Innovation, standardization, and imitation in the product cycle model

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Abstract

We develop a product cycle that is much more akin to Vernon's original vision of the product cycle, in which standardization of production techniques is required for the international transfer of technology to the developing South. We show that, since stronger intellectual property rights (IPR) encourages standardization and thus technology transfer, it can enhance the long-run innovation rate in the developed North. This is because less production remains in the North, which leaves more resources in the North for R\Dactivity. Specifically, we show the possibility of an inverted-U relationship between IPR and innovation (and resulting economic growth). Our result suggests that a balanced approach (not too strong and not too weak) is required to enhance economic growth in the world economy.

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1 Introduction

Vernon (1966), in a seminal paper that describes the natural life cycle for a typical commodity, identified standardization of production techniques as a key element for the international transfer of technology. Vernon (1966) argued that new goods are initially manufactured in the country where they are first invented (developed country, the North). In his argument, two factors are required to shift the locus of production to the less-developed South. One is the emergence of appropriate (dominant) designs and the other is the standardization of production techniques.

Recently, Antràs (2005) developed a simple theoretical model of the product cycle, which stresses the standardization of production technology, to show that only when a production technology is sufficiently standardized can it shift to the South. However, in his model, rates of standardization and innovation are exogenous.

One contribution of our paper is to develop a product cycle model in which standardization and innovation are endogenously determined with voluntary decisions by agents. The key feature of our model, which is only one departure from Helpman's (1993) product cycle model, is to allow for agents who standardize production techniques developed and used by original innovators: the original innovator who invents and introduces a new product in the North is distinguished from the agents of standardization, named "standardizers." In line with the Vernon–Antràs model, we assume that the South can imitate only goods that are manufactured with standardized, less costly technologies.[1]

In the model, a standardizer, by incurring fixed cost, invents a more efficient production method. While the patent is exclusively held by the original innovator, a successful standardizer needs to sell his/her know-how to reduce the production cost compared to that of the original innovator/patent holder. As a result of Nash bargaining, the value for a "standardized" good is shared by the innovator and the standardizer.

We apply this model to examine the effects of intellectual property rights (IPR) protection.[2] An interesting result is that, contrary to that of Helpman (1993),[3] stronger IPR can enhance long-run rates of innovation and growth: there can be an inverted-U relationship between IPR protection and the long-run rate of innovation. That is, protection measures that are either too strong or too weak can discourage innovation; rather, a balanced approach is required.

The logic behind our result is the following. Stronger IPR reduces the probability of imitation for standardized Northern products, so that it encourages standardizers. An increase in the number of standardized products, which are the only products that

[1] Vernon (1966) considers that standardization is driven by profit-maximizing, voluntary decisions of *original innovators*. Our model is at odds with his original view. Our view, rather, is closer to that of Arrow (1962), who shows that an incumbent monopolist never provides new innovation in his/her own market. Our companion paper (Akiyama and Furukawa 2006) shows similar results to the current paper in a setting reflecting Vernon's original view.

[2] The broader issuer of IPR protection is at the center of much of the current discussion on international trade, innovation, and development of countries, as reflected, for example, in the Trade Related Aspects of Intellectual Property Rights (TRIPs) agreement. Our result suggests that stronger IPR in the South would be good for innovation in the North if the channel for standardizing production technologies is dominant: stronger IPR policies in the South (e.g., the TRIPs agreement) in fact may enhance innovation in the North and thus the growth rate of the world economy.

[3] Helpman (1993) shows that stronger IPR always decreases the long-run rate of innovation.

can be imitated, enhances imitation and the resulting international transfer of technology. Therefore, less production remains in the North and Northern resource scarcity is relaxed: more resources will be devoted to R&D activity, encouraging innovation and growth. Allowing for standardization, we present a mechanism whereby a strengthening of IPR protection can have a positive effect on innovation.

The remainder of the paper is structured as follows. The next section presents a dynamic model for a product cycle with standardization. Section 3 derives equilibrium conditions for this economy and shows the main result.

