Intellectual Property Rights, Institutional Quality and Economic Growth

Lewis S. Davis and Fuat Şener[1]

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Abstract

We consider intellectual property rights (IPRs) in a Schumpeterian growth model in which patent holders face the threats of profit loss due to imitation and complete valuation loss due to outside innovation. We disaggregate IPR policies by distinguishing between the quality of the IPR regime and the intensity of IPR enforcement. An increase in the quality of the IPR regime unambiguously promotes growth. However, the relationship between IPR enforcement intensity and growth follows an inverted U-shaped curve. The growth-maximising intensity of IPR enforcement is decreasing in institutional quality. We also investigate the model's welfare implications and examine the economy under a no-growth equilibrium.

Key words: Technological Change; Institutional Quality; Growth; Imitation; Innovation; Intellectual Property Rights.

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[1] Department of Economics, Union College, Schenectady, NY, USA. Corresponding author: davisl@union.edu

1. Introduction

In endogenous growth theory, the protection of Intellectual Property Rights (IPRs) is considered one of the central institutional requisites to generate long-run technological progress. The mechanism is straight forward and well known. IPR protection through patents secures short-term monopoly profits for successful innovators, and these profits provide the key incentive for private agents to engage in costly and risky R&D activities.

Even though early endogenous growth models stressed the role of IPRs in promoting growth, it is only recently that researchers have used these models to investigate how the *degree* of IPR enforcement affects the rate of innovation and social welfare. [2] Grossman and Lai (2004) and Kwan and Lai (2003), Eicher and Garcia-Peñalosa (2007) model imperfect IPR enforcement by assuming that patent holders face a positive probability of losing their market to imitators. In these models, increased IPR enforcement deters imitation, increases the expected returns to innovation, and raises the equilibrium rate of growth. In the context of welfare though, these models identify an interior level of IPR enforcement as welfare-maximising IPR policy. This is because a stronger IPR regime exerts mainly two competing effects on welfare: a dynamic welfare gain through increased innovation rate and a static welfare loss through reduced consumption.

Dinopoulos and Syropoulos (2007) consider a largely neglected and less salutary side of IPRs. They construct a Schumpeterian growth model in which incumbent patent holders may

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[2] See Romer (1990), Segerstrom et al. (1990) and Grossman and Helpman (1991) among others. For example, in the horizontal innovation model of Romer (1990) patents are perfectly enforced and infinitely-lived, while in the neo-Schumpeterian models of vertical-innovation by Aghion and Howitt (1992) and Grossman and Helpman (1991, Ch.4) patent holders face the threat of potential replacement by successful innovators. None of these models consider the possibility of illegal infringement of a patent holder's rights. We should also note that there exists a large literature that examines IPR issues from an international trade and foreign direct investment perspective in endogenous product cycle settings. For recent papers, see Dinopoulos and Segerstrom (2010), Gustafsson and Segerstrom (2010), Sener and Zhao (2009), Sener (2006), and the references therein.

devote resources to activities such as lobbying, private litigation and trade secrecy in an attempt to deter further innovation and preserve their monopoly power.[3] While Dinopoulos and Syropoulos do not investigate IPR enforcement as a policy issue, their model implies that factors that facilitate these "rent-protection activities" by current patent holders increase the research costs of potential innovators and thereby reduce the equilibrium growth rate. Davis and Sener (2010) develop a Schumpeterian growth model that incorporates *both* imitation and innovation deterring behavior by patent holders. In particular, they investigate the growth and welfare effects of subsidies/taxes directed at R&D and rent-protection activities of private agents.

In this paper, we develop a model similar to Davis and Sener (2010) in that we consider both innovation and imitation deterring aspects of IPR enforcement. We depart from Davis and Sener at two levels. First, we provide a more disaggregated treatment of IPR protection by modeling separately three dimensions of IPR protection: the intensity of IPR enforcement, the quality of the IPR regime, and the technical ease of imitation. The first two factors affect both innovation and imitation deterrence. The last factor influences only imitation deterrence and therefore is the element of IPR protection that is most closely related to that in Grossman and Lai (2004) and Kwan and Lai (2003). Second, we focus on public IPR enforcement by considering the intensity of IPR enforcement as a policy tool whose implementation requires real resources. [4]

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[3] Existing estimates suggest that innovation-deterring activities have a significant effect on the cost of research. For example, Lerner (1995) finds the cost of patent litigation cases started in 1991 will account for 27 percent of total R&D expenditures of US companies in that year.

[4] See Maskus (2000) for a comprehensive overview on IPRs in the global economy. According to Maskus (p. 173), the ongoing cost of administering the TRIPs (Trade Related Aspects of Intellectual Property Rights) agreement are estimated at US$1 million for Egypt and US$1.1 million for Bangladesh, though as he notes, these estimates should be treated with caution as they are based surveys of IPR experts in each nation. Maskus (p. 173-174) also notes that these values may substantially underestimate administrative costs: "One of the largest costs of the implementing an effective administration system is that it would divert scarce technical and professional resources … out of other productive activities."

We then study the interplay between the intensity of IPR enforcement and the quality of the IPR regime in the context of innovation and welfare.

The intensity of IPR enforcement is a policy variable and captures the fraction of resources devoted to total IPR enforcement, including both innovation and imitation deterrence.[5] The quality of the IPR regime captures the ability of the IPR regime to mobilise enforcement resources away from innovation deterrence and towards imitation deterrence. In that sense, the quality of the IPR regime refers to the *de facto* efficiency of IPR protection and is closely tied to the quality of institutions of contract enforcement and property rights protection, e.g. the quality of courts, the rule of law and the control of corruption. Our quality measure captures the IPR regime's effectiveness in distinguishing between threats to incumbent patent holders due to illegitimate imitation and threats due to legitimate innovation. Because institutional variables are in part determined by slowly changing cultural norms, we treat the quality of the IPR regime as being outside the realm of the policy makers' control. In contrast, the intensity of IPR enforcement may be freely chosen by policy makers.

Our setting is a Schumpeterian growth model with a continuum of industries. In each industry, entrepreneurs participate in R&D races to innovate higher quality products. Successful innovators drive out incumbent firms and enjoy temporary monopoly power. During their tenure, monopolists face two threats: permanent replacement by outside innovation and the temporary loss of their market to imitators. The level of IPR enforcement is in proportion to the amount of resources in the economy. This creates a mechanism by which the resource requirement in innovation and thus R&D difficulty increases at the rate of population growth. The resulting model belongs to the class of fully-endogenous non-scale Schumpeterian growth model in which

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[5] In this sense, our model captures the notions of lagging and leading patent breadth as proposed in the patent design literature. The former limits imitation whereas the latter limits innovation. See O'Donoghue and Zweimueller (2004), Chu (2009) and Li (2001) for models of endogenous growth with patent breadth.

policy changes affect the steady-state innovation rate by altering the fraction of resources devoted to R&D.[6]

Our first result concerns the distinct innovation effects of the two dimensions of IPR enforcement. We find that an increase in the quality of the IPR regime has a strictly positive effect on the rate of growth. In contrast, an increase in the intensity of IPR enforcement has a positive effect on the rate of growth if and only if the imitation threat faced by innovators is higher than a threshold level. Moreover, we identify an inverted-U relationship between the intensity of IPR enforcement and innovation activity. When IPR intensity is low, increasing IPR promotes growth. Beyond a certain level of enforcement, increases in IPRs has a detrimental effect on growth. Thus, the model establishes a growth-maximising level of IPR intensity. [7]

Our second result concerns the relationship between growth-maximising intensity of IPR enforcement and institutional quality. We find that for countries with high-quality IPR regimes, maximising growth calls for a relatively low intensity of IPR enforcement. For countries with intermediate-quality IPR regimes, maximising growth calls for a relatively high intensity of IPR enforcement. Hence, in an interior equilibrium range, the growth-maximising intensity of IPR enforcement is decreasing in the quality of the IPR regime. Finally, countries with sufficiently

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[6] The other class consists of semi-endogenous non-scale growth models where policy changes exert only a temporary impact on the innovation rate with no steady-state impact. For semi-endogenous growth models see, among others, Jones (1995) and Segerstrom (1998). For fully-endogenous growth models see Dinopoulos and Syropoulos (2007), Aghion and Howitt (1998, ch. 12), Sener (2008), Dinopoulos and Thompson (1998). See Dinopoulos and Şener (2007) for a recent analysis of scale-invariant growth theory, and also Jones (2005) for a comprehensive overview. Fully-endogenous growth models have recently received more empirical support than semi-endogenous growth models, see e.g. Ha and Howitt (2007), and Madsen (2007, 2008), Ang and Madsen (2010). For arguments in favour semi-endogenous growth, see Jones (2005).

