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Firm-level innovation models

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Abstract

This paper provides a critical review of firm-level innovation models. The paper summaries different categories of innovation model and identifies their achievements. One of the chief contributions models is that many countries go substantially into the management of innovation and the decision-making processes within the firm. However, in general, there is a lack of empirical evidence to verify existing models, weak theoretical underpinnings, This article looks at various models of innovation processes as well as at diffusion of innovation models. It summarizes current theories on both managing innovation processes and creating innovative organizations.

Keywords: innovation models, innovation processes, managing innovation

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1 Introduction

In the past 30 years or so, firm-level models of innovation have proliferated and become ever more sophisticated. One of the chief contributions of industrially advanced country (IAC) models is that many of them go substantially into the management of innovation and the decision-making processes within the firm. In doing so, they go 'beneath' higher level general models of innovation and delve deeply into the nature of innovation itself. At the same time, 'latecomer' firms from the developing countries have increasingly built a competitive presence on the international stage.
However, the relevance of IAC innovation models to such firms is, as yet, unclear. The purpose of this paper is therefore, to provide a critical review of firm level innovation models in the advanced countries.

2 Five Generations of Innovation Models

Since the 1950s, there has been a proliferation of innovation models, each purporting to explain and/or guide the process of innovation within industrial firms. In a seminal contribution to the field, Rothwell argued that the post-war era was characterised by successive waves of technological innovation associated with a corresponding evolution in corporate strategy.
Before examining individual models, it is useful to emphasise five caveats stressed by Rothwell in his introduction to the five generations:
1. The evolution from one generation to another does not imply any automatic substitution of one model for another; many models exist side-by-side and, in some cases, elements of one model are mixed with elements of another at any particular time;
2. Each model is always a highly simplified representation of a complex process that will rarely exist in a pure form;
3. Often the progress from one generation to another reflects shifts in dominant perception of what constitutes best practice, rather than actual progress;
4. The most appropriate model will vary from sector to sector, and between different categories of innovation (e.g. radical or incremental);
5. The processes that occur within firms are to an extent contingent on exogenous factors such as the pace of technological change.

2-1 The first generation models of innovation, so called technology push models, were simple linear models developed in the 1950s ,which treated innovation as a sequential process that took place in discrete stages.

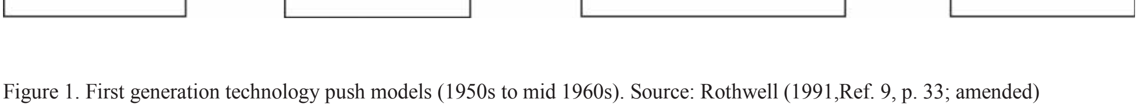

Figure 1. First generation technology push models (1950s to mid 1960s). Source: Rothwell (1991,Ref. 9, p. 33; amended)

2-2 Second Generation: Demand Pull Models (Mid 1960s–1970s)

Rothwell14 argues that in the latter half of the 1960s empirical studies of innovation processes began to emphasise market led (or need pull) theories of innovation. These were again linear in nature, stressing the role of the marketplace and market research in identifying and responding to customer needs, as well as directing R&D investments towards these needs. In these models, the marketplace was the chief source of ideas for R&D and the role of R&D was to meet market demands.

2.3 Third Generation: Coupling or Interactive Models (1970s)

Detailed empirical studies during the 1970s showed that both the above linear models (technology push and market pull) were extreme and atypical examples of industrial innovation. In particular, Mowery and Rosenberg argued that innovation was characterized by a coupling of (and interaction between) science and technology (S&T) and the marketplace. The coupling model presented in Figure 3 was described by Roth well as 'a highly simplified, but nevertheless more representative model of the innovation process'.

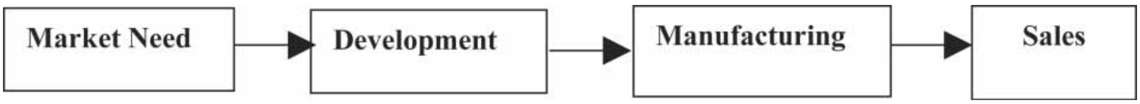

Figure 2. Second generation demand pull models. Source: Rothwell (1991, Ref. 9, p. 33)

2.4 Fourth Generation: Integrated Models (1980s)

Although third generation models were non-linear with feedback loops, Rothwell nevertheless criticised them as being essentially sequential in nature.

