Strategic Patent and Trade Secret Policy to Prevent Unintended Technological Outflow in Global Economy

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Abstract

We study optimal patent policy when costly imitations are abound. We introduce a new notion of breadth of patent system based on the statistical dominance of distribution of heterogeneous imitation cost of followers. Industry varies the degree of breadth while the extent to which the breadth differs also vary across countries. The country with narrower patent has comparative advantage in imitation products and it tends to have shorter patent duration.

JEL Classification: **F12, F13, F23, O31, O33, O34**
Keywords: **costly imitation, technology outflow, patents, innovation and imitation, sector heterogeneity, comparative advantage.**

1 Introduction

When multinational firms compete in a global market, unintended outflows of technological knowledge to the foreign competitors via patent system will create a major problem for the original patent holder because it may not be able to cultivate the expected monopoly profits. Rival firms imitate the patented product or invent around the original patent and they may take away the monopoly from the patent holder. A patent gives its owner a legal monopoly position for a period of time and expectation of this future profit serves as a source of incentives to invent a new product in the first place. At the same time, the system also contributes to the dissemination of the new ideas by making the patented information available to public. This second role of the patent system – dissemination – causes the unintended outflow of trade secret from some firms to their competitors.

For example, in the market for LCD (Liquid Crystal Display) panel, SHARP, a Japanese company, is the original patent holder (of many technologies relating to LCD) and was a dominant manufacturer up to the fourth generation, 4G, of the panel. [1] Japanese manufactures had over 80% market share in production capacity in 1997, but lost its share to 13% (as oppose to Taiwanese 45% and Korean 38%) in 2006 because of tough competition with other Asian rivals, who caught up with the Japanese technology possibly due to the unintended technology outflow of their trade secrets. Part of this technological outflow is said to be because of "defensive applications" of patents under **narrower** patent system in Japan. Under the first-to-file patent system, many investors try to file their new innovations in order to defend from the future litigation risk. But the application to the patent alone requires dissemination of the technological knowledge. It has been reported that the "Patent application"database website of the Japanese Patent Office had been heavily accessed by Taiwanese and Korean companies since the late 1990s. (*Nikkei* BP *Chizai* [Intellectual Property] Awareness, 2005)

In reference to the system of "Enveloppes Soleau" (the Soleau Envelope) in France and Belgium, the current patent system (for other countries like Japan) can be rightfully amended to include a way for firms to keep its "trade secret" as secrete and yet to be protected its legal right to use the technology as a first inventor by creating a way to register the trade secret in an official manner like a la Soleau envelope.

This paper introduces a theoretical model where different industries have

[1] The size of the panel is represented by generation; the 4G is 680 x 880 and 730 x 920. The 4 G was up to the 23 inch display and the 5 G made 42 and 60 inches available

different degrees of ease of technological imitation and looks at welfare impact to the society depending on which patent system serves them better. The model of costly imitation from Gallini (1992) is extended to include multiple industry with heterogeneous imitation cost and to be applied to the issues within the global economy. The degree to which the countries differ in cost of imitation can be interpreted as the differences in breadth[2] of patent system. By looking at the statistical dominance of the distribution of imitation cost, I define the different degrees in breadth of patent system mathematically.

I look at the cases of autarky for different breadth countries as well as the welfare changes when they open to trade. Comparative advantage arises from the difference in patent breadth. The more the country trades, the more imitation products are coming in from abroad.

Depending on which industry the country has a comparative advantage in, the optimal patent and trade secret system may change. We try to come to introduce an optimal strategic patent and trade secret policy for a particular country depending on its comparative advantage parameters.

The remaining part of the paper is organized as follows: the next section develops the basic model of costly imitation. Section 3 extends the basic model to introduce two countries and multiple industries with heterogeneous imitation cost. Section 4 discusses further extension of the model by adding different assumptions. The final section summarizes the results and suggests some possible extensions.

2 The Basic Model

Let us first introduce a basic model of innovation and imitation for a given industry. Later we will expand this basic model by introducing two countries and a continuum of industries with heterogeneous cost of imitation. But for now consider only one industry. This part closely follows the work by Gallini (1992).

