

The Evolution and Use of a Policy and Research Tool: assessing the technological capabilities of firms

Howard Rush
Centre for Research in Innovation Management
University of Brighton

John Bessant
The Business School
University of Exeter

Mike Hobday
Centre for Research in Innovation Management
University of Brighton

Eoghan Hanrahan
Enterprise Ireland

Mauricio Zuma Medeiros
FIOCRUZ, Brazil

Howard Rush H.J.Rush@Brighton.ac.uk

Professor of Innovation Management at CENTRIM (Centre for Research in Innovation Management) University of Brighton. His research focuses on the development of innovation capabilities, Innovation management in complex products and systems; benchmarking of science and technology policy; development of firm level innovation management tools; evaluations of research and technology institutes, socio-economic forecasting.

John Bessant jbessant@exeter.ac.uk

Research Director and Professor of Innovation and Entrepreneurship at The Business School, Exeter University. He was awarded a Fellowship with the Advanced Institute for Management Research and was also elected a Fellow of the British Academy of Management. He has acted as advisor to various national governments and to international bodies including the United Nations, The World Bank and the OECD.

Mike Hobday MichaelGHobday@gmail.com

Visiting Professor at CENTRIM (Centre for Research in Innovation Management), Brighton University. His research examines how firms in East and South East Asia catch

up and overtake leading Western companies. He also works on innovation in high value complex products and systems.

Mauricio Zuma Medeiros Zuma@bio.fiocruz.br

Executive Director of the Foundation for Scientific and Technological Development in Health at Fiotec, Brazil; coordinating the New Aseptic Fill-finish Facility Project of Bio-Manguinhos/Fiocruz. He has a doctorate from SPRU: Science and Technology Policy Research at the University of Sussex.

Eoghan Hanrahan, Eoghan.Hanrahan@enterprise-ireland.com

Civil Servant working for Enterprise Ireland. He has a doctorate from CENTRIM, University of Brighton.

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Abstract

Firms differ widely in their technological capabilities. Innovation policies are likely to be more or less successful depending upon the level of such abilities of those firms to which a policy is aimed. Without data on the proficiencies, strengths and weaknesses of firms within the target group(s), the construction and application of innovation or industrial policies are likely to miss salient factors in the ability of firms to benefit from the support that is intended. An in-depth knowledge of firms' capabilities can allow policymakers to target support according to the specific needs of firms. This paper describes the Technology Capability Audit Tool (or CAT) that was designed to assist policymakers in differentiating between firms and in understanding their level of 'innovation readiness'. Examples of the use of the CAT are presented from South Korea, Thailand, Ireland, Brazil and the UK.

1 Introduction

It is widely accepted that technological are essential underpinnings for innovative activity and, as such, they have been the focus of numerous government policy initiatives.

However, such capabilities are not a given endowment among firms and, consequently, firms differ widely in their capabilities. Such differences are fundamental to their ability to compete. Different industrial policies are, therefore, likely to be more or less successful depending upon the capabilities of those firms (or type of firms) to which a policy is aimed. 'Broad brush' policies aimed at the lowest common denominator (or highest) of firms are unlikely to maximise their impact in those firms that are deficient in some aspect of such capability [best to stick to one term] or be unnecessary for those that are already proficient. Policymaking needs to be more finely attuned to the relative capabilities of the firms they are seeking to support.

Empirical data on capabilities, including the proficiencies, strengths and weaknesses of those firms within the target group(s) can assist with the construction and application of innovation and wider industrial policies and help ensure that firms are able to benefit from the support that is intended. Such knowledge can allow policymakers to devise and target support according to the specific needs of firms and groups of firms which fall into different categories based upon their capabilities.

This paper describes the technology capability audit tool (or CAT), specifically designed to assist policymakers in differentiating between firm capabilities and different levels of 'innovation readiness'. The initial development and use of the CAT was as part of a World Bank project on South Korea and the Knowledge-Based Economy (Hobday, Rush, Bessant 2001 and Hobday, Rush Bessant 2004). Prior to this, during the 1980s and 1990s there was little micro-level research on firm capabilities, a weak information base, and a lack of research methods for assessing capabilities needed especially for understanding the challenges facing latecomer firms in the transition phase from catch up to leadership status.

