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Endogenous specialization of heterogeneous innovative activities of firms under the technological spillovers

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ABSTRACT

This paper proposes a reduced form model of dynamic duopoly in the context of heterogeneous innovations framework. Two agents invest into expansion of variety of available products and into the improvement of quality of existing products simultaneously. Every newly introduced product has its own dimension of quality-improving innovations and there is a continuum of possible new products. In the area of quality innovations the costless imitation effect is modelled while in the area of variety expanding innovations agents are cooperating with each other. As a result the specialization of innovative activity is observed. This specialization arises from strategic interactions of agents in both fields of innovative activity and is endogenously defined from the dynamics of the model.

1. Introduction

It is widely known that modern firms have multiple research projects with some of them being more directed to new products creation while others being directed to the improvement of existing ones. It is also known that some firms tend to specialize more in products creation while others are more active in the improvements of existing products. Current paper tries to provide an insight into the mechanism, which defines the direction and degree of specialization of R&D activities of such multiproduct firms.

The main focus of the paper is thus on the modelling of strategic interactions of agents in the field of innovations. To this end, the production activities of the agents are not explicitly modelled. This allows drastically simplifying the analysis and achieving the explicit solution. For that, the assumption of constant prices on existing markets is adopted. This assumption follows the practice in the literature (Dawid et al., 2010). Only the investment activities related to the introduction of new products and their further refinement are accounted for. It is assumed that there exists a continuum of potential products which may be invented/introduced, and each of these products may be further improved upon through innovations, specific for each such a new product. Creation of new products is related to product innovations and improvement of quality of each

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new product is related to process innovations in the literature. Both types of innovations require specific types of investments. Such a view on innovations is in line with definition of vertical and horizontal innovations as put in Rosenkranz (2003).

The range of new products is bounded from above by some number N. The model does not include any kind of explicit resource constraint and resource constrained version of the current model may be considered in the spirit of Baveja et al. (2000) to allow for analysis of unbounded range of potential product lines. The intuition behind this boundary is to treat the range N as the range of versions of some basic, industry-defining product, and thus N as the innovations capacity of such an industry and not as the space of ideas (which is usually unbounded) from works by Aghion and co-workers.

In particular, the notion of variety expanding and quality improving innovations follows the setup of vertical and horizontal innovations of Peretto and Connolly (2007) and earlier Aghion and Howitt (1992). As in these aforementioned, the process of creative destruction is assumed to govern the quality improving process: every step in vertical innovation for any product i destroys completely the demand for older generations of this product. Hence, every such dimension i is rather the line of products of type i than a single product, being affected by product life cycles. Introduction of a new car model onto a market destroys the demand for older cars and only newer ones are bought. In this setup, introduction of every new product i is the opportunity to develop the new line of such "cars", rather than a new model of the same car. However, I refer to variety expansion innovations as product creation and subsequent development of associated generations of products in line i as products improvement for simplicity.

Both agents participate in the joint R&D partnership devoted to the creation of new products and may use freely these newly created products in their further activities. At the same time each new product has to be further improved in its characteristics (referred to as "quality" throughout the paper) separately by each of the agents, before it can enter the market. Such a structure assumes joint lab financing for fundamental research (products creation) while quality improving process is managed privately by each agent. For all the new products this quality characteristic is zero for both agents at the time of product's creation. However, due to possibly different efficiencies of investments into the development of the products' qualities, eventually one of the agents may become the leader in this quality development. In this case I allow for undirected technological spillover between agents: at each time when one of the agents has lower quality for a given product, he/she benefits from partial spillover from the development of this product's quality by the other agent. The model itself allows for constant leadership, symmetric outcome and leapfrogging, but current paper concentrates on constant technological leadership case only to demonstrate the specialization effect in the most simple form.

This framework allows catching two major issues relevant for dynamic interactions in the field of innovations. First, it is shown that the technology spillovers in the form of costless imitation do not lead to the incentive to decrease investments into qualities of products for both agents simultaneously (as it should be in case if only one direction of innovations being considered), if one would account for their cooperation on the more fundamental level of creation of new products. One of the agents, which eventually becomes the leader (due to higher quality investments efficiency), does not benefit from the spillover effect, while the other one, which positions him/herself as a follower, reduces his/her own investments to benefit from this technological spillover created by the activities of the first agent.

Next, in the direction of variety expansion the united efforts of both agents are distributed unevenly. There is a natural specialization of investment activities of both agents. The agent, who is benefiting from the technology spillovers in process innovations (named "the follower" in the sequel of the paper), puts more investments into the product introduction activities. In an effect the agent who is the most efficient in one or another type of innovative activities carries the major burden of investments in this direction while benefiting from the investments of the other agent in the other type of innovations.

The rest of the paper is organized as follows. In the next section a brief summary on relevant studies is presented. Further on, the formal setup of the model is described. It is solved sequentially, employing the Hamilton–Jacobi–Bellman and Maximum Principle approaches. Upon obtaining analytical results the dynamics of the optimal investment strategies for both agents are considered. The Results section establishes the main result of the paper. The robustness of this result and extensions are discussed in the concluding section of the paper.

2. Related research

Broad literature on the effects which imitation is causing on innovation activity exists. One of the examples is the work of Gallini (1992), but imitation there is costly and the model is static. Another more recent work on dynamic interactions of R&D firms is that of Judd (2003). In this paper the author analyzes the multi-stage innovative race between multiple agents with multi-product situation, and this is rather close to the suggested approach. He finds out that there is an ambiguity in the results of a game, namely a given player may increase his expenditure when the other agent is ahead of him, while this is not profitable for him as an imitator.

The recent paper on product and process innovations in differential games framework Lambertini and Mantovani (2010) assumes fully dynamical model of the duopoly competition of innovating firms. However, this paper does not handle heterogeneity of innovations and hence is reduced to the differential game with two states, while the current paper allows for distributed nature of innovations and all products differ from each other in their investment characteristics. This is more in line with the setup of Lambertini (2003), but with fully dynamic context.

The next feature of the suggested model is the R&D cooperation on the level of products variety expansion (product innovations). It is argued that such a situation is more typical for R&D firms then the full-scale competition on both levels.