[2] The definition of breadth of patent (Scotchmer 2004): how different another product must be in order not to infringe the original patent. It can be defined in two ways. (1) product space ... how substitutable these goods are. (2) technology space ... how costly it is to find a noninfringing substitute for the product market. This paper primarily focuses on the definition of (2).

2.1 Assumptions of the basic innovation and imitation model for an industry

In this section I outline the assumptions of the simple model for one industry. Within an industry, there is one innovator. The innovator comes up with an idea for a particular good and decide whether to pay R&D (research and development) cost $C \geq 0$ to make an idea marketable. I assume here that all innovators will succeed in research once they invested C. If the prospect of future market is not bright, then the innovator might avoid investing in R&D. (This option may not be interesting in one industry model, but it will become important when we consider policy issues with many industry.) Once the good is developed, the innovator faces an option of whether the innovation should be patented or kept secret.

If this new product is patented, then the original inventor is awarded a monopoly over the innovation for T periods, after which the content of innovation is available at no cost to all firms in a competitive market. Although the patent can protect the innovator from direct copying of the innovation, rival firms can invent around the original invention and will come up with a patent-noninfringing imitation at cost $K \geq 0$. For the same industry, I assume that all potential rivals share the same imitation entry cost of K. (This assumption is made in favor of simplicity.) Following Gallini (1992), I assume there is a free entry into this imitation market. Because of free entry, the rival imitators will enter the market until the profits from imitation are dissipated. Suppose there are $m \geq 0$ imitators. Further assume that the original innovator and m imitators will compete simultaneously in the market in an oligopolistic manner, and each of them (including the innovator) earns gross profit per period of $\pi(m)$. Therefore, the imitations are considered perfect substitute for the original product and all production firms are considered symmetric once they engage in production. (These assumptions are made also in favor of simplicity.) At this moment I make the model silent about the production cost of both kinds of product.

The original innovator can also choose not to patent the product. In this case, the innovator keeps the innovation as trade secret and will face the risk of duplication by some rival firm(s). Here I assume with probability $p \in (0, 1]$ that the innovation becomes available to others at no cost, in which case the original inventor earns zero return on investment; otherwise it enjoys the monopoly status indefinitely. If p were 0, then no innovators would prefer the patent option because the option of trade secrecy strictly dominates. Therefore, we only consider the case where $p > 0$. Later, when we examine the optimal patent policy, we should note that the application of *the Soleau Envelope* can be thought of as reducing the size of p.

The timing of the decisions is as follows: [1] a potentially marketable idea arrives in an innovator. [2] The innovator decides whether to invest in R&D by paying C or not to do research (because expected profit does not cover the cost). [3] The innovator (who invested ex ante) chooses whether or not to patent. [4] If the innovation is patented, then rival firms make decisions about imitation. [5] Production takes place and profits to firms accrue.

Because, in the end, this paper will look at the governmental policy regarding patent system, there will be a precedent step to this whole process: [0] The government will choose the optimal patent system by picking T and p. However, I will discuss this step in later sections as we will expand the model into a continuum of industry and will also introduce global competition. For now let us take policy variables to be given.

As usual, we solve this game by backward induction. Let us start from stage [4].

2.1.1 Imitation decisions by rivals

We start from the case where the innovator has patented his or her innovation. A rival firm will consider entry decision into a possible imitation market. For the imitation to be profitable, the following condition must be satisfied.

$$\pi(m)\int_0^T e^{-rt}dt = \pi(m)\beta(T) \geq K \tag{1}$$

where $r \in (0,1)$ is a common discount rate per period and let $\beta(T)$ denote the cumulative discount factor for time length T. An imitation firm takes T, m, and K as given. T is a duration of patent which can be a subject of change in stage [0] where the government picks optimal patent policy. $\pi(m)$ is a gross profit for a firm (innovative and imitation firms are assumed symmetric in the production market) from marketing of the product when the number of rival firms is m. K is a cost of the competing rival firms to invent around the patent. In this section we will treat K to be given exogenously, but in the next section we will look at various sizes of K which varies from industry to industry. (We use capital K to denote the realized value for this particular industry while we will use small k in the next section to denote varying imitation cost as a random variable.)

