# Boon or bane:

# The impact of intellectual property rights on innovation*

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**Abstract**

Satisfactory answers on the effect of intellectual property rights (IPR) protection on innovation have not yet been given. There exist models where IPR protection contributes to increasing innovation rates and others where it hinders innovation. In this paper I reconcile these two opposing theories. This is accomplished by plugging a recent international offshoring model into a product cycle model with endogenous innovation and imitation. Thereby I obtain an interior solution for the growth-maximizing IPR protection level, which implies that the marginal effect of IPR on growth is positive below this cutoff-level and negative above it. I derive sufficient conditions for the shape of the labor market equilibrium curves and perform numerical comparative statics. The driving mechanism for my result is that intermediate levels of IPR protection imply intermediate levels of offshoring, trading off benefits from increased leverage of new ideas with the costs of a rising imitation risk.

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# 1 Introduction

An important question in academics and policy making is the role of intellectual property rights for economic well-being. Often is suggested that patent laws mostly benefit developed nations that account for the majority of patent filings. A second crucial question that I adress is the optimal level of international production sharing. Should developed nations try to focus on jobs with a high skill requirement and value added, such as research & development (R&D)? May international outsourcing of large parts of the value chain harm research efficiency? What about the effectiveness of patent protection when more knowledge is transferred abroad to international affiliates. And do developing countries lose from too lax IPR protection if the risk of imitation is crucial in business makers' decision of where to locate their production sites (Economist, 2007)?

In this paper I try to give answers to these questions. My model is in line with the product cycle literature where innovation and imitation are endogenous processes, rewarded with monopoly profits in future periods. Moreover, northern firms can offshore their production to the South to save on short-run production costs and increase incentives for innovation. At the same time however, offshoring increases the leakage of knowledge to the South and thus the risk of imitation. I find that the optimal IPR strategy typically features intermediate levels of protection. This does not depend on whether the objective of maximization is the steady-state growth rate or of an intertemporal welfare function in North or South.

The literature on international product cycles started out as an idea by Vernon (1966) and was formalized later on by Grossman & Helpman (1991) in a variety expansion model. In their model the production of goods is an activity separate from an R&D sector in which new patentable blueprints are developed that add to the economy's knowledge capital stock. These new varieties are only developed in the North and at some point in time can be imitated by Southern producers, which shifts the location of production. They find that a higher rate of imitation has positive feedback effects on the innovation rate in the North. The reason is that a negative demand effect for innovation, implied by a higher discount rate and thus a lower present value of a patent is dominated by a positive supply effect, a fall in Northern wages caused by a reduction in the share of Northern varieties, which makes innovative activity less costly. A similar result is identified in a quality ladder model by Segerstrom, Anant & Dinopoulos (1990) who analyze the length of patent duration. In their model, prolonged protection lowers the rate of innovation because the cost of innovation rises with rising wages in the North, due to expanded labor demand from the production sector.

Helpman (1993) is more explicit about the timing of events. Intuitively, it takes time until changes in the rates of innovation and imitation will ultimately have a notable impact on the share of product varieties in the two countries. This may imply that a rising imitation rate may induce a temporary drop in the rate of innovation, before the wage effect outlined in Grossman & Helpman (1991) is suffiently strong. Moreover, he introduces foreign direct investment (FDI) as a second channel of international technology transfer. In his and subsequent models FDI is typically both, horizontal and vertical in nature. Northern varieties can be entirely produced in the South and then sold in the South or exported to the North. This does not change the outcome discussed above. However, it can make the North gain in terms of welfare from a reduced imitation rate in the South because the number of Northern varieties can be increased and thus profit income raised. Lai (1998) presents a model where less imitation facilitates the shift of production from Northern firms to their Southern affiliates, freeing Northern resources to move into the research sector. Subsequently, a higher share of production is performed in the South, whereas the global rate of product development rises. Put differently, the effect on from imitation on the present value of intertemporal profits dominates the effect on per-period profits through the wage rate.