2 The Model

This section presents the basic model, based on Helpman's (1993) product cycle model. Helpman (1993) constructs a two-region variety expansion model with exogenous imitation. Only one departure from the Helpman model allows for the presence of "standardizers," who invent more effective production methods for the products that are manufactured exclusively by original innovators, who first invent and introduce the products. We assume that the original innovators have exclusive rights to the patent, so that a successful standardizer can earn from monopoly rents only if he/she sells his/her know-how on a more effective (less costly) method of production than that of the patent holder of the product (i.e., the original innovator). As a result of Nash bargaining, the innovator and standardizer share the value of the standardized product.

As is apparent from the above, standardization of technologies is assumed to lead to a reduction in the production cost in this model. The intuition is that a standardized technology is simpler and easier to use, and thus a standardized product can be manufactured more efficiently than a non-standardized one. Our view is, of course, incomplete because it does not stress the role of the factor intensity of hi-tech inputs (e.g., skilled labor). The literature often has identified standardization as an increase in the intensity of low-tech inputs (see Antràs 2005), and hence standardized products can be manufactured with lower production costs as a result of the increased share of low-tech (lower-priced) inputs. Nevertheless, it is useful to analyze many of the important issues.

Time is continuous and extends from zero to infinity. There exist two regions, the innovative, developed North and the imitative, less developed South. The North introduces new products at a endogenously determined rate, $g = \dot{n}/n$, where n equals the number of products available.

2.1 Standardization

As already mentioned, we allow for the standardization of production techniques in the model. Newly invented products are manufactured initially with a complex, unpolished, hard-to-learn technology (the non-standardized technology). Assume that this "non-standardized technology" is costly but safe: an innovator who manufactures the good with non-standardized technology incurs a *higher* average cost, but he/she cannot be imitated by the South. A non-standardized technology is assumed to require $\lambda > 1$ units of labor per unit output, and hence its marginal cost is λw^N, where w^N denotes the wage rate for Northern labor. This view is much more akin to the Vernon–Antràs view of the product cycle: only when production techniques are sufficiently standardized can the technology be transferred internationally. Let n^N denote the number of non-standardized products. Once an outside agent in the North (i.e., standardizer) invents a simpler, more efficient, easier-to-learn technology (the standardized technology), this successful standardizer must bargain with the patent holder of the relevant product (i.e., original innovator). Let $\hat{n}^N$ denote the number of Northern (yet to be imitated) products that are manufactured with standardized technology. As is apparent from the above, this standardized technology is less costly but risky: the producer who manufactures using the standardized technology has a *lower* average cost, but he/she may be imitated by the South and then lose his/her monopoly power. A standardized technology requires one unit of labor per unit output, and its marginal cost is $w^N < \lambda w^N$.

2.2 Imitation

Following Helpman (1993),[4] the South imitates Northern products at the exogenous rate $\mu = \dot{n}^S / \hat{n}^N$, where n^S denotes the number of products that the South knows how to produce, while $\hat{n}^N$ denotes the number of products that have been standardized and not yet imitated by the South: $n^S + n^N + \hat{n}^N = n$. Then, the evolution of the number of imitated products can be represented as $\dot{n}^S = \mu \hat{n}^N$. The rate of imitation, μ, also represents the hazard rate of the Poisson process, at which the monopoly power of Northern innovators with standardized technology ceases to exist on the next date.

2.3 Consumption

Individuals who live in both regions have identical preferences. An individual in region i, $i = S, N$, supplies L^i units of labor inelastically, and consumes n differentiated products, with $n = n^S + n^N + \hat{n}^N$. At any instant, individuals choose consumption and saving so as to maximize

$$U = \int_0^\infty e^{-\rho t} \ln u_t dt \ , \tag{1}$$

where ρ denotes the subjective discount factor and $\ln u$ is the instantaneous utility function, which depends on the composite of differentiated products and has the form of a symmetric constant elasticity of substitution (CES):

