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On the coexistence of innovators and imitators

Roy Cerqueti [a], Fabio Tramontana [b], Marco Ventura [c,*]

[a] Department of Economics and Law, University of Macerata, Italy
[b] Department of Economics and Management, University of Pavia, Italy
[c] Italian National Institute of Statistics (ISTAT), Rome, Italy

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ABSTRACT

The article develops a model laying a foundation for the idea that the relationships between competitors in the knowledge diffusion market can be described by a Lotka–Volterra system. The model can accommodate both the scenario of prey–predator and that of competition between innovators and imitators. Analytic results and numerical simulations show that a stable coexistence equilibrium is feasible under both scenarios. The work also discusses the conditions under which these results are achievable.

1. Introduction

The controversial issue of protection of *intellectual property rights* (IPR), or more generally innovation, has been long debated, and actually, it does not seem to come at an end. The major reason of controversy emerges because of the presence of a trade-off faced by authorities when deciding the IPR degree of protection. In turn, the trade-off emerges from the public good nature of knowledge. At one extreme of the trade-off there are the alleged benefits that IPR convey to society. In particular, IPR increase the incentives to invest resources in the creation of new technological knowledge because of the positive effects in terms of the appropriability and tradability of the new knowledge. For this reason, in recent years, many countries have put into place more effective or rigorous protection policies, such as the establishment of the Court of Appeals of the Federal Circuit by US Congress and the EU directive 2004/48 on the enforcement of intellectual property rights. At the other extreme, strong protection brings about drawbacks by creating monopolies.

One of the ways followed in the literature to model the degree of IPR protection is to introduce imitation, via an exogenous imitation rate, competing with innovation, as imitation is commonly considered as an inverse measure of IPR protection [8,11,15]. Among many, Furukawa [10] finds that under some circumstances, the rate of innovation has an inverse-U shape as a function of imitation. This theoretical finding is also supported by Aghion et al. [1] who find strong evidence of an inverted-U relationships between competition and innovation. At its very essence this strand of the literature

* Corresponding author at: Italian National Institute of Statistics (ISTAT), Econometric Studies and Economic Forecasting Division, p.zza Dell'Indipendenza4, Rome 00185, Italy. Tel.: +39 0 6 4673 3665; fax: +39 0 6 233 232 419.
E-mail address: mventura@istat.it (M. Ventura).

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implies that relaxing IPR to a certain extent, i.e., allowing for imitation, can be beneficial.

In the literature related to the broad field of knowledge diffusion, the Lotka–Volterra system has been extensively used ([2,5,13,14,16,22], just to cite a few). However, all of these contributions assume a Lotka–Volterra type joint dynamics, but none of them derive it. Differently, our contribution aims at moving a first step to start filling this gap. In agreement with the aforementioned literature, we start out from the idea that imitation plays an important role in speeding up the rate of innovation diffusion and is an inverse measure of IPR protection; in other words, imitation can accidentally mitigate the innovation diffusion lag.[1] In the model presented in this paper, innovators and imitators are regarded as competing for the same asset and entry the market requires undergoing sunk costs. Expanding the methodology proposed by Dixit and Pindyck [9], we show that it is possible to derive the long run joint dynamics of imitators and innovators as a Lotka–Volterra system. To this extent, our theoretical contribution provides theoretical support to the evolutionary view of knowledge diffusion.

More precisely, we derive the joint dynamics of imitators and innovators under two scenarios obtained through an appropriate selection of the variation range of the parameters of the system. The two scenarios are consistent with prey–predator interactions, in which innovators are regarded as preys and imitators as predators, and competitive interactions, occurring when both species suffer from each other's existence.

Analytical results and numerical simulations show that among the three possible types of equilibria (extinction, one category and coexistence), the coexistence equilibrium—i.e., the equilibrium associated to the simultaneous existence of innovators and imitators in the long run—can be achieved under both scenarios and it is a stable configuration. From an economic point of view, the circumstances under which this result is achievable can be read in the sense that in order to coexist, the relationship between the two species must be thoroughly balanced. A certain amount of competition between the two sub-populations is desirable, but there must be a limit to the extent to which one population can hamper the others' activity. This result is in line with the above-cited literature claiming that stronger IPR protection is not always the best possible choice.

