Technological Forecasting & Social Change 111 (2016) 22–30

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

Innovation, imitation and policy inaction

Roy Cerqueti [a,*], Anna Grazia Quaranta [b], Marco Ventura [c]

[a] Department of Economics and Law, University of Macerata, Italy
[b] Department of Mathematics, Alma Mater Studiorum, University of Bologna, Italy
[c] Econometric Studies and Economic Forecasting Division, ISTAT, Italian National Institute of Statistics, Rome, Italy

ARTICLE INFO

Article history:
Received 26 March 2015
Received in revised form 23 February 2016
Accepted 2 June 2016
Available online 16 June 2016

JEL classification:
O31
O34
C61
C63

Keywords:
Imitation
Innovation
Intellectual property
Inaction region
Optimization model
Numerical simulation

ABSTRACT

The paper deals with the controversial issue of intellectual property rights. We deal with an optimization problem to model the optimal government's behavior in presence of dynamic uncertainty and intervention costs. More specifically, we search for the optimal strategies to be implemented by a policy maker to optimally balance the number of innovators and imitators. The problem is first tackled from a purely theoretical perspective and then by implementing extensive numerical simulations on the basis of empirical data. By the theoretical perspective, we obtain a rigorous proof that optimal strategies depend on the initial value of the number of imitators and not on the initial ratio between innovators and imitators, whereas the simulations provide us with intuitive insights from an economic point of view, along with a validation of the theoretical results. The results support the evidence that governments choose the possible widest bandwidth and minimize the size of interventions so as to curb intervention costs.

1. Introduction

The role of governments in the process of technological development and diffusion is generally crucial but varies across countries and over time. When an economy is far from the technological frontier, it can grow quickly by imitating. Because the technology already exists, the flow of ideas is relatively non problematic and the major task is to manage the flow of resources. However, when a country is on the frontier, it can grow quickly only by innovating, which requires managing the flow of ideas and resources equally (Hikino and Amsden, 1994).

There can be also other reasons that lead governments to change their policies. Conventional wisdom holds that granting intellectual property rights (henceforth IPR) will stimulate the incentive for firms to devote resources to innovative activity and encourage the disclosure of inventions so that others can use and build upon research results, stimulating economic growth (Denicolò and Franzoni, 2003). Therefore, the existence of IPR is essentially regarded as a social need. Put another way, even when the social benefits of inventions exceed the costs, potential innovators without patent protection, and more in general IPR protection, may decide against innovating altogether.

Recently, this classical rational for the existence of IPR has been challenged. Many scholars argue that IPR protection is not essential to appropriately rewarding the innovators and/or that the damages it provokes to society exceeds the benefits (Pollock, 2007; Boldrin and Levine, 2002). As a consequence, one of the main issues that policy makers have to deal with is the extent of innovation protection they should provide.

The objection to strong IPR protection, or even to the existence of IPR, originates from the fact that all monopolies introduce a distortion, a deadweight in the economy. This deadweight shows up in different ways, in different forms and has been modeled in very different setups. Sohn (2008) compares the payoffs accruing from innovation versus imitation activities and shows that, although imitation weakens the incentive to innovate, it can benefit society on the whole by leading to a larger number of innovations. Fershtman and Markovich (2010) find that imitation may be beneficial when firms have different *R&D* abilities in that it may provide higher consumers' surplus and higher value for firms than a strong patent protection regime. Bessen and Maskin (2009) argue that, although imitation reduces the current profit of the firms who innovate, it raises the probability of further innovation and thereby improves the prospect that firms will make another profitable discovery later on. A very similar result is obtained by Belleflamme and Picard (2007), studying the dynamic effect of piracy. When innovation is sequential and complementary, standard reasoning about

* Corresponding author at: University of Macerata, Department of Economics and Law, Via Crescimbeni, 20, 62100 Macerata, Italy.

http://dx.doi.org/10.1016/j.techfore.2016.06.001
0040-1625/

patents and imitation is deceptive. Imitations becomes a spur to innovation while strong patents become an impediment.

It has been theoretically (Koléda, 2005; Furukawa, 2007) and empirically (Aghion et al., 2005) claimed that the rate of innovation is an inverse-U shaped function of imitation, which, in turn, is an inverse measure of IPR protection. The straightforward consequence of this finding is that relaxing IPR protection can be beneficial whenever its level is above the apex of the inverse-U function.

Summarizing the controversy, on the one hand, imitations (both legal and illegal) have a positive effect from the perspective of society, accidentally mitigating the damage introduced by monopolies and speeding up innovation diffusion. On the other hand, an excessively large number of infringements can kill innovation activity, thus damaging the production of knowledge. Moreover, the absence of innovation in turn can lead to the extinction of imitators, who are left with nothing to imitate. It follows that innovators and imitators must coexist. This endogenous relationship has been described in the literature through the well known Lotka-Volterra model, whose use in economics was first examined by Andersen (1994) and which has been applied with a specific focus on innovation in Bharagava (1989), Morris and Pratt (2003), Watanabe et al. (2003), Castiaux (2007), Lee et al. (2005), Kim et al. (2006), Michalakelis et al. (2012), Balaz and Williams (2012), Chang et al. (2014), Guidolin and Guseo (2015) to cite only a few. Recently, Cerqueti et al. (2015) have shown that assuming the Lotka-Volterra co-dynamics for innovators and imitators is consistent with economic theory. Surprisingly, despite the extensive use of this model, to the best of our knowledge, no efforts have been made to introduce the effects of public interventions. This paper aims at filling this gap and providing practitioners and academics with a modified random Lotka-Volterra scheme that complies with the above. The introduction of randomness captures the link between innovation dynamics and the uncertainty due to the $R\&D$ phase. This makes the model more complicated, but also much more realistic, hence leading to consistent formulations of prescriptions and forecasts.