$$u_t = \left[\int_0^{n_t} x_t(j)^{\frac{\sigma-1}{\sigma}} dj \right]^{\frac{\sigma}{\sigma-1}} \ , \tag{2}$$

where $\sigma > 1$ denotes the elasticity of substitution between any two products and $x_t(j)$ denotes consumption of a product indexed by j at date t. It is well known that, due to a symmetric CES form, the solution to the static optimization problem can be represented as:

$$x_t(j) = p_t(j)^{-\sigma} \frac{E_t}{P_t^{1-\sigma}} \ , \tag{3}$$

[4] See also Lai (1998), Eaton and Kortum (1999), and Kwan and Lai (2003).

which is the demand function exhibiting constant price elasticity, $\sigma > 1$. Here $p_t(j)$ is the price of product j at date t, $E_t \equiv \int_0^{n_t} p_t(j)x_t(j)dj$ represents the aggregate spending on differentiated products, and P_t is the price index at date t satisfying $P_t = \left[\int_0^{n_t} p_t(j)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$. From Eqs. (2) and (3), we can derive the following indirect instantaneous utility function:

$$\ln u = \ln E - \ln P , \tag{4}$$

which implies that real spending, E/P, determines the level of instantaneous utility.

A Northern consumer maximizes welfare with preference (1) and an indirect utility (4) subject to a natural intertemporal budget constraint. It is well known that the solution to this dynamic optimization problem can be given as the following Euler equation:

$$\frac{\dot{E}^N}{E^N} = r^N - \rho , \tag{5}$$

where E^N represents consumption spending of Northern consumers and r^N represents the nominal rate of interest.

Following Helpman (1993), we assume that there are no financial capital flows between the two regions, so that the North finances investment in R&D entirely from domestic savings. The trade account is therefore balanced at every point in time: the aggregate spending in the North equals the aggregate domestic production, $E^N = \int_{n^S}^{n} p(j)x(j)dj$. Note that product $j \in [0, n^S]$ is manufactured in the South, while product $j \in [n^S, n]$ is manufactured in the North.

The South spends all of its income on consumption goods because there is no investment owing to the lack of international capital flows: per capita expenditure on consumption in the South is equal to the Southern wage rate, w^S.

2.4 Production

As defined above, producing one unit of non-standardized product requires one unit of labor in the North (the marginal cost is λw^N). On the other hand, the marginal cost of producing a standardized, non-imitated product is w^N, which is lower than that of the non-standardized product. Thus, owing to the constant price elasticity,

$$p^N = \frac{\sigma \lambda w^N}{\sigma - 1} \qquad \hat{p}^N = \frac{\sigma w^N}{\sigma - 1} , \tag{6}$$

where p^N represents the price of non-standardized products and $\hat{p}^N$ represents that of standardized products. Clearly, $p^N > \hat{p}^N$ holds.

Once the South imitates products that have been manufactured using standardized technology, these are available to all Southern producers. Thus, imitated products are competitively produced in the South. The price of the remaining n^S products is equal to the marginal cost in the South: $p^S = w^S$.[5]

[5] We assume that $\hat{p}^N > p^S$ holds in equilibrium to ensure that imitated products are manufactured in the South.

Combining the demand functions in (3) with the Northern prices (6), we can express the monopoly rents as:

$$\pi = \frac{p^N x^N}{\sigma} \qquad \hat{\pi} = \frac{\lambda^{\sigma-1} p^N x^N}{\sigma} , \tag{7}$$

where x^N represents the per product consumption of a non-standardized Northern product. Since $\lambda^{\sigma-1} > 1$, the profit for standardized products $\hat{\pi}$ is higher than that for non-standardized products π.

3 Equilibrium

This section derives the equilibrium conditions of this economy.