All these contributions do not consider the endogenous character of imitation in their comparative statics analysis. Moreover, while Grossman & Helpman (1991) assume that Southern ressources are required to imitate and thus can also analyze the effects of tightness on the Southern labor market, this channel is shut down in the other studies. However, Mansfield et al. (1981) showed that the costs of imitation are roughly two thirds of the costs of innovation. Only very few products can be imitated at a cost of less than 20% of the innovation costs. Hence, a theoretical model should account for the fact that resources have to be allocated to an imitative research sector in the Southern country. The imitation rate can then be endogenized by the introduction of a parameter that represents the level of intellectual property rights (IPR) protection. This parameter usually enters linearly into the labor requirement for imitation which is a costly activity to circumvent the IPR protection. Equating the cost of imitation with profits from imitation then determines the allocation of labor to production and imitation in the South.

Glass & Saggi (2002) were the first to take the role of intellectual property rights into consideration. Tighter IPR protection increases the labor requirement in imitative research so that profitable imitation will be conducted at a lower rate. Still it implies that more Southern labor is allocated to this sector when intersectoral mobility is perfect, decreasing the level of endogenous FDI from North to South, so that less Northern varieties are sourced from the South. As a result, more Northern labor has to move into the production sector, lowering the rate of innovation. In Branstetter et al. (2007) this result is reversed because of a dominating effect on demand for innovation from the present value of the implied profit stream. In their model tighter IPR protection increases the cost of FDI due to higher wages in the South, but even stronger is the effect from a lower risk of imitation when having Northern varieties manufactured in the South via FDI. Hence, increasing IPR protection attracts more FDI to the South. Finally, Branstetter and Saggi (2009) conclude that IPR protection increases the rate of innovation in the North, when imitation is endogenous and thereby confirm the result by Lai (1998) but stand in contradiction with the results from Glass & Saggi (2002).

However, recent progress in the literature on international integration spread the view that production can be sliced into tasks that differ in their costs of international sourcing. Grossman & Rossi-Hansberg (2008) introduced the notion of trade in tasks, opposed to trade in goods. I build upon the above mentioned contributions in the product cycle literature, accounting for firms' decision to offshore production up to a marginal task $I$, which is determined by the relative wage and the task-specific offshoring costs. All tasks featuring a lower cost of international coordination than $I$ are sourced from abroad, hence yielding endogeneous savings on production costs that depend on the shape of the offshoring cost function $t(i)$, as shown by Grossman & Rossi-Hansberg (2008).

I find that the introduction of such task-specific heterogeneity in the offshoring costs is able to reconcile opposing theories. More precisely, I observe that a sharpening of IPR protection raises the innovation rate when IPR protection is loose, as described by Brannstetter and Saggi (2009). However, when protection is already tight a further increase can be harmful as in Glass & Saggi (2002). In other words, there exists an interior solution for the level of IPR protection to maximize the global growth rate, as well as Northern and Southern intertemporal welfare.

The remainder of the paper is organized as follows. Section 2 outlines the model, while section 3 analytically characterizes the equilibrium. Section 4 derives further results numerically and section 5 concludes.

## 2 The model

The model economy consists of two countries, North and South, where variables that refer to the latter are indicated by an asterisk (*). However, I abstain from using this differentiation if not necessary for distinction. Both countries are inhabited by a fixed amount of consumers, each supplying one unit of labor inelastically.

## 2.1 Consumer optimization

The intertemporal utility function of a representative consumer in both countries is given by

$$W = \int_0^\infty U(t) e^{-\rho t} \mathsf{d}t \tag{1}$$

where $\rho$ is the discount factor and the utility in each period $U(t)$ has the form

$$U(t) = \left( \int_0^{N(t)} x_j(t)^{\frac{\sigma-1}{\sigma}} \mathsf{d}j \right)^{\frac{\sigma}{\sigma-1}} \tag{2}$$

where $x_j(t)$ is consumption of variety $j$ at time $t$ and $\sigma$ is the constant elasticity of substitution between varieties. Since trade in final products is costless it does not matter where these varieties are produced. Intratemporal utility maximization yields a demand function

$$x_j(t) = \frac{E(t) p_j(t)^{-\sigma}}{\int_0^{N(t)} p_j(t)^{1-\sigma} \mathsf{d}j} \tag{3}$$

where $p_j(t)$ is the price of variety $j$ at time $t$ and the term in the denominator is the well-known Dixit-Stiglitz price index. Intertemporal utility $W$ is maximized subject to an intertemporal budget constraint

$$\int_0^\infty e^{-rt} E(t) \mathsf{d}t \leq \int_0^\infty e^{-rt} w(t) \mathsf{d}t + A(t) \tag{4}$$

