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This paper presents a model to explain differences among process innovations in the rate of diffusion. This model is built largely around one hypothesis— the probability that a firm will introduce a new technique is directly related to the proportion of firms already using it and the profitability of doing so, but inversely related to the size of the investment required. When confronted with data for a sample of major industrial innovations, this model seems to stand up very well. (The *SSCI*® and the SCI® indicate that this paper has been cited in more than 210 publications.]

The Diffusion of Industrial Innovations

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In the middle and late 1950s, I became interested in the economics of technological change, a topic that both economists and technologists recognized as important, although very little research was going on in the area at that time. Joseph Schumpeter had put forth a variety of interesting ideas, but there was a very limited body of statistical knowledge that had been accumulated. My colleagues at the Graduate School of Industrial Administration at Carnegie Institute of Technology (now Carnegie-Mellon University), where I was a young (about 25 years old) assistant professor, encouraged me to devote time to research on this topic.

One of the first topics I chose to explore was the diffusion of industrial innovations. The rate of diffusion is of great importance. Once an invention is commercially introduced, the battle is only partly won, since it must still gain widespread acceptance and use. The full social benefits of an innovation will not be realized if its use spreads too slowly. However, at that time, there was little or no data available concerning how rapidly—or slowly—new industrial techniques diffused, and no mathematical or econometric models to predict how rapidly—or slowly—a particular new technique would spread. To try to obtain the necessary data, I interviewed a large number of executives and engineers in the steel, coal, railroad, and brewing industries, and developed a considerable database from surveys I carried out of firms in these industries. One thing that struck me was how cooperative these firms were. I became convinced that the only way that economists would achieve a reasonably adequate understanding of many aspects of technological change was through detailed empirical work of this sort.

At the same time, it was necessary to model the diffusion process as best I could. Earlier, in 1954 and 1955,1 held a Fulbright fellowship to study mathematical statistics at University College, London, where I learned a little about stochastic processes. Thus, my first inclination was to construct a stochastic model of this sort. While this model fit the data very well, as shown in the paper, a simpler, deterministic version also did very well; and, this deterministic version has generally been used in subsequent work. This version predicts that the growth of the number of adopters of an innovation will conform to the logistic curve, and the diffusion rate will be linearly related to the profitability of the innovation. Thus, it helps to explain why the diffusion process often conforms to the familiar S-shaped growth curve. (An example is the diffusion of hybrid corn, as noted by Z. Griliches.[1])

Initially, the paper attracted attention because it showed how slowly many major industrial innovations had spread in the US. Given the emphasis in the early 1960s on policies to accelerate economic growth, these results were of widespread interest. For example, the National Science Foundation published a brief summary of the paper's findings, and I was asked to present the results at various meetings. Subsequently, it was used as a basis for forecasting the diffusion of new industrial products. For example, Blackman found this model to be useful in his studies of the US aircraft-engine industry.[2] Also, evidence began to mount that this model worked surprisingly well in other countries. (For instance, see R. Hsia.[3]) As time went on, this model became a standard method of forecasting and analyzing the diffusion process. (See A. Romeo.[4]) While a host of more complex models of this type have been developed in the 30 years that have elapsed since the publication of this paper, this basic model still is widely used. (See E. Mansfield[5] and V. Mahajan and Y. Wind.[6])

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5. **Mansfield** E. The diffusion of industrial robots in Japan and the United States. *Res. Policy* 18:183-92, 1989.
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