[7] We should note that a number of recent models can generate an inverted U-shaped relationship between IPR enforcement and economic growth albeit through substantially different mechanisms rather than innovation-deterrence. Furukawa (2007) and (2010) generate such a mechanism by considering the negative effects of IPRs on experience accumulation through learning-by-doing. See also Akiyama and Furukawa (2009) and Horii and Iwaisako (2007). Two recent papers Qian (2007) and Lerner (2009) provide empirical support for the inverted-U relationship. However, the empirical literature does not offer a consensus on this issue. See Park (2008) for an extensive overview of the theoretical and empirical literature.

low levels of IPR regime quality can be trapped in a no-growth boundary equilibrium, in which case even large marginal changes in the intensity of IPR enforcement are not sufficient to generate growth

We also conduct a welfare analysis and identify two channels through which IPR enforcement affects welfare: a dynamic effect associated with innovation changes and a static effect associated with real consumption and price changes. Since growth is not monotonically increasing in IPR enforcement, our model predicts that increased IPR enforcement can lead to a dynamic gain or loss. This is a departure from the literature where IPR enforcement always leads to a dynamic gain as it raises growth. We find that economies can have too much or too little IPR enforcement depending on their parameters. We show this ambiguity explicitly by conducting extensive numerical simulations. We also find that the growth-maximising intensity and the welfare-maximising intensity levels are very close and that growth and welfare have the same inverted U shape when mapped against IPR enforcement intensity. We thus conclude that the dynamic effects of increased IPR intensity nearly always dominate the static effects. We also examine the effects of increased quality of IPR regime on welfare and found that welfare is monotonically increasing in the quality of IPR regime. This is because the innovation rate is always increasing in the quality of the IPR regime and again dynamic effects dominate the static effects.

Finally, we examine optimal welfare policies by combining boundary and interior equilibrium analysis under the feasible range of IPR regime quality levels. We find that for countries with relatively high quality IPR regimes, welfare maximisation calls for an optimal IPR enforcement intensity in the interior range. For countries with levels of IPR regime quality below an identifiable threshold, welfare maximisation implies complete abolishment of IPR protection.

For these countries, welfare in the boundary equilibrium with no innovation dominates welfare in the interior equilibrium with positive innovation. Intuitively, the welfare gains to promoting competition and eliminating monopoly power in such economies dominates attempts to generate growth.

By incorporating a measure of institutional quality into the analysis, we are able to address an issue on which the current theoretical literature is silent: how the costs and benefits of IPR enforcement differ across countries at different levels of development. Following the Jones critique (1995) of the early endogenous growth models, growth theorists have worked to eliminate scale effects from their models, but the non-scale growth theory cannot support models in which the growth rate is a function of the level of per capita income. Such a model would exhibit what Davis (2008, p. 408) identifies as "intensive scale effects," which tend to "generate explosive pattern of rising returns [to capital] and accelerating output." Here, this potentially explosive feedback loop does not occur because the level of economic development is proxied by the (exogenous) quality of institutions rather than with the level of per capita income.

2. The Model

The economy consists of a continuum of industries. In each industry, entrepreneurs hire workers to create higher quality products. Successful innovators obtain patents to hold the exclusive legal right to use their technology. Consumers prefer higher quality products over lower quality ones by a certain margin. By engaging in limit pricing, patent holders can force the lower-quality producers out of the market. While enjoying monopoly power, patent holders face two threats: permanent replacement due to successful innovation and temporary loss of their market to imitators. More intense IPR enforcement works to deter both innovation and imitation activities targeted at incumbents.

2.1 Households

There is a unit continuum of infinitely-lived dynastic households. Each household starts at time $t = 0$ with a single member and grows at an exogenous rate $n > 0$, such that population size at time t is given by $N(t) = e^{nt}$. Households discount future utility at a rate $\rho > 0$, so that dynastic utility is given by

$$U = \int_0^\infty e^{-(\rho-n)t} \log u(t) dt, \tag{1}$$

We assume the household discount rate is positive: $\rho - n > 0$. Households consume goods from a unit continuum of industries indexed by $\theta \in [0,1]$. Instantaneous per capita utility, $u(t)$, is defined as follows:

$$\log u(t) = \int_0^1 \log\left[\lambda^k Z(k,\theta,t)\right] d\theta \tag{2}$$

The variable $Z(k,\theta,t)$ is the consumption of good θ of quality k at time t. The parameter $\lambda > 1$ defines the size of quality improvements. Each household allocates its per capita consumption expenditure c to maximise log $u(t)$ given prices at time t. Adjusted for quality, goods in an industry perfect substitutes, so that households purchase only the good with the lowest quality-adjusted price. Moreover, products enter the utility function symmetrically, thus households spread their consumption expenditure evenly across the continuum of industries. The resulting demand functions are identical across industries, with

$$Z(k,\theta,t) = cN(t) / p \tag{3}$$

where *c* is per capita consumption expenditure and *p* is the price of the purchased good.

Maximising (1) subject to the standard intertemporal budget constraint and considering (3) produces the familiar equation of motion for *c*:

$$\frac{\dot{c}}{c} = r - \rho \tag{4}$$

where r is the market rate of interest. In the steady state, $r = \rho$ such that consumption expenditure is constant. Economic growth takes the form of increases in utility due to the introduction of higher quality goods available at a constant set of prices.

2.2. Production

In each industry along the continuum, there exists a successful innovator who has the exclusive legal right via a patent to produce the highest quality good. The incumbent's patents, however, are imperfectly enforced. In particular, we assume that at each point in time, there exists a positive probability *m* that the incumbent's patents will not be enforced.

When patents are perfectly enforced with probability (1 - *m*), the quality leader (i.e., the patent holder) competes with followers who can produce the one-step-down quality product. Production of one unit of good requires one unit of labour regardless of the quality level. Thus the marginal cost of production equals the wage, which is taken to be the *numeraire*: $w = 1$. Given the equal production costs, the patent holder can drive the followers out of the market by engaging in limit pricing. More specifically, the leader offers the lowest quality-adjusted price by charging $p = \lambda$. The followers cannot do better than break even and exit the market. Provided the incumbent's patent is successfully enforced, the instantaneous monopoly profit is given by:

$$\pi(t) = \left[\frac{\lambda - 1}{\lambda}\right] cN(t), \tag{5}$$

where $\lambda - 1$ is the profit margin and $cN(t)/\lambda$ is the total output sold.

With probability *m*, the incumbent's patents are not enforced and the quality leader competes with a large number of imitators who can produce the same quality level product. In this case, production takes place under competitive conditions. Price competition implies marginal cost pricing, $p = 1$, and profits are driven to zero. Combining the levels of production under a competitive market $mcN(t)$ and the monopoly market $(1 - m)[cN(t) / \lambda]$, the expected production of a representative good at each moment in time, is given by

$$Z^e(t) = \left[\frac{1+(\lambda-1)m}{\lambda}\right] cN(t) \tag{6}$$

Equation (6) shows that expected consumption of each good is increasing in the probability of imitation *m*, since in a competitive market goods are offered at a lower price compared to a monopolised market. We note that the average price for goods prevailing in the market is

$$P(m) = \frac{\lambda}{1+(\lambda-1)m} \in [1, \lambda] \tag{7}$$

which lies in the interval $P(m) \in [1, \lambda]$ and is decreasing in *m*. Exploiting symmetry across industries and a unit interval of industries, we derive employment in the production sector as:

$$N_Q(t) = \left[\frac{1+(\lambda-1)m}{\lambda}\right] cN(t) \tag{8}$$

2.3. IPR Enforcement

The extent of IPR enforcement $X(t)$ depends on the total resources devoted to patent protection, which is given by

$$X(t) = N_X(t) = kN(t) \tag{9}$$

In this equation, $k \in [0,1]$ is the fraction of total resources devoted enforcement, which we will refer to as the intensity of IPR enforcement. IPR enforcement protects patent holders against two threats: temporary loss of their market to imitators and permanent replacement by a successful innovator. The relative strength of patent protection against these threats depends on the quality of the IPR regime. A higher quality IPR regime allocates more resources to imitation deterring and less resources to innovation deterrence. We introduce the parameter $\gamma \in [0,1]$ to capture the allocative role of IPR regime. In particular, the strength of innovation deterrence and imitation deterrence are given by $X_R = (1-\gamma)X$ and $X_M = \gamma X$. Substituting from (9), we have

$$X_R = (1-\gamma)kN \tag{10}$$

$$X_M = \gamma kN \tag{11}$$

Since patent protection systems are intended to promote innovation by protecting the rights of innovators from illicit imitation, a larger value of γ indicates that more IPR enforcement resources are devoted to this task. In contrast, a lower value of γ indicates that a larger portion of the total patent protection effort is devoted to deterring innovation. In this regard, a low value of γ may be interpreted as a large gap the between *de jure* and *de facto* patent protection.