The tool generated interest in other policy communities. Subsequently it was put to use in another World Bank study examining the role of transnational corporations (TNCs) in technological capability building in Thailand (Hobday, Rush 2007). This study examined the capabilities of subsidiaries of exporting TNCs and showed how their location within different types of global value chain architectures influenced their technological capability development.

Following these first two applications of the audit tool, it was made available to policy oriented researchers in different parts of the world. Two in-depth applications have taken place in Ireland and Brazil respectively. The Irish study (Hanrahan 2007) assessed the impact and implications of government support mechanisms on R&D by examining changing firm capabilities in relation to policy. The wider objective was provide evidence for policy makers concerned to ensure whether the State was getting a commensurate return on the investments made through its Research, Technology and Innovation (RTI) initiative and whether the model of direct funding was appropriate for an economy that was in transition from a manufacturing to a knowledge-based economy. The tool provided a critical firm level input into this assessment.

The use of the tool in the Brazilian study (Zuma Medeiros, 2010) was as part of an in-depth study of firm capabilities the Brazilian vaccine industry. This sector has been heavily supported by the public policies of successive governments in order to serve a fast-growing public market. Besides validating the qualitative evidences gathered during the fieldwork the CAT helped to illuminate the distinct roles played by firm capabilities in relation to technology acquisition strategies. By examining firm capabilities the research identified key constraints on progress related to both managerial and policy issues.

All four of these applications are summarised in more detail below. A fifth application was part of a regional policy programme aimed at small and medium sized firms who participated in experience sharing and learning networks in the South-east of England. This example is discussed in the conclusions of the paper where we explore possible avenues for updating and extending the use of the audit tool.

2 Theoretical Basis

The Technology Capabilities Audit Tool was intended as helping to bridge the gap between our theoretical understanding of the principals of capability development and policy practice. As described by Rush, Bessant and Hobday (2007), our understanding of the related concepts of technological capability and absorptive capacity has undergone extensive deepening through numerous empirical studies since the 1990s. Contributors such as Cohen and Levinthal (1990) explored the ability to “recognise the value of new, external knowledge, assimilate it, and apply it to commercial ends”. Together with others, notably Zahra and George(2002) and Martin, Massy and Clark (2003), our understanding of the distinctiveness between such capabilities related to acquisition, assimilation transformation, application and exploitation (of the new knowledge), provided a sound basis for attempts to categorise firms.

The furthering of our understanding of the different components (or skills) which technology capability depends upon comes from a rich innovation studies literature and we specifically drew upon contributions made by Arnold and Thuriaux (1998) who described four degrees of a firm’s level of knowledge relating to technological capability, and Bell’s (2003) competency level model for technological innovation in which firms move from “acquiring and assimilating imported technologies” through to “technological

deepening and upgrading” and on to “closing in on the international technological frontier”.

Other important researchers upon whose contributions we learned from included Dutrénit, (2000), Figueiredo (2001), Teece and Pisano (1994) and Hamel and Prahalad (1994). Organisational learning studies also underpin the significance of capability development in firms and here we drew upon, amongst others, Argyris and Schon (1978), Garvin (1993), Stata (1989) and Leonard-Barton (1992).¹

3 CAT Framework

The audit tool helps to locate firms within four archetypes that were dependent upon their level of maturity along nine components considered to be important for ‘technological capability’. The term ‘technological capability’ specifically refers to those activities that enable firms to chose and use technology to create competitive advantage. The nine components (Bessant, Rush, Hobday 2002) that have been incorporated into the tool include:

- 1. Initial awareness of the need to change and willingness to begin looking inside and outside the firm for possible triggers for change.*
- 2. Searching out triggers for change - picking up demand signals from the market or within the firm about changes needed or picking up signals about potential opportunities raised by new technological developments.*

¹ These and other influences on the tool's theoretical underpinnings are elaborated on by Rush, Bessant and Hobday (2007).

