1.0.2 Modeling the innovation process

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First Published August 28, 2018 Final Updated July 14, 2021

Abstract

This section presents an outline of a model of the innovation process. As models which look at the process from the perspective of information flows, this chapter first provides an overview of the linear and chain-linked models, and then introduces a model that looks at the process from the perspective of determinants of innovation. In contrast to the latter, I take up a non-deterministic view of the innovation process and examine its practical implications in terms of whether it is possible to plan innovation.

Keywords

Linear model, chain-linked model, technology push, demand pull, appropriability, technology opportunity, complementary assets, non-determinism, social constructionism

1 Introduction

This paper outlines a "model" of the innovation process. The term "model" has been adopted in many disciplines and for various purposes. Models are typically used to schematically represent the structure, process, and behavioral patterns of a certain subject. There are two types of models—namely, descriptive models and normative models—which are general representations of the procedures, methods, and so on necessary for achieving a goal. The innovation process model discussed here is a descriptive model, and is a schematic description of the process by which innovation is realized. There are variations in such innovation process models, depending on what one focuses on among process components. In this paper, I present a model focusing on the flow of information and another focusing on the determinants of innovation.

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I also discuss a “non-deterministic” view of the innovation process as a critical perspective for models that focus on determinants.

Although the subject of this paper is the process of “innovation” rather than “scientific and technological innovation” as it corresponds to the wording of the previous studies referred to here, this paper considers “innovation” as practically synonymous with “scientific and technological innovation” because the innovation examined by the previous studies includes the R&D process of science and technology; the conceptual distinction between the two is discussed in another paper. Accordingly, I also discuss the significance and limitations of innovation process models in providing perspectives on science and technology innovation policy.

2 Information flow models: The linear and chain-linked models

Figure 1 presents Kline and Rosenberg’s (1986) depiction of the innovation process as a linear model, which is how it was commonly considered in Western Europe after the Second World War. In this model, the innovation process is viewed as a series of stages through which technical information is generated: namely, development, manufacturing, and marketing.

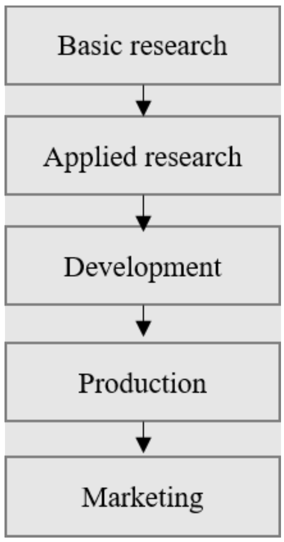

Figure 1. The linear model
Source: Kline and Rosenberg (1986)

If the real-world innovation process is as this model suggests, countries and companies that wish to promote innovation must first focus on the research stage. However, in reality, countries and companies that make huge research investments do not always secure an advantage through innovation. This suggests that the real innovation process is far more complex than the linear model assumes.

Kline and Rosenberg (1986) thus proposed the chain-linked model to comprehensively describe the flow of information associated with innovation (Figure 2). The chain-linked model consists of three layers:

"research," "knowledge," and business process flow. The business process from discovering a potential market to producing and distributing a product to meet the needs of that market is not simply carried out in stages over time; rather, information is often fed back to earlier stages in order to solve problems that arise. In Figure 2, the step-by-step chain is depicted as "C," and the feedback circuit as "f" or "F." Moreover, while existing knowledge may be referred to in order to resolve an issue arising at a given stage, the matter becomes a research problem if it cannot be solved with existing knowledge; this pathway is represented as K-R. In rare cases, the results of scientific research may lead to rapid innovation (D), or the products of innovation, such as measuring instruments and machine tools, may promote scientific research (I).