In the previous section, we assume that there are no international capital flows between the two regions, so that $E^N = \int_{n^S}^{n} p(j)x(j)dj$. Using (3) and (6), we can rewrite this condition as:

$$E^N = p^N x^N (n^N + \lambda^{\sigma-1} \hat{n}^N) . \tag{8}$$

Let V and $\hat{V}$ denote the values of a non-standardized producer and a standardized, non-imitated producer, respectively. The value of an innovator with non-standardized technology V is equal to the present value of its expected streams of profits. An innovator will bargain with a successful standardizer at probability $m \equiv (\dot{\hat{n}}^N + \dot{n}^S)/n^N$, where the denominator is the number of non-standardized innovators and the numerator, $\dot{\hat{n}}^N + \dot{n}^S$, is the gross increase in the number of standardized products, equaling the net increase $\dot{\hat{n}}^N$ plus the number of standardized products that are shifted to the South. That is, m is the hazard rate of the Poisson process, at which a non-standardized innovator encounters a successful standardizer and, as a result of Nash bargaining, the value of the expected stream of monopoly rents by producing the product manufactured using the standardized technology is shared by the innovator and standardizer. The reservation values of the standardizer and the innovator are, respectively, zero and V (the original value of the innovation without standardized technology), so that, as a result of the bargaining, they share the increase in value gained by the standardized, more efficient technology, $\hat{V} - V$. Let $\alpha \in (0,1)$ be the fraction that the innovator receives. Therefore, the innovator's value V increases to $V + \alpha(\hat{V} - V)$ and the standardizer's value is $(1-\alpha)(\hat{V} - V)$: the sum of these two values is $\hat{V}$. The parameter α represents the strength of the innovator's bargaining power, which might be affected, for example, by the patent system and IPR laws.

Under these circumstances, arbitrage in asset markets implies:

$$r^N V = \pi + \dot{V} + m\alpha(\hat{V} - V) , \qquad r^N \hat{V} = \hat{\pi} + \dot{\hat{V}} - \mu \hat{V} , \tag{9}$$

reflecting the fact that only standardized products can be imitated by the South.

Assuming that innovating a new product requires $1/n$ units of labor and standardizing a non-standardized innovator's technology requires b/n units of labor as inputs, then free entry to R&D activity implies that the equilibrium values cannot exceed their costs: $\min\{bV, (1-\alpha)(\hat{V} - V)\} \leq \frac{bw^N}{n}$. We hereafter assume $(1-\alpha)(\hat{V} - V) = bV$

to restrict ourselves to the most interesting case, in which both innovation and standardization take place. Then we rewrite this free entry condition: $\hat{V} = \left(1+\frac{b}{1-\alpha}\right)V$. Combining this relationship with Eqs. (7)–(9), the hazard rate that non-standardized innovators face, m, can be expressed as:

$$m = \frac{1-\alpha}{b\alpha}\left[\frac{(\hat{\lambda}-1)E^N}{\sigma nV\left(n^N/n+\lambda^{\sigma-1}\hat{n}^N/n\right)} - \mu\right] , \tag{10}$$

where $\hat{\lambda} \equiv \lambda^{\sigma-1}/[1+b/(1-\alpha)]$. Using (7)–(10) again, we can have the law of motion for V as:

$$r - \frac{\dot{V}}{V} = \frac{\hat{\lambda}E^N}{\sigma nV\left(n^N/n+\lambda^{\sigma-1}\hat{n}^N/n\right)} - \mu \ . \tag{11}$$

Next, we turn to the labor market in the North: Northern labor can be used for production for non-standardized and standardized products with size $n^N+\hat{n}^N$, for innovation ($\dot{n} = ng$), and for standardization ($\dot{\hat{n}}^N + \dot{n}^S = mn^N$). From the demand function and the pricing equation, (3) and (6), the labor-market clearing condition in the North yields:

$$g = L^N - \frac{bmn^N}{n} - \frac{\sigma-1}{\sigma}\frac{E^N}{nV} , \tag{12}$$

where use has been made of $\dot{n}^S = \mu\hat{n}^N$.