2.4. Imitation

We model the probability of imitation *m* as an endogenous variable determined by

$$m = \frac{\mu N(t)}{X_M(t)}. \tag{12}$$

In this equation, *m* increases with *N(t)*: the larger the population size, the greater the number of potential imitators and the larger the probability of imitation. This in the spirit of Aghion and

Howitt (1998, Chapter 12). Substituting in from (11) and noting that the probability of imitation cannot exceed one, we have

$$m = \min\left\{\frac{\mu}{\gamma k}, 1\right\}. \tag{13}$$

We use three parameters in order to distinguish between different sources of constraints on potential imitators. The first parameter $\mu > 0$, which we refer to as the *technical ease of imitation*, captures the technological constraints on imitation. The legal constraints on imitation are captured by two factors, the quality of the IPR regime γ and the intensity of IPR enforcement *k*. Equation (13) above implies that other things equal, the probability of imitation *m* will be higher in countries with lower γ and lower *k*. Note also that with μ and γ given, equation (13) defines the threshold level of *k* necessary for patent holders to capture some of the market for their good as: $\bar{k} = \frac{\mu}{\gamma}$. Below this threshold intensity of IPR enforcement, the probability of imitation *m* equals one, indicating that imitators capture the entire market at every point in time.

2.5 Innovation

Entrepreneurs in each industry participate in R&D races to invent higher quality products. At any point in time, the current patent holder faces multiple entrepreneurs who seek to replace her as the market leader by discovering the good one step up the quality ladder. An entrepreneur *j* that invests R_j(t) in research at time *t* discovers the next higher-quality product with instantaneous probability

$$i_j = \frac{R_j(t)}{X_R(t)} \tag{14}$$

where $R_j(t)$ is the entrepreneur's investment in R&D.[8] Note that the probability of innovation is decreasing in X_R, a characteristic that reflects the innovation deterring effects of patent protection. Let $V(t)$ denote the value of a successful innovation and a_R the unit labour requirement in R&D. Free-entry into R&D implies:

$$\begin{cases} i_j V(t) - a_R R_j(t) \le 0 \\ R_j(t) \ge 0 \end{cases} \tag{15}$$

where strict equality must hold in exactly one of the lines of (15). $i_j V(t)$ is entrepreneur *j*'s expected reward from undertaking R&D and $a_R R_j(t)$ is her expenditure on R&D. Substituting (10) and (14) into (15), we can express the free entry condition in R&D as follows:

$$\begin{aligned} & V(t) \le a_R (1-\gamma) k N(t) \\ & i \ge 0 \end{aligned} \tag{16}$$

where at least one equation holds with equality. Provided the innovation rate *i* is positive, the first line of (16) will hold with equality, indicating that the value of a patent equals the cost of innovation. If the cost of innovation exceeds the value of a patent, then the second line of (16) will hold with equality and *i* will be zero.

The probability of successful innovation is assumed to be independently distributed over entrepreneurs, industries and time. For a representative industry, the rate of innovation is found by summing over the probability of innovation of each researcher:

$$i = \sum_j \frac{R_j(t)}{X_R(t)} = \frac{R(t)}{(1-\gamma) k N(t)} \tag{17}$$

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[8] Note that in the absence of patent enforcement $X_R = 0$, the level of innovation is indeterminate. While the value of a patent is zero, equation (14) implies that the probability of innovation is infinite. This indeterminacy is a result of assuming that the innovation deterrence is the only barrier to a successful discovery. If we assume instead that the denominator of (14) includes an additive term, $\varepsilon > 0$, unrelated to legal costs and maybe related to technological constraints, then innovation will be zero in the absence of patent enforcement. We do not explicitly model such costs to facilitate the exposition but simply note that no resources are devoted to research in the absence of patent enforcement.

In each industry, the arrival of innovations follows a Poisson process with intensity *i*, which we call the rate of innovation. Total employment in the research sector is given by:

$$N_R(t) = a_R R(t). \tag{18}$$

2.6. Valuation of Patents

In equilibrium, the value of a patent *V(t)* is determined by an arbitrage condition that holds that at each point in time, which equates the expected returns on the stocks issued by the successful innovator to the market interest rate *r*(*t*). This condition takes the form:

$$rV(t) = (1-m)\pi(t) - iV(t) + \dot{V} \tag{19}$$

The left-hand side of this equation is the return available to the firm's owners if they were to invest an equivalent sum in risk-free bonds. On the right-hand side, the first term is the expected profit flow taking into account the probability of imitation, the second term is the expected instantaneous capital loss due to replacement by a successful innovator, and the final term captures the capital gain due to the increase in the value of the firm.

Substituting $\dot{V}(t) = nV(t)$, which follows from (16), and $r = \rho$, the equilibrium condition for the market interest rate, into (19) gives an expression that relates the value of the firm to instantaneous profit:

$$V(t) = \left[\frac{1-m}{\rho - n + i}\right]\pi(t) \tag{20}$$

This expression implies that the value of the firm equals monopoly profits π discounted by the effective discount rate, $\rho^* \equiv \frac{\rho - n + i}{1-m}$, which is the household's discount rate $\rho - n$ adjusted upward to compensate investors for the risk of replacement and the expected loss of profits to imitators.

2.7. The First Steady State Condition: The Free Entry Condition

We establish the steady-state equilibrium by reducing the model to two equations in *i* and *c*. First, we substitute (5) and (20) into the free-entry condition (16). This provides

$$\left[\frac{1-m}{\rho-n+i}\right]\left[\frac{\lambda-1}{\lambda}\right]c = a_R(1-\gamma)k \tag{21}$$

where the left hand side is the expected discounted rewards from successful innovation while the right hand side is the marginal cost of innovation.

As shown in Figure 1, the free-entry condition *FE* is an upward sloping line in *c*-*i* space. The intuition is as follows. An increase in consumption expenditure *c* raises the monopoly profits and thus the rewards from R&D. This encourages entry in R&D races and the intensity of innovation *i* increases. The zero profit condition is restored via a fall in the value of patents triggered by the increased replacement rate *i*. The horizontal and vertical intercepts of the FE curve are given by $c_{FE} = a_R(1-\gamma)k(\rho-n)\left[\frac{1}{1-m}\right]\left[\frac{\lambda}{\lambda-1}\right] > 0$ and $i_{FE} = -(\rho-n) < 0$, and the slope of the *FE* locus is given by

$$\left.\frac{di}{dc}\right|_{FE} = \frac{(\lambda-1)(1-m)}{\lambda a_R(1-\gamma)k} > 0 \tag{22}$$

where the sign of (22) follows from $k > \bar{k} = \frac{\mu}{\gamma}$. If $k < \bar{k}$, then *m* = 1 and the *FE* locus is a horizontal line at $i_{FE} = -(\rho-n) < 0$. Below the level of *c* indicated by the horizontal intercept, c_{FE}, the returns to innovation are insufficient to generate positive *i*. In this case, all resources will be devoted to the production of goods and none to innovation. Thus, as shown in Figure 1a, the locus of points consistent with the FE condition is given by the portion the (21) that lies in the first quadrant along with the horizontal axis along the interval $(0, c_{FE})$.

2.8 The Second Steady State Condition: The Resource Constraint

Labour is supplied inelastically; thus, labour supply is equal to population size $N(t)$. Workers may be employed in production or R&D. Since there is a unit measure of industries, we can write the labour market equilibrium condition as

$$N = N_Q + N_X + N_R \tag{23}$$

In equilibrium, labour allocated to each activity will grow at the rate of population growth, so that the share of labour in each activity remains constant. Substituting in from (8), (9), (17) and (18), we can express the resource constraint as

$$1 = \left[1 + (\lambda - 1)m\right]\frac{c}{\lambda} + a_R(1-\gamma)ki + k \tag{24}$$

In this expression, the first term is the share of resources devoted to goods production, which also equals real consumption, the second term is the share of resources devoted to R&D, and the final term is the fraction of resources employed in IPR protection.

