CSTI BRIEFING NOTE

THE DIFFERENT ROLES OF TECHNOLOGY IN TECHNOLOGICAL EMERGENCE

Technological innovation keeps industries competitive, providing financial gains, jobs and national security. The announcement of a number of strategic initiatives that prioritise support for R&D in particular technical domains has demonstrated the commitment a number of governments have to supporting technological innovation. Such initiatives include the Eight Great Technologies in the UK and the Key Enabling Technologies programme in the EU. These programmes support a range of technologies, some of which support further innovation. Understanding the different types of technology can help government better target R&D investment.

This briefing note focuses on the different types of technologies which can be supported to increase the likelihood of, and hasten, technological innovation. It provides a framework that can be used to conceptualise these different technologies and some of its implications and concludes with a selection of remarks on the implications specific to public policy.

This briefing note aims to support those assessing research projects and aiming to support technology development, whether they be government bodies, universities or private firms, by encouraging ample consideration of the different types of technology involved in technology emergence.

Different categories of technology: a portfolio

National governments support a portfolio of technology through public funding and legislation. Technological innovation keeps industries competitive, providing financial gains, jobs and national security (Sainsbury, 2007). The breadth of government action needs to ensure that this portfolio amply covers the various technologies and other requirements that support the emergence of a new technology and potentially the emergence of a new industry. Figure 1 shows a number of different categories of technologies that can enable and hasten technology development. These categories arise from Tassey (1997, 2004, 2007) and a review of international government approaches to supporting advanced materials (Featherston & O'Sullivan, 2014) and field work.

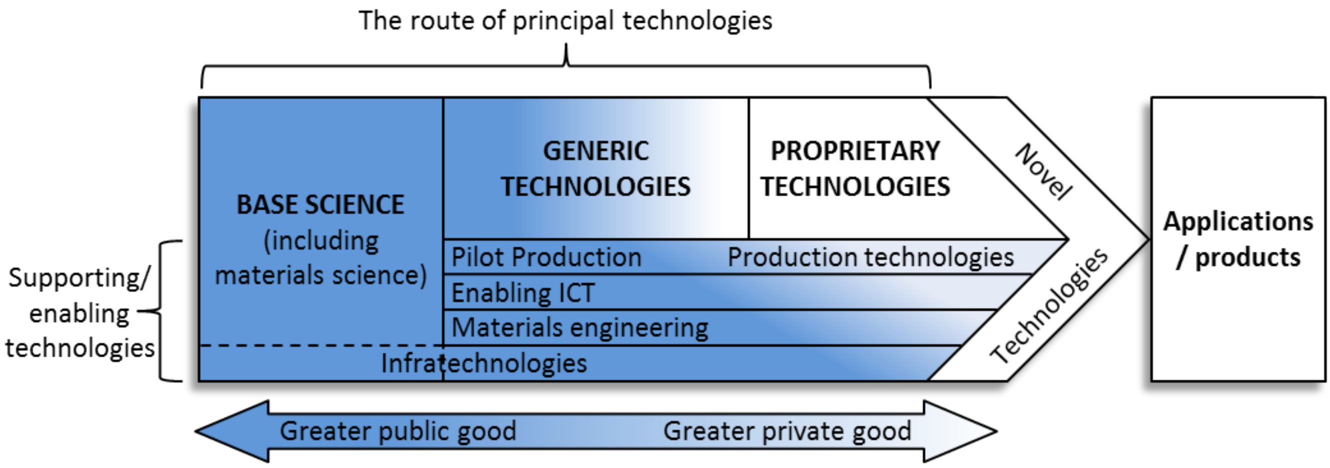

Figure 1: Schematic highlighting important categories of technologies involved in developing a principal technology
NB: The shading implies the approximate level of public good of technologies in the categories

Technology categories

This sections clusters and defines the categories of technology outlined in Figure 1. The technologies are depicted in a single block in Figure 1 to reduce the visual complexity related to the nonlinear nature of technology development.

Base science – this is fundamental research where technological possibilities are conceived of or discovered or both. Much of the work done in base science is done in publicly funded research institutions, such as universities. Research that adds to the base science includes fundamental work done in mathematics, physics, chemistry, life-sciences, engineering and the social sciences (e.g. design).

The route of a principal technology

Application platform technology – where the technology has become a (generic) platform technology which can be configured, possibly with other technologies, to form a proprietary technology. Tassey (2007, p. 110) refers to this as the point where the technology has been demonstrated ('proof of concept'). The public good of the technology begins to fall when the product goes through phases of prototyping and ownership of the resulting configurations start to be identified or assigned.

Proprietary technology – where a technology has reached a point of specificity in configuration and application that patent/ industrial design rights/ design patents can be recognised/ registered/ acquired.

Supporting/ enabling technologies

Production technologies – are technologies developed to help fabricate and manufacture an emerging technology. It includes the novel, specifically developed or established technologies and processes that are used to fabricate an application platform technology. These will often be precise, but time consuming and with small batch sizes (often batch sizes of one). It also includes the pilot technologies, which are developed with or after the prototyping stages of the principal technology and are trialled at a predicted needed scale-up level (sizes/quantities). At the later stages of development, production technologies are often developed that manufacture the technology at lower costs, reduced production times, greater repeatability or any combination of these (e.g. greater repeatability in decreased time often leads to greater production numbers). At different stages and to different degrees, production technologies are integrated with other production technologies and a greater industrial framework so that they can be integrated into current products and/or within the current industrial setting.

Information and communication technologies (ICT) – includes technologies such as modelling and simulation, process control, production control and coordination tools. ICT tools play a role in other technology categories, supporting the development and production of an emerging technology.