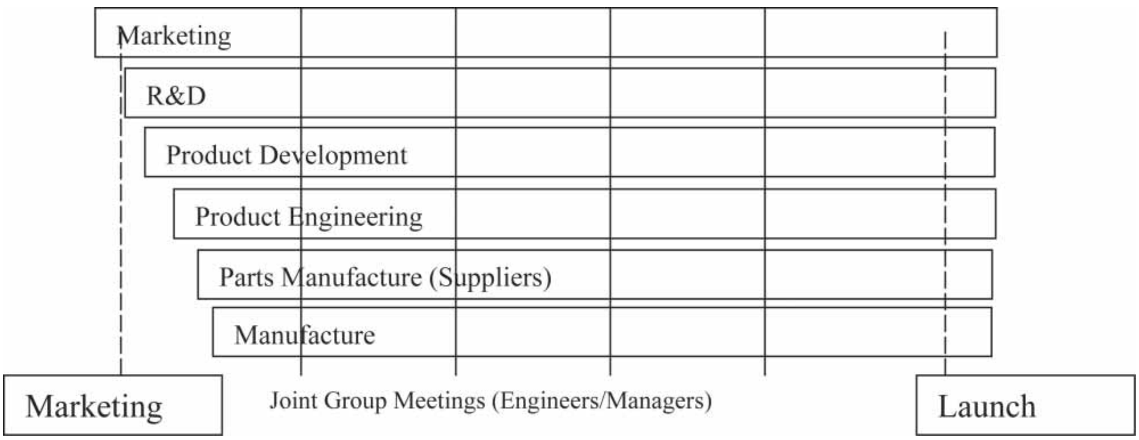

Figure 3. An integrated (fourth generation) innovation model. Source: Rothwell (1993, Ref. 7, p. 22)

2.5 Fifth Generation Systems Integration and Networking Models (Post 1990)

Fifth generation systems integration and networking models emphasised the learning that goes on within and between firms, suggesting that innovation was generally and fundamentally a distributed networking process. These models were based on observations during the 1980s and 1990s of an increase in corporate alliances, partnerships, R&D consortia and joint ventures of various kinds. These interpretations were extensions of fourth generation integrated models, further emphasising vertical relationships (e.g. strategic alliances with suppliers and customers) and with collaborating competitors. According to
Rothwell the fifth generation approach was brought about by time pressures on leading edge innovate sophisticated electronic tools in order to increase the speed and efficiency of new product development across the entire network of innovation, including in-house functions, suppliers, customers and external collaborators. As Roth well put it: 'G essentially is a development of 4G in which the technology of technological change it itself changing'20 and 'G represents the electronification of innovation'.

Many of the most successful innovators in the Industrial Revolution were thus incentivized by multiple mechanisms: although in many cases they relied on patents or secrecy to protect the rent-generating intellectual property rights, as often they placed their knowledge in the public domain and relied on superior technology or competence.

Innovativeness was a strong signal of competence, and competence was what people hiring consultants wanted. Self-employed engineers such as James Brindley and John Rennie, or architects like Joseph Jopling, (who won a Society of Arts gold medal for arch construction improvements), made their living by signaling their professional competence through coming up with improvements in the techniques they used.

It is interesting to note that for modern data hiring inventive employees seems also a good strategy to
maximize the impact of innovations. Singh and Agrawal (2010) estimate (using modern US patent citation data) that when firm recruit inventors, the citation of the new recruits' prior inventions increases by more than 200 percent even if these patents are held by their previous employer. They also argue that the effect is persistent even though one might expect that the tacit knowledge of the inventor diffuses fast within a firm.

Thus Bryan Donkin, a prodigiously gifted tweaker, with 11 patents to his name and a reputation to match, received commissions from the excise and stamp ofice, the East India office and none other than Charles Babbage (to estimate the cost of building his calculating machine).
was seen, whether correctly or not, as an official imprimatur of technological expertise. Reputation for expertise resulted in new commissions for their workshops.44 Again, it is not easy to quantify this, but

professional engineers, especially civil and mechanical engineers, often worked on specific commissions and consultancies.
Some of these commissions came from the government, others from overseas, but most of them were local manufacturers and colliers who needed something specific installed or built.
The model for this way of organizing the engineering profession was set by the great John Smeaton, after James Watt the most influential engineer of the eighteenth century.