As shown in Figure 1, the *RC* condition is a downward sloping line in *c*-*i* space. The intuition is that an increase in goods production triggered by a rise in *c* will imply less resources available for innovation and thus a decline in *i*. The horizontal and vertical intercepts of the *RC* locus are given by $c_{RC} = \dfrac{\lambda\gamma k(1-k)}{\gamma k + (\lambda - 1)\mu} > 0$ and $i_{RC} = \dfrac{1-k}{(1-\gamma)a_R k} > 0$, respectively, and the slope of the *RC* locus is given by

$$\left.\frac{di}{dc}\right|_{RC} = -\frac{\gamma k + (\lambda - 1)\mu}{\lambda(1-\gamma)a_R\gamma k^2} < 0. \tag{25}$$

As with the free-entry condition, these expressions assume $k > \bar{k} = \dfrac{\mu}{\gamma}$, such that the probability of imitation *m* is less than one.

2.9 Interior and Boundary Equilibria

The model supports both interior and boundary equilibria. We use "*" to represent equilibrium values. In an interior equilibrium, $i*$ is positive, and $i*$ and $c*$ are jointly determined by intersection of the *FE* and *RC* loci as shown in *Figure 1a*. The corresponding expressions for per capita consumption expenditure $c*$ and innovation rate $i*$ are given by

$$\begin{aligned} c* &= 1-k+a_R(1-\gamma)(\rho-n)k \\ i* &= \frac{(1-k)(\lambda-1)(\gamma k-\mu)-\left[\gamma k+(\lambda-1)\mu\right]a_R(1-\gamma)k(\rho-n)}{\lambda a_R(\gamma-\gamma^2)k} > 0 \\ m* &= \frac{\mu}{\gamma k} \end{aligned} \tag{26}$$

In the first line of (26), we see that $c*$ equals the wage rate (normalised to one) minus the fraction of resources allocated to IPR enforcement, k, which is equivalent to a lump-sum tax, plus income from the household's assets. From (16), the equilibrium value of patents held by households is given by $V = a_R(1-\gamma)kN$, which implies that the per-capita income flow generated by these assets is $(\rho-n)V/N = (\rho-n)a_R(1-\gamma)k$.

As illustrated in *Figure 1b*, a boundary equilibrium occurs provided $c_{FE} > c_{RC}$. In this case, no resources are allocated to R&D, the rate of economic growth is zero, and consumption expenditure is determined by the intersection of the RC condition with the horizontal axis:

$$\begin{aligned} c** &= \frac{\lambda(1-k)}{1+(\lambda-1)m**} > 0 \\ i** &= 0 \\ m** &= \min\left\{\frac{\mu}{\gamma k},1\right\} \end{aligned} \tag{27}$$

The first line of (27) indicates that in the boundary equilibrium, c** is equal to real consumption $(1-k)$ multiplied by the price level $P(m)=\dfrac{\lambda}{1+(\lambda-1)m}$. Note that in the boundary equilibrium we must allow for the possibility that the probability of imitation *m* is one. Thus, we do not impose the impose the condition $m=\dfrac{\mu}{\gamma k}$ in the first line of (27), preferring the more general expression $m=\min\left\{\dfrac{\mu}{\gamma k},1\right\}$.

As noted above, a boundary equilibrium occurs provided consumption expenditure in each industry is insufficient to generate the stream of expected profits necessary to compensate innovators for the cost of R&D. The condition for a boundary equilibrium may be expressed in terms of the quality of the IPR regime as follows:

> ***Proposition 1***: Given $k\in(\mu,1)$, there exists a unique value of gamma $\tilde{\gamma}(k)\in\left(\dfrac{\mu}{k},1\right)$ such that the interior equilibrium obtains if and only if $\gamma>\tilde{\gamma}(k)$ and the boundary equilibrium obtains otherwise. Given $k\in(0,\mu]$, the boundary equilibrium obtains for all $\gamma\in(0,1)$.

We will refer to the locus of points $\left(\tilde{\gamma}(k),k\right)$ as the *boundary equilibrium threshold*. The intuition for *Proposition 1* is discussed below where we address the comparative static effects of an increase in the quality of the IPR regime.

3. Comparative Statics of IPR Enforcement

In this section we investigate the impact of changes in IPR enforcement on the equilibrium values of the endogenous variables, namely the innovation rate *i* and consumption expenditure *c*. We consider the impact of one policy variable, the intensity of IPR enforcement *k*, and two exogenous parameters, the quality of the IPR regime γ and the technical ease of imitation μ. Because the previous literature has tended to associate the strength of IPR protection with μ, comparing the effects of μ with those of γ and k allows us to highlight the additional insights we gain by modeling IPR enforcement in a more disaggregated fashion.

3.1 An increase in the intensity of IPR enforcement

We first investigate the effects of an increase in the intensity of IPR enforcement *k*. In the FE condition, a larger *k* exerts two competing effects on R&D profitability.

- The *research cost effect of innovation deterrence*: A larger *k* increases R&D costs by increasing the R&D resource requirement $a_R X_R$.
- The *market protection effect of imitation deterrence:* A larger *k* increases the profit flows of innovators by reducing the probability of imitation *m*.

The direction of the shift in the FE curve depends on the relative magnitudes of these effects. We find that an increase in *k* shifts the *FE* curve upward if and only if $m > 1/2$. In this case the market protection effect of IPR enforcement dominates the research cost effect, indicating an increase in the profitability of R&D activity.

In the labour market, a higher intensity of IPR enforcement *k* generates three effects on the resource allocation.

- The *resource-using effect of IPR enforcement*: A larger *k* directly increases the share of resources allocated for IPR enforcement.

- The *resource-using effect of innovation deterrence*: A larger k increases the unit labour requirement of R&D, $a_R X_R$, and thereby increases the resources required to perform any given level of innovation.
- The *resource-saving effect of imitation deterrence*: A decline in the probability of imitation m implies a higher fraction of monopolised markets in the continuum of industries. Since a monopolised market produces less output relative to a competitive market, an increase in the share of monopolised markets reduces the demand for resources for goods production and frees up resources for innovation.

The shift in the RC curve depends on the magnitude of these competing effects.

To resolve the ambiguities, we differentiate equations (26) with respect to k, which implies:

$$\frac{dc^*}{dk} = -1 + a_R(1-\gamma)(\rho - n),$$

$$\frac{di^*}{dk} > 0 \quad \text{iff} \quad m^* = \frac{\mu}{\gamma k} > \frac{1}{2 - k + a_R(\rho - n)k(1-\gamma)}. \tag{28}$$

In the first line of (28) the first term is the marginal resource cost of k. The second term is the marginal rise in the income flow from household's patents due to one more unit of k. Thus c^* will increase if and only if the at the margin the income flow gain exceeds the resource cost of additional enforcement.

It follows from the second line of (28) that more intense IPR enforcement captured by a larger k can boost i^*if and only if the imitation probability m^* is higher than a critical level. This condition is more likely to hold at lower levels of IPR enforcement quality γ, higher levels of technical imitation ease μ and lower levels of IPR intensity k. Intuitively, the growth-promoting effects of higher IPR enforcement (namely, the market protection and resource-saving effects) must dominate the growth-suppressing effects (namely the research cost and resource-using effects). We address to this relationship in more detail in the section on growth and IPR policy below, following the presentation the remaining comparative static results.

3.2 An increase in the quality of the IPR regime

An increase in γ shifts IPR enforcement resources from deterring innovation to deterring imitation. It follows from equation (12) that a larger γ renders imitation more difficult and reduces the probability of imitation m. This increases the *market protection effect of imitation deterrence* and, thereby, increases the rewards from R&D. In the meantime, as seen in (14), a larger γ reduces the share of IPR enforcement resources, reducing the *research cost effect of innovation deterrence*. Because both effects raise the profitability of R&D activity i, the *FE* curves shifts up for any given c. In the labour market, the lower m generates a *resource-saving effect of imitation deterrence* and frees up resources for innovation i. At the same time, a larger γ reduces the unit labour requirement in R&D, reducing the *resource-using effect of innovation deterrence.* Thus the *RC* curve shifts up for any given c. With both curves shifting up in Figure 1a, the equilibrium innovation rate i clearly increases, however the change in consumption expenditure c is ambiguous. To resolve the ambiguity, we differentiate equation (26), which indicates $\frac{dc^*}{d\gamma} = -a_R(\rho - n)k < 0$. The fall in c^* results from the decrease in the income flow coming from household's assets.

Two observations are in order when we compare the impact of an increase in γ to an increase in k. First, when there is an increase in IPR enforcement quality γ, the unit labour requirement of R&D $a_R X_R$ decreases. This is in contrast to the case of an increase in k, which causes $a_R X_R$ to increase. The reason is that a larger IPR enforcement intensity acts to deter *both* imitation and innovation without distinguishing between the two, whereas an increase in the quality of the IPR regime increases imitation deterrence while decreasing innovation deterrence. Second, unlike an increase in the intensity of IPR enforcement, and increase in the quality of enforcement does not require additional resources to be allocated to enforcement activities. In short, all effects triggered by an increase IPR quality γ work to boost R&D.