Let us first consider the property of the function $\pi(m)$. Because m is the number of imitating firms, it can possibly be integer. But here we assume m to be nonnegative real number in order to avoid complications of the integer analysis. (Gallini 1992) It is safely assumed the function $\pi(m)$ to be nonincreasing. If the market conduct is the one of Cournot, then the function must be strictly decreasing. Here we assume that $\pi'(m) \leq 0$.

Free entry assumption does not allow the inequality in (1) to be strict for $m > 0$ when we allow the non-integer m case.

Consider now the different duration of patent T. If T is long, then left side of inequality (1) will be larger given m. (Note that $\beta(\cdot)$ is strictly increasing in T.) If T is too short (shorter than a certain threshold), then it might be the case that the condition (1) will never hold for any $m \geq 0$. Such a threshold depends on the size of K and let us denote the threshold as $T_M(K)$. This can be calculated as

$$T_M(K) = -\ln\left(1 - \frac{rK}{\pi(0)}\right)\frac{1}{r} \tag{2}$$

where $\pi(0)$ is a monopoly profit.

For $T < T_M(K)$, there is no imitation. For $T \geq T_M(K)$, imitation is profitable and the number of rival firms satisfies

$$\pi(m)\beta(T) = K \tag{3}$$

because rivals will imitate until profits are dissipated. Because of free entry (into imitation market) assumption, rival imitators will earn just enough gross profit over the patent duration such that the accumulation of return covers the imitation (entry) cost K.

We now turn to one stage backward: patent decision by the original innovator, namely, stage [3].

2.1.2 Patent decisions by the innovator

The innovator can choose between patenting the innovation and keeping it as trade secret. After the original innovator patents the product, there can be two cases: the one without imitation and the other with m imitators.

(i) Patent and no imitation case (P) If there are no imitators (maybe because cost of imitation K is too high for rivals or T is too short; both will be determined simultaneously in a single industry case, but two conditions can be separate in multiple industry case), then the expected profit of the innovator from successful patent $E\Pi^P$ is written

$$E\Pi^P = \pi(0)\int_0^T e^{-rt}dt = \pi(0)\beta(T) \tag{4}$$

where $r \in (0,1)$ is the same common discount rate as rivals. $\pi(0)$ represents monopoly profit during the patent life T. Note that the value of this (4) depends positively on T.

(ii) Patent and imitation case (M) If there are m imitators (maybe because K is low and/or T is long enough), then the original innovator earn also the per period return $\pi(m)$ along with other rival imitators. Using (3), the expected profit for the innovator with imitation $E\Pi^M$ is

$$E\Pi^M = \pi(m)\beta(T) = K \tag{5}$$

which has the same value as rivals. So the return no longer depends on the patent duration T. Because of free entry assumption, the number of entering imitators m will adjust such that $\pi(m)\beta(T) = K$ holds for any T within the relevant range.

(iii) No patent and trade secrecy case (S) When the innovator decide to keep the innovation as secret (trade secret option), then the expected profit from this option $E\Pi^S$ is

$$E\Pi^S = (1-p) \cdot \pi(0) \int_0^\infty e^{-rt} dt = (1-p)\pi(0)\beta(\infty) \tag{6}$$

because with probably p the innovation is available to anyone at no cost and the market will become competitive and the innovator makes no profit, otherwise the innovator keep its monopoly indefinitely.

We now have to look at the relative sizes of (i), (ii) and (iii).

No imitation region $K \geq \pi(0)/r$: Patent versus Secrecy If $K \geq \pi(0)\beta(\infty) = \pi(0)/r$, then no rival firms enter in the imitation market for any T. $E\Pi^M$ is irrelevant. We only compare $E\Pi^P$ and $E\Pi^S$. Given the value of $p > 0$, we can calculate the threshold value of $T_S(p)$ above which patenting dominates trade secrecy. We can calculate this as

$$T_S(p) = -\frac{\ln p}{r} \tag{7}$$

which is nonnegative because $p \leq 1$.