Actually, the Lotka-Volterra (Lotka, 1956 and Volterra, 1926) setting has already been extended by mathematical biologists[1] in the context of impulse control problems (Liu and Rohlf, 1998; Liu et al., 2005, just to cite a few). By a purely mathematical point of view and in the context of impulse control, the optimal strategies found in these contributions do not contemplate the opportunity of endogenously identifying neither the size of interventions, nor the dates, which are indeed fixed. For instance, Zhang et al. (2003, 2005) introduce controls exogenously by introducing a constant amount of predators into the population at periodic intervals of given length. Baek (2008) deals with constant and proportional controls in a deterministic framework, to capture the presence of biological and chemical controls in the environmental setting. Akman et al. (2015) consider a stochastic model but provide a control of the prey-predator paths by applying a deterministic rule. Differently, we add to the literature by including the entity and the time of the intervention as control variables of the problem. In so doing, we include further reasonable sources of complexity in our setting. We point out that our model is tailored to account for industrial economic features, and control stems from a rational maximizing behavior, perfectly in accordance with economic theory. This is far from the general idea of the Lotka-Volterra systems, which usually deals with species evolutions and biological themes. More specifically, the paper deals with the trade-off between private and social interests generated by IPR protection and the problem of optimal government interventions. The paper assumes the perspective of a policy maker who wishes to optimize the relationship between innovations and imitations, given that the latter is an inverse measure of IPR protection. A unbalance between the two "populations" is costly to society: too many imitations are a drawback for the economy, while too little reduce the rate of innovation diffusion. As a consequence, the governments should intervene whenever the ratio between innovations and imitations (IPR protection) is not optimal (according to predefined criteria). This seemingly straightforward task is made difficult by the fact that innovation is a dynamic phenomenon evolving in an uncertain environment and optimization needs to be carried out continuously, and this of course has a cost. Hence, the governments must intertemporally balance the costs and benefits of intervening. Unfortunately, public interventions are costly and the cost is largely sunk. The most remarkable consequence is that there will be a non-intervention region, the so called "inaction region". Whenever the ratio lies in this region the governments finds it optimal not to intervene even though IPR protection in not at its maximizing value, and the two populations coexist (Stokey, 2009). Moreover, after an intervention is carried out and IPR optimally reset, uncertainty will make future dynamics of innovation and imitation unpredictable in the sense that it is not possible to know a priori whether the ratio will go up or down with respect to the optimal point chosen by the governments. This occurrence generates unpredictability in the next intervention, both in terms of timing and optimal value, which in turn will depend upon altered market situations.

The paper aims at modeling this complex problem by determining the optimal inaction region, which is defined in terms of an upper and a lower threshold of interventions and by return points. The latter are the points at which the ratio is set after the intervention, within the inaction region, while the former constitute the boundary of the inaction region itself. Given that resetting the value of the ratio from above or below entails different costs, it follows that the two thresholds are not necessarily symmetrical, but crucially depend on the cost of interventions. A relative increase in the number of innovators requires investing public resources to subsidize and foster $R\&D$, or to make the enforcement system more effective. In addition, fighting counterfeiting has a cost. This very complex reality is implemented in a model of dynamic uncertainty in which innovators and imitators interact and the governments wishes to maximize a public utility function, subject to intervention costs. In our model, the maximization model takes on the form of an optimal control problem in a stochastic setting.

The control problem is analyzed from two different perspectives. The first is purely theoretical and provides a rigorous description of the key elements of the problem, after which a formal solution of the model is provided. Two facts emerge from the theoretical study: i) the value function of the optimization problem can be regarded as the unique solution of the Hamilton-Jacobi-Bellman equation, ii) the optimal controls do not depend on the initial value of the ratio between innovators and imitators. Second, the problem is simulated and solved by implementing extensive numerical techniques on the basis of a consistent set of parameters. This allows us to obtain more intuitive insights from an economic point of view, along with a validation of the theoretical results. The interested reader can find a mixed theoretical simulation approach in control problems in He and Liu (2008), Castellano and Cerqueti (2012), Cerqueti (2012), Cerqueti and Quaranta (2012), Gollmann and Maurer (2014) and Cerqueti et al. (2016). The numerical optimization technique adopted is a Monte Carlo methodology with a grid search. For a proper description of the numerical procedures, refer to Rust (1996), He and Zhang (2013), Cai et al. (2015) and the monograph of Ensor and Glynn (1997). In particular, the numerical results show that the government optimal strategies consist in choosing the widest possible bandwidth and minimizing the size of interventions.

Given this premise, countries endowed with a more efficient enforcement system are expected to have a lower cost of interventions and, therefore, they are expected not to tolerate relatively low values of the ratio. This consideration may help in explaining different behaviors among apparently similar countries. For instance, the same laws on IPR apply in all EU countries, but actual interventions are quite different. Italy in particular is known for its high number of illegal imitations. To the best of our knowledge, this paper is the first one which deals with

[1] The extended Lotka-Volterra model is used to study how to control for pests using a mix of biological control, i.e. predators, and proportional control, i.e. chemical pesticides.