The article proceeds as follows. Section 2 presents the set up of the model. The derivation of innovators and imitators' activation rates follow in Section 3, and the solutions of the system is presented in Section 4. Section 5 offers an economic interpretation of the results of the previous Section. Finally, Section 6 concludes.

2. The set up of the model

Consider an industry composed of a given number of firms. Each firm is risk neutral, acts competitively and has rational expectations about the underlying stochastic process and the decision rules of other firms. Moreover, each firm has the capacity to produce the flow of one unit of output, which it can activate by incurring a sunk cost. There are no variable costs of production, and the elasticity of demand is large enough to ensure that each firm that has paid its sunk cost will want to produce at its capacity level. Uncertainty is firm specific or independent across firms, and the inverse demand function for each firm is as follows:

$$P_t = Y_t D(Q_t), \qquad t>0, \tag{1}$$

where P_t is the price faced by the firm at time t, Q_t is the current output flow at time t, and $D(Q_t)$ is a decreasing function, comprising the non-stochastic part of the inverse demand function. As each firm produces one unit of output, the current output flow equals the number of active firms, which we treat as a continuous variable, consistent with Dixit and Pindyck [9].[2] Y_t can be interpreted as an idiosyncratic demand shock reflecting changes in relative tastes for the firms' products, ultimately capturing a shift to profitability at time t. As in Dixit and Pindyck [9], these shocks can be the source of a competitive advantage that allows firms to enter the industry acting either as innovators or as imitators. By paying an entry cost R, any firm can get an initial draw Y_0 of its demand shock Y_t from a known distribution. Thereafter, $\{Y_t\}_{t>0}$ will follow a geometric Brownian motion process that is firm specific or independent across firms:

$$dY_t = \alpha Y_t dt + \sigma Y_t dz_t \qquad t>0, \tag{2}$$

where $\{z_t\}_{t>0}$ is a standard Brownian motion while $\alpha \in \mathbb{R}$ and $\sigma > 0$ represent the drift and the diffusion coefficients of the stochastic process $\{Y_t\}_{t>0}$, respectively. After the payment of the cost R, a firm observes the value Y_0. Each firm can start actual operation by paying a further sunk cost. Thus, some firms decide to invest in the development of new products and, hence, act as *innovators*, while other firms aim at reproducing the innovations performed by the innovators, being so *imitators*.

If Y_0 exceeds a critical threshold $Y^{(N)}$, a would-be innovator pays the investment cost I and becomes an active producer. Otherwise, it lets $\{Y_t\}_{t>0}$ evolve and activates if and when $Y^{(N)}$ is reached. Analogously, a would-be imitator pays a fixed investment cost K, with $K < I$, to enter the market and an appropriate share of the innovators' income if and when $\{Y_t\}_{t>0}$ randomly fluctuating exceeds a critical threshold $Y^{(M)}$. Otherwise, it keeps waiting and lets $\{Y_t\}_{t>0}$ evolve. Let us denote as N_t, M_t respectively, the number of innovators and imitators at time t that will reach the activation decision. We assume in our model that the activation thresholds $Y^{(N)}$ and $Y^{(M)}$ vary with the number of innovators and imitators that are currently active in the market; substantially, at time t, the activation thresholds are $Y^{(N)} = Y^{(N)}(N_t, M_t)$ and $Y^{(M)} = Y^{(M)}(N_t, M_t)$. We clarify the stylized points set out so far by means of a simple example.

Example 1. *R can be representative of a situation where a pharmaceutical company can develop a new drug by incurring the research cost. The would-be innovator patents the drug, but unless the profit estimate is sufficiently high, i.e., whenever it reaches a threshold, the firm will not incur the additional investment expenditure I that is necessary to begin production. Such a profit threshold is affected by the number of firms currently working on*

[1] Caballero and Jaffe [4] estimated that the median lag between a cited patent and the citing patent is 9–10 years.

[2] A formal rigorous treatment of the resulting continuum of random variables and their law of large numbers would be far too lengthy and out of the scope of this paper. For the basis of rigorous theory, we refer to Judd [12].