3. *Looking at core competencies - recognition of requirements for technology through a systematic and regular audit of its current competencies and a comparison of those, which it needs to develop or acquire in order to become or remain competitive.*
4. *Development of a technology strategy - some clear idea of where to change and why (the priorities).*
5. *Assessment and selection – exploration, assessment and comparison of the range of technological options available. Selection of the most appropriate option based upon this comparison.*
6. *Acquisition of the technology through direct purchase or via some form of licence, collaboration, alliance, etc. - this is likely to involve extensive negotiation around price, specification, transfer of knowledge, property rights, etc.*
7. *Implementation and absorption of the technology within the firm - this may involve extensive project planning and management activities and require configuration of both technology and organisation to get a good and workable fit.*
8. *Operation of the technology and learning about how best to use it - this may involve extensive learning and development.*
9. *Learning through the process to develop internal capabilities, which will sustain technological development in the long term.*

Below are 'thumb-nail' summaries for each of the four categories, as originally described in Hobday, Rush and Bessant (2001). The four categories can be represented as a 'staircase' of capability levels, from Type A to Type D. This simple form of configuration is typical of a variety of frameworks found in studies and organisational and technological capabilities such as, for example, in Baden-Fuller and Stopford (1994) and Arnold and Thuriaux (1998) or, at a more technical level, in the Carnegie Mellon Capability Maturity Model (Humphrey 1989).

Type A Firms: Unaware/Passive

These companies are weak and ill prepared in all major areas of technology acquisition, use, development, strategy and so on. Help is required in: enabling these firms to recognise the need for change, developing a strategic framework for manufacturing and other activities; identifying relevant and appropriate changes; acquiring and implementing necessary technologies. They also require assistance in sustaining this process of change over the long-term. In manufacturing, these firms probably focus on assembly and have yet to move on to production engineering. The need is therefore to improve assembly capabilities and begin to develop engineering skills in order to improve efficiency and productivity and to provide opportunities for moving on later to process innovation and new product development.

Type B Firms: Reactive

The needs of this group centre first on the development of a strategic framework for technological change, so that key priority areas can be addressed. Allied to this, are needs in searching wider for solutions, in exploring new concepts (for example changing production layout rather

than simply acquiring new machinery), and in acquiring and implementing new product and process capabilities. In the longer-term, such firms could be expected to develop an internal capability for strategic upgrading and require less and less support. In manufacturing, these firms may well have moved on from assembly and have technician and engineering skills upon which to build. Their next 'stage of development' could well be to develop the capabilities to innovate with process technology.

Type C Firms: Strategic

The needs of this group are essentially around providing complementary support to internal capabilities and challenging existing business models. Improving access to specialist technical and marketing expertise, enabling access to new networks of technology providers (for example, overseas sources) can assist them to think 'outside' of the industrial box they find themselves in, should the need arise. Such firms may also benefit from occasional, project-based support from consultancy companies or from specialist research and technology organisations, locally or internationally. They may benefit from improved access to graduates and from linking up with universities, which offer new ideas, access to advanced technology and new skills. Typically, in manufacturing, these firms will have acquired process innovation skills and new product development capabilities. The next step is to build up the R&D capabilities necessary to launch challenging new products on the international stage.

Type D Firms: Creative

The needs of this group are mainly centred on complementing existing internal capabilities with outside sources, assessing risks and uncertainties and sustaining their position as market 'rule breakers'. They tend to be open companies, which collaborate and learn from partners in the external environment and invest in developing new technologies and resources, for example in leading universities around the world. From time to time projects emerge with threaten to disrupt their existing businesses and they are often in a strong position to convert such threats into new market opportunities. Such firms may need to develop new contacts with specialist groups (domestic and overseas) in order to resolve complex technical problems and generate new opportunities. Typically, these firms will have strong R&D capabilities in house, or alternatively they will have the internal skills needed to outsource R&D and new product.

The tool was designed so that it could be applied to an entire firm, or to a division of a transnational corporation. It can (and has) be applied in countries with different industrial structures (e.g. concentrated and dispersed), to small and large firms, as well as foreign, local or joint venture. The objective of the tool was to facilitate the gathering of information on innovation capabilities within the firm as a means of support to policymakers in their attempts to design innovation policy which could be targeted to firms, whether in specific or multiple sectors, regions, or across the economy. Depending upon how widespread the tools was used (i.e. the number of firms within the sample), the data could also be used for quantitative analysis across the whole sample.