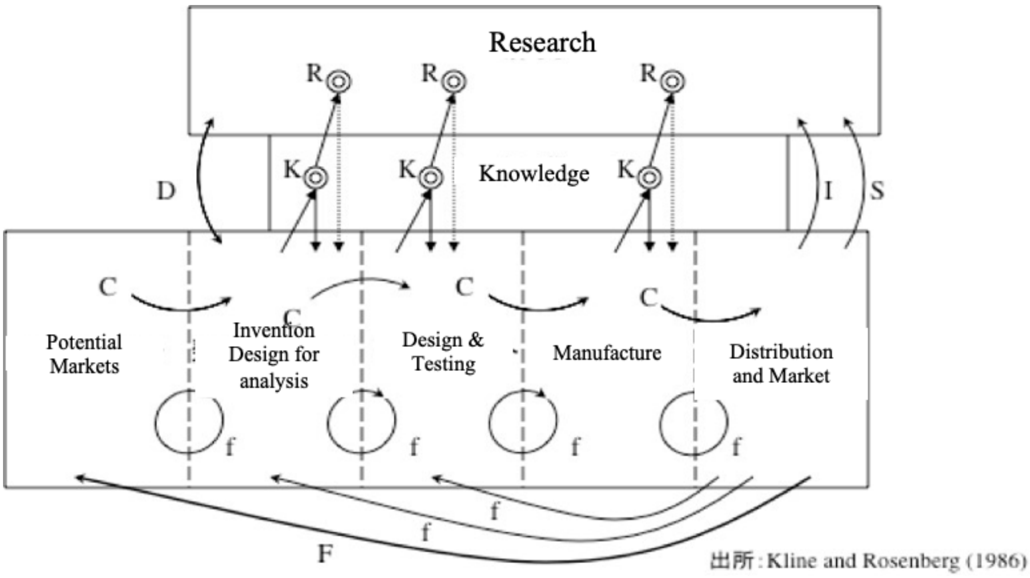

Figure 2. The chain-linked model.

The chain-linked model schematically depicts how each stage of the innovation process has complex interrelationships due to the existence of various feedback loops. Significantly, unlike the assumptions of the linear model, this schema suggests that various stages, not only research, can be the starting point for innovation. Another feature of this model is that it explicitly shows the hierarchy of knowledge as a stock accumulated by activities carried out across the flows of research and business processes (Nagata, Akiya, 2003).

3 The determinants of innovation model

The classical hypotheses regarding the determinants of innovation are known as "technology push" and "demand pull." The former view emphasizes the creation of new technologies as a factor that generates innovation, while the latter emphasizes the existence of demand. Numerous studies have sought to identify which of these is the dominant factor (Utterback, 1974; Mowery and Rosenberg, 1979). Of course, such empirical research also led to the discovery of more essential determinants.

Figure 3 presents the model of the innovation process proposed by Goto Akira (2000). Although this model deliberately simplifies and depicts the flow of information in a linear fashion, it specifically illustrates the phases in which the determinants of innovation operate.

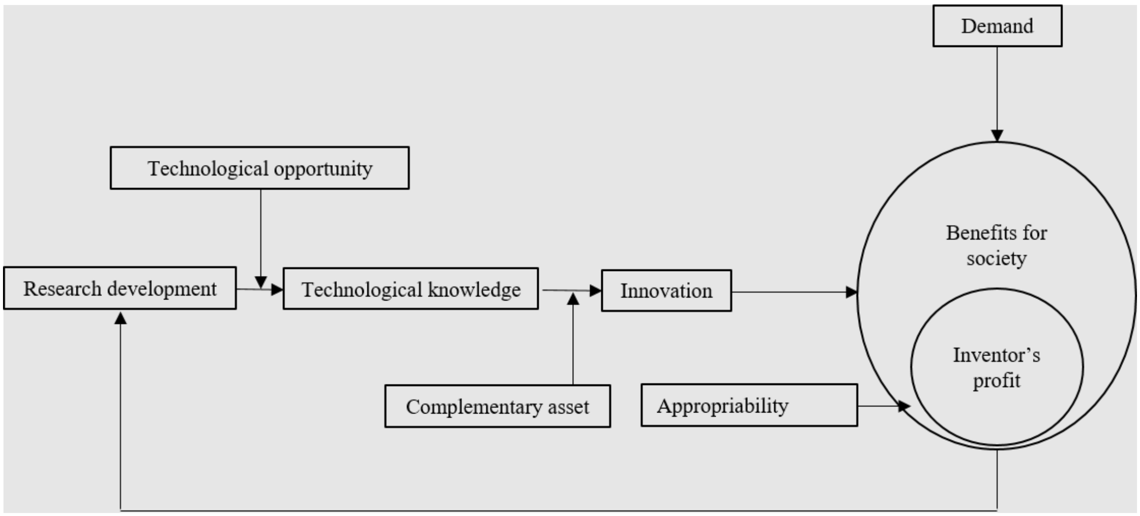

Figure 3. The innovation generation mechanism.