Lemma 1 *For a given value of $p \in (0,1]$ and for a large size of imitation cost $K \geq \pi(0)/r$, the innovator decides to patent if $T \geq T_S(p)$, and decides to keep the innovation secret if $T < T_S(p)$.*

After patenting, there is no imitation in $K \geq \pi(0)/r$.

Imitation region: Imitation versus No imitation If $K < \pi(0)/r$, then imitation can occur depending on the size of patent length T. By comparing $E\Pi^P$ and $E\Pi^M$, we can calculate the threshold value $T_M(K)$ above which imitation occurs. We draw this value from (2):

$$T_M(K) = -\frac{\ln\left(1 - \frac{rK}{\pi(0)}\right)}{r} \tag{8}$$

which is positive.

Lemma 2 *For sufficiently small size of imitation cost $K < \pi(0)/r$, the imitation occurs if $T \geq T_M(K)$, and the imitation does not occur if $T < T_M(K)$. For the values $K \geq \pi(0)/r$, no imitation occurs for any T.*

The bold line OAB in Figure 1 illustrates the expected return for the innovator for $K < \pi(0)/r$ who decides to patent. The region OA follows $E\Pi^P$ when $T < T_M(K)$, the region AB follows $E\Pi^M = K$ when $T \geq T_M(K)$. We still do not know if the innovator want to patent or keep it secret.

Imitation region: Patent versus Secrecy One more concern is the relative size between $E\Pi^M$ and $E\Pi^S$. If $K < E\Pi^S = (1-p)\pi(0)\beta(\infty) = (1-p)\pi(0)/r$, then trade secrecy strictly dominates patents for all T.

Lemma 3 *Given the size of imitation cost $K < (1-p)\pi(0)/r$, the innovator will choose trade secrecy for any T.*

Otherwise, the bold line $CDAB$ in Figure 1 shows the expected return for the innovator when $(1-p)\pi(0)/r \leq K < \pi(0)/r$. When $K \geq (1-p)\pi(0)/r$, we know that $T_S(p) \leq T_M(K)$. We summarize this result.

Lemma 4 *Given the size of imitation cost $K \in [(1-p)\pi(0)/r, \pi(0)/r)$, the innovator chooses trade secrecy for low value of $T < T_S(p)$, and decides to patent the innovation if $T \geq T_S(p)$. After patenting, the innovator can maintain its monopoly for $T < T_M(K)$ and face competition from imitating rivals for $T \geq T_M(K)$.*

The expected return for the innovator is summarized as a proposition.

Proposition 1 *When the imitation cost is* $0 \leq K < (1-p)\pi(0)/r$*, the innovator earn* $E\Pi^S = (1-p)\pi(0)/r$ *for all duration of patent* T*. When the imitation cost is* $(1-p)\pi(0)/r \leq K < \pi(0)/r$*, the innovator earn*

$$\begin{cases} E\Pi^S = (1-p)\pi(0)/r & \text{for} \quad 0 \leq T < T_S(p) \\ E\Pi^P = \pi(0)\beta(T) & \text{for} \quad T_S(p) \leq T < T_M(K) \\ E\Pi^M = K & \text{for} \quad T_M(K) \leq T \end{cases}.$$

When the imitation cost is $\pi(0)/r \leq K$*, the innovator earn*

$$\begin{cases} E\Pi^S = (1-p)\pi(0)/r & \text{for} \quad 0 \leq T < T_S(p) \\ E\Pi^P = \pi(0)\beta(T) & \text{for} \quad T_S(p) \leq T \end{cases}.$$

The proposition shows the expected return for the innovator for different values of T *and* K*.*

Proof. This proposition summarizes the results in all lemmas above. ■

For small size of imitation cost, the innovator keeps the invention secret and earns the expected return from secrecy. For large size of imitation cost, the innovator may choose to patent the innovation for large patent duration.