Three versions of the tool were constructed for use in different situations or as resources allow. A short, self-assessment version consists of twenty-four key questions, each of

which is rated on a four-point scale. Various questions relate to each of the nine components and, from the possible total of 96 points, using a scoring template, one can calculate the company's overall technology capability level (within the four categories) and detail strengths and weaknesses according to each of the nine components. This version of the tool was designed to be completed by the firms themselves and provides a quick and simple indication of where the firm has strengths and weaknesses. It has the advantage that it could be conducted as a postal or email survey to a wide number of participants. However, the small number of questions means that it is not possible to explore each component of technological capability deeply and is, therefore, only able to provide an overview assessment.

A longer and more comprehensive version of the tool was designed to be used by development support agencies, innovation management researchers, innovation consultancies, or, by firms themselves provided they have the appropriate in-house expertise. This version of the tool provides the opportunity to explore issues in greater depth and to follow-up on particular themes. For each of the nine components, the tool has multiple questions, provides definitions and descriptions of the underlying themes behind each question, and guidelines on how to interpret the responses. As with the short survey version, each question is scored on a four-point scale and the interviewee does scoring. The longer version allows for examples to be explored and other material to be brought to bear which corroborates the answers to key questions. It takes approximately an hour to complete in an interview format and, typically, one would expect to conduct the interview with senior and informed technical and strategic management.

The third version is the use of the CAT as part of a case study. Here a very detailed assessment is achieved based upon a wide range of questions which explore aspects of the technological change process. It involves multiple interviews with the managers across

the organisation. The same framework as the self-assessment and interview tool is used but in addition, there are some structured tools, which can be employed to help explore particular issues in depth (e.g. competitiveness profiling, competence mapping and strategy analysis). As such it provides an in-depth review of technology management within the firm and allows for examples to illustrate and clarify the assessment. Clearly it requires considerably more time and access than the interview tool version. It also requires a degree of researcher/interviewing skills and is most likely to be used as part of an academic research project.

4 Application of the CAT

4.1. South Korea

The context of this study by Hobday, Rush and Bessant (2001, 2004) was concern that although leading South Korean firms had made significant strides through the formula of low cost 'catch-up competitiveness', they faced a strategic dilemma as they approached the innovation frontier. Korean exporters, having progressed from basic assembly to technology-intensive manufacturing, now had to decide whether they should continue to follow the leaders who generated new product ideas and explored new markets, or should compete in international markets through attempting to develop, via in-house R&D, their own range of leading products and systems. There had been considerable operational and technological restructuring in leading Korean firms as a response to the financial crisis of the late 1990's, but little micro-level research on the effects of such restructuring on technological capabilities. In designing policies for Korean industry, these changes needed to be understood and responded to. This study applied the CAT to a sample of twenty-five firms operating mainly in electronics and automobile exporters, small capital goods and machinery suppliers, food processing companies, and chemical and pharmaceutical

producers. The sample deliberately focused on high performing firms across a range of sectors, in order to explore issues facing firms at the 'highest' stages of development in Korea.

The sample was not intended as being statistically representative but together with additional interviews and company information resulted in case studies, which allowed an in-depth assessment of the continuing impact of the financial crisis. The majority of firms analysed fell into Category C (the 'strategic' grouping). Firm-level assessments revealed the capabilities, strengths and weaknesses and strategies by which firms were attempting to move beyond their advantages in manufacturing process innovations, towards new product creation. This represented a major transition, which required a greater depth of technological capabilities, as well as a more sophisticated and dynamic capital good sector in Korea.

The main limitation of this approach was that the sample would not allow conclusions on the overall position of Korean industry, or the problems and opportunities facing SMEs. However, the aim was to select industries on the basis of export importance, technology-intensity, and export vs. local market orientation. Given the small size of the sample, the findings were indicative, although they did point to some fairly consistent results regarding the level of technological capabilities among Korea's leading companies and the challenges facing them. The audit illustrated that many of these firms could not, as yet, contribute to the technological frontier due to constraints in their own technological and organisational capabilities.