3.3 A decrease in the technical ease of imitation

As seen in (13), a fall in the technical ease of imitation μ decreases the probability of imitation m and triggers a *market protection effect* similar to that induced by an increase in imitation deterrence. This increases the expected returns to *R&D* activity and shifts the *FE* curve up for a given c, in Figure 1a. In the labour market, the lower m implies a reduction in the fraction of competitive industries. This generates a *resource-saving effect* since monopolised industries produce less than competitive industries. Thus, the *RC* curve shifts up for a given c. Changes in μ do not generate research cost effects or other resource allocation effects. With both curves shifting up, i^* increases whereas the change in c^* is ambiguous. Totally differentiating equation (26), we find the $\mathrm{d}c^*/\mathrm{d}\mu = 0$. This is because in equilibrium changes in μ exert no influence on neither the income flow generated from assets $a_R(1 - \gamma)k$ and nor on the resources used in IPR enforcement k.

Table 1 summarises the comparative static results for k, γ and μ and identifies the mechanisms through which each parameter change operates. We note that the existing growth literature has identified the rate of imitation as the primary measure of the (lack of) IPR protection. Because of this, this literature has identified the market protection and resource-enhancing effects of imitation deterrence. These effects are also present in our model, and indeed are characteristic of increases in both the quality of the IPR regime and the intensity of

IPR enforcement. However, we also identify additional mechanisms through which IPR enforcement may affect economic outcomes. In particular, we identify the asymmetric effects of changes in the intensity and quality of the IPR regime on innovation deterrence. Finally, we consider the resource cost of IPR enforcement. None of these additional effects are present in the existing literature.

4. IPR Enforcement and Economic Growth

In this section we investigate the relationship between the exogenously given quality of the IPR regime γ, and the innovation-maximising intensity of IPR enforcement. We also examine the boundary equilibrium.

The condition in the second line of (28) may be used to identify the *maximum innovation locus*, which is defined by the parameter values (γ, k) for which $\frac{di^*(\gamma,k)}{dk} = 0$. Solving this condition for *k* provides an expression for the innovation-maximising value of *k* as a function of γ:

$$\hat{k}(\gamma) = \frac{2}{1 + \frac{\gamma}{\mu} - a_R(\rho - n)(1-\gamma)}. \tag{29}$$

As shown in Figure 2, in γ–k space this locus intersects the *k*-axis at a positive value $\hat{k}(0) = \frac{2\mu}{\mu + a_R(\rho - n)\mu - 1} > 0$, and has a negative slope, $\frac{d\hat{k}}{d\gamma} = -\frac{1}{2}\left[a_R(\rho - n) + \frac{1}{\mu}\right]k^2 < 0$. Thus, for a country in an interior equilibrium, the level of intensity of IPR enforcement that maximises the innovation rate is lower with higher quality IPR enforcement. Note also that below the *maximum innovation locus*, the innovation rate is increasing in *k*, while at points above this locus the innovation rate is decreasing in *k*. To complete the analysis we turn our attention to the boundary equilibrium. Figure 2 combines the innovation-maximisation locus with the

Boundary Equilibrium threshold identified in *Proposition 1*. This allows us to depict graphically the relationship between *i* and *k* for different values of γ. The following proposition shows that the shape of the *BE threshold* is consistent with that shown in Figure 2:

Proposition 2:

A. Given $(k,\gamma)\in(\mu,1)\times(0,1)$, the following hold:

   a. If $k<\hat{k}(\tilde{\gamma}(k))$, then $\frac{d\tilde{\gamma}(k)}{dk}<0$.

   b. If $k>\hat{k}(\tilde{\gamma}(k))$, then $\frac{d\tilde{\gamma}(k)}{dk}>0$.

   c. If $k=\hat{k}(\tilde{\gamma}(k))$, then $\frac{d\tilde{\gamma}(k)}{dk}=0$.

B. Let γ_0 be defined by the intersection of the *maximum innovation locus* and the *boundary equilibrium condition*. It follows that there exists a $k\in(0,1)$ such that the rate of innovation is positive if and only if $\gamma>\gamma_0$.

The proof of *Proposition 2* is presented in the appendix.[9]

Indicated in Figure 2, at points to the left of the *BE threshold* locus, the quality of the IPR regime is too low to support positive equilibrium levels of innovation, $\gamma<\gamma_0$. As a result, *i** = 0 and innovation is unresponsive to marginal changes in the intensity of IPR enforcement. In contrast, points to the right of the *BE threshold* are marked as *IE* to indicate an *Interior Equilibrium* and positive innovation rates. Within the IE regions, *i* is increasing in *k* for points below the *maximum innovation locus* and decreasing in *k* for points above the locus.

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[9] This appendix is available online. See: http://minerva.union.edu/senerm/ and http://minerva.union.edu/davisl/.

We summarise these results in the following proposition:

> ***Proposition 3***: The innovation-maximising intensity of IPR enforcement $\hat{k}$ depends on the quality of the IPR regime γ in a non-linear fashion. In a country with $\gamma \le \gamma_0$, the rate of innovation *i* will be zero regardless of the intensity of IPR enforcement *k*. In contrast, in a country with $\gamma > \gamma_0$, positive innovation rates *i* will occur for some feasible levels of *k*. In these countries, $\hat{k}$ is decreasing in γ.

The idea that growth-maximising intensity of IPR enforcement intensity will be lower in countries with high institutional quality may strike some readers as counter intuitive. The logic of this outcome is as follows. Consider two countries with the same level of IPR enforcement intensity *k* and assume that there is an institutional change that *reduces* the quality of the IPR regime γ for one of the countries. For this county, a net innovation gain will materialise from increasing *k*. More specifically, the change in the growth-promoting effects minus the change in growth-suppressing effects due higher *k* will be positive. Hence, this county will respond to reduced institutional quality by increasing its intensity of IPR enforcement.

In the context of Figure 2, we now consider the relationship between the intensity of IPR enforcement *k* and the innovation rate *i* for a country in an interior equilibrium with the quality of IPR regime as $\gamma_1 > \gamma_0$. Let $k^L(\gamma_1)$, $\hat{k}(\gamma_1)$, and $k^U(\gamma_1)$ be the values of *k* defined by the intersections of the line $\gamma = \gamma_1$ with the lower branch of the BE locus, the maximum innovation locus, and the upper branch of the BE locus, respectively, as shown in Figure 2. For $k \in \left(0, k^L(\gamma_1)\right)$, the economy will be in a boundary equilibrium and the innovation rate is zero. For $k \in \left(k^L(\gamma_1), \hat{k}(\gamma_1)\right)$, the economy is in an interior equilibrium and the innovation rate is positive. Moreover, within this range, the innovation rate is increasing in the intensity of IPR enforcement until it reaches its maximum value at $k_1 = \hat{k}(\gamma_1)$. For $k \in \left(\hat{k}(\gamma_1), k^U(\gamma_1)\right)$ the innovation rate positive and decreasing in the intensity of IPR enforcement. And, finally, for $k \in \left(k^U(\gamma_1), 1\right)$ the economy is once more in a boundary equilibrium and the innovation rate is equal to zero. The corresponding relationship between *k* and *i* is also shown in Figure 3 as an inverted U-shaped curve.

The analysis presented above suggests caution in choosing the intensity of IPR enforcement. Unlike the existing literature which posits a monotonic relationship between IPR enforcement and the rate of innovation, we find that beyond some threshold level of *k*, increases in IPR enforcement intensity actually decrease the equilibrium rate of innovation. Moreover, the innovation-maximising level of IPR enforcement varies inversely with the quality of a country's institutions of IPR enforcement. In countries with high quality IPR regimes, this indicates less scope for increasing innovation through devoting more resources to IPR enforcement. Thus, they will choose lower levels of *k* to maximise *i*. In contrast, in countries with lower quality IPR regimes this implies greater scope for increasing innovation by increasing the resources devoted to IPR enforcement. Thus, they will choose higher levels of *k* to maximise *i*. Finally, the model suggests that for countries with sufficiently low quality institutions of IPR enforcement, attempts to spur innovation through the protection of IPRs may be entirely ineffectual.