with $E(t)$ as consumer expenditure and $A(t)$ is the value of assets in period $t$. This implies the usual Euler equation for consumption expenditure derived from intertemporal welfare maximization

$$\frac{\dot{E}}{E} = r - \rho. \tag{5}$$

with $r$ as interest rate on the capital market. Wages, prices, and thus expenditure are assumed to be constant over time so that utility per period rises linearly with the number of varieties available. I define the growth rate of varieties $g := \dot{N}/N$ which allows me to express the intertemporal welfare along the balanced growth path written as

$$W = \frac{U(0)}{\rho - \frac{g}{\sigma - 1}} \tag{6}$$

where $N(0)$ is normalized to one and which is well defined for $\rho > g/(\sigma - 1)$. This relationship makes clear the trade off between short-run and long-run optimality. A myopic government focusing only on short-run utility $U$ might potentially harm long-run welfare, if the growth rate $g$ is negatively affected.

## 2.2 Manufacturing sector

In the following I drop time- and industry-indices where they are dispensable. Firms produce different varieties of an otherwise identical consumption good. Precondition for production of a variety is the existence of a blueprint which is not revealed to other firms in the economy. Blueprints for production in the North must previously be developed in an innovative research sector. Innovation in the South is prohibitively costly. However, in the South there exists an imitative research sector, copying existing Northern varieties, which thereafter can be produced by a Southern firm. Subsection 2.3 below describes in more detail how blueprints in the two countries are developed.

Production of each variety requires the performance of a unit interval of tasks that only differ in the costs that are caused if they are performed offshore. I refer to these costs as offshoring costs $\beta\tau(i) \geq 1$. These costs are generally assumed to represent such things as the content of tacit information of each task. However, the concept is sufficiently general to accomodate more features to the costs of unbundling the production process. These may include the more difficult transmission of knowledge from production to the research sector when production is performed abroad, such as in Naghavi & Ottaviano (2009). As is standard in the offshoring literature, I order tasks from 0 to 1 with a index $i$ so that the offshoring cost schedule rises monotonously in $i$, $\tau'(i) \geq 0$.

By assumption, wages in the South are lower than in the North $w/w^* > 1$. This allows Northern firms to resort to offshore production of all tasks $i \leq I$, where $I$ is the marginal task implicitly defined by

$$\beta\tau(I) = \frac{w}{w^*}, \tag{7}$$

so that offshoring costs for the marginal task equal the wage of Northern workers relative to Southern workers. As shown by Grossman & Rossi-Hansberg (2008), this implies per-unit production costs of $w\Theta(I)$, where the offshoring saving factor is defined as

$$\Theta(I) := 1 - I + \frac{\int_0^I \tau(i)di}{\tau(I)} \tag{8}$$

with $\Theta'(i) \leq 0 \, \forall \, i$. The demand structure outlined above yields markup pricing with $p = w\Theta(I)\sigma/(\sigma -$

1). Profits for each Northern firm are thus given by

$$\pi = (p - w\Theta(I))x = \frac{w\Theta(I)x}{\sigma - 1} \tag{9}$$

where one should bear in mind that $x$ is still endogenous in this relationship, depending on $w$ and $I$.

Southern firms produce varieties that have been successfully imitated. Due to the wage difference they do not use offshore production. Thus, their per-unit production costs are simply given by $w^*$. With positive offshoring costs as described above, necessarily $w^* \leq w\Theta(I)$. I assume that the wage difference in the two countries is sufficiently high so that Southern firms can set monopoly prices according to the elasticity of substitution, the so called "wide-gap case" from Grossman and Helpman (1991). This case is formally characterized by the condition $w^*\sigma/(\sigma-1) \geq w\Theta(I)$ or $\beta\tau(I)\Theta(I)\sigma/(\sigma-1) \leq 1$.[1] Thus, Southern firms earn profits

$$\pi^* = (p - w^*)x^* = \frac{w^*x^*}{\sigma - 1}. \tag{10}$$

Given the preference structure, relative demand for varieties from the two countries only depends on relative prices such that

$$\frac{x}{x^*} = \frac{p}{p^*}^{-\sigma} = [\Theta(I)\beta\tau(I)]^{-\sigma} \tag{11}$$

and the relative profits of the two types of firms are given by

$$\frac{\pi}{\pi^*} = [\Theta(I)\beta\tau(I)]^{1-\sigma} \tag{12}$$

## 2.3 Research sector

Research conducted during one time period yields a success with a certain probability $1/a$. With many researchers, however, there is no aggregate uncertainty in the innovation process, despite of the presence of idiosyncratic uncertainty. Hence, a blueprint for a new variety can be developed in the North at a cost $C = wa/N$, where $N$ is as above the stock of all consumed varieties, which is identical to all blueprints ever developed in the North. The appearance of $N$ in this cost equation is a spillover from present knowledge in line with Grossman & Helpman (1991), Aghion & Howitt (1992), or Romer

