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Product innovation incentives by an incumbent firm: A dynamic analysis☆

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ABSTRACT

We employ a dynamic framework to study how product innovation activities of a firm are influenced by its investments in production capacity of an established product and vice versa. The firm initially has capacity to sell an established product. Additionally, it also has the option to undertake an R&D project, which upon completion allows the firm to introduce a new vertically and horizontally differentiated product to the market, thereby extending its current product range. The breakthrough probability of detecting the new product depends on both the value of the firm's R&D stock and its current R&D investment. It is shown that the initial production capacity for the established product influences the intensity of R&D activities of the firm. In particular, there are constellations such that for large initial production capacity for the established product the firm never invests in R&D and the new product is never introduced. For small initial capacity the firm keeps investing in R&D implying that eventually the new product is always introduced. Finally, for an intermediate range of initial capacity levels the firm initially invests in product R&D, but then reduces these investments to zero. In this scenario the new product is introduced with a positive probability, which is however substantially smaller than 1. From a technical perspective this analysis gives the example of a new type of Skiba threshold phenomenon in the framework of a multi-mode optimization model.

1. Introduction

The overall aim of this paper is to develop and exploit a dynamic framework of analysis that allows studying the optimal investment strategies of established incumbent firms under consideration of the uncertainty about future changes in the market structure. The considered changes in the market structure are due to changes in the range of products offered on the market which are triggered by product innovations of incumbent firms. As the ability to introduce new products is typically

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based on innovation efforts of the innovating firm, such changes are endogenous results of firm strategies and industry dynamics.

In particular, this paper studies the problem of a firm undertaking R&D activities to come up with a new (vertically and horizontally) differentiated product and at the same time adjusts the capacity for the established product. The main feature of our setup is that the change in market structure induced by the new product introduction is explicitly modeled and that the hazard rate of innovation is a function of both the intensity of investment in R&D and the accumulated knowledge stock. This latter feature distinguishes the present paper from Dawid et al. (2013a) where innovation was considered as an exogenous stochastic process. In order to focus on the interplay between the stochastic dynamic R&D process and the production capacity adjustments we abstract in our setting from competition effects.

We develop a dynamic model, where an incumbent firm offers an established product. At some ex ante unknown point in time the range of products is enlarged, because the firm obtains the option to introduce a new product, which is vertically and horizontally differentiated from the existing product. This option results from successfully finishing a R&D project, which requires continued R&D investments. The timing of the breakthrough is stochastic and cannot be perfectly predicted. Capacities cannot be transferred between the production of different products, and therefore the introduction of the new product reduces the value of the existing capacity. The firm's objective is to maximize its total discounted profits by optimally selecting its investments in production capacities for the different products it offers and, before the new product is introduced, by choosing its innovation effort.

The problem outlined above is of substantial real-world relevance. It has been shown e.g. by Chandy and Tellis (2000), that a large fraction of product innovations are introduced by established incumbents. For such firms there are important feedback effects between their strategies on established markets (like capacity investments) and innovation strategies aiming at the introduction of new products that extend the product range. The main contribution of this paper is to consider the effect of an expected change in the market structure on investment behavior in the established market, as well as the feedback between capacity investments for the established product and innovation efforts, in a dynamic framework. In spite of the large literature on capacity investments and innovation incentives a rigorous integrated analysis of these effects is so far missing.

The considered market environment captures in a stylized way the dynamic emergence of new 'submarkets' in an established market and its effect for the established product before and after the occurrence of the new product. Real world examples resembling such a setting are numerous. For example, in the TV industry major producers of standard CRT television sets have started the production of flat-screens around the year 2000. Although the production processes for these two variants are based on very different technologies, for many years firms offered both products simultaneously. Another example along these lines is the (time-phased) introduction of hybrid cars by many car manufacturers, which opened a new submarket in this industry co-existing with established markets. It should be noted that a common feature of these examples is that the introduction of the new products becomes possible due to the availability of a new technology, or more generally due to technological progress. In such situations the capacity devoted to the established product typically can hardly be transferred to the production of the new product.

The main research question to be addressed within the framework sketched above is how the incentive to invest in innovation activities is influenced by the (current) capacity for the established product. In particular, we explore two issues. First, we examine under which circumstances capacity of the established product might have long lasting effects in the sense that it prevents the firm from innovating at all. Second, we consider the effect of capacity of the established product on the distribution of innovation time in cases where the new product is developed. In the latter scenario we also characterize how the investment in established product capacity is adjusted in light of the anticipation of a future new product introduction.

Establishing the firm's optimal investment strategies requires solving a two-mode piecewise deterministic dynamic optimization problem, where the two modes correspond to the pre-innovation and post-innovation phase. Our approach to solving the model is to analytically characterize the solution as much as possible before using a numerical method of collocation to complete the analysis. Furthermore, we employ an innovative numerical method that allows us to delineate the basins of attraction of two different long-run steady states emerging in our model. We show that the initial values of established product capacity and knowledge stock determine whether the incumbent firm eventually introduces the new product or not. There are constellations such that for large initial capacity for the established product the firm never invests in R&D and the new product is never introduced, whereas for small initial capacity the firm keeps investing in R&D as long as the innovation has not arrived. In this scenario the new product is always introduced. Finally, for an intermediate range of the production capacity the firm initially invests in product R&D, but then reduces these investments to zero. In this scenario the new product is introduced with a positive probability, which is however substantially smaller than 1.

Endogenizing the R&D activities of an incumbent gives rise to a number of new insights. For instance, we show that there is a non-monotonic relationship between the degree of horizontal differentiation of the new product and capacity accumulation on the established market prior to innovation. If the new product is a close substitute to the established one, then this does not only influence the degree of cannibalization after the new product introduction, but the firm is also less willing to invest in R&D during the innovation phase. This delays the expected arrival of the innovation, which fosters investment of the firm in the established product. The interplay of these effects gives rise to the non-monotonicity.

Our analysis is the first to establish a dependency of long run outcomes on initial conditions in a multi-mode framework. Compared to the established literature on Skiba phenomena in dynamic optimization problems (see e.g. Skiba (1978) or Haunschmied et al. (2005)), our analysis adds the observation that there are initial conditions such that each of the two