Coordination among internal ‘owners’ of capabilities

External Capabilities (Networking)

Access external knowledge

- Science
- Technology, techniques
- Artifacts, practices
- Know-how, tacit knowledge
- Information resources

Manage producer/user relations

Access partners with needed complementary assets

- Complementary knowledge
- Complementary production
- Complementary supply-chain role

Exhibit 4 Simple Hierarchy of Company Types

Company Types	
Research Performers	• Research department or equivalent • Able to take long run view of technological capabilities
Technological Competents	• Multiple engineers • Some budgetary discretion • Able to participate in technology networks
Minimum-Capability Companies’	• One engineer • Able to adopt / adapt packaged solutions • May need implementation help
Low-Technology SMEs	• No meaningful technological capability • No perceived need for this • May be no actual need

Exhibit 5 A Policy Repertoire for Improving Technological Capabilities

Strategic Capabilities

- Business capability development, especially marketing
- Business and technology audits; mentoring
- Awareness programmes, including visits and comparisons
- Feasibility assessments

Internal Capabilities

Manage tangible technology base

- Product development assistance
- R&D tax breaks
- State-subsidised R&D programmes
- Manufacturing consultancy

Develop and manage appropriate intangible resources

- Quality programmes
- Placements of qualified personnel, eg engineering graduates
- Loans of research personnel
- Training needs analysis and training programmes

Create needed organisation

- Technology management courses

External Capabilities (Networking)

Access external knowledge

- Innovation ‘cheques’ or credits
- Science parks
- Technology centres
- Research institutes and associations
- Technology development networks
- Technology transfer programmes and brokerage
  - Research-industry
  - Company-to-company
- University liaison officers
- Faculty industrial placements
- Subsidy to university/industry R&D collaborations
- Technology information services
- Metrology programmes and services

Manage producer/user relations

- Procurement programmes
  - State procurement
  - Company supplier development

Access partners with needed complementary assets

- Partner-search programmes
- Inter-company network programmes

Exhibit 6 A "Staircase" for Developing Company Capabilities