For intermediate size of imitation cost, the return for the innovator looks like Figure 1. There are 3 regions. For small duration, the innovator chooses trade secrecy. For intermediate duration, the innovator chooses patenting and keeps its monopoly position. For large duration, the innovator's patent will be imitated by rival firms and earns fixed return which is the same as the size of the imitation cost.

When vary both K **and** T **: Trade Secrecy Region** Now we can vary both K and T. It is shown in Figure 2. The curve OAB comes from the equation (8) that shows the combination of K and T above which the imitation occur. The shaded region where the union of sets $K < (1-p)\pi(0)/r$ and $T < T_S(p)$ will define represents the innovator's choice of trade secrecy.

2.1.3 Research decision by the innovator

Although the model in this section closely follows Gallini (1992), it seems that she assumed the cost of research to be zero or $C = 0$. But I choose not to follow Gallini (1992) about this presumption. This subsection's analysis is not in Gallini (1992) and it is completely redone by the author.

Now we go back one step further: [2] The innovator decides whether to invest in R&D by paying C or not.

Here, the innovator must compare these expected returns (given in Proposition 1) with the cost of research C. If expected return is higher than C, then the innovator will conduct R&D. Otherwise, the innovator will not invest in research.

The case for $C > K$. If we only consider one industry, it is probably natural to assume that $C > K$. i.e. The cost of original invention must be higher than the cost of imitation. We look at such a case first.

If $0 \leq K < C < (1-p)\pi(0)/r$ or $0 \leq K < (1-p)\pi(0)/r < C < \pi(0)/r$, then $E\Pi^S - C > 0$ for all T. All innovators will keep the innovation secret.

If $(1-p)\pi(0)/r \leq K < C < \pi(0)/r$ is the case, then no innovator will invest in research for large patent duration: $T_M(K) \leq T$.

If $\pi(0)/r \leq K < C$, then no one will conduct research for all T.

The case for $C \leq K$. In the next section, we will look at the case of heterogeneous cost of imitation. In this case the presumption of $C > K$ may no longer make sense. We will look at varieties of imitation cost which may or may not surpass the original cost of innovation.

Two things can be noted. First, it may be natural to assume that C is also heterogeneous among industries. However, this paper will assume that C is common for all industries. This is a choice made by the author in order to focus on the issue of heterogeneity of imitation cost rather than the invention cost. Second, because C is common and K is heterogeneous, we may have some cases where $C \leq K$. We can justify such case as the following reasoning. If the innovation was done by some genius and its imitation by regular people is inexplicably difficult no matter how much money they put in.

3 Extension of the basic model

The world consists of two countries: Home and Foreign. For now, we say Home has narrower patent system while Foreign has broader patent system which we will define precisely later.

Imagine a continuum of goods indexed by $z \in [0, 1]$. The industry can be characterized by heterogeneous imitation cost $k(z)$ and $k^*(z)$ for Home and Foreign. We now let the indexation to be both $k(z)$ and $k^*(z)$ are increasing in z without loss of generality. (Similarly to the model by Dornbusch, Fischer and Samuelson, 1977.) This means lower value of z means the sector which is relatively easy to imitate. The higher the value of z, the more difficult the imitation becomes. Now, $k(z)$ and $k^*(z)$ are assumed to be distributed with cumulative distribution $F(k(z))$ and $F^*(k^*(z))$ over $[0, \overline{K}]$. Their density functions can be denoted as $f(k(z))$ and $f^*(k^*(z))$. (Here we assume the support for Home and Foreign is the same.) Let us set the value $\overline{K} = \pi(0)/r$ so that we will exclude the case where imitation is irrelevant (never occurs).

Definition 1 *Home is said to have broader patent system than Foreign if the distribution $F(\cdot)$ first-order stochastically dominates $F^*(\cdot)$.*

If this is the case, then for all industry z, it is more costly to imitate in Home than in Foreign.[3] Therefore, for a given industry, it is easy to imitate in Foreign than in Home. See Figure 3.