In the R&D stage, "Technological Opportunities" act as a factor that effectively brings about the creation of new technological knowledge. Technological opportunities are opportunities provided by various sources of information surrounding research and development, and specifically refer to acquired information that can lead to proposals for new projects or solutions to problems in existing projects.

In the phase where the generated technological knowledge manifests as innovation, "Complementary Assets" are the factor determining success or failure. Of course, innovation is not achieved by new technical knowledge alone. In the process of embodying this technological knowledge into new products and manufacturing methods to generate profit in the market, having the necessary production facilities and sales networks or favorable terms of access to them is vital. The assets needed to realize such innovations are called complementary assets.

The magnitude of the overall benefit generated by an innovation is defined by demand. Appropriability is a factor affecting the ability of a company to recover profits. Appropriability refers to the extent to which a company that realizes an innovation can recoup profits from it. Profit earned as inventor's profit becomes a source of funds for new research and development. Thus, under conditions where appropriability is low and much of the profit is subject to spillover, it will be difficult for firms to pursue innovation sustainably. Appropriability is known to be influenced by various factors, including the strength of rights protection under the patent system, the implicit nature of technical knowledge itself, and the experience curve effect (Teece,1986; Levin et al., 1987; Cohen et al., 2002).

4 A non-deterministic perspective on the innovation process

Models of the innovation process that focus on determinants are premised on the view that the existence of some antecedent factor, such as a new technology or latent demand, determines the direction of subsequent innovation. A “non-deterministic” view has been proposed in contrast to this “deterministic” view, one in which the direction of innovation is formed by the interaction between various interpretations of a technology. According to this view, once an interpretation is fixed, a pseudo-causal relationship is observed in the technological development process (Toshihiko Kato, 1999).

This kind of non-deterministic perspective falls within “social constructionism,” which holds that our perception of reality is socially constructed. Support for the claim that interpretations of technology influence the direction of innovation can be found in the technological history of the bicycle. According to Bijker et al. (1987), the early bicycle—mass-produced around 1870 and known as the Penny-Farthing or Ordinary (Figure 4)—was welcomed by young men who interpreted it exclusively as a sporting tool. Although this type of bicycle was faster, it was not accepted by other social groups, such as ladies in dresses, because of its dangerously high saddle position. Consequently, the safety bicycle, with a low saddle position and a chain-driven rear wheel, was developed. However, in the nineteenth century, the use of bicycles for sport became dominant and the safety bicycle was considered to have been a commercial failure.

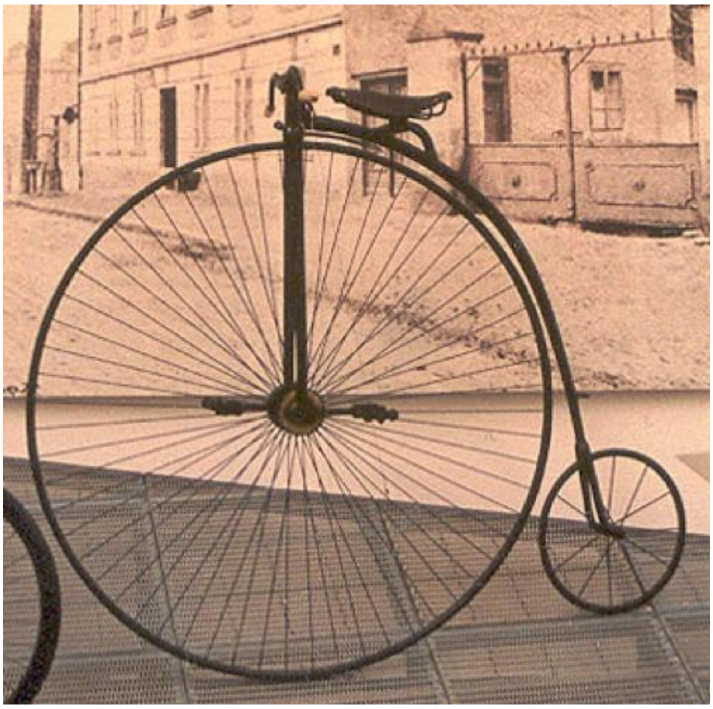

Figure 4. A Penny-Farthing.
Source: Wikimedia Commons

This example illustrates how the dominant interpretation of the bicycle’s use at the time resulted in the safety bicycle failing to become an established innovation for a long time, despite the existence of both the latent demand for the bicycle as a tool for fast and safe transportation and the technology to realize it.

