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The evolution of market structure in semiconductors: the role of product standards

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Abstract

This paper looks at the role of product standards in determining the evolution of market structure in semiconductors. Theory suggests that product standards, along with learning-by-doing effects, lead to market concentration and persistence of leadership in product innovation. Empirical evidence supports this with some qualifications. The market concentration hypothesis is confirmed for all submarkets of the semiconductor industry. Persistence of leadership is obtained for markets based on proprietary product standards. In the market for microprocessors, we have persistence of leadership in product innovation that is accompanied with overall market dominance. For microcontrollers, we observe persistence of leadership in product innovation, but not concomitant overall market dominance. Whereas learning-by-doing effects seem to be strong in the small market for microprocessors, they are weaker in the much larger market for microcontrollers. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

Explaining the evolution of market structure is a major research programme in the industrial economics literature (Sutton, 1995). The objective is to construct a general class of models that can explain the evolution of market structure across a broad range of industries. Easily identifiable and observable variables should help to partition the space of possible outcomes for market structures and explain their evolution. The empirical investigations adopting this approach have shown that several propositions are testable for both a broad range of industries (Sutton, 1991) as well as for single industries. Examples for the latter are the role of R&D in the pharmaceutical industry (Matraves, 1996) and learning-by-doing in the semiconductor industry (Gruber, 1994).

A related issue is the explanation of persistence of market leadership over a long period of time, especially if the industry is concerned with repeated innovation. The extreme patterns found in the theoretical literature concern leapfrogging or persistence

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of leadership. What type of pattern emerges ultimately depends on features such as the type of price competition or the beliefs of the agents (Vickers, 1986; Beath et al., 1987; Budd et al., 1993). The problem is that most of these features are not directly observable and this makes it difficult to empirically test theoretical propositions. Nevertheless, detailed analysis of industry-specific characteristics, such as learning effects, allows making of some progress. Gruber (1994) has shown the conditions under which the learning curve generates persistence of leadership in product innovation in semiconductor memory chip markets. The interplay of learning-by-doing and market size is crucial for generating this pattern: persistence of leadership is obtained if market size does not exceed a certain threshold level.

This paper explores a further feature with a strong bearing on market structure in the semiconductor industry: proprietary product standards. Starting off with the seminal papers by Katz and Shapiro (1985; 1986) and Farrell and Saloner (1985; 1986), the theoretical literature on product standards has become vast. We have learned that the number and types of standards produced by market forces depend very much on the basic assumptions on firm behaviour and consumer beliefs: a firm that is able to establish early an industry standard for a product should have a large market share in this. This advantage can be consolidated through repeated product innovation with backward compatibility. The standard can be protected in several ways, such as technological competence and by invoking intellectual property.

This paper elaborates on the evolution of market structure in other types of semiconductors such as microprocessors and microcontrollers. These chips are somewhat different from memory chips as they perform logic operations instead of simply storing information. They are what is referred to as a 'computer on a chip'. The manufacturing process of logic chips is similar to memory chips. The main difference is in the design. Memory chips are very much a commodity with little scope for differentiating products of the same generation. The above logic chips are based on proprietary standards which deliver scope for product differentiation and 'lock-in' of customers. Standards are an additional element bound to strengthen the persistence of leadership patters.

The learning curve is pervasive in the production of semiconductors and, given certain conditions of appropriability of learning-by-doing and market size, naturally produces persistence of leadership over a sequence of product innovations (Gruber, 1992). The firm, Intel, has maintained its leadership for all of the products analysed here, except for dynamic random access memories (DRAMs). The main hypothesis of this paper is as follows: given that with logic chips, we observe the persistence of leadership, this may not only be due to the learning curve, but also to product standards. In other words, the learning-by-doing effect is reinforced by the positive feedback on sales due to the leading standards. This hypothesis is supported by the observation that the market for microcontrollers is larger than that for DRAMs. But differently from DRAMs, the market for microcontroller displays persistence of leadership in product innovation.

This paper is arranged as follows. Section 2 presents the analytical framework of the model of the evolution of market structure and shows the relevance of learning-by-doing and standards. Section 3 is a brief description of the main market characteristics of the semiconductor industry. Section 4 further explores the memory and logic chip markets and then discusses the main propositions concerning the evolution of market structure. Section 5 draws the conclusions.

2. The theoretical framework

One of the objectives of the recent theoretical literature on the evolution of market structure (Sutton, 1991, 1998) is the identification of minimum conditions for a concentrated market structure. In this context, a market is said to be concentrated if the market share of the largest firm is bounded away from zero for any increase in market size. Sutton (1998) shows that important determinants that generate a concentrated market structure are learning-by-doing as well as product standards. The sequel discusses the two characteristics.

2.1. Learning-by-doing

The learning-by-doing principle is usually related to cost-reducing effects of increasing cumulative out-

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