Finally, we derive the law of motion for n^S. By definition, $\dot{n} = \dot{n}^N + \dot{\hat{n}}^N + \dot{n}^S$, from which we can obtain the following expression:

$$\frac{\dot{\hat{n}}^N}{\hat{n}^N} = \frac{mn^N}{\hat{n}^N} - \mu \ . \tag{13}$$

The dynamic equilibrium is fully characterized by Eqs. (5) and (10)–(13). To analyze the dynamic equilibrium, it is useful to define new variables: $v \equiv E^N/(\sigma nV)$, $\zeta \equiv n^N/n$, which denotes the fraction of products that have not been standardized, and $\eta \equiv \hat{n}^N/n$, which denotes the fraction of products that have been standardized but not imitated yet (which we associate with the rate of standardization). Noting these definitions, we can reduce the equilibrium conditions (5) and (10)–(13) into the following three differential equations:

$$\frac{\dot{v}}{v} = \frac{\hat{\lambda}v}{\zeta+\lambda^{\sigma-1}\eta} - (\rho+\mu+g) , \tag{14}$$

$$\frac{\dot{\zeta}}{\zeta} = \frac{g}{\zeta} - \frac{1-\alpha}{b\alpha}\left[\frac{(\hat{\lambda}-1)v}{\zeta+\lambda^{\sigma-1}\eta} - \mu\right] - g , \tag{15}$$

$$\frac{\dot{\eta}}{\eta} = \frac{1-\alpha}{b\alpha}\frac{\zeta}{\eta}\left[\frac{(\hat{\lambda}-1)v}{\zeta+\lambda^{\sigma-1}\eta} - \mu\right] - (\mu+g) , \tag{16}$$

and one equation

$$g = L^N - \frac{(1-\alpha)\zeta}{\alpha}\left[\frac{(\hat{\lambda}-1)v}{\zeta+\lambda^{\sigma-1}\eta} - \mu\right] - (\sigma-1)v \, . \tag{17}$$

It follows that Eqs. (14)–(17) form an autonomous system of three differential equations in (v, ζ, η). Note that since n_0, n_0^N, and $\hat{n}_0^N$ are given as the initial conditions, ζ and η are state variables and v is a jump variable in this system. For any initial values that the economy inherits, (ζ_0, η_0), a market equilibrium for this economy is a path of (v_t, ζ_t, η_t) that satisfies (14)–(17).

We are now ready to examine the effects of a strengthening of IPR protection (defined as a reduction in the rate of imitation, μ) on a balanced growth path (BGP). All endogenous variables grow at constant rates or remain constant: then $\dot{v} = \dot{\zeta} = \dot{\eta} = 0$ along a BGP. Let the BGP value of any variable y (e.g., v, ζ, η, g, etc.) be y^*. From Eqs. (14)–(17), we have:

$$\frac{\sigma-1}{\hat{\lambda}}(\rho+g^*+\mu)\left(\frac{\lambda^{\sigma-1}f(g^*)}{g^*+\mu}+1\right) = L^N - g^* + \frac{f(g^*)}{g^*}\left[L^N-(1+b)g^*\right] , \quad (18)$$

where $f(g;\mu) \equiv \frac{1-\alpha}{b\alpha\hat{\lambda}}\left[(\hat{\lambda}-1)(\rho+g)-\mu\right]$, which is a linear increasing function in g $f' > 0$ and $f'' = 0$. Eq. (18) determines the effect of IPR protection on the long-run (BGP) rate of innovation. It is easy to verify that most variables (e.g., the spending of each region, E^N and E^S, the numbers of non-standardized and standardized products, n^N and $\hat{n}^N$, and the wage rates of both regions, w^N and w^S) grow at the same rate as the BGP rate of innovation, g^*. Therefore, examination of the effect on g^* is required to understand the long-run properties of this economy.