3.1 Key Results of the Model

We can partition the type space depending on the size of the imitation cost. For now we take the variables T and p of patent system to be given.

3.1.1 Trade secrecy versus Patent

When does an innovator keep the innovation secret? When does he or she patent? By comparing $E\Pi^S$ and $E\Pi^P$, and solve for K, we come up with the following lemma.

Lemma 5 *Given p, there exits a threshold value $K_S(p) \in [0, \overline{K}]$ where sectors $k < K_S(p)$ will keep the invention secret and sectors $k > K_S(p)$ will patent the innovation.*

This threshold depends only on the probability p.

$$K_S(p) = E\Pi^S = (1-p)\pi(0)\beta(\infty) = (1-p)\frac{\pi(0)}{r}$$

The reduction of p increases the threshold value $K_S(p)$.

[3] There might be several explanations why the imitation cost is cheaper in Foerign for a given industry. (1) the patent system is borader in Home and narrower in Foreign, either because of the legal regulation or because of enforcement conduct. (2) the wage of scientists who engage in imitation activities are cheaper in Foreigh than in Home.

The relationship between C and $K_S(p)$ If we assume positive cost of innovation, then the relative location of C and $K_S(p)$ matters.

[1] When $0 \leq C < K_S(p)$, then every innovator $k < K_S(p)$ will keep the invention secret.

[2] When $K_S(p) < C < \overline{K}$, then everyone $k < C$ will no longer engage in R&D activity.

If we compare social welfare between above two cases, the case [1] has higher welfare value than [2] for a given value of $C \geq 0$. Therefore, given the value of p and if case [2] prevails, then the government has an incentive to make the situation close to case [1] by lowering C or by raising the value of $K_S(p)$ (by reducing p).

In the long run, the government can affect the reduction of the innovation cost C by investing in human capital for natural science. In the short run, any policy that reduces the value of p will increase the value of $K_S(p)$ and will make the case [2] become the case [1]. The adoption of "the Soleau Envelope" is one way to do that.

Proposition 2 *For a given initial value of p, and when the cost of research C is higher than the threshold value $K_S(p)$, a policy that can reduce the probability of trade secret being available at no cost to others should increase the overall social welfare. The stronger protection of the trade secret such as "the Soleau Envelope" can increase social welfare.*

This result discusses one possibility to support "the Soleau Envelope" policy.

3.1.2 Imitation versus Nonimitation

In this section we take T to be given. When do rival firms enter the imitation market? When do they not to enter?

Lemma 6 *Given T, there exits a threshold value $K_M(T) \in [0, \overline{K}]$ where sectors $k < K_M(T)$ will see rival imitators and sectors $k > K_M(T)$ will observe monopoly by the original innovator.*

This threshold depends on the patent length T.

$$K_M(T) = \pi(0)\beta(T) = \pi(0)(1 - e^{-rT})/r$$

The value of $K_M(T)$ is increasing in the patent length T.

In the single industry case analyzed in Gallini (1992), the optimal length of the patent was such that there is no imitation: T solves $K = K_M(T)$ for a given K.

$$T(K) = -\ln\left(1 - \frac{rK}{\pi(0)}\right)/r$$

This was because the imitation cost K paid by m firms is considered complete waste to the society.

3.2 The Optimal Patent System

Let us look at the optimal patent system for both countries in their autarky.

Proposition 3 *In autarky, the socially optimal length of patent for Home is longer than the one for Foreign.* $T > T^*$.

Proof is given later.

Proposition 4 *In autarky, the socially optimal threshold (imitation) value* $K_M(T)$ *for Home is higher than the one for Foreign.* $K_M(T) > K_M(T)^*$.

Proof is given later.

If optimal patent requires that $K_S(p) = K_M(T)$, then we must set

$$T = -\frac{\ln p}{r}$$

and the partition of the type space will be the one with trade secret and the one with patent without imitation. But we do not know if this is the case or not.

4 Extension: Different Assumptions

What if we assume the following?