The inverted U-shaped relation between IPR enforcement on innovation in Figure 3 contrasts strongly with the early literature on optimal IPRs, in particular, Grossman and Lai (2004) and Kwan and Lai (2003). This literature has only identified the market protection and resource-enhancing effects and hence posits an unambiguously positive relationship between innovation and IPR enforcement. Our departure is a direct consequence of our incorporating both the market protection and research cost effects of IPR enforcement, as well as the associated resource distortions. Moreover, our model qualifies the relationship between IPR enforcement and growth by demonstrating that a marginal increase in the intensity of IPR enforcement is more likely to increase innovation in economies with relatively lower IPR enforcement quality γ, higher imitation technology parameter γ and lower levels of IPR intensity k .

5: Steady-State Welfare Analysis

As in the standard quality-ladders growth model of Grossman and Helpman (1991, Ch. 4), the economy immediately jumps to the steady-state without exhibiting transitional dynamics. [10] Using this property, we can express steady-state welfare as a function of the model's key endogenous variables. At any instant in time, a share *m* of goods in the continuum is available at a competitive price, $p = 1$, while the remaining $(1 - m)$ goods are produced by patent holders and sold at the monopoly price $p = \lambda$. Instantaneous utility is given by $\log u_t = \int_0^{m*} \log\left(\lambda^{k_t} c*\right) d\theta + \int_{m*}^{1} \log\left(\lambda^{k_t - 1} c*\right) d\theta$. Substituting this expression into equation (1), we have

$$W* = (\rho - n)U(c*, i*) = \left[\frac{\log\lambda}{\rho - n}\right] i* + \log c* + m* \log\lambda - \log\lambda \tag{30}$$

Equation (30) indicates that welfare is increasing in *i*, *c* and *m*. The first two terms are standard in the literature, capturing the dynamics gains associated with faster arrival of innovations and the static gains associated with increased consumption. We also have a third term, which captures the static gains from having access to goods offered at competitive prices by imitators.

5.1 Welfare in the Interior Equilibrium

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[10] The intuition is that *c* and *i* are all choice variables and thus other endogenous variables which are functions of *c* and *i* reach their steady-state levels at time zero.

We consider a social planner who can choose the levels of γ, k and μ to maximise steady-state welfare W^* in an interior equilibrium with $i^* > 0$ and $1 > m^* > 0$. We first investigate the effects of an increase in k. Differentiating (30) with respect to k, using the steady-state expressions gives:

$$(\rho - n)\frac{dU}{dk} = \frac{\partial U}{\partial i^*}\underbrace{\frac{di^*}{dk}}_{+/-} + \frac{\partial U}{\partial m^*}\underbrace{\frac{dm^*}{dk}}_{-} + \frac{\partial U}{\partial c^*}\underbrace{\frac{dc^*}{dk}}_{+/-} >< 0 \qquad (31)$$

An increase in the intensity of IPR enforcement k exerts competing effects on welfare. First, it may increase or decrease the steady-state innovation rate i^*. Thus the dynamic effect is ambiguous. Second, it increases the fraction of competitively-priced goods m. Third, it may increase or decrease consumption expenditure, as described in the discussion of (28). Thus, the static effect may be either positive or negative. Further substitution of the derivative expressions does not enable us to sign dU/dk. Thus we conduct extensive numerical simulations. We choose the following benchmark parameters: $\lambda = 1.25$, $n = 0.01$, $\rho = 0.07$, $k = 0.02$, $\gamma = 0.4$, $\mu = 0.002$, $a_R = 114$.[11]

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[11] The size of innovations, λ, corresponds to the gross mark up (the ratio of the price to the marginal cost) enjoyed by innovators and is estimated as ranging between 1.05 and 1.4 (see Basu, (1996), and Norrbin, (1993)). The population growth rate, n, is calculated as the annual rate of population growth in the US between 1975 and 1995 according to the World Development Indicators (World Bank, 2009). The subjective discount rate, ρ, is set at 0.07 to reflect a real interest rate of 7 percent, consistent with the average real return on the US stock market over the past century as calculated by Mehra and Prescott (1985). The share of aggregate resources going to IPR enforcement k is set at 0.02 and the fraction that is allocated to blocking imitation γ is set at 0.40. There are no readily available empirical estimates for these parameters and thus we attempted make some common sense assumptions to set the benchmark. We set $k = 0.02$ so that the share of labour allocated to IPR enforcement is in the neighborhood of the share of R&D labour, which is estimated to be around 1-2 percent. We set $\gamma = 0.4$ such that relatively more resources are allocated to blocking innovation versus imitation. This keeps our benchmark closer to the standard quality ladders model where all IPR enforcement, in the absence of imitation, goes to innovation blocking. We choose $\mu = 0.002$ such that $m = 0.25$, that is, a quarter of the industry continuum is taken up by imitators and the rest is taken up by innovators. This again keeps our benchmark closer to the standard model without imitation. We choose a_R such that the innovation rate $i = 5.6$ percent. The resulting growth rate in utility $g = i \log\lambda$ is 1.25 percent, which is between 0.5 percent (Denison's (1985) estimate for long-term growth driven by knowledge advancements) and 2 percent (the average US GDP per capita growth rate from 1950 to 1994 as reported in Jones (2005)). In general, the benchmark parameters and outcomes are in line with the recent theoretical growth papers that use numerical simulations (see Jones (2002), Sener (2008), Steger (2003) and Segerstrom (2007).) We used *Mathematica* version 8 for our numerical simulations. The *Mathematica* programs are available upon request.

Using benchmark values, we found that the optimal level of k is $k^{OPT} = 0.0094 \approx 0.01$. To determine whether the intensity of IPR enforcement is at the optimal level, a current benchmark level k^B has to be compared to k^{OPT}. We found that a reasonable benchmark range is $k^B \in (0.005, 0.05)$ which keeps i^* in the 0-9 percent range. Hence it is possible that there can be too much or too little IPR enforcement depending on the level of k. In the range $k^B > k^{OPT}$, there is too much IPR protection and in the range $k^B < k^{OPT}$, there is too little IPR protection.

We then investigate how k^{OPT} responds to variations in the parameters. We allowed for the parameters to change, keeping i^* within 0-20 percent range. We found that k^{OPT} remains highly stable around 0.01 in response to variations in λ, n, ρ, k and a_R. Nonetheless, when we allowed for changes in γ and μ, we had different results. We found that as μ increases, the optimal k level k^{OPT} increases. The intuition is that as the probability of imitation m increases with an increase in the ease of imitation μ, the growth-promoting effects of more IPR enforcement generated by higher k become stronger and dominate the growth-suppressing effects. We should note the positive static effect of higher m on welfare through the increased share of competitively priced goods and the ambiguous static effect of k on consumption expenditure c. However, these static effects are dominated by the dynamic effects associated with innovation changes.

We found that as γ decreases, k^{OPT} increases. The mechanism is again through impact of lower γ on imitation. As the quality of the IPR regime γ falls and imitation probability m increases, the growth-promoting effects of more IPR enforcement via higher k become stronger and dominate the negative growth effects. We should again note the positive static welfare effects through m and c, which are dominated by the dynamic effects. To sum up, in economies with higher μ and lower γ, the optimal policy calls for relatively more intense IPR enforcement, that is a higher k^{OPT}.

We next investigate the effects of an increase in γ. Differentiating (30) with respect to γ, using the steady-state expressions gives:

$$(\rho - n)\frac{dU}{d\gamma} = \frac{\partial U}{\partial i^*}\underbrace{\frac{di^*}{d\gamma}}_{+} + \frac{\partial U}{\partial m^*}\underbrace{\frac{dm^*}{d\gamma}}_{-} + \frac{\partial U}{\partial c^*}\underbrace{\frac{dc^*}{d\gamma}}_{-} >< 0 \tag{32}$$

An increase in the quality of the IPR regime γ exerts competing effects on welfare: a positive dynamic effect by increasing i^* and a negative static effect by reducing both m^* and c^*. Further substitutions do not enable us to sign the total derivative. Using numerical simulations we found that the dynamic gains always dominate the static losses; hence, the optimal level of γ converges to its upper limit of one. We note that when γ goes to 1, the innovation rate i^* converges to infinity. Thus, realistically the policy maker would set optimal γ to some upper bound $\gamma^U <<1$.

Finally, we investigate the effects of an increase in μ by differentiating (30) with respect to μ:

$$(\rho - n)\frac{dU}{d\mu} = \frac{\partial U}{\partial i^*}\underbrace{\frac{di^*}{d\mu}}_{-} + \frac{\partial U}{\partial m^*}\underbrace{\frac{dm^*}{d\mu}}_{+} + \frac{\partial U}{\partial c^*}\underbrace{\frac{dc^*}{d\mu}}_{0} >< 0 \tag{33}$$

A decrease in the ease of technical imitation μ produces two competing effects on welfare: a positive dynamic effect by increasing i^* and a negative static effect by reducing m^*. Further substitutions do not enable us to sign the total derivative. Using extensive numerical simulations we found that the dynamic gains always dominate the static losses, and thus the optimal level of μ converges to its lower limit of zero. We note that when μ goes to 0, imitation probability m

converges to zero as well and the model boils down to the standard model with perfect patent enforcement.