Materials engineering – is the development of new materials and materials properties, often through novel materials configurations and manipulation, to attain suitable properties for, or that enhance the functioning of, a novel technology (both alone as an application platform technology and as part of a proprietised configuration).

Infratechnologies – are the technologies used to support the development of a product, production technologies and ICT technologies. These include measurement and testing equipment, common facilities, technical interfaces between technologies, analysis techniques and databases.

These technical categories exist in an even more complicated context, which includes the skills of the people participating in the emergence of a technology and the relevant standards and standards development strategies. Principal technologies often need development in these contextual areas as well as in the supporting technologies.

The generalised nature of this diagram means that some of the distinctions drawn in it can be somewhat blurred for particular principal technologies. For example, the distinction between materials engineering and the development of the principal technology can begin to break down when innovation is materials driven and a novel material is patterned to make a device.

IN FORMULA ONE

Manufacturers in the FIA Formula One World Championship use carbon-fibre-reinforced polymer (CFRP) for their cars as well as in the production of the cars. Developments in the material not only support the development of the principle car parts, but also underpin a number of the associated manufacturing processes. Measurement and characterisation tools and ICT also underpin research in CFRP and enable future developments.

Implications

Implications of the ‘system of technologies’

Figure 1 highlights the different categories of technologies that can be used to support the development of a novel technology. In order to support the novel technology, developments within these supporting technologies may be needed to help overcome the barriers faced by the principal technology. Without these developments, a principal technology may not realise its full potential or may not be able to be applied in an industrial setting. These are important considerations when thinking about how to leverage research and develop a technology further (in both technology ‘push’ and ‘pull’ instances).

The distinction between the different types of technology shown in Figure 1 also contributes to distinguishing emerging technologies from emerging industries. A new technology can be integrated into an existing product, enable a new product to be developed or (on occasion) enable a whole new industry to emerge (through variations of a product, a number of product types or an industry of supporting products). These different applications have different supporting technology requirements. Figure 1 shows some of the categories that need to be considered to varying degrees for the different potential applications of a novel technology. As a principal technology is developed, they accumulate and build to become a set of technologies that assisted a principal technology overcome emergence barriers.

Figure 1 also shows the different (approximate) levels of public good involved in the various categories of technology (Tassey, 2004). This assignment of public good is not intended to assign responsibility, but rather to map out the diversity of technologies and their characteristics with respect to spillovers and appropriability (which discourage private investment).

The linkages between the different types of technologies and different stages of development are key to the discussion about technology development. Figure 1 shows the ever-present importance of these linkages by keeping the different categories of technology together in one block. It also shows the underpinning nature of the supporting technologies and how they need to be present for a technology to emerge and create value. The linkages between technologies and a lack of technology development in a key area offer considerable barriers to a technology’s progression.

Implications for public policy

Projects and initiatives that aim to support a principal technology develop should consider the role and needs of the supporting technologies. A crucial barrier to the development of a technology could be overcome by developments in one or more of these supporting technologies. Such barriers could prevent a technology realising its full potential or hinder it from realising any value at all. The varying levels of public good indicate areas where public support can help overcome negative externalities (particularly spillover) in technology development. Finally, the boundaries and links between the technology types highlight potential obstacles that might impede the development of a new a new technology and the possible timing of these obstacles in the process of its emergence. These can be used to guide programmes that aim to support technology development.

These implications are particular relevant for the UK’s current Industrial Strategy and other policies that aim to support industrial activity. The development of novel technologies are a key focus of the UK’s sector strategies, and the development of supporting technologies are equally relevant for these technical advances. This includes particular relevance for any manufacturing related policies in the UK. The above conceptualisation of technology development can be used to inform these policies.

Supporting R&D processes

The implications discussed above have process implications for anyone involved in technology based R&D, particularly if they are developing R&D priorities; developing policy; or selecting, supporting or conducting R&D projects. A number of the tools used to support these processes, including technology roadmaps, can be deployed in a way to consider the system of different technologies that support technology development. Processes that employ these tools then more accurately reflect these dynamics of technology emergence and support more informed decision making related to technology R&D.

IN THE UK’S EIGHT GREAT TECHNOLOGIES

The UK Government’s Great Technologies focus differently on the technologies described above. The propsed focus of Robotics and Autonomous Systems, for example, is both on principle technologies and enabling technologies. Advanced materials, however, is covered almost entirely by Base science and Materials engineering.

References

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CSTI research on the roles of technology in innovation

Dr Charles Featherston (crf33@cam.ac.uk) leads a programme of research to better understand technological and industrial emergence and how these can be supported by public policy, particularly through the use of frameworks and tools such as technology roadmapping. Current projects include:

- **Historical roadmapping** - Using historical roadmaps to understand different emergence dynamics
- **Comparing published public sector advanced materials strategy related documents** - understanding the different types of documents published that describe and support public advanced materials strategies
- **Pathways to manufacturing** - comparing theory and practice relating to manufacturability challenges and colelcting lessons regarding how they might be overcome
- **Supporting the development of standardisation strategies** - understanding how tools can be used to support the development of standardisation strategies

For further information, please see: http://tiny.cc/crf33

FOR FURTHER INFORMATION

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ABOUT CSTI

CSTI, led by Dr Eoin O'Sullivan (eo252@cam.ac.uk), carries out applied research exploring what makes national innovation systems effective at translating new science and engineering ideas into novel technologies and emerging industries. Key research themes include: economic value capture from industrial innovation systems; innovation system regulations and standards; technological emergence; manufacturing systems; and the public research base and innovation development

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