

Innovation, Imitation, and Market Structure

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Abstract

How do market structure and the characteristics of goods affect the incentives to create new goods (to innovate) and to copy them (to imitate). In this paper we consider an economy in which goods differ according to their production technology, which determines the market structure, and according to the fraction of R&D (think knowledge or information) that it takes to create them. After innovation takes place, imitation is possible but at some cost which reflects the nature of the good. We show in a dynamic general equilibrium model that the behavior of innovation and imitation are very different for different types of goods and technologies. This in turn has important implications for the protection of intellectual property. We describe the optimal protection of intellectual property for different product types in a calibrated version of this economy. Our results indicate that the optimal patent protection differs a lot for different types of goods and bears little resemblance to current U.S. policy.

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1 Introduction

In the main town square in Prague, Czech Republic, there is a remarkable astronomical clock that was built in the middle of the 15th century. According to tourist guides the town fathers were so pleased with the clock and so eager to prevent other cities from imitating it that they had the inventor killed after it was completed to protect their innovative investment. That is certainly one way to protect intellectual property rights. The world of designer clothing represents another extreme. Now, photographs of new designs at fashion shows are posted almost instantly on the Web and can be copied, produced abroad, and hit the market even before the originals do.¹ It is a world where very quick imitation is taken for granted and there is no protection for the intellectual property of the designers. Yet, the designers keep innovating.

These examples represent the extremes of attitudes and policies toward intellectual property protection and it is clear that such attitudes have varied over time and across industries. Charles Dickens, for example, was famously critical of the United States because his books were routinely pirated there with little or no compensation to him. At the time there were no international copyright laws. In recent years there has been a very strong movement to establish and enforce Universal Intellectual Property Protections as provided for under the World Trade Organization Agreement.² At the same time there has been a significant expansion in the domain of intellectual property protection through the extension of copyright protections (the "Sonny Bono Law"), the patenting of business software solutions (the Amazon "one click" patent), and the prosecution of Napster. There are some authors like Lawrence Lessig (2001) who has sought more balance between the rights of innovators and the rights of consumers,

¹"Before Models Can Turn Around, Knockoffs Fly," Eric Wilson, *The New York Times*, 9/4/07.

²See for example J.H. Reichman (1995). "Universal Minimum Standards of Intellectual Property Protection Under the TRIPS Provision of the WTO Agreement" *The International Lawyer*, Vol 29, #2, 1995.

and some like David Levine and Michele Boldrin (2005) who have argued that there is no justification for intellectual property protection.

The problem of intellectual property protection is complicated because policies to protect intellectual property must balance the incentives to innovate or the private economic gains from innovation, against the gains to society from imitation or entry and the resulting competition that allows more people to consume the good in question. We want new goods to be created but we also want them to be consumed by many. There is a lot of inherent appeal to the basic idea that intellectual property protection preserves the incentives of innovators to create new goods. Granting monopoly power for some period of time to the creators of new goods allows them to profit from their creativity and hard work and thus stimulates innovation. The only problem with this basic idea is that it is contravened by a lot of evidence - not just anecdotal evidence like the fashion industry example but many empirical studies that have looked in considerable detail at the role that patents play in protecting innovations.

In this paper we analyze formally the role of intellectual property protection in an explicit model of innovation and imitation. This is a model where there is, in principle, an explicit role for government protection of the intellectual property of innovators. We use this model to study the relationship between the technological structure of the industry and the evolution of prices and competition. We also consider how the optimal design of intellectual property protection varies with the nature of technology. Before describing the model we first review the empirical evidence.

2 The Evidence

There have been many studies that have examined the role of intellectual property protection, particularly in the form of patents, on the innovative efforts of firms and their ability to capture the returns from innovation. The results have been

surprisingly consistent over time and across studies. Although patent protection has strengthened and broadened over time and patent rates and infringement suits have increased, the evidence suggests that patent protection does not stimulate the innovative efforts of firms and is not important for protecting the returns to innovation except perhaps in the pharmaceutical industry.

Edwin Mansfield (1986) surveyed senior R&D executives in a random sample of 100 firms in 12 industries. His research was designed to determine the effect of the patent system on the rate of innovation. He found that, with the exception of the pharmaceutical and chemical industries, the patent system was of very little importance to the innovation process.

Levin, Klevorick, Nelson, and Winter (1987) surveyed 650 senior R&D managers in more than 100 manufacturing industries in 1983. Their results suggested that patents were among the least effective means of appropriating gains from both product innovations and process innovations. With the exception of the pharmaceutical industry, firms did not report patents as an important tool for profiting from innovations.

A subsequent study by Cohen, Nelson and Walsh (2000) surveyed a population similar to that of Levin et. al. and asked broadly similar questions of a group of R&D managers in 1994, a decade later. Importantly, this was a decade in which the scope and scale of patent protection in the U.S. increased dramatically. Nevertheless, their results continued to show that patents were relatively unimportant for protecting the gains from innovation even though they are widely used.

Most valuable for our goal in this paper is an empirical study by Mansfield, Schwartz and Wagner (1981). They focused on a sample of very specific innovations in several industries rather than a survey of R&D managers. They reported some surprising findings about the relationship between innovation and imitation and the role of patent protection. They found that, even with patent protection, imitation occurs quite frequently and relatively quickly after innovation. Mansfield et. al.

(1981) studied 48 important innovations in four sectors. They found that 70% of innovations were patented and 71% were imitated. They also found that imitation is faster and less costly than innovation and that the R&D intensive goods were less costly to imitate. These findings inform the structure of the model economy we describe in the next section. The relationship between the incentives to imitate and the incentives to innovate are crucial for understanding the issue at hand. Mansfield's detailed findings helped us structure how we think about the problem.

3 The Model

Consider an infinite-horizon continuous time economy. The economy consists of identical households who have taste for variety. A household's contemporaneous utility is

$$u(\mathbf{c}, l) = \phi \log \mathbf{c} + (1 - \phi) \log l, \quad 0 < \phi < 1,$$

with $\mathbf{c} = \left[\int_0^N c_i^\theta di \right]^{\frac{1}{\theta}}$, $0 < \theta < 1$, where c_i denotes the consumption of good i , N is the number of goods that the household consumes, and l is leisure time. Households seek to maximize lifetime utility by picking consumption and leisure. At time zero the households problem is

$$\max_{\{c_{it}\}_{i=0}^{N_t}, l_t} \int_0^\infty u(\mathbf{c}_t, l_t) e^{-\delta t} dt, \quad \delta > 0.$$

s.t.

$$\int_0^{N_t} p_{it} c_{it} di + \frac{da_t}{dt} + \tau = w_t(1 - l_t) + r a_t$$

where p_{it} is the price of the i th good, a_t is the households' assets, N_t is the number of different goods consumed, w_t is the wage rate at time t and τ is the lump-sum government tax.³

³Using the first order condition with respect to consumption of two different varieties i and j yields

$$\frac{c_i}{c_j} = \left(\frac{p_j}{p_i} \right)^{\frac{1}{1-\theta}}.$$

The production technology exhibits decreasing returns to scale,

$$f_t(n) = An^\alpha e^{\gamma t}, \quad A > 0, \quad 0 < \alpha < 1, \quad \gamma > 1,$$

where n is the amount of labor used, A is a time independent productivity parameter, and α is the employment elasticity of output which will determine the returns to scale. This production technology is common to all producers. Productivity increases exogenously at rate γ .

We know that with fixed costs of entry and constant returns to scale, industries will have only one producer. That case is uninteresting in this context so we consider decreasing returns. Clearly, the outcomes we are studying are going to depend heavily on how close an industry is to constant returns. We address these issues further in the next sections.

3.1 Innovation and Imitation

New goods can be innovated by incurring a one time fixed cost, $\kappa > 0$. This fixed cost includes the cost of product specification, pilot plant and prototype, plant and equipment, and manufacturing and marketing startup as well as the innovation cost that goes for direct research and development. We think of the latter as representing the knowledge or information content of a good and this is going to be an important dimension along which goods differ. A software program, for example, is going to have a much higher fraction of R&D than say a consumer durable.