Regardless of the value of k, the domestic firms never be able to imitate even if they pay k. But the foreign firms can imitate by paying k^*. This may be the case where national treatment is not present in IPR protection.

So in a sense, we say the following:

K for domestic innovation: $K = \infty$

K for foreign innovation: $k \sim F(k)$

5 Conclusion

This paper extends the model of costly imitation by Gallini (1992) by introducing multiple industry with heterogeneous imitation cost. The existence of imitation confers the breadth of patent system in technology space. It is natural to think that the breadth of patent varies from industry to industry. When we compare the overall differences in breadth of patent system for different countries, the model in this paper proposes a statistical dominance as a definition of overall breadth of the patent system. Given this new definition of breadth of patent, this paper looks at various issues relating to the patent system in the context of global economy.

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Figure 1

Expected Profit for the Innovator

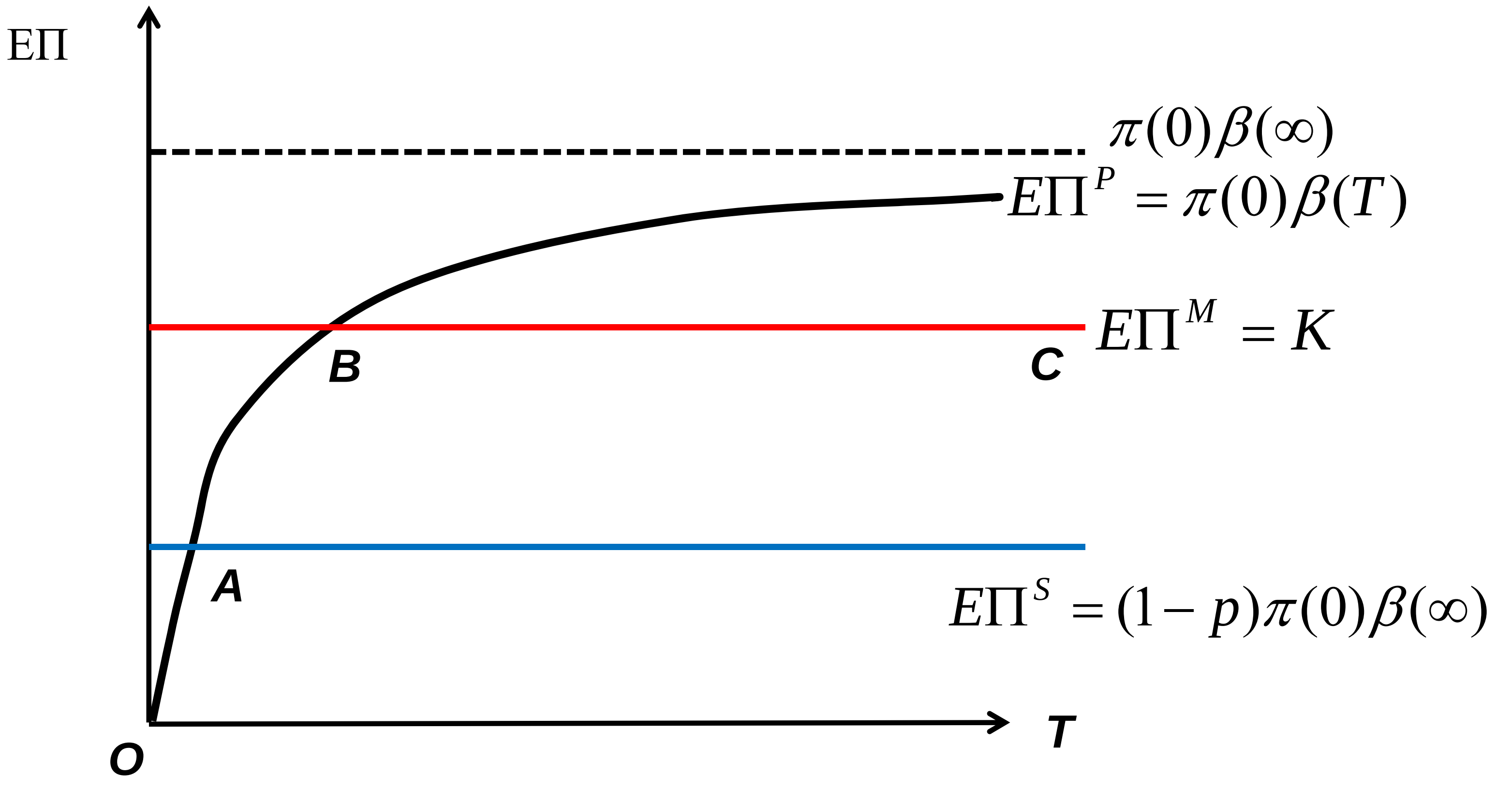

Figure 2

Imitation, Monopoly and Trade Secrecy

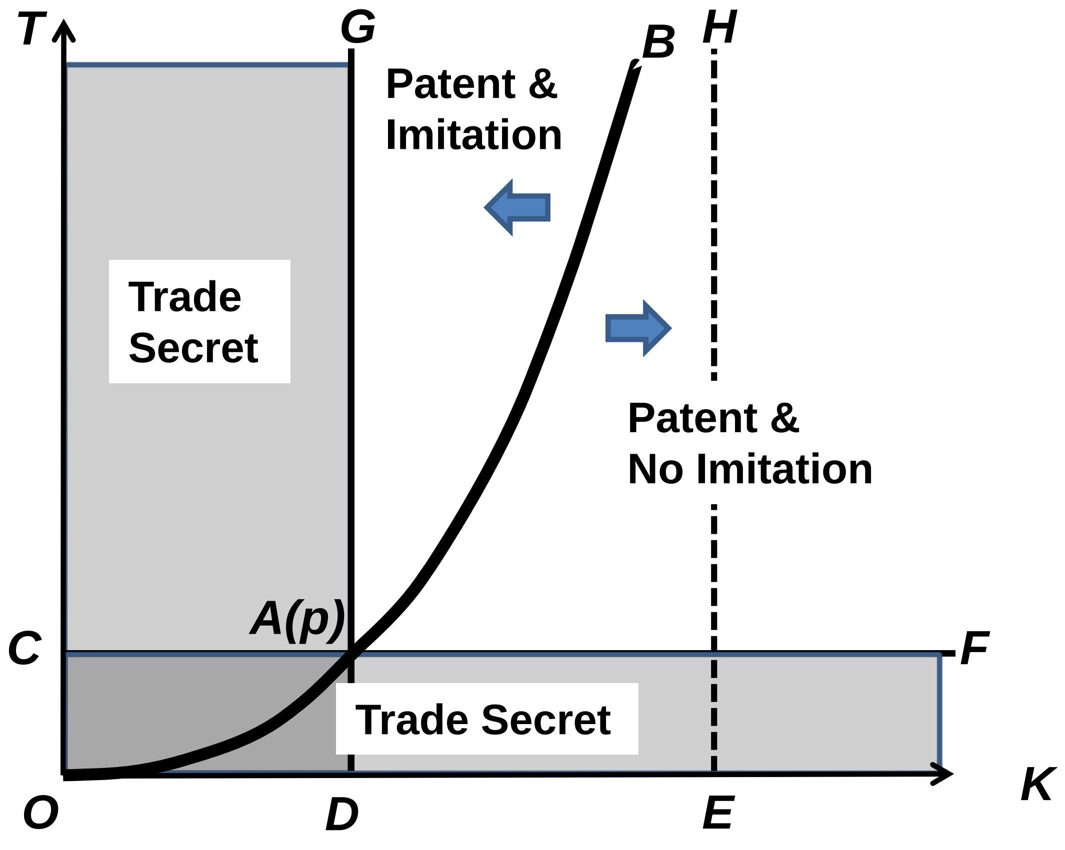

Figure 3

Distribution of imitation costs:
Home has broader patent system
~ F 1st order statistically dominates F*