5.2 Welfare in the Boundary Equilibrium

Substituting the values for c^{**}, m^{**} and $i^{**} = 0$ from (27) into (30), we express the boundary equilibrium welfare in terms of k, γ and μ:

$$W^{**}(k,\gamma,\mu) = (\rho - n)U^{**}(k,\gamma,\mu) = \log\left[(1-k)P(m)\right] + m\log\lambda \tag{34}$$

where $m = \min\left\{\dfrac{\mu}{\gamma k}, 1\right\}$. Since there is no innovation, all terms capture the static effects. The first term is the log utility of consumption expenditure c^*, which is real consumption $(1 - k)$ multiplied by the price level $P(m)$. The second term captures the welfare gains from access to imitated goods at competitive prices.

We consider the level of welfare-maximising k in the context of boundary equilibrium. Differentiating W^{**} with respect to k gives

$$\frac{dW^{**}}{dk} = -\frac{1}{1-k} + \left(\log\lambda - \frac{\lambda - 1}{1 + (\lambda - 1)m}\right)\frac{dm}{dk}.$$

Interestingly, the term in parenthesis, which corresponds to dW/dm, is not strictly increasing in m. One might have expected that in a static equilibrium an increase in the fraction of competitive markets would always lead to higher welfare. However, that is not the case. This is because changes in m exert two competing effects on boundary equilibrium welfare. First, a higher m implies lower prices for a subset of goods and thus increased real consumption for these goods (the first term in parenthesis). Second, a higher m reduces c^* and hence the real consumption of all goods (the second term in parenthesis). With diminishing returns to each variety of consumption good (due to log utility), the welfare *loss* from foregoing equal consumption for all goods is increasing in m up to a certain level and it is decreasing after that. Hence, conditional on being restricted to a boundary equilibrium, welfare is maximised when all goods are offered at the same price. This occurs when $m = 1$ or $m = 0$.

5.3. Integrated Welfare Analysis

We now plot welfare against k combining the interior and boundary equilibrium welfare analysis. Let us first define k^L and k^U as the lower and upper bounds of a range for k in which an interior equilibrium is attained, such that $i^* > 0$ for $k \in (k^L, k^U)$ as illustrated in Figure 4 for high γ. Let us also note that for $k \in (0, \mu/\gamma)$, we have $m = 1$; and for $k \in (\mu/\gamma, 1)$, we have $0 < m < 1$. These follow from $m = \min\left\{\frac{\mu}{\gamma k}, 1\right\}$. The resulting welfare function for the complete range $k \in (0, 1)$ turns out to be a piecewise function which can be identified as follows:

- When $k \in (0, \mu/\gamma)$, it follows that $m^* = 1$ and $i^* = 0$. The economy is in a boundary equilibrium with fully competitive industries. Welfare is given by equation (34) with $m = 1$ substituted, which implies $W^{**} = \log[1 - k]$.
- When $k \in (\mu/\gamma, k^L)$, it follows that $m^* \in (0,1)$ and $i^* = 0$.The economy is still in a boundary equilibrium but with both monopolist and competitive industries. Welfare is given by W^{**} in equation (34).
- When $k \in (k^L, k^U)$ it follows that $m^* \in (0,1)$ and $i^* > 0$: the economy is in an interior equilibrium again with two industry types. Welfare is given by W^*, equation (30).
- When $k \in (k^L, 1)$ it follows that $m^* \in (0,1)$ and $i^* = 0$, the economy is in a boundary equilibrium with two industry types. Welfare is given by W^{**} in equation (34).

We plot the resulting welfare functions under three different of IPR enforcement quality levels γ. Firs is the case of high γ, where the economy can attain a positive innovation rage $i^* > 0$ and a welfare-maximising level of k, k^{OPT}, is observed within the interior equilibrium. More specifically, k^{OPT} maximises welfare in the range with $i^* > 0$ and $m^* \in (0,1)$.

Second is the case of a medium levelγ, γ^{MED}, which is the threshold level of γ where the economy is just indifferent between welfare with positive innovation and welfare with no innovation. To see the implications consider a slight downward deviation from γ^{MED} . In this case, the economy can still attain a positive level of innovation rate $i^* > 0$ but the welfare maximising policy does not coincide with a positive innovation rate. The welfare level attained by choosing k in the interior equilibrium range, turns out to be lower than the welfare level attained by forcing to economy to a boundary equilibrium with $k = 0$. Such a policy implies $m = 1$, complete elimination of IPR protection and thus monopoly markets. This is indeed a curious case. It implies that when the institutional quality level is below a threshold level γ^{MED}, policies aimed at generating positive innovation via IPR enforcement can actually lead to *inferior* welfare outcomes compared to policies aimed at minimising monopoly distortions by completely foregoing IPR enforcement.

The above results have particular relevance in the real world policy making. In the case of sufficiently high institutional quality, the growth-maximising and welfare-maximising levels of k are quite close. Therefore by focusing on growth maximisation the policy maker is less likely to make a mistake that leads to a substantial deviation from maximum welfare. However, in the case of low institutional quality, the policy maker’s focus on maximising growth will lead her to choose an IPR enforcement level that is well above the welfare maximising level. In this case, the policy maker's focus on growth maximisation may result in large deviations from maximum welfare.

For completeness, we also investigate the case with very low institutional quality. In this case at no level of $k \in (0,1)$ can the economy attain a positive level of i^*. The welfare maximising level of k is thus zero. If the policy maker focuses on getting the economy closer to the positive innovation range, this again would lead to an inferior outcome compared to choosing $k = 0$. Hence, completely foregoing IPR protection to minimise monopoly distortions dominates over establishing IPR protection in an attempt to generate positive growth.

6. Policy Implications and Conclusion

We investigate the relationship between IPR enforcement, innovation and welfare in a Schumpeterian growth model in which the enforcement of IPR has both imitation and innovation deterring effects. The model distinguishes between the intensity of IPR enforcement and the quality of the IPR regime. Our first main result is that there exists an inverted-U relationship between the intensity of IPR protection and innovation activity. At low levels of IPRs, increasing IPR intensity is good for growth. However, as the level of IPR intensity increases, IPR protection becomes less effective and eventually counterproductive for growth. This implies the existence of a growth-maximising level of IPR that stems from the interplay between innovation-deterring and imitation-deterring aspects of IPR enforcement. Thus our model highlights both the positive and negative aspects of IPR protection.

Second, we examine the interaction between institutional quality and IPR enforcement. For countries with lower institutional quality, the growth-maximising IPR enforcement intensity is higher, and for countries with higher institutional quality the IPR intensity is lower. This implies that institutional quality and IPR enforcement can be considered as substitutes by the policy maker. Since institutional quality captures the *de-facto* efficiency of the IPR protection and thus linked to stable parameters that are not necessarily in the policy maker's tool box, the lesson for a growth-maximising policy maker operating in a low institutional quality environment is to substitute higher IPR enforcement for institutional quality. Analogously, the lesson for a policy maker operating in a high institutional quality environment is to consider less IPR enforcement.

The analysis presented above has several implications for policy makers. First, by explicitly modeling innovation-deterring activities undertaken by incumbent firms following the spirit of Dinopoulos and Syropoulos (2007), we share many of the concerns raised by Boldrin and Levine (2004a, 2004b, and 2008), where they warn about the downside of rent-seeking behavior that follows institutionalised monopoly creation through IPRs. Unlike Boldrin and Levine, however, we incorporate a positive social role for intellectual property based on Schumpeter's perspective that monopolies secured by IPR protection are "a necessarily evil" to promote innovation. As a result, while our analysis suggests that policy makers should consider the innovation-deterring effects of rent seeking by patent holders, it does not suggest that most economies would benefit from the abolition of intellectual property.