Eq. (18) is so complex that it is difficult to analyze it analytically. We thus calculated a number of numerical examples. A representative example is depicted in Figure 1, where we assume that μ has an upper bound to ensure that $0 \leq \eta^*$. In most examples, the long-run rate of innovation has an inverted U-shaped configuration as a function of μ, which is an inverse measure of IPR protection. Hence, we can show the following proposition:

Proposition 1 *Tightening of IPR protection can increase the long-run rate of innovation.*

Proposition 1 asserts that there exist examples for which stronger IPR enhances the long-run rate of innovation when the protection is too strong. When it is too weak, relaxing IPR, conversely, encourages long-run innovation. This result contrasts sharply with Helpman (1993), who demonstrated a negative relationship between IPR protection and long-run innovation.

The logic behind this result is easy to grasp: the key factor is standardization, which is only one departure from the Helpman model. Stronger IPR protection (a reduction in the rate of imitation) means that standardizers are safer from imitation, leading to an increase in the expected monopoly rent of standardized producers. While non-standardized producers are not affected directly by a decrease in the rate of imitation, stronger IPR increases the number of products that have been standardized, which equals the number of products that can be imitated. It follows that more production shifts to the South owing to increased imitation. Finally, less production remains in the North, so that more resources in the North can be devoted to R&D activity (innovation is enhanced).

Appendix

Derivation of Eq. (18)

Using (14) and (15), we determine the relationship between ζ^* and g^* as

$$\zeta^* = \frac{g^*}{g^* + \frac{1-\alpha}{b\alpha\hat{\lambda}}\left[(\hat{\lambda}-1)(\rho+g^*)-\mu\right]} \ , \tag{19}$$

and the relationship between η^* and g^* as

$$\eta^* = \frac{\frac{1-\alpha}{b\alpha\hat{\lambda}}\left[(\hat{\lambda}-1)(\rho+g^*)-\mu\right]}{\left[g^* + \frac{1-\alpha}{b\alpha\hat{\lambda}}\left((\hat{\lambda}-1)(\rho+g^*)-\mu\right)\right]\frac{g^*+\mu}{g^*}} \ . \tag{20}$$

Eq. (17) also can be rewritten as:

$$v^* = \frac{1}{\sigma-1} = \left[L^N - \frac{g^*\frac{1-\alpha}{\alpha\hat{\lambda}}\left[(\hat{\lambda}-1)(\rho+g^*)-\mu\right]}{g^* + \frac{1-\alpha}{b\alpha\hat{\lambda}}\left[(\hat{\lambda}-1)(\rho+g^*)-\mu\right]} - g^*\right] \ . \tag{21}$$

Substituting (19)–(21) into (14) leads to Eq. (18). ||

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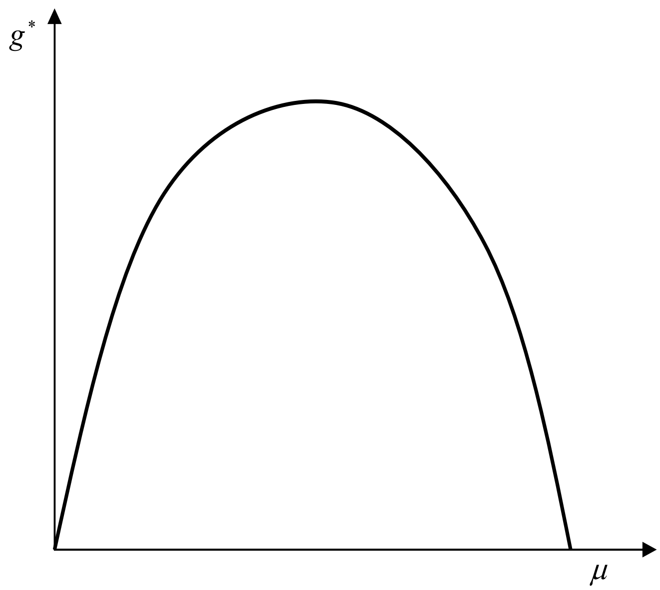

Figure 1: IPR protection and long-run innovation: a suitable parameter set is, for example, $\alpha = 0.8$, $\lambda = 2.15$, $\rho = 0.5$, $\sigma = 5$, $b = 0.1$, and $L^N = 1$.