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# Intellectual Property Framework and Dynamics of Technology Change under Sequential Innovation

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Abstract

A large number of modern consumer focussed industries are characterised by fast paced technology driven innovations - smart phones and other computing devices, software, home audio and video technologies, automobiles, pharmaceuticals etc. being a few notable examples. Such industries are research driven and are characterised by their unique technological ecosystems. Competition within such industries is not limited to pricing and marketing strategies alone, but is driven by R&D as well, whereby new features, new variants and upgraded technology is constantly being introduced to attract customers (Frambach, 1993). Consequently, firms often tend to use the existing intellectual property (IP) framework within their industries as a standard tool against rivals – both for defensive and offensive purposes (Litchenber, 2002).

This paper focuses on industries engaged in "sequential innovations", where new innovations are possible by investing in R&D to improve existing stock of technology (Bessen, 2009), and examines using agent based models, the impact of alternative IP protection norms and regulations on – first, the evolutionary path of technology development and emerging market structure, and second, the dynamics of technology progress and the nature of competition in technology as a function of the IP protection framework.

We examine three alternative IP protection frameworks – Open Access (OA), Patent Licensing (PL) and Secrecy (S), and compare their impact on the dynamic evolution of both firm and industry level technology and competition using agent based simulations. Firms in the model invest in R&D in every period to improve the existing stock of technology, where the existing stock could be their own or a rival's past technology, and the IP regime determines the strategies available for exchange of technology stock between rival firms (for example, copying, licensing, reverse engineering etc.). Firms use a simple profit based reinforcement learning algorithm to choose the frequency with which they use the available strategies under each regime. How much they invest in improving the stock depends on past profitability, and the outcome of this investment is stochastic in nature. A parameter $\epsilon$ controls the stochastic nature of research outcome – with high values of $\epsilon$ making bigger jumps in technology more probable for a given level of investment. Budget conscious heterogeneous consumers in the simulations base their purchase decisions every period, on the level of technology in the product they currently use, levels of technology available in the new products and on price. Consumers invest in a new product, only if the available products represent a significant jump in technology compared to the existing product they are using. This is represented through a threshold parameter $\gamma$ - high value of which indicates that consumers are conservative in their purchases, and would require the new technology to be significantly better than their existing ones for them to consider making a purchase. Apart from $\gamma$ and $\epsilon$ we also test the effects of size of the market (number of consumers) and size of competition (number of firms) on the outcome of the model. The patent and secrecy regimes are characterized by a few additional parameters, such

as probability of successful infringement, royalty fee, penalty of unsuccessful infringement in case of PL and reverse engineering cost in case of S.

Results indicate that both $\gamma$ and $\epsilon$ affect the technology trajectory of the industry. Lower conservativeness in consumers results in higher levels of technology overall, across all IP frameworks. Moreover, lower conservativeness in consumers implies that the technology trajectory is a step function of time, where there are episodes of marginal incremental progress inter-spaced with rare large jumps in technology levels. In terms of market structure, increased conservativeness in consumers result in more egalitarian distribution of market shares, where no single firm is able to dominate the market, and even if one of them does dominate, is not able to maintain its dominance for too long a period. Hence, higher values of $\gamma$ result a in smoothening of the technology trajectory itself although at the cost of overall technology level achieved in the industry. Along with it, we see higher levels of competition and coexistence of rival firms in the market. As expected, increasing $\epsilon$ results in higher levels of technology overall, but contrary to expectation, increases the length of incremental progress episodes in the technology trajectory. In all cases, the presence of a single dominant firm slows down the overall pace of technology progress within an industry, coinciding with episodes of incremental improvement. However, the largest jumps in technology occur when one dominant firm is overtaken by a previously smaller player through introduction of a new technology which is adopted by a large number of consumers. A comparison of the regimes themselves showed that, in general, higher levels of technology are reached and higher levels of investment in R&D are carried out, when the industry is characterised by OA or PL, compared to S.

Additionally, the size of the market has a positive impact on the industry level investment in R&D and technology and the number of firms has a negative overall impact on both. Within the patent regime, weakening the enforcement structure (in terms of increased probability of firms being able to infringe a patent successfully), enhances technological progress and inter firm technology transfer. Within the secrecy regime, increasing reverse engineering costs result in decline in technology progress and R&D investments in the industry.