In applying the audit tool, it became clear that there was a large difference between those firms that were barely strategic and those that had mastered strategy formation and execution. The results suggested that firms that fell into the strategic category had

developed strong technological capabilities in order to support their core manufacturing operations and, in some cases had world class manufacturing process technology. Many were also highly effectively in following product design. However, the results suggested that industry lacks upstream capabilities in capital goods, product creation, key components and basis research.

Most firms in the sample scored highly in most areas of the audit tool, although there were noticeable weaknesses in risk and project management. Some firms were highly strategic but most were still some distance from the 'creative' stage. At the time the audit was conducted, most of these firms were not in a position to make a significant contribution to the world innovation frontier through R&D or via the creation of new product design. Many were simply not able to compete in highly complex products or services or in a position to challenge existing business models.

The audit did provide evidence that since the economic crisis of the late 1990s, firms had grown stronger and more confident in manufacturing exports, had broadened their product range, and were developing some innovative new hardware design capabilities. But the repercussions of the crisis continued to be felt and for many firms, a move from longer to shorter-term R&D, more closely related to business needs, had tended to undermine attempts to strengthen basic research capacity. The audit pointed to some positive signs, such as technological collaborations with foreign partners but usually this was where there was a need for investment rather than a change in attitude or strategy. Perhaps the most important finding was the need to improve their access to capital goods and services, which for the most part, remained heavily dependent upon imports from Japan and the US.

Although these findings were, in general, consistent across the sample, the study described some important difference between sectors and suggested a number of policy avenues that were worth exploring related to the development of advance research consortia, support for regional clusters of machinery firms, promotion of inbound FDI and the development of overseas technology networks.²

4.2 Thailand

This research by Hobday and Rush (2007) was conducted because of policy concerns that, although transnational corporations were playing an important role in the export-led growth strategies of some developing countries, the performance of local subsidiaries in upgrading their capabilities was highly variable. The project explored and compared the strategies and practices of different types of TNC towards upgrading. As part of this exercise it was considered important to gain a better understanding of the firm-level motivations, barriers, upgrading pathways, and decision-making processes, etc., which impinged upon the level of capabilities achieved by firms. Thailand was seen as being an interesting example, particular because TNC subsidiaries were perceived a being lacking in technological capabilities compared to other countries in the region. As Thailand's export growth had been largely dominated by foreign-owned TNC subsidiaries producing electronic hardware (e.g. consumer goods, computing and telecommunications equipment, hard disc drives and semiconductor components) it was decided to focus attention on this sector. Because of a paucity of published data on electronics in Thailand, and virtually nothing on exporting TNC subsidiaries, a multi-firm case study approach was adopted and

² The audit results were also made available to and used by other local policy analysts who put forth their own specific future policy measures (see, for example, Woo and Sul, 2001).

in-depth interviews and the application of the CAT with a sample of fifteen electronics exporting firms across the sector.

The interviews, validated by the CAT application, indicated that the main focus of the TNC subsidiaries had largely been in the area of acquiring and upgrading technical and engineering skills required for the assimilation and improvement of existing technology. The majority of the firms in the sample fell into either category A ('unaware' or 'passive') and B ('reactive'), with a smaller group of category C (strategic) and little attempt had been made to develop the competencies required for new product or process innovation.

The study followed standard methods in terms of sample selection in order to explore different pathways of change and to allow for some comparison across firms based upon ownership, maturity, firm size, and corporate strategy. As an exploratory study, the intention was to identify trends for further study. As such, the study obtained a rough benchmark assessment of each of the firms, which together with additional data generated via interviews and documents provided by the firms, proved sufficient to cross-case comparisons. Information was collected on each of the nine components of the tool, numbers of R&D engineering and technical staff, types of equipment used, the main focus of production activities, interaction with HQ, methods used for analysing technology, links with local institutions and suppliers, decision-making processes, technology related strategies, etc.

Although the size of the sample (which was biased toward larger firms) only allowed for tentative conclusions as to the overall structure of the Thai electronics industry, it did find interesting differences in levels of capabilities development between primary electronic product and component exporters and first-tier suppliers of finished components based

upon, amongst other things the business models preferred and attitudes (e.g. to their value and supply-chain) adopted by different national ownership groupings.