The perception that some "determinant," be it latent demand or new technology, existed ahead of time is only "hindsight" constructed once the safety-type bicycle was established as an innovation.

5 Can innovation be planned?

The determinants of an innovation can only be recognized after the innovation in question has been established. If we view the message of the non-deterministic perspective in this way, it becomes nothing more than common sense. However, accepting this as common sense will help practitioners working to promote innovation eliminate preconceptions about the innovation process. It is important to note that even if the causal model linking innovation to some antecedent factor is always established with the benefit of hindsight, this does not mean that approaches that attempt to promote innovation systematically with some causal hypothesis are invalid.

To understand this point, it is helpful to review the process leading to the creation of the Post-It, a product innovation created by 3M. 3M has an unwritten rule known as the "15 percent rule," which allows employees in the R&D department to spend 15 percent of their working hours on any project they wish. The adhesive used in Post-Its was the result of a trial-and-error process by Spencer Silver, who was in charge of development and used the 15 percent rule. It was initially interpreted as a "failure" because it would stick to anything but peel off easily. However, Arthur Fry, a researcher in the Commercial Tape Division, heard a report about the adhesive at an internal technical meeting. One Sunday in 1974, while singing a hymn in the church choir, Fry wondered if it would be possible to keep the bookmarks from falling out of the booklet, thus realizing an application for the adhesive. Fry proceeded to develop the "non-slip bookmark" on his own initiative. After distributing prototypes internally, he convinced the Commercial Office Supply Division of the product's value. The Post-it was commercialized in 1981, eight years after Silver's report and seven years after the idea was conceived by Fry.

The adhesive used for the Post-It was not created as part of a plan to develop a bookmark that would not fall out. Indeed, the development of "non-slip bookmarks" was not originally part of the Office Supply Division's plan. In this sense, the product and innovation that became a pillar of 3M's earnings was very the product of chance. A company without the 15 percent rule in place would likely not have had the opportunity to create an unusual adhesive in the first place. Today, it is widely known that 3M has an eleventh commandment: thou shalt not kill an idea. If the company did not have such an ethos, researchers would have been prohibited from pursuing topics that were not part of their division's agenda. Therefore, it can be said that "even if the development of the Post-It was partly the rule of the confluence of coincidences, the environment at 3M that made its development possible was not a product of coincidence" (Collins and Porras, 1994).

6 Implications for science, technology, and innovation policy

As described above, discussions to construct a model to serve as a framework for understanding the complex innovation process clearly demonstrate that even when the innovation process involves the creation of technological knowledge, the starting point is not necessarily research. Moreover, innovation is formed by a chain of information originating from the discovery of problems at various stages. Research on the determinants of innovation, which provides the knowledge underlying the assumptions of the model, has revealed that the formation of innovation involves not only technological opportunities that affect the efficiency of R&D, but economic factors like the appropriability of benefits, access to complementary assets, and the scale of demand. These earlier studies have policy implications: as long as policies aimed at stimulating innovation remain restricted to supporting corporate R&D and measures to improve the research capabilities of universities and public research institutions, the effects of those policies will be limited. Those in charge of science and technology innovation policy are thus required to engage in policymaking by envisioning not just the R&D phase, but the innovation process in full. Furthermore, recent research on the innovation process has given rise to the view that recognition of the presence of determinants prior to innovation is the product of hindsight gained after the innovation is established, and that the real innovation process is socially constructed through interactions between diverse actors. This view suggests that innovation is difficult to promote in a planned way because it is the unanticipated result of interactions between actors. However, as we have seen in the case of the Post-It, even if the combination of technology and needs that form a certain innovation is the product of chance, the odds of such a combination can only occur under certain organizational and institutional conditions. As such, even if it is impossible to identify the specific determinants of innovation in advance and achieve innovation in a planned manner, we can expect a certain degree of effectiveness from a policy approach that scientifically identifies and develops the organizational and institutional conditions that increase the probability of innovation.

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