Chapter 17

Competition and Complementarity in Diffusion: The Case of Octane

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17.1 Introduction

The standard ontogenic (*life-cycle*) model of technological evolution can be characterized briefly as follows (Ayres, 1987): (1) a radical invention (**birth**) creates a new technology; (2) it is commercialized on the basis of performance and rapidly developed by a series of improvements and modifications (**infancy**); (3) it is successful enough in the marketplace to attract many variants and imitators who hope to exploit a growing market (**adolescence**); (4) the pace of technological change finally slows down enough to permit standardization and exploitation of economies of scale, and competition on the basis of price rather than performance (**maturity**); and finally a new and better technology supplants it (**senescence**).

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The standard model involves substitutions in the adolescent and senescent stages. During the adolescent stage, the new and dynamic technology is gradually penetrating the markets of its predecessor. During the senescent stage it, in turn, is being displaced from its markets by its successor. The substitution of a new technology for an older one is often modeled as a deterministic process, following a simple mathematical formula such as a logistic function or a Gompertz curve (see, for example, Linstone and Sahal, 1976; Mahajan and Peterson, 1985; Mahajan and Wind, 1986).

However, complex social systems – including the system of innovation, adoption and diffusion of technology – are inherently nonlinear. As such, they must be expected to exhibit the characteristics of nonlinear dynamical systems. Among these characteristics is the occurrence of **non-equilibrium** steady-state behaviors (such as limit cycles and quasi-periodic motion) that temporarily emulate the behavior of simpler systems, but eventually depart from it (Crutchfield *et al.*, 1986). In short, social systems cannot be expected to always behave in accordance with any given simple model. Indeed, simple behavior, when it does occur, is likely to be an example of non-equilibrium steady state. Hence, from the standpoint of fundamental dynamical theory it seems likely that more can be learned by analyzing cases where the simple models fail than cases where they seem to work well (e.g., Fisher and Pry, 1971).

In particular, the simple deterministic substitution model that is normally assumed assumes that a substitution process, once it has proceeded past a certain threshold, inevitably proceeds to completion (unless it is interrupted by a further substitution). This implies the existence of an underlying self-reinforcing (*lock-in*) mechanism of some sort. Such mechanisms are intrinsically nonlinear in nature. A number of examples have been examined by Arthur (1983, 1988a, and 1988b). Obviously, the large number of cases where the substitution process has proceeded according to this script can be regarded as indirect evidence of the pervasiveness of self-reinforcing mechanisms. Yet, there are significant exceptions. Such a case is the subject of this chapter. We examine the technological evolution of fuels for spark-ignition internal combustion engines (e.g., automobile engines) since the beginning of the present century. The chapter concludes with a discussion of some possible explanations for the failure of "antiknock" additives to displace cracking as a means of raising gasoline octane, or conversely.