The study also found a wide distribution of capabilities amongst firms in the sample. Those with relatively weak capabilities tended to have technology decision-making tightly controlled by the parent HQ, which, as part of their corporate strategy, only transferred technology strictly required for assembly. By contrast, those firms with higher levels of capabilities also had strategies in place to further develop their capabilities. The corporate strategies of their partner companies tended to favour decentralisation and encouraged their subsidiaries to move to higher levels of production (if not development).

The results suggested that no one single policy aimed at capability upgrading in this sector would be appropriate and that policies needed to be tailored according to the type of subsidiaries and the level of capability. This was closely linked to what the authors referred to as 'policy receptiveness' on the part of the firms, which was determined by the extent to which the corporate strategies of TNCs allowed for decentralisation in terms of technology operations and the willingness to allow the local subsidiaries to engage with those policies and institutional support mechanisms which aim at upgrading. The results suggest that there would be a higher return on efforts aimed towards specific groups of firms that are receptive to upgrading policies and little to be gained by encouraging capability building if it was counter to the strategy of the parent corporation.

4.3 Ireland

Noting that existing evidence as to whether governments should provide R&D subsidies to companies was inconclusive, the Irish study by Hanrahan (2007) was designed to assess the impact of State support mechanisms on R&D.

The research employed both the short or simple self-assessment version of the CAT as well as its more in-depth interview approach.

The short audit tool was sent to members of the Irish Medical Device Association (because of their stated interest in promoting R&D within the sector). Fifteen members of the association responded, representing 25% of their membership, of which about three-quarters had received R&D support from the government. Respondent firms mainly fell into categories C and D, indicating a high awareness and application of most of the nine technological capacity components included in the CAT. However, the majority of firms in this sample, regardless of category type, indicated weaknesses involving technology acquisition and interaction with external sources of knowledge (e.g. universities).

The sample of firms in the second sample (those receiving direct support from the RTI) were audited using both the short self-assessment survey tool as well as the longer version. Interestingly, the responses from the 28 firms (from eleven sectors) to the interview-based audits were much starker in terms of the deficiencies identified. Scores were relatively high on the first four components with an average of 3.4. However, scores were consistently much lower on components 5 – 9 at only 2.2, with learning falling as low as 1.8. This indicated that most companies were good at strategic planning and very aware of market requirements and the position of the company but, the same companies showed huge gaps in their ability to assess technologies, implement and monitor them or on how technological absorption takes place. Even with a slightly higher score (2.5) for linkages to external sources of knowledge, there was an uncertainty in how to further develop such interactions. These results raise major concerns that if firms do not have the fundamental capabilities associated with components 5 – 9, then they are unlikely to conduct effective R&D, take advantage of R&D spill overs, or absorb technology and knowledge from

external sources. These results suggest that while such companies abilities in strategic planning and market positioning may make them seem like good candidates for government support, the deficiencies exhibited indicate that they will be unable to make effective use of such support or prosper when such support ends, given the low scores on the learning component.

The CAT, in segmenting the companies that had received government support, illuminated the shortcomings and mismatch between a broad policy initiative which does not differentiate between firms and the individual needs of the companies seeking support. The study concluded that while R&D subsidies are likely to remain important, the support needs to be more highly targeted in order to address a firm's shortcomings and barriers to capability development.

4.4 Brazil

The development of the vaccine industry has long been considered one of the success stories of Brazilian industry. This is a sector that had experienced strong growth over several decades based upon a Sprotected internal market and growing public demand. Starting in the late 1970's, public policy (influenced by the Brazilian balance of payment difficulties which restricted Brazil's ability to import vaccines and the high compliance risk of the firms to Good Manufacturing Practices) led to the strengthening the local (public) manufacturers.

This study by Zuma Medeiros (2010) illustrated how technological capabilities developed in the sector fits into 'catch-up' model exhibited by many latecomer firms and industries in industrialising countries. It has followed a pattern of foreign technology acquisition over

several distinct phases during which the leading firms have moved from the 'reactive' (Type B) to the 'strategic' category (Type C) as described in the CAT. This approach has contributed to the industry being able to service the rapidly expanding National Immunization Programme (PNI). It has also played an important role in the industry making significant strides in the development of its technological capabilities, although the sector is still somewhat behind reaching the 'creative' level (Type 4) as they have not been able (or willing) to take a lead in vaccine development reaching significant external markets. Since the mid-1980s, the strategic approach taken by the leading firms has resulted in improvements in competencies through the hiring of skilled personnel, growing investment in R&D, training, and strengthening linkages with external sources of knowledge, both domestically and abroad.