[1] In the "narrow-gap case" Southern firms set prices slightly below Northern firms' production costs to capture the entire demand for that variety. This limit price-setting can also be interpreted as Bertrand price competition. Qualitative results are identical in the two pricing environments.

(1990).[2] Successful research in the South means the disclosure of a Northern production blueprint and entails costs $C^* = w^* a^* / \gamma n I$, where $\gamma \in (0; 1]$ is a parameter that characterizes protection of intellectual property rights (IPR) and $n$ is the stock of Northern production blueprints not already disclosed to Southern firms. Intuitively, imitation is less costly when $\gamma$ is close to 1, meaning little IPR protection and when the number of unrevealed varieties is high. The limiting case with no IPR protection is normalized to $\gamma = 1$.[3] Moreover, imitation is less costly if the share of offshore provided tasks is high, since it increases the Southern knowledge about Northern varieties. As already mentioned above, the growth rate of all Northern varieties is defined as $g := \dot{N}/N$, which on the balanced growth path is also the growth rate of unrevealed Northern varieties $\dot{n}/n$ and of Southern varieties $\dot{n}^*/n^*$. The imitation rate is $m := \dot{n}^*/n$.

Entry into research is free in both countries. I abstain from analyzing the trivial case where research is not profitable and, hence, the rate of variety development is equal to zero. Instead I assume that the no arbitrage condition holds with equality, giving a relationship of per-period profits and the value of a Northern firm as

$$\pi + \dot{v} = rv + mv \tag{13}$$

which implies that profits from successful innovation exactly compensate for interest payments forgone and the risk of losing through imitation the entire firm value $v$. The imitation risk term $mv$ drops out for the Southern no arbitrage condition, yielding $\pi^* + \dot{v}^* = rv^*$.

With my assumption on constant expenditure over time I have $r = \rho$, as shown above. Furthermore I know that firm values decrease at a rate of $g$. Using the fact that the value of a firm must equal the cost of research in equilibrium I obtain

$$\frac{wa}{N} = \frac{\pi}{\rho + g + m} \qquad \text{and} \qquad \frac{w^* a^*}{\gamma n I} = \frac{\pi^*}{\rho + g} \tag{14}$$

so that output in the two countries is given by

$$nx = \frac{\rho + g + m}{g + m} \frac{ag}{\Theta(I)} (\sigma - 1) \qquad \text{and} \qquad n^* x^* = \frac{g + \rho}{g} \frac{a^* m}{\gamma I} (\sigma - 1). \tag{15}$$

[2] Jones (1995) argues that spillovers have the form $N^\phi$ with $0 < \phi < 1$. This "semi-endogenous growth theory" makes the growth rate exogenous, only depending on the population growth rate.

[3] I obtain identical results in a specification where intellectual property rights affect only profits but not labor demand. The intuition is that a share $1 - \gamma$ of profits has to be given away to have authorities turn a blind eye on imitation. Such a specification would replace the foreign zero profit condition in equation (14) by $w^* a^* / nI = \gamma \pi^* / (\rho + g)$ and eliminate the $\gamma$ from equations (21) and (22).

Furthermore, from equation (14) I can solve for the relative profits of Northern and Southern firms as

$$\frac{\pi}{\pi^*} = \frac{\rho + g + m}{\rho + g} \frac{g}{g + m} \frac{a\gamma I \beta \tau(I)}{a^*} \tag{16}$$

and combined with equation (12) from above I obtain the imitation rate in equilibrium as

$$m = \frac{\Phi}{1 - \Phi}\rho - g \tag{17}$$

where

$$\Phi := (\beta\tau(I))^{\sigma} (\Theta(I))^{\sigma-1} \frac{\gamma I g}{(\rho + g)} \frac{a}{a^*}. \tag{18}$$