3-conclusion

Each of the five generations of IAC innovation model reflects a growing body of academic knowledge and deeper analytical insights into the innovation process. Although first and second generation models tend to exclude vital elements of the innovation process, the later more sophisticated models incorporate feedback loops from later to early stages of innovation, and from the S&T environment and government policies to the firm and vice versa. Fourth and fifth generation models also account for the pre-innovation idea generation stage. The fifth generation network model attempts to show the benefits to be gained from automating the innovation process through the use of sophisticated information technology systems.

The need for variety and innovation in innovation models implies that models (especially stages models) cannot be used either as prescriptions or lessons for contemporary latecomer firms, or for explaining previous paths of firm level innovation (except perhaps at a very general level). Latecomer innovation paths are likely to vary according to the distinctive resources of a particular firm and its specific stage of backwardness. Therefore, it is likely that empirical research will find that many firms did not follow particular paths specified in models and that significant differences exist and persist among firms, even within the same sector. However, innovation models can be quite useful both for understanding and for practical purposes if used appropriately. One important use of innovation models is to use them to ‘benchmark’ new patterns and thereby make sense out of them. Indeed, without such a benchmark it would be very difficult to analyse the different patterns of firms and therefore very difficult to build new, more sophisticated and accurate models. To summarise, on the one hand, innovation models should not be used: to assume a particular historical behaviour on the part of a firm or group of firms; to recommend any specific form of innovation behaviour on the part of existing firms; . to inform policies to support particular forms of innovation, except perhaps at a very general level (e.g. to support creative experimentation); . as a decision making tool within firms, unless it is made clear that each firm will need to tailor and adapt the model to its own resources and circumstances.

On the other hand, innovation models can be very important as benchmarking tools for understanding the actual pattern followed by firms. They can also be useful for practice and strategy, as long as managers use them as a method for identifying actual practices and tailor them to suit their own particular market circumstances, resources and capabilities.

This is not to say that innovation research and innovation models have no practical or analytical use. Firm-level models can be very useful for firm strategy and implementation processes, as long as managers tailor them to suit their own particular circumstances,140 M. Hobday resources, needs and experiences. By using models in this way, firms can help clarify key innovation variables and processes, and develop a distinctive innovation strategy. From an analytical perspective, innovation models would be more convincing if they were located within an appropriate body of theory that could deal with external contingencies, strategic choices and the distinctive competencies of the firm in question. For firm level innovation management purposes, modern resource-based theories of the firm provide one possible body of theory, making explicit the assumptions and purposes of the models, and helping to 'embed' innovation within the broader context of firm activities and decision making.

Finally, despite finding a positive impact on employment, sales and export, we could not clearly support a significant result in terms of productivity. However, as also suggested by Benavente et al. (2005), R&D activities take some time to have a productive impact, and therefore more time might be needed to obtain conclusive results in terms of productivity. Given the data available for this evaluation, we could not show conclusive evidence on long-run impacts.

This paper clearly shows the need for more frequent impact evaluations of public policies aimed at supporting the investment in R&D of private firms, in particular when these policies grant non-reimbursable resources. This does not imply any additional burden for program operations.

Notes and References

So far, most of these firms have been from a small number of Asian economies, principally South Korea and Taiwan (M. Hobday, Innovation in East Asia: the Challenge to Japan (Aldershot, Edward Elgar, 1995)). Hopefully, other advanced developing nations, such as China and India, may find the issue of firm innovation models of interest as they seek to compete internationally. Because of the substantial differences between the levels of development of different developing countries and firms, the paper is mainly concerned with those firms approaching the innovation frontier.

The technology frontier is defined as the point at which R&D becomes central to overall competitive strategy and advantage of the firm. For an assessment of Korean firm 'leadership' innovation in important electronic components such as semiconductor dynamic random access memories (DRAMs), see Y. Choi, Dynamic techno-management capability: the case of Samsung semiconductor sector in Korea, PhD Thesis, Department of Economics and Planning, Roskilde University, 1994, and in thin film transistor/liquid crystal displays (TFT/LCDs), see T. S. Oh, Catching-up and forging ahead of latecomer firms: the catch up of the thin film transistor liquid crystal display industry in Korea, Unpublished MSc Thesis, SPRU, University of Sussex, UK, 2002.

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