In addition to the extensive in-depth interviews conducted in the leading firms in this sector, the simple survey CAT was used across a large number of staff in the largest firm in the Brazilian vaccine industry. The survey was conducted with staff in those positions for a University degree was the minimum requirement. There were 123 completed responses to the survey, representing 22.9% of eligible respondents. The results of the survey corroborated the evidence gathered from interviews and document analysis and positioned the company on the border between the 'strategic' (Type C) and 'creative' (Type D) levels of the CAT. The average score on the nine components measured was 3.1, but the survey illuminated areas in which the firms would need to improve in order to complete the 'transition' phase and become internationally competitive. Competency improvements were still required in areas such as R&D, engineering, project management, knowledge management, and marketing.

The research shows that although support for the sector remained high through successive governments and has led to the development of significant innovative

capabilities, the strategy followed to this point in their transition may have reached its limits. According to Zuma Medeiros (2010) the unfinished transition may also be a by-product of the continuous foreign technology acquisition, suggesting that a new management and strategic approach will be necessary if further advance is to occur.

5 Conclusions

The four examples of the uses of the tool described above come from different countries and cover a wide range of firm capabilities and associated policy issues and concerns. We presented three versions of the tool which were used and, in some instances, more than one version in the same study. Although we are aware of other uses of the tool (some mentioned below), these examples were selected because of the depth of information that is publically available on each of the research studies.

The empirical research in Korea, Thailand, Brazil and Ireland clearly show how the design of the CAT can provide a useful conceptual framework and data collection device at the firm level. Without it, it would have been difficult to identify the specific strengths and weaknesses of the firms that allow us to locate firms within the four archetypes in the staircase framework presented earlier. By providing detail of each of the nine capabilities audited, organisational development strategies could be introduced to help a firm move to the next step. When used on a large enough sample, the CAT can inform policy-makers of the prevalence of strengths and weaknesses across a sector (or region).

While assessing the overall policy impact of the CAT is beyond the scope of this paper, given the many changing variables that affect the policy process³, using the

³ Bessant, Rush and Hobday (2001) stress that policy-making also need to take into account at least four other important factors which impact on firm performance and opportunities: These include:

data collected by the tool provided policy-makers with the information required to begin a new type of discussion with firms and other stakeholders in which the focus is on the nature and depth of capabilities that exist or are required across different types of firms. Used appropriately it could enable those civil servants charged with developing and enacting industrial policy to move away from broad-brush policy making in which 'one size fits all' towards an evidence-based policy approach. One could envision this being done on a regional basis, where vast differences are typically found between levels of capabilities in different parts of any country, or on a sectoral basis, depending upon the industrial composition or endowment of each sector.

All four studies clearly had important policy implications for their respective topics, areas and sponsors. Taken together, we observed that the development of technological capabilities resulted from extended and deliberate learning processes. Therefore, policies designed to assist firms in the development of capabilities need to distinguish between types of firms and their different stages of development. Innovation policies with highly specific learning objectives tailored to those types of firms which can best benefit from the type of learning they foster are likely to be more successful than less well targeted policies. To achieve this, policymaking and implementation required a more sophisticated and fine-tuned understanding of where their target firms were currently located in terms of their underlying capabilities. The tool can help policy-makers to design mechanisms that focused resources in areas of greatest need.

(a) the impact of indirect or 'implicit' technology policies (e.g. educational, trade, competition, economic and industrial); (b) other non-policy conditions facing firms (e.g. the macroeconomic context, the business cycle of particular sectors and the strengths and weaknesses of local entrepreneurial capabilities); (c) the available modes of support for firms (e.g. private sector, market-led mechanisms, government direct support, and government indirect self-help support mechanisms); and (d) evidence of success (or otherwise) of technology policy initiatives in other countries.