There exist three channels which influence the imitation rate $m$ in equation (17) via the exogenous parameter of IPR protection $\gamma$ and the endogenous variables $g$ and $I$: (1) the imitation rate increases when intellectual property protection is relaxed as can be seen from the partial derivative $\partial m/\partial\gamma = (m + \rho + g)(m + g)/\rho\gamma > 0$; (2) the imitation rate increases with the innovation rate, shown by $\partial m/\partial g = m(2g + \rho + m)/g(g + \rho) > 0$ for $m > 0$; (3) the imitation rate increases with the offshoring volume[4] $\partial m/\partial I > 0$ since $\tau(I)\Theta(I)$ and $I/\Theta(I)$ both increase in $I$; and (4) the imitation rate increases with higher technological offshoring costs $\partial m/\partial\beta = (m + \rho + g)(m + g)\sigma/\rho\beta > 0$.

## 2.4 Labor markets

I assume that workers are free to move between the research sector and the production sector. Moreover, Southern workers have the choice to work for domestic companies or can perform offshore production for Northern firms. This means that wages for homogenous workers are equal in all occupations.

Northern workers only perform a fraction $1 - I$ of tasks domestically. Thus, the full employment condition satisfies

$$L = \frac{a\dot{N}}{N} + (1 - I)nx \tag{19}$$

and inserting from above I obtain

$$\begin{aligned} L &= ag + (1 - I)\frac{g + \rho + m}{g + m}\frac{ag}{\Theta(I)}(\sigma - 1) \\ &= ag + (1 - I)a^* (\beta\tau(I)\Theta(I))^{-\sigma} \frac{(\rho + g)}{\gamma I}(\sigma - 1). \end{aligned} \tag{20}$$

[4] A derivation of this partial derivative can be found in the appendix.

Analogously, full employment in the South is given by

$$L^* = \frac{a^* \dot{n}^*}{\gamma n I} + n^* x^* + n x \beta \int_0^I \tau(i) \mathsf{d} i \tag{21}$$

which can be written as

$$\begin{aligned} L^* &= \frac{a^* m}{\gamma I}\left(1 + \frac{\rho + g}{g}(\sigma - 1)\right) + \frac{g + \rho + m}{g + m} \frac{a g}{\Theta(I)}(\sigma - 1)\beta \int_0^I \tau(i) \mathsf{d} i \\ &= \frac{a^*}{\gamma I}\left[\frac{\Phi}{1 - \Phi}\rho - g\right]\left(1 + \frac{\rho + g}{g}(\sigma - 1)\right) + a^* \left(\beta \tau(I) \Theta(I)\right)^{-\sigma} \frac{(\rho + g)}{\gamma I}(\sigma - 1)\beta \int_0^I \tau(i) \mathsf{d} i \end{aligned} \tag{22}$$

where the first term on the right-hand-side is labor used for imitative research and Southern production, while the second term represents labor in Northern offshore production.

# 3 Analytical solution

A steady-state equilibrium is defined by the condition the number of varieties $N$, as well as $n$ and $n^*$, grows at a constant rate $g$, whereas output $x$ and profits $\pi$ of each firm decrease by $g$ in each period. Wages, prices, and expenditure are normalized to remain constant and all other variables are constant as well. Furthermore, the innovation rate $g$ and the imitation rate $m$ must be strictly positive and the offshoring volume $I \in [0; 1]$. In the appendix I show that a unique equilibrium exists under the additional assumption that not less than half of all varieties are still manufactured in the North, $g \geq m$. Moreover, I show in the appendix that the domestic full employment curve is concave as indicated in figure 1.

In this equilibrium, a tightening of intellectual property rights (reduction of $\gamma$) shifts the domestic as well as the foreign full employment curve to the right. It can be seen that such a shift originating from $A$ is likely to increase the innovation rate initially as in $A'$ but a further reduction of $\gamma$ leads to a reduction of innovative activity indicated by $A''$. Moreover, it is easy to see that the offshoring volume unambiguously increases with a tighter IPR protection, since the potential imitation risk at a given offshoring volume is reduced. I summarize these results in the following propositions.

**Proposition 1** *A tightening of IPR legislation (reduction of $\gamma$) shifts the domestic and foreign labor market curve to the right. This unambiguously increases the offshoring volume. The effect on the growth rate $g$ is ambiguous.*