By incorporating the innovation and imitation deterring effects of IPR enforcement, our model encompasses the notions of lagging and leading patent breadth as proposed in the patent design literature (See O'Donoghue et al. (1998) and O'Donoghue and Zweimueller (2004)). In this literature lagging breadth "limits imitation by specifying inferior products that other firms cannot produce", whereas "leading breadth limits future innovators by specifying superior products that other firms cannot produce" (O'Donoghue and Zweimueller (2004, p. 82)). More recently, Chu (2009) and O'Donoghue and Zweimueller (2004) have constructed endogenous growth models with leading patent breadth and complete lagging breadth. Like these models, our analysis suggests that policy makers consider the tradeoff between the innovation and imitation deterring effects of IPR policy. However, we differ from these models by highlighting the central role that institutional quality plays in determining this tradeoff and *de facto* implications of a given level of IPR enforcement for innovation and growth. More specifically, we find that the optimal level of IPR enforcement will differ across countries with different institutional frameworks.

Finally, we find that in the neighborhood of an interior equilibrium with sufficiently high institutional quality, the relationship between IPR enforcement and welfare is largely determined by the dynamic effects of IPR enforcement and that the static effects are small by comparison. Hence, the growth-maximising policy recommendations apply equally well to welfare maximisation. However, when institutional quality is sufficiently low, the welfare maximising policy can point to zero IPR protection even though positive growth is feasible through some level of IPR protection. Intuitively, for these types of economies completely foregoing IPR protection to minimise static monopoly pricing distortions dominates over generating positive dynamic effects. To summarise: while the static efficiency costs of IPRs may be important to countries with low institutional quality in which the growth effects of IPR enforcement are likely to be small, they should be of secondary concern for policy makers in relatively developed countries.

Several extensions of the model remain to be explored for future research. Our closed economy model can be extended to a North-South setting and can be used to analyse the effects of increased Southern IPR protection. The model can also be extended to incorporate the distinctions between publicly-funded basic research and the resulting interaction between IPR policy and private-public R&D. We believe that such extensions can bring the competing aspects of IPR policy more to forefront of economic research.

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Table 1: Summary of Comparative Static Effects

	Imitation Deterrence Effect	Innovation Deterrence Effect	Direct Resource Cost	Equilibrium Innovation Rate	Equilibrium Consumption Expenditure
dk >0	+	+	+	?	?
d$\gamma > 0$	+	-	0	+	-
d$\mu < 0$	+	0	0	+	0

Source: Authors

Figure 1a: Steady-State Equilibrium with Positive Innovation

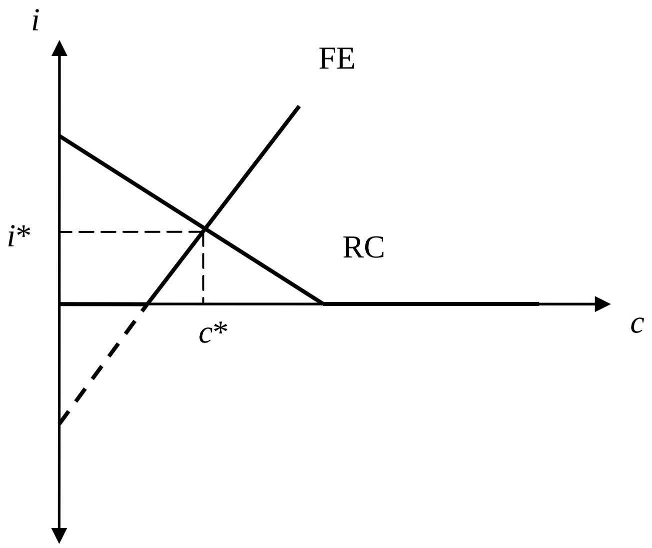

Figure 1b: Steady-State Equilibrium in the Boundary Equilibrium

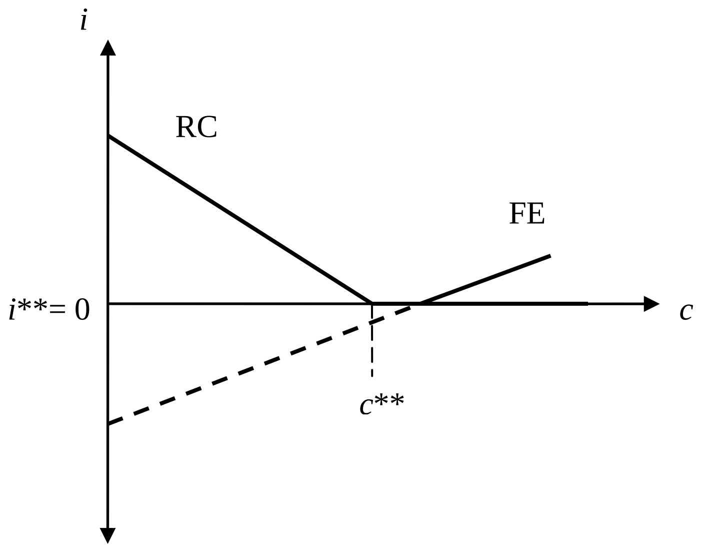

Figure 2: IPR Policy and Innovation

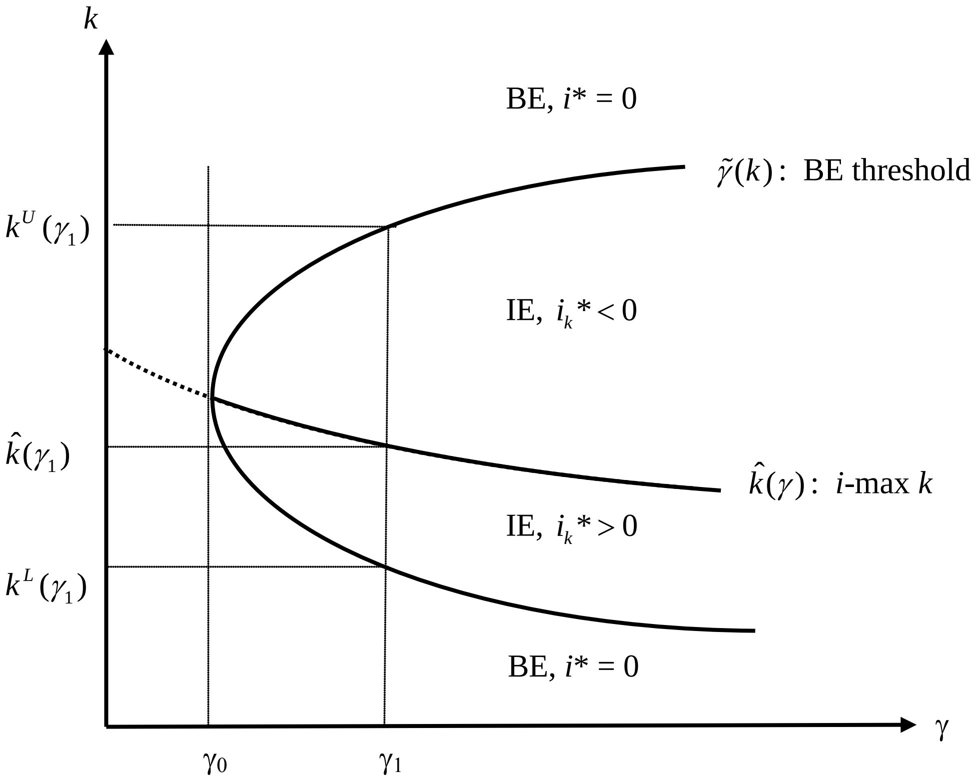

Figure 3: Innovation and Intensity of IPR Enforcement

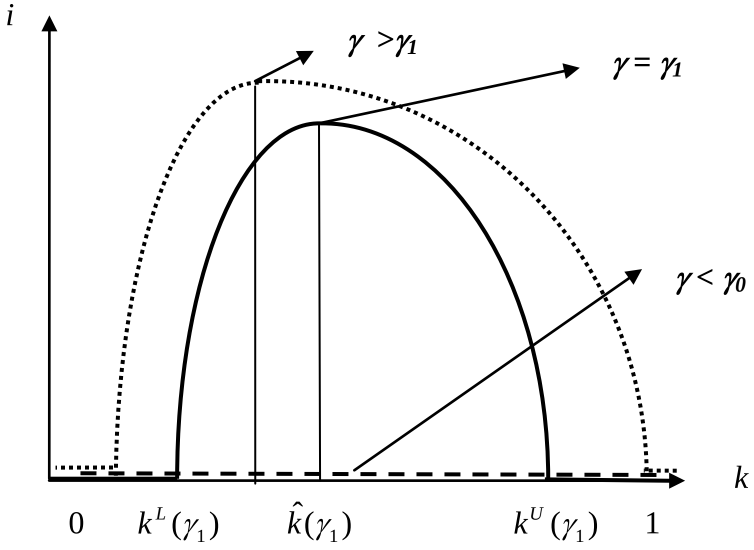

Figure 4: Welfare and Intensity of IPR Enforcement