Regarding the different 'needs' of each of our four categories of firms, five different modes of support used in a variety of countries have been identified (Bessant, Rush, and Hobday 2001). These include support for the formation of networks and clusters, learning networks, facilitating supply chain learning, the use of intermediaries such as innovation agents or consultants, and the use of or creation of structural connections (such as Research and Technology Organisations). Firms falling into category A (Unaware or Passive) might gain considerable benefit from awareness campaigns, benchmarking and other measurement/comparison processes and technological 'signposting' activities in which problems are clearly articulated. At the other extreme of the four category typology (our type D category of Creative firms) advanced foresight and programmes, and international technological intelligence support are likely to be more appropriate.

During implementation care must also be taken to differentiate between firms in the same category depending upon how well they score on different parts of the tool. In the Thailand and Korean studies, for example, there were a clustering of firms on the border between categories and, in the latter study, there were major differences between sectors. As was also seen in the Irish example, firms typically fell into categories C or D. However, closer analysis indicated that for some a bias was introduced as high scores were recorded on components 1 through 4 but much lower scores for 5 to 9. As indicated above, these firms were not necessarily best placed to make effective use of the financial support provided because of capability weaknesses on several key components. In this case, additional assistance in strengthening their positioning on these components would have

been advisable to maximise the return on investment, especially in terms of the development of R&D capability. Those firms who the CAT identified as being weak on the 'implementation' component, for example, might have gained considerable benefit from a partnering arrangement with an experience Research and Technology Organisation or a University with staff of proven abilities in this area.

Another use of the tool that we are familiar with was part of a regional development policy indicative located in the South-east of England. The ProfitNet⁴ programme, run by the University of Brighton, consists of a series of experience-sharing learning networks (over 35 to date, with over one thousand small and medium size firms having participated over the last four years). One of the workshops offered to network members included a redesigned version of the short audit tool which focused on the awareness and the capabilities required to assess, access, assimilate, adapt, apply and appropriate external knowledge. The workshop, which was attended by 25 small companies, examined the importance of such capabilities and provided opportunities for firms to share experiences. Firms provided self-assessments of their abilities at the workshop and were followed-up at a later date to monitor any change in their performance as a result of the action learning that they may have undertaken as part of a ProfitNet group.

The CAT tool is also being used with SMEs in Korea where, in 2004, it was piloted with 21 firms (Lim 2004). This has been followed up by an on-going project for the Korean Ministry of the Knowledge Economy which is using the tool to evaluate the growth potential of firms. The assessments are based on the logical assumption that there will be

⁴ <http://www.brighton.ac.uk/profitnet/>

a correlation between high scores on innovation capabilities and high growth potential. One hundred and twenty firms were audited in 2012 and so promising were the results that the project has now been extended.⁵

Regarding implications for the further evolution of the CAT itself, as the tool was initially developed a decade ago, the field of innovation management has moved on and it could be useful to tailor the CAT to address new concerns. For example, our knowledge has deepened in areas such as user-led and open innovation, managing complex products and systems, as well as sustaining vs. disruptive innovation paths. It would be useful to adapt and tailor the tool to address firm capabilities in these contexts and re-evaluate the tool to assess firm capabilities in relation to policies designed to support firms. This would require changes both to the components incorporated and the questions used to elicit information for scoring.

Regarding weaknesses, the different versions of the tool need to be assessed for consistency between them. In the Irish study, for example, nearly half the firms that completed both the short and the longer interview versions changed their rankings between versions. Some went up and some down. In another study, there was some indication that when the self-assessment tool is used, there may be a response bias towards over scoring.

Another two interesting suggestions were forthcoming from the Irish study. If the tool is to be used as an assessment of policies, then a before and after application would be useful. But a more elaborate reconfiguration of the tool is also suggested in order to increase its 'power'. As was also seen in the Korean and Thai examples, the differences

⁵ Personally communication from Chaisung Lim (16 August 2013), director of the Research Institute for Global Management of Technology for Catching Up (GMOT), Miller School of the Management of Technology, Konkur University, Seoul.

amongst firms even in the same category can be significant and that strong scores on some components might tend to mask lower scores on others when averaged together. Hanrahan (2007) argues that four categories may not be sufficient and suggests that with further segmentations of the CAT, the policy instrument is likely to be sharper and more effective.

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