Let optimal total expenditure level at time t be E_t . Then optimal consumption of each variety will be

$$c_i = \frac{E_t p_i^{-\frac{1}{1-\theta}}}{\int_0^{N_t} p_{it}^{-\frac{\theta}{1-\theta}} di}$$

Total expenditure through time will evolve according to

$$E_{t+1} = E_t \beta (1 + r_t).$$

Imitation of an existing product is also possible, but only with a lag⁴ and only if a fixed cost is paid. The fixed cost of imitating a product at age s ⁵ is

$$C(s) = \kappa [\lambda e^{-\rho s} + (1 - \lambda)], \quad s \geq 0, \quad \rho > 0,$$

where s is the time after innovation of the product. The imitation cost has two components. An imitator usually spends much less time and money on research than the innovator because the product's existence and characteristics provide an imitator with a great deal of information that the innovator had to obtain through his own costly research. Let's assume that a fraction λ of the innovation cost is research that the imitator can benefit from. The time it takes to imitate a new product can generally be reduced by spending more money. Each product's imitator is confronted by a time-cost trade-off function, which is the relationship between the amount spent by the imitator and the length of time it would take to imitate this new product. Therefore, the cost of imitation decays exponentially at rate ρ after innovation, i.e. imitating a product becomes easier as the product gets older.⁶ On the other hand, an imitator often has to go through the same steps as the innovator with respect to pilot plant or prototype construction, investment in plant and equipment, training the employees, and manufacturing and marketing start-up. A fraction $(1 - \lambda)$ of innovation cost represents the sorts of costs that do not decay with time. In our taxonomy, high λ goods tend to be knowledge or information goods.⁷

3.2 Intellectual Property Protection

We assume there is a government that can provide protection for the innovators against imitation. Let a denote government expenditure on protection of intellectual

⁴This lag is only to insure that an innovator is always ahead of his imitators in terms of product introduction date. We do not parameterize this lag and take it as a non-binding small interval.

⁵The time subscripts will be omitted in expressions where its omission is not likely to create a confusion to keep expressions simple.

⁶Even reverse engineering takes time and spreading that over time is less costly.

⁷The structure of imitation and innovation considered here follows Mansfield et. al (1981) findings

property rights per product right protected, and suppose the cost of imitation depends on a . Specifically, for each unit of output flow an imitator produces, he incurs a (flow) cost $\Lambda(a)$ in addition to the cost of production. Assume that $\Lambda(0) = 0$, $\Lambda'(a) > 0$, $\Lambda''(a) < 0$. Here a can be interpreted as the scope of protection. Clearly, increasing the scope of protection deters imitation but it also increases the cost of administering such a patent. The assumptions on Λ ensure that the cost of administering the protection for a marginal increase in the scope increases more rapidly than the benefit of the increased protection. Thus, in brief, the government can increase the cost of imitation by spending more on the protection of intellectual property rights, but there are decreasing returns to doing so. The government finances this patent protection activity by levying a lump-sum tax τ on the agents. There is a second dimension to patent protection which is the duration of the protection offered. We denote the duration by T in our model. Clearly, increasing both the scope and the duration provides better protection for innovators but depending on the features of the product the innovators may prefer increasing one dimension at the cost of decreasing the other.⁸ For the government the benefit from better protection is clear; it encourages innovation. The cost of better protection is twofold; the increased cost of protection and decreased competition in the product market which results in higher prices for the consumers.

Households receive income from labor and from their ownership of the firms. All firms and assets are owned by households and profits generated by innovators and imitators go to them. All agents have access to a credit market where they can borrow and lend at a rate r .

The government seeks to maximize households' life-time utility by picking an optimal patent protection policy. This involves picking a scope of protection a , and the duration of protection T . For simplicity we will assume that the scope of protec-

⁸In this setup these features will be how costly imitation will be compared to innovation (λ), and the returns to scale in production technology, (α).

tion has to be constant throughout the life of protection.⁹ Let a_s denote protection expenditures for a product of age s , then

$$a_s = \begin{cases} a, & \text{for } 0 \leq s \leq T \\ 0, & \text{for } s > T \end{cases}$$

The government commits to its patent protection program. The government finances the cost of protection by a lump-sum tax on households, and it balances its budget at every date.

After paying the fixed innovation cost κ , at each point in time, an innovating firm picks the optimal price for its product. Let's consider the problem of an innovator of a product of age s . There may be many imitators coexisting with the innovator in the industry. Let m_s ¹⁰ be the number of producers of the innovators's product including the innovator himself (number of imitators plus one). Then the problem of an innovator firm with product at age s at time zero will read

$$V^o(s) = \max_{\{p_{s+t}^o\}_{t=0}^{\infty}} \int_0^{\infty} \underbrace{\left[p_{s+t}^o D(\mathbf{p}_{s+t}) - w \left[\frac{D(\mathbf{p}_{s+t})}{Ae^{\gamma t}} \right]^{\frac{1}{\alpha}} \right]}_{\text{profit of the innovator}} e^{-\delta t} dt,$$

where $\mathbf{p}_{s+t} = [p_{s+t}^o, p_{s+t}^1, p_{s+t}^2, \dots, p_{s+t}^{m_{s+t}}]$ and $D(\mathbf{p}_{s+t})$ is the demand for the product of the firm given the prices charged; p_{s+t}^o is the price that the innovator charges, and p_{s+t}^i is the price that the i th imitator charges¹¹. Also $V^o(s)$ gives the value of this innovator firm. It is easy to show that the amount of labor used by the innovator firm is $\left[\frac{D(\mathbf{p}_{s+t})}{Ae^{\gamma t}} \right]^{\frac{1}{\alpha}}$.

⁹This assumption is quite realistic too. In practice, it is hard to come up with cases where the scope of patent protection changes with the age of the product.

¹⁰From here on, we omit the time subscript for simplicity of notation. Also, in some places current time is taken as time 0 for convenience of notation.

¹¹Similarly the problem of an i th imitating firm of a product at age s at time zero is given by

$$V^i(s) = \max_{\{p_{s+t}^i\}_{t=0}^{\infty}} \int_0^{\infty} \left(p_{s+t}^i D(\mathbf{p}_{s+t}) - w \left[\frac{D(\mathbf{p}_{s+t})}{Ae^{\gamma t}} \right]^{\frac{1}{\alpha}} \right) e^{-\delta t} dt$$

3.3 Equilibrium

In the absence of patent protection, there is symmetry across producers (both the innovator and the imitators). Let t_i denote the time difference between dates at which the innovator and the i th imitator start producing. In equilibrium, due to free entry no innovator and imitator should make any profits. Consider the value of an innovating firm at the date of innovation, $V_t^o(0)$. Since the first imitator imitates t_1 units of time after innovation date, the innovator produces the product alone as a monopolist between time t and $t+t_1$. Let Π_{t+j}^o , $0 \leq j \leq t_1$ denote the profit stream of the innovator between time t and $t+t_1$. Since there won't be any difference between the innovating firm and any imitator, the value of the imitating firm when the first imitator imitates should be equal to the value of the first imitating firm at that date. Therefore,

$$V_t^o(0) = \int_0^{t_1} \Pi_t^o e^{-\delta t} dt + e^{-\delta t_1} V_{t+t_1}^1(t_1).$$

Similarly, between time $t+t_1$ and $t+t_2$ the innovating firm and the first imitator produce in the market together. Let Π_{t+j}^1 , $t_1 \leq j \leq t_2$ denote the profit stream of these firms during that time. Hence,

$$V_{t+t_1}^1(t_1) = \int_{t_1}^{t_2} \Pi_{t+y}^1 e^{-\delta(y-t_1)} dy + e^{-\delta(t_2-t_1)} V_{t+t_2}^2(t_2).$$

In general, the value of the i th imitator will be given by

$$V_{t+t_i}^i(t_i) = \int_{t_i}^{t_{i+1}} \Pi_{t+y}^i e^{-\delta(y-t_i)} dy + e^{-\delta(t_{i+1}-t_i)} V_{t+t_{i+1}}^{i+1}(t_{i+1}).$$

In equilibrium, if there is product innovation, the cost of innovation has to be equal to the value of an innovating firm, i.e.,

$$\kappa = V_t^o(0).$$

Also, in equilibrium, if the i th imitator of a product imitates at product age s then the cost of imitation has to be equal to the value of imitation, i.e.,

$$C(s) = \kappa [\lambda e^{-\rho s} + (1 - \lambda)] = V^i(s),$$

Using these equilibrium conditions, it follows that, in equilibrium,

$$\begin{aligned}
\int_0^{t_1} \Pi_t^o e^{-\delta t} dt &= \kappa - e^{-\delta t_1} C(t_1), \\
&= \kappa - e^{-\delta t_1} [\lambda \kappa e^{-\rho t_1} + (1 - \lambda) \kappa], \\
&= \kappa (1 - \lambda e^{-(\rho + \delta) t_1} - (1 - \lambda) e^{-\delta t_1}),
\end{aligned}$$

and

$$\begin{aligned}
\int_{t_1}^{t_2} \Pi_{t+y}^1 e^{-\delta(y-t_1)} dy &= C(t_1) - e^{-\delta(t_2-t_1)} C(t_2), \\
&= [\lambda \kappa e^{-\rho t_1} + (1 - \lambda) \kappa] - e^{-\delta(t_2-t_1)} [\lambda \kappa e^{-\rho t_2} + (1 - \lambda) \kappa], \\
&= \kappa (\lambda e^{-\rho t_1} + (1 - \lambda) - \lambda e^{-(\rho + \delta) t_2 + \delta t_1} - (1 - \lambda) e^{-\delta(t_2-t_1)}),
\end{aligned}$$

which can be carried on recursively¹². Let m^o denote the eventual number of imitators for a product. The m^o th imitator should also be making zero profits in equilibrium. Therefore,

$$\int_{t_{m^o}}^{\infty} \Pi_{t+y}^{m^o} e^{-\delta(y-t_{m^o})} dy = \frac{1}{\delta} \Pi^{m^o} = C(t_{m^o}).$$

where Π^{m^o} denote the profit stream of each firm when m^o firms produce together. Notice that if there is no more imitation after the m^o th imitator, from time t_{m^o} on, the benefit of imitation should be less than the cost,

$$\int_{t_{m^o}}^{\infty} \Pi_{t+y}^{m^o+1} e^{-\delta(y-t_{m^o})} dy = \frac{1}{\delta} \Pi^{m^o+1} < C(x) \text{ for all } x \geq t_{m^o}.$$

The condition for optimal imitation date is as follows¹³. Consider the imitation time decision of the i th imitator. Assuming that the number of imitators in the

¹²In general for the i th imitator, the condition reads

$$\begin{aligned}
\int_{t_i}^{t_{i+1}} \Pi_{t+y}^i e^{-\delta(y-t_i)} dy &= C(t_i) - e^{-\delta(t_{i+1}-t_i)} C(t_{i+1}), \\
&= [\lambda \kappa e^{-\rho t_i} + (1 - \lambda) \kappa] - e^{-\delta(t_{i+1}-t_i)} [\lambda \kappa e^{-\rho t_{i+1}} + (1 - \lambda) \kappa].
\end{aligned}$$

¹³Notice that there are m^o unknown imitation dates and $m^o + 1$ equilibrium no-profit conditions for imitation. However these $m^o + 1$ conditions together give the no-profit condition for the innovator. To see that add the left and right hand sides of these conditions to get $V_t^o(0) = \kappa$.

lifetime of the product is more than i , the i th imitator should be indifferent about postponing its date of imitation by a small period of time. So,

$$\frac{d(V_{t+t_i}^i(t_i))}{dt_i} - \frac{dC(t_i)}{dt_i} = \Pi_{t+t_i}^i - \rho\lambda\kappa e^{-\rho t_i} = 0.$$

Here the opportunity cost of delaying imitation by a small time period is profit flow during that time $\frac{d(V_{t+t_i}^i(t_i))}{dt_i} = \Pi_{t+t_i}^i(t_i)$ and the benefit from the delay is the reduction in the cost of imitation, $\frac{dC(t_i)}{dt_i}$. If the imitation date is optimal the cost should be equal to the benefit. Integrating this condition between t_i and t_{i+1} yields the no-profit condition. Therefore once the no-profit conditions hold, the optimality conditions for the imitation time decisions for the imitators will also hold. Using these conditions the equilibrium pattern of imitations can be computed.

Until the first imitator starts to produce the innovator enjoys pure monopoly. So he picks its price with a markup equal to $\frac{1}{\theta}$ as a monopolist would do. Let's consider what would happen when the first imitator also starts to produce. Two producers, the innovator and the imitator, will be playing the Bertrand Game. Since the production function exhibits decreasing returns to scale one may think that the equilibrium will be one with marginal cost pricing where both firms charge $p^* = \frac{w}{f'(n)}$. However that won't be a Nash equilibrium. It is easy to show that there are prices $p > p^*$ that yield a higher profit for one firm given that the other firms charge p^* . This problem can be handled by assuming that firms have to satisfy all the demand at the price that they pick. In that case, a firm will not gain from charging a price higher than p^* , in fact it will lose all of its potential customers. In general, then, with this assumption, if there are $m > 1$ producers, their charging $p^* = \frac{w}{f'(n)}$ will be a Nash Equilibrium.

It is easy to show that the employment in this economy is constant at $n = \phi$. So total output at time t will be $y_t = \gamma^t A \phi^\alpha$. In equilibrium, all products of the same age will have the same price.

3.4 Balanced Growth

Productivity is increasing exogenously at the fixed rate γ . Since innovation and imitation costs are constant it can be shown that growth in this economy will be through the introduction of new goods not through increasing consumption of each good. Along a balanced growth path the consumption of each good of a specific age will be constant. Leisure and work effort are constant as well. The number of goods N and the number of innovations at a point in time n grow at rate γ . Total consumption $\int_0^N p_i c_i di$ grows at rate γ as well. The number of imitators of a product at age s , m_s will be constant through time. Resources spent on innovation and imitation will also grow at rate γ .

We can consider the efficiency properties of this economy by starting with the simple case where there is no imitation in equilibrium ($\lambda = 0$). In this case the innovators are able to charge monopoly prices for their products forever. The potential static inefficiency due to monopoly pricing will not actually appear since products are totally symmetric and, with log utility, wealth and substitution effects created by higher prices exactly cancel out and the labor supply decision is not distorted. When we consider the equilibrium incentives for innovation, the fact that innovators do not capture all of the social surplus from their innovation is offset by the extra profit incentives present for the innovators. So the lack of private incentives from the first is totally compensated by the extra profit incentive and it turns out that private innovators have just the socially optimal incentive to innovate. Hence there is no dynamic inefficiency. Thus, in the absence of imitation, equilibrium R&D activity and the amount of innovation is Pareto efficient.

Now consider the case where there is imitation in equilibrium ($\lambda > 0$). Clearly, when a product is imitated, the innovators will not have the socially efficient incentives to innovate. Thus, with imitation there will be underinnovation. More interesting is that, in equilibrium with $\lambda > 0$, there will also not be enough imitation. Since the production technology exhibits decreasing returns to scale (and $\lambda > 0$), due to

productive efficiency imitation is socially desirable. Consider the efficiency condition for the optimal timing of innovation for a potential innovator. If the imitator postpones the date of imitation his benefit is the decline in the imitation cost, i.e. $\frac{dC(t_i)}{dt_i} = \rho\lambda\kappa e^{-\rho t_i}$, whereas his loss is the profit that he could make during that short instance if he had imitated. Let's assume that including this imitator there would be i producers. His loss then will be $\Pi_{t+t_i}^i$. The social benefit from waiting to innovate is the same as the private benefits, i.e. $\rho\lambda\kappa e^{-\rho t_i}$. The social loss due to waiting is the amount of extra output net of the labor cost that would be produced during this time multiplied by the marginal utility of consumption.

The share of R&D costs in the total product development cost λ is a critical variable for innovation and imitation. It is easy to show that the smaller this share is the more attractive it will be to innovate rather than imitate in a partial equilibrium sense —of course in equilibrium both innovators and imitators will make zero *ex-ante* profits. In the extreme, if λ is zero all of the investment activity will be directed at product innovation rather than imitation. In this case imitation will be as costly as innovation but the present value of profit from innovation will always be higher. Hence, nobody imitates in equilibrium. This is summarized by the following

Proposition 1 *If $\lambda = 0$, then there is no imitation in equilibrium. Patent protection is unnecessary.*

The other critical variable for innovation and imitation is the extent of decreasing returns, α . As α gets larger, the cost advantage of a potential imitator diminishes. At the extreme if there is constant returns to scale, i.e. $\alpha = 1$, an imitator will not have a cost advantage and, in equilibrium, it will not be able to make profits to cover the imitation costs. Therefore it is clear that there will be no imitation in equilibrium unless there are decreasing returns to scale. Thus

Proposition 2 *If $\alpha \geq 1$, then there is no imitation in equilibrium. Patent protection is unnecessary.*

Let p_s , m_s , y_s denote the price, the number of producers and the total output of an age- s product in equilibrium. The following proposition states that for $0 < \lambda < 1$ and $\rho > 0$, the number of producers, total output will be increasing whereas the price of the product will be decreasing through time. After some time though there will be no more entry and the price and output from then on will be constant. If, on the other hand, $\lambda = 1$, i.e., all of the entry cost is R&D cost, assuming that $0 < \alpha < 1$, entry will not ever stop and price and output will always be increasing. The intuition is simple. As long as $\lambda > 0$, the entry cost will converge to $(1 - \lambda)\kappa > 0$, as the product ages, but the benefit from entry is always strictly decreasing in the number of producers. Accordingly, there will always be a finite number of entrants:

Proposition 3 *Assume that $0 < \lambda < 1$ and $\rho > 0$. In equilibrium, $p_s \leq p_{s-1}$, $m_s \geq m_{s-1}$, and $y_s \geq y_{s-1}$. There exists an age s^o after which price, number of producers and total output of a product is constant, i.e., $p_j = p^o$, $m_j = m^o$, and $y_j = y^o$ for $j \geq s^o$.*

The fraction of innovation cost that actually goes to R&D, λ , affects the equilibrium innovation and imitation decisions in important ways. The following proposition compares the equilibrium in two economies with different R&D shares in the innovation cost. Consider these two economies with the same number of products. It can be shown that the present value of all future profits from innovating one more product is higher in the low λ economy. This means that, in equilibrium, the number of products in the low λ economy will be higher. In both economies imitation cost will erode through time after innovation and will converge to $(1 - \lambda)\kappa$. As the imitation cost converges down to $(1 - \lambda)\kappa$, the number of imitators also converges to a fixed number, m^o . Since the eventual cost of entry is lower in the high λ economy, m^o should be higher. Therefore it can be shown that the eventual number of producers, and eventual total output will be higher, whereas, the eventual price will be lower in the high λ economy. Naturally, then, concentration given as the share of the some

fixed number of the largest producers in the total industry output will be lower in the high λ economy. Interestingly, although the final number of imitators, and output is high, and final price is low in the high λ economy, there is no monotonicity in this relationship. It can be shown that, up to some time after innovation, number of imitators is actually lower in the high λ economy. This is because a higher λ gives more incentives to postpone the imitation dates initially. We illustrate this numerically in the next section but it is summarized on the following:

Proposition 4 *Consider two economies identical except for λ . Let the fraction of innovation cost that goes to research, λ , be higher in the second economy, $\lambda_1 < \lambda_2$. Then, in equilibrium; a) number of goods is higher in the low λ economy, b) the concentration after the industry matures is lower in the high λ economy, c) $m_1^o \leq m_2^o$, $p_1^o \geq p_2^o$, and $y_1^o \leq y_2^o$, d) there exists a time x after innovation such that $m_1^t \geq m_2^t$, $y_1^t \geq y_2^t$, and $p_1^t \leq p_2^t$ for $0 \leq t < x$, whereas, $m_1^t \leq m_2^t$, $y_1^t \leq y_2^t$, and $p_1^t \geq p_2^t$ for $t > x$.*

A change in λ affects the efficiency condition for the optimal timing of imitation, $\Pi_{t+t_i}^i - \rho\lambda\kappa e^{-\rho t_i} = 0$, through two channels. Consider an increase in λ . First an increase in λ increases the incentive to wait. The additional incentive to wait, $\rho\kappa e^{-\rho t_i}$ is decreasing in the time of imitation. The second channel is through the change in profits. An increase in λ decreases the number of goods, and increases the profits at all levels. Here three cases are possible. First, the first effect dominates at all imitation dates so the extra incentive for waiting from an increase in λ outweighs the profit effect at all imitation dates. Therefore all imitation dates are postponed. But this clearly contradicts the profit effect making the value of innovation smaller. The second alternative is that the profit effect dominates at all imitation dates and imitation occurs sooner at all levels. The third alternative is that the extra waiting incentive dominates up to some date after which the profit effect takes over. Whether

the second or the third case is the outcome depends on whether

$$\frac{\partial [\Pi_{t+t_1}^1 - \rho\lambda\kappa e^{-\rho t_1}]}{\partial \lambda}$$

is positive or not. If it is positive an increase in λ will make all the imitation dates sooner. Otherwise, there exists some imitation number up to which imitation is postponed and after which imitations happens sooner.

Another important factor that shapes the innovation and imitation decisions is the extent of decreasing returns in the production function. Without enough decreasing returns, imitating an existing product will not be profitable. As long as $\lambda < 1$, or, ρ is finite, the innovating firm has the upper hand in this setup and absence of decreasing returns deters all future imitation. Strong decreasing returns on the other hand invites imitation because of the high prices creating room for enough profits. The following proposition compares two economies identical except the extent of returns to scale. Since lack of decreasing returns deters imitation, it allows the innovator to appropriate the innovation cost more easily. Thus, in an economy where the production technology exhibits less decreasing returns, innovation will be more attractive. In equilibrium, there will be more innovation and products in an such an economy. These are summarized in the following:

Proposition 5 *Consider two economies without government protection identical except for α . Let the extent of decreasing returns be higher in the second economy, i.e., $\alpha_1 > \alpha_2$. Then, in equilibrium; a) the number of goods is higher in the high α economy, b) $t_i^2 < t_i^1$, imitation is earlier in the low α economy; c) concentration is lower in the high α economy.*

In the following section we parameterize the model economy and solve it as a numerical example.

4 A Numerical Example

We use the following parameterization as the benchmark.

Technology parameters	$A = 1, \gamma = .02, \alpha = 0.5$
Preference parameters	$\delta = 0.04, \phi = 0.3, \theta = 0.2$
Innovation and imitation	$\kappa = 10, \lambda = 0.5, \rho = .2$

First we study the effects of λ on equilibrium innovation and imitation. We solve the benchmark economy and a second economy which is identical to the benchmark one except a larger fraction of innovation cost is R&D cost. Let $\lambda = 0.75$ for the second economy. Figure 1 plots the imitation profiles for these economies. Imitation continues for a longer period of time in the high λ economy. It takes around 8 units of time in the low λ economy before a new product matures, (imitation stops) whereas, it takes 13 units of time in the high λ economy. The final number of imitators and producers is 20 for the economy with $\lambda = 0.5$, whereas, it is 55 for the economy with $\lambda = 0.75$. So eventually the concentration of the industry is lower for the high λ economy. But, the evolution of the industry is such that it is a lot more concentrated early on —proposition 1, part d. For high λ , there is more incentive for an imitator to wait initially because for each unit of time he waits his cost of entry goes down by $\rho\lambda\kappa e^{-\rho}$ amount which is increasing in λ . Therefore higher λ provides more incentives for a potential imitator to postpone the date of imitation. But eventually number of imitators becomes higher. Figure 2 plots total amount of output of a product during its life cycle in these two economies. Again eventual output is higher in the high λ economy but during transition to maturity less output is supplied to the market for a while.

Figure 3 gives the price of a product during its life cycle in the high and low λ economies. The initial prices are the same in both economies when only the innovating firm is producing. The price charged after imitation stops is lower for the

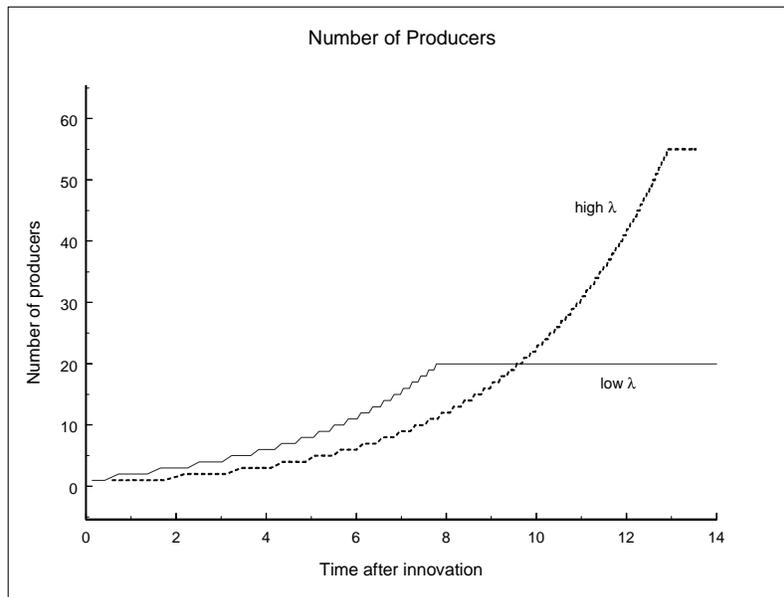


Figure 1: Number of producers along the life cycle of a new product.

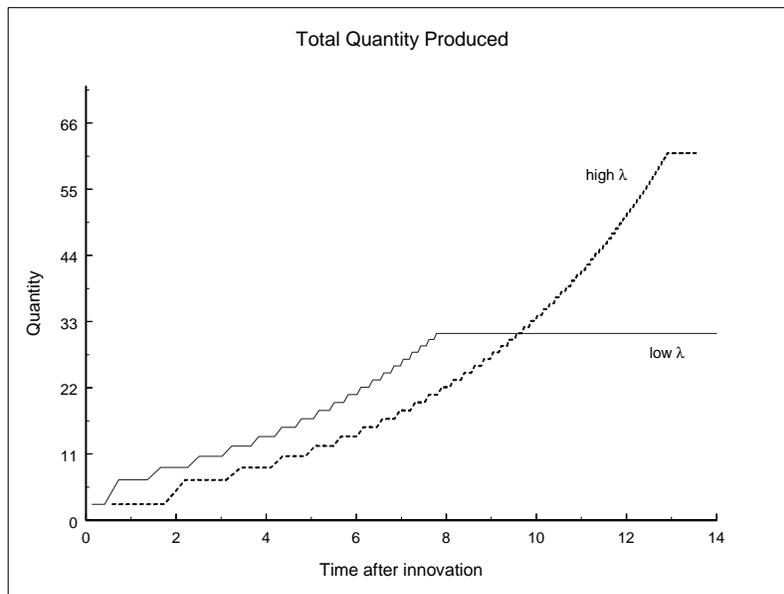


Figure 2: Total output supplied along the life cycle of a product.

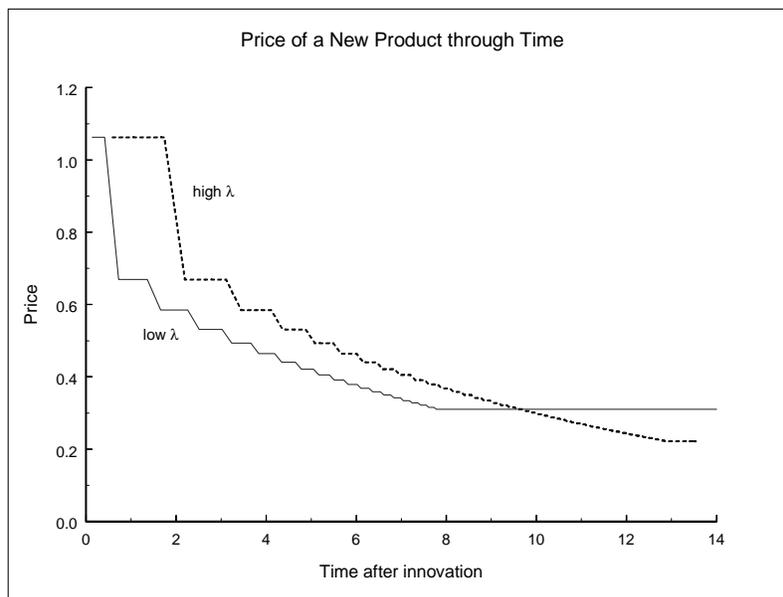


Figure 3: Price of a new product through time.

high λ economy. Since total output supplied to the market is initially low in the high λ economy, the equilibrium price is higher for a while compared to the low λ economy. So, newer goods are more expensive initially, when they are new, whereas, cheaper eventually when they are old in the high λ economy compared to the low λ economy. Figure 4 shows the profits per producer. Final profits after the product matures is lower in the high λ economy because of the higher number of producers. However, initially, when the product is new it brings more profits to the producers in the high λ economy. The second important factor that shapes the equilibrium innovation and imitation is the extent of decreasing returns. We solve the model economy for $\alpha = 0.5$ (the benchmark case) and $\alpha = 0.3$. Figure 5 plots the evolution of the number of imitators for a new product. The total number of producers is monotonically higher—therefore concentration is lower—in the low α (stronger decreasing returns) economy. Figure 6 shows total output produced during the life

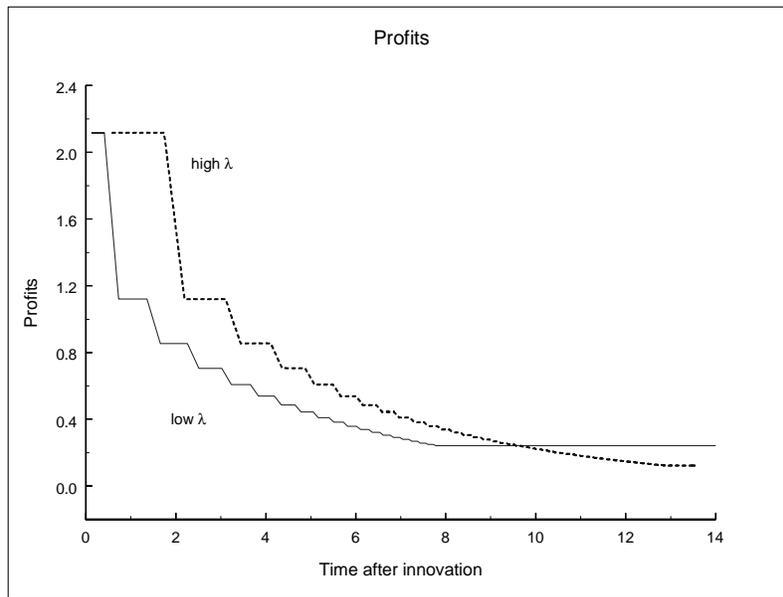


Figure 4: Profits per firm along the life cycle of a product.

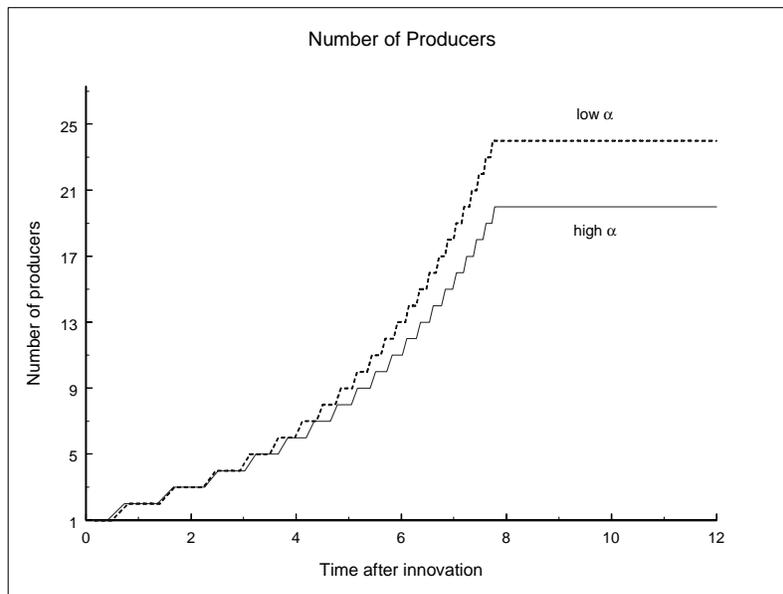


Figure 5: Number of producers along the life cycle of a new good.

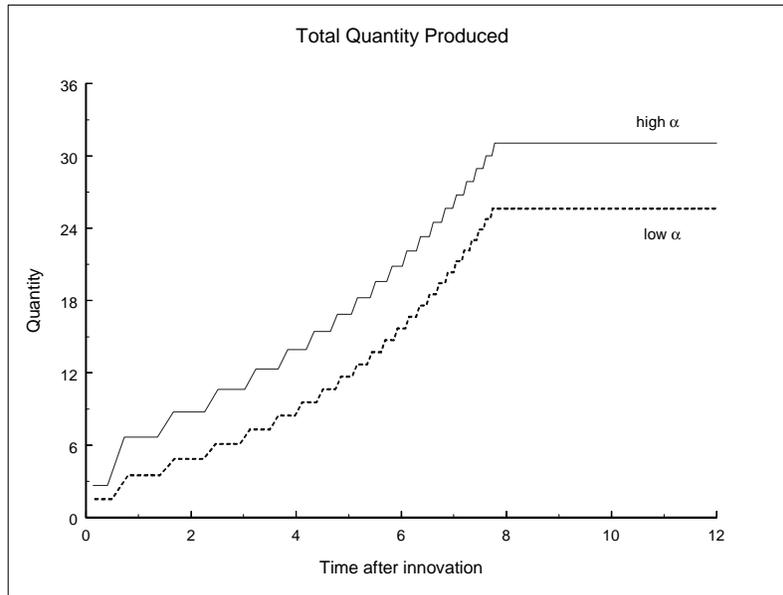


Figure 6: Total quantity of output supplied to the market.

cycle of a new good. Although number of producers is higher in the low α economy total output supplied is monotonically higher in the high α economy. Although these two margins of production (number of firms vs. amount each firm produces) work in opposite directions, since entry is costly, total output supplied in the high α economy is always higher. Figure 7-8 give the price of a new product and profits per firm during the life cycle of a new good. Prices are cheaper in the economy with weaker decreasing returns whereas profits are higher.

5 Innovation with Government Protection

Assume now that there is a government that can provide protection for the innovators against imitation. Let a denote government expenditure on protection of intellectual property rights per product, and suppose the cost of imitation depends on a . Specifically, for each unit of output flow an imitator produces he incurs a (flow) cost $\Lambda(a)$

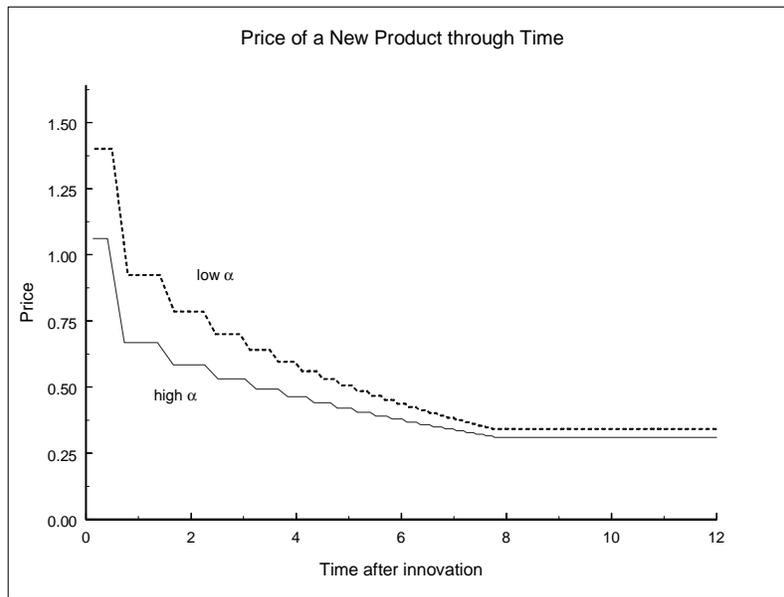


Figure 7: Price of a new good along its life cycle.

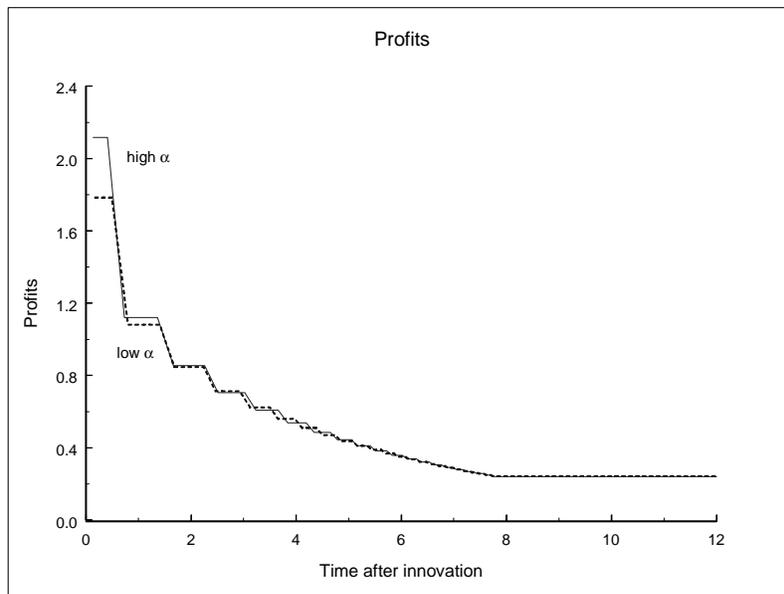


Figure 8: Profits per firm along the life cycle of a new good.

in addition to the cost of production. Assume that $\Lambda(0) = 0$, $\Lambda'(a) > 0$, $\Lambda''(a) < 0$. Thus, the government can increase the cost of imitation by spending more on the protection of intellectual property rights. The government seeks to maximize households' life-time utility by picking an optimal level of expenditures on property right protection,

$$a_s = \begin{cases} a, & \text{for } 0 \leq s \leq T \\ 0, & \text{for } s > T \end{cases}$$

throughout the life of an innovation. Thus the government has two dimensions in its protection program, intensity of protection a , and the duration of protection T . The government can commit to its product right protection program forever. The government finances the cost a_t by a lump-sum tax on households, and it balances its budget at every date. The problem of the i th imitator will now read

$$V^i(s) = \max_{\{p_{s+t}^i\}_{t=0}^{\infty}} \left[\int_0^{\infty} p_{s+t}^i D(\mathbf{p}_{s+t}) - w \left[\frac{D(\mathbf{p}_{s+t})}{Ae^{\gamma t}} \right]^{\frac{1}{\alpha}} - \Lambda(a)D(\mathbf{p}_{s+t}) \right] e^{-\delta t} dt$$

Notice that the equilibrium no-profit conditions stated earlier will still hold except now profits for imitators at each date will be less given the imitation costs, i.e. $\Lambda(a)D(\mathbf{p}_{s+t})$.

Government's budget constraint reads

$$a \int_0^T n_{t-x} dx = \tau,$$

where the left hand side is total government expenditure on patent protection and the right hand side is total tax revenues. The efficiency condition for optimal patent scope is

$$\frac{\partial u(\mathbf{c}, l)}{\partial c_i} \frac{1}{p_i} \int_0^T n_{t-x} dx - \int_0^N \frac{\partial u(\mathbf{c}, l)}{\partial c_x} \frac{\partial c_x}{\partial p_x} \frac{\partial p_x}{\partial a} dx = \frac{\partial u(\mathbf{c}, l)}{\partial N} \frac{\partial N}{\partial a}.$$

Here the left hand side is the total cost of an increase in the scope and the right hand side is the benefit of this increase. The first term on the left hand side is the cost of increasing the scope of patent protection by a small amount because of the necessary

increase in the patent protection expenditures. The second term is the total utility change due the price changes that would be induced by an increase in the intensity of protection. Since we can easily show that $\frac{\partial c_x}{\partial p_x} < 0$ and $\frac{\partial p_x}{\partial a} \geq 0$, the second term on the left hand side is also cost term. The right-hand side gives the benefit from an increase in the intensity of protection. Clearly, $\frac{\partial u(\mathbf{c},l)}{\partial N} > 0$, and $\frac{\partial N}{\partial a} > 0$.

The efficiency condition for optimal patent life reads

$$\frac{\partial u(\mathbf{c},l)}{\partial c_i} \frac{a}{p_i} n_{t-T} - \int_0^N \frac{\partial u(\mathbf{c},l)}{\partial c_x} \frac{\partial c_x}{\partial p_x} \frac{\partial p_x}{\partial T} dx = \frac{\partial u(\mathbf{c},l)}{\partial N} \frac{\partial N}{\partial T}.$$

Here the left hand side is the total cost of an increase in the duration of patent protection and the right hand side is the benefit of this increase. The first term on the left hand side is the cost of increasing the duration of patent protection by a small amount because of the necessary increase in the patent protection expenditures. Again, the second term is the total utility change due the price changes that would be induced by an increase in the duration of protection. We can easily show that $\frac{\partial c_x}{\partial p_x} < 0$ and $\frac{\partial p_x}{\partial T} \geq 0$, the second term on the left hand side is also a cost term. The right-hand side gives the benefit from an increase in the duration of protection. Again, $\frac{\partial u(\mathbf{c},l)}{\partial N} > 0$, and $\frac{\partial N}{\partial T} > 0$.

In the following the stationary equilibrium for this economy is defined.

Definition 1 *Stationary equilibrium in this economy consists of consumption \mathbf{c} , leisure l , number of innovations n , number of producers m_s , prices p_s and government protection policy (a, T) such that i) households utility is maximized, ii) innovator firms and imitator firms maximize profit, iii) government pick the patent protection policy (a, T) in order to maximize households utility, and the labor and commodity market clearing conditions hold.*

Proposition 6 *Consider the economy with government protection. Let a and a' be two protection intensities with $a' > a$. Then, in equilibrium, a) number of products is higher in the more intense protection economy; b) $t_i < t'_i$, imitation dates are*

later in the more intense protection economy; c) price decline is slower, and, d) the concentration is higher in the more intense protection economy.

Products where production technology exhibits strong decreasing returns require more intense government protection for a longer period of time. When the technology exhibits strong decreasing returns it is hard for the innovator to appropriate a significant portion of the social benefits that his product creates since decreasing returns kicks in long before the firm is able to penetrate a large chunk of the potential market. Innovators of information goods in this dimension fare well without much government protection since information good production technologies typically exhibit very small decreasing returns.

Proposition 7 *Consider economies with government protection with two different α 's, $0 < \alpha_1 < \alpha_2 < 1$. In the economy that the production technology exhibits less decreasing returns (α_2 economy) optimal government protection for intellectual property rights is such that, $a_2 < a_1$ and $T_2 < T_1$.*

Technologies where a larger fraction of the cost of new products goes to R&D (like software and most of the other information intensive goods) call for more intense government protection for the first few years after the product is introduced. One can show that for such products the best protection policy is to provide the innovator a less competitive environment early on until this becomes very costly because imitation cost shrink very fast. For such products innovation and welfare are very sensitive to the type of protection. The following conjecture states these ideas.

Consider economies with government protection with two different λ 's, $0 < \lambda_1 < \lambda_2 < 1$. In the economy that the larger fraction of the cost of product introduction goes for R&D (λ_2 economy) optimal government protection for intellectual property rights is such that, $a_2 > a_1$ and $T_2 < T_1$.

6 Numerical Examples with Government Protection

The propositions of the previous section give us some broad ideas about how market structure and technology affect intellectual property protection. In this section we describe some numerical results based on a parametrized version of our model. We present some results on optimal government protection of intellectual property for economies exhibiting different production technologies and ease of imitation. We choose functional forms and parameter values based in part of the findings of Mansfield et. al. (1981) as described in the Appendix.

Let the discount factor parameter $\delta = 4\%$ and the rate at which imitation cost declines $\rho = 10\%$. Let θ and ϕ in the utility function be 0.3 and 0.25 respectively. Let the innovation cost κ be 0.1. Let the cost function for protecting the intellectual property rights be $\Lambda(a) = \Psi a^v$ with $\Psi = 0.2$ and $v = 0.5$, which roughly yields $\tau = 2\%$ of output at the benchmark steady state. Let $\lambda = 0.3$ and $\alpha = 0.3$ be the benchmark case.

The following three tables report some statistics of interest for economies with different values of α and λ . Here N denotes the number of products at the transformed (stationary) steady state. The column named concentration gives the fraction of output produced by the innovator in the first 20 units of time after the good is introduced. The fifth column $\frac{\text{Private Returns}}{\text{Social Returns}}$ gives the fraction of social surplus an innovator can internalize from his innovation in the absence of government protection. This provides us with a measure of how much the economy without patent protection is lacking incentives to innovate. The last column gives us welfare gains from patent protection program computed in a compensation of variation sense.

Table 1 presents the results from an economy where λ is low ($\lambda = 0.3$) for three different returns to scale levels, $\alpha \in \{0.3, 0.5, 0.9\}$. Low-tech industries like textiles would be an example where λ is low, i.e. a small fraction of product development

costs is actually R&D costs.

The number of different products, N , is low in the strong decreasing returns economy since the innovator cannot appropriate his investment in R&D. Strong decreasing returns encourages imitation resulting in a less concentrated industry. For $\alpha = 0.9$ around 19% of the total output of a product is produced by the innovator of the product. That percentage goes down to 5% in the $\alpha = 0.3$ economy. Only 14% of the social surplus from innovating a new product can be internalized by the innovator showing the extent to which innovation is discouraged by future imitation. These are all statistics from the $\lambda = 0.3$ and $\alpha = 0.3$ economy without government protection on innovation. Once there is government protection the government's optimal protection policy becomes $a = 0.71$ and $T = 12.4$. So government provides patent protection for 12.4 units of time with the intensity of protection equal to 0.71. Welfare gains from patent protection calculated in the compensation of variation sense is 11.2%, i.e. households in the economy with government protection on innovation are willing to give up 11.2% of their total consumption in order to maintain the government protection —this is just a comparison of two different economies at their steady state, it is not a calculation about what happens if policy changes.— If we keep λ at 0.3 and increase α , it becomes easier for the innovators to internalize the surplus from their innovations. As can be seen in Table 1 number of different varieties, concentration, and $\frac{\text{Private Returns}}{\text{Social Returns}}$ ratio all go up. There is not that much need for government protection of innovation and the duration and intensity (scope) of optimal government protection go down. For $\alpha = 0.9$ government protects innovations with intensity $a = 0.21$ for only 6.9 units of time. The welfare gains from government protection also shrinks down to 2.3%.

		N	Concentration	$\frac{\text{Private Returns}}{\text{Social Returns}}$	a	T	Welfare gains
$\lambda = 0.3$	$\alpha = 0.3$	2.31	0.05	14%	0.71	12.4	11.2%
	$\alpha = 0.5$	2.73	0.11	19%	0.52	10.3	6.5%
	$\alpha = 0.9$	4.52	0.19	35%	0.21	6.9	2.3%

Table 1: Statistics from an economy with low λ

Similarly, Table 2 illustrates the results from an economy where λ is moderate ($\lambda = 0.5$) for three different returns to scale levels, $\alpha \in \{0.3, 0.5, 0.9\}$. Since it is easier to imitate new products now —compared to the $\lambda = 0.3$ case— without government protection there is less products, less concentration, and the innovators are unable to internalize the surplus from their innovation. Government’s optimal protection policy is now a more intense but a shorter one. The welfare gains from government protection is larger now.

		N	Concentration	$\frac{\text{Private Returns}}{\text{Social Returns}}$	a	T	Welfare gains
$\lambda = 0.5$	$\alpha = 0.3$	1.72	0.03	11%	0.93	11.9	14.3%
	$\alpha = 0.5$	2.44	0.09	15%	0.70	9.2	8.9%
	$\alpha = 0.9$	3.92	0.14	23%	0.42	5.9	5.8%

Table 2: Statistics from an economy with a moderate λ

Finally, Table 3 illustrates the results from an economy where λ is quite large ($\lambda = 0.9$). A large portion of product development cost is now R&D costs. Information intensive goods like high-tech products or software are examples of high λ goods. Government protection of innovations is very important in this environment. Without

government protection innovators can internalize only a small fraction of the surplus that they generate. This causes the number of innovations to be smaller in the absence of government protection. Interestingly, the nature of protection is quite different in the case of high λ . The results suggest providing stronger protection for a shorter duration.

		N	Concentration	$\frac{\text{Private Returns}}{\text{Social Returns}}$	a	T	Welfare gains
$\lambda = 0.9$	$\alpha = 0.3$	1.21	0.02	5%	1.96	10.8	19.2%
	$\alpha = 0.5$	2.03	0.06	11%	1.32	8.7	14.7%
	$\alpha = 0.9$	2.91	0.09	14%	0.98	5.4	12.9%

Table 3: Statistics from an economy with high λ

7 Conclusion

The numerical examples shown above illustrate that the process of innovation, imitation and industry evolution are very different for different types of goods. Goods that require proportionately more R&D to create and exhibit less decreasing returns in production lead to a very different structure of industry and industry evolution. First, for goods where a large part of innovation cost is actual R&D costs, the industry exhibits more concentration, less output, higher prices, and higher profits initially for a significant period of time. This is true in spite of the fact that in our model, except for a short period of time when the innovator is alone in the market, there is perfect competition with no static inefficiency. This is purely because when a larger part of innovation cost is the R&D cost, it pays for the imitators to postpone their imitation. Therefore, observing relatively more concentration, less output, higher prices and profits for information intensive goods should not automatically raise suspicions of uncompetitive behavior. Second, these two salient features of "knowledge" goods

(high share of R&D costs and weaker decreasing returns) tend to affect the industry structure and evolution in opposing directions resulting in rich behavior depending on which effect dominates.

Our results indicate that for high λ products government protection of innovations is more important. The right kind of protection for these products is strong protection with a relatively short duration. High α products call for a less intense but again a short lived protection. Therefore for knowledge goods the optimal intensity of protection depends on whether λ is high enough for α , but it is more likely that the λ effect will dominate and an intense protection will be necessary. There is no ambiguity on the duration side though. Both high λ and high α work in the same direction and cut the duration of protection. In brief, although optimal intensity is ambiguous and depends on exact α 's and λ 's of the good, it is more likely that information intensive or knowledge goods will call for a more intensive patent protection with a short duration.

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8 Appendix: Imitation Time and Cost Calibration

Mansfield et. al.(1981) examined 48 innovations in four sectors. All were major new products, central to the main business of the innovator, 70 per cent were patented, 71 per cent were imitated and only one innovation was licensed. Imitation costs (all costs of developing and introducing the product) exceeded \$1 million in 30 cases and \$5 million in 12 cases, and the ratio of imitation costs to innovation costs averaged some 65 per cent on average. Imitation times (measured from the start of the applied research to commercial introduction) averaged some 70% of the innovation times, and the correlation between the ratio of imitation to innovation costs and imitation to innovation times was 0.8 across the 48 innovations. Sixty percent of the patented innovations in the sample were imitated within four years, and patents caused a (median) rise of some 11 per cent in the ratio of imitation to innovation costs (for unpatented products, patents would have raised the relative cost ration by about 6 per cent). For about half the innovations, patents were estimated to have delayed

imitative entry by less than a few months (in 15 per cent of the cases, patents delayed entry by four years or more). Not surprisingly, patents were observed to have a much bigger impact on imitators in drugs (the median rise in the ratio of imitation to innovation costs was 30 per cent in drugs). Roughly 50 per cent of the patented innovations were unlikely to have been introduced in the absence of patent protection, and about 36 percent of the R&D actually carried out might not have been done.

Clearly, the time it takes to imitate a new product can generally be reduced by spending more money. Each product's imitator is confronted by a time-cost trade-off function, which is the relationship between the amount spent by the imitator and the length of time it would take to imitate this new product. Mansfield (1981) computes the elasticity of cost with respect to time using a time-cost trade-off function for 39 products. they found a median value of this elasticity as around 0.7, which means a 1% reduction in time results in about 0.7% increase in cost, on average.¹⁴

One would expect that a product's ratio of imitation cost to innovation cost to be inversely related to the proportion of the product's innovation cost that goes for research (rather than product specification, pilot plant and prototype, plant and equipment, or manufacturing or marketing startup). An imitator usually can spend much less time and money on research than the innovator because the products existence and characteristics provide the imitator with a great deal of information that the innovator had to obtain through his own research. On the other hand an imitator often has to go through many of the same steps as the innovator with respect to pilot plant or prototype construction, investment in plant and equipment, and manufacturing and marketing startup. Mansfield (1981) tests this hypothesis using the following simple regression

$$C_i = \alpha_0 + \alpha_1 R_i + \dots$$

¹⁴They obtain the elasticity of cost with respect to time for 39 products. In 5 cases, it was less than 0.25; in 10 cases it was between 0.25 and 0.5; in 12 cases it was between 0.5 and 1.0; in 10 cases it was between 1.0 and 2.0; and in 2 cases it was over 2.0.

where C_i is the i th product's ratio of imitation cost to innovation cost, and R_i is the percentage of the innovation cost that went for applied research in the case of the i th product. They include some other variables which they think might the imitation cost - innovation cost relationship which we omit here. They find the regression results as

$$C_i = 0.838 - 0.00684R_i + \dots$$

(11.8) (3.80)

where t -ratios are given in parentheses. So R_i is statistically significant and a 10% increase in R_i decreases C_i by around 7%. We use this result in our calibration.

Imitation cost may also affect an industry's level of concentration. We would expect an industry's concentration level to be relatively low if its members' products can be imitated easily and cheaply. To estimate the relationship between the mean imitation cost and the concentration level for 16 industries, Mansfield et. al.(1981), regress each industry's 4-firm concentration ratio, K_i , on \bar{C}_i , mean value of the ratio of imitation cost to innovation cost, the result being

$$K_i = 6.22 + 61.5\bar{C}_i$$

(8.80) (12.8)

with an $R^2 = 0.60$. We use this information also for calibration.

Holding constant the discounted profit that the imitator expects to earn by imitating a new product, the new product is more likely to be imitated if the imitation cost is small. To see this effect Mansfield et. al.(1981) carries out a logit analysis to determine whether C – the ratio of imitation cost to innovation cost – influences the probability that entry of this sort occurred within 4 years of innovation in their sample. Let P be the probability that such entry did not occur, they find that

$$\ln\left(\frac{P}{1-P}\right) = -3.10 + 3.92C.$$

(2.04) (1.97)

So higher imitation cost seems to decrease the probability of imitation as expected. We use these numbers in our calibration.