Dynamic models of research and development

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Chapter 5

Summary

This thesis studies process innovation in global, dynamic perspective. In contrast to the existing literature, all possible values of firms' unit costs, including those above the choke price, are considered. This allows research efforts to precede production. Furthermore, the analysis is not limited to equilibrium paths, but considers all trajectories that are candidates for an optimal solution. This includes the determination of critical points - points at which the optimal investment function qualitatively changes. In particular, it includes the determination of the value of unit costs for which R&D investments are terminated and for which they are not initiated at all. The size of these critical cost levels is affected by the conduct of firms. In consequence, different market regimes can lead to qualitatively different long-run solutions, despite starting from an identical initial technology. This global approach makes it possible to see not only how different variables of interest (e.g., spillovers, R&D efficiency) affect the investments on existing markets, but also how they influence the likelihood that a new market will be formed, and if so, how its likely structure relates to them.

Chapter 2 introduces the global framework by characterizing investment and production decisions of a monopolist that are globally optimal. A distinct characteristic of the optimization problem is the presence of multiple equilibria while at the same time the Arrow-Mangasarian sufficiency conditions are not met. In models of this type, the qualitative properties of optimal solutions may change if parameters are varied. For a global analysis, we therefore have to use bifurcation theory. This gives us a bifurcation diagram that indicates for every possible parameter combination the qualitative features of any market equilibrium. The analysis yields four distinct possibilities: (i) initial unit costs are above the choke price and the R&D process is initiated; after some time production starts and unit costs continue to fall with subsequent R&D investments; (ii) initial unit costs are above the choke price and the R&D process is not initiated, yielding no production at all; (iii) initial unit costs are below the choke price and the R&D process is initiated; production starts immediately and unit costs continue to fall over time, and (iv) initial unit costs are below the choke price and the initiated R&D process is progressively scaled down; production starts immediately but the technology (and production) will die out over time; the firm leaves the market. The strength of the analysis is that all these cases can emerge from the same unifying framework.

Chapter 3 extends the analysis of an innovating monopolist in Chapter 2 to the case with two firms involved in different levels of cooperation. It compares two different scenarios across the four types of industry dynamics outlined in Chapter 2. In the first scenario, firms cooperate in R&D and compete on the concomitant product market. In the second scenario, cooperation in R&D is extended to collusion in the product market. The chapter then compares the qualitative properties of these two scenarios in order to assess the potential set-back of R&D cooperatives in that they can serve as a platform to coordinate prices. It yields three key findings: (i) if firms collude, the range of initial unit costs that leads to the creation of a new market is larger, (ii) collusion in the product market accelerates the speed with which new technologies enter the product market, and (iii) the set of initial unit costs that induces firms to abandon the technology in time is larger if firms do not collude in the product market. In particular, it is shown that there are parameter configurations for which collusion in the product market yields higher consumer surplus as well as total surplus. This analysis presents a problem for competition policy because it shows that prohibiting collusion in the product market per se is not univocally welfare enhancing. It also shows that the associated welfare costs might not surface because a prohibition of product market collusion affects R&D investment decisions prior to the production phase. Any decision not to develop further some initial technology does not materialize as a welfare cost because no production is visibly affected.

Chapter 4 considers a differential game in which two firms compete both in R&D and on the product market. To capture strategic interactions between firms in as realistic way as possible, a solution to the game is sought in the class of feedback Nash equilibria, where the possibility of discontinuous investment functions requires a special treatment. A solution to the stochastic game is considered as an approximating solution to the deterministic game when the random noise level tends to zero. A numerical approximation to the value function is obtained using a variant of the numerical method of lines. The chapter analyzes how spillovers affect the investments of firms, how they influence the likelihood that a given initial technology will be developed further and, thus, a new market will be formed, and how the likely structure of a new market relates to them. The obtained results qualify the indication in the literature that higher spillovers might be socially beneficial as they might prevent the monopolization of the industry. It is shown that this pro-competitive effect of larger spillovers holds only up to a certain point and that, consequently, lower cost asymmetries can suffice to induce the monopolization of the industry at larger spillovers. Moreover, it is shown that through increasing complementarities in R&D, larger spillovers increase the chance that an expensive technology that calls for investments in advance of production will be brought to production. Though, the level to which such a technology is developed can be lower at larger spillovers due to lower R&D investments of firms that try to free-ride on each other along the way. In this sense, spillovers increase production efficiency only up to a point. Stochasticity is found to increase the likelihood that a given initial technology will be developed further as well as the likelihood that the ensuing product market will be competitive. The reason for this is that a higher chance of a large favorable shock to unit costs at larger levels of random noise stimulates firms to invest more. It also enhances the endurance of the follower. Furthermore, both predation and preemption can emerge in the model as a consequence of firms' optimal decisions.

There are several possible directions for future research. All the models in this thesis allow for only a single technological process being developed by a firm at a time. A natural extension is to allow for several technologies, with different levels of substitutability on the product market, being developed simultaneously. Next, this thesis considers process innovation only.

The global framework needs to be extended so to allow for a proper combination of process and product innovation. The analysis in Chapter 4 opens up a possibility of studying the incentives of asymmetric firms for cartelization and the stability of different R&D cooperatives among asymmetric members in global perspective. In all models considered, the level of spillovers was assumed to be exogenous. However, in practice, firms usually select, or at least influence, the amount of information they share strategically. This calls for the endogenization of spillovers within the global framework. Furthermore, in contrast to Chapter 2 and Chapter 3, the study of the differential game in Chapter 4 was in many ways limited to some representative configurations of parameters. A more complete analysis of solutions to differential games awaits the development of bifurcation methods for non-convex optimization problems with multidimensional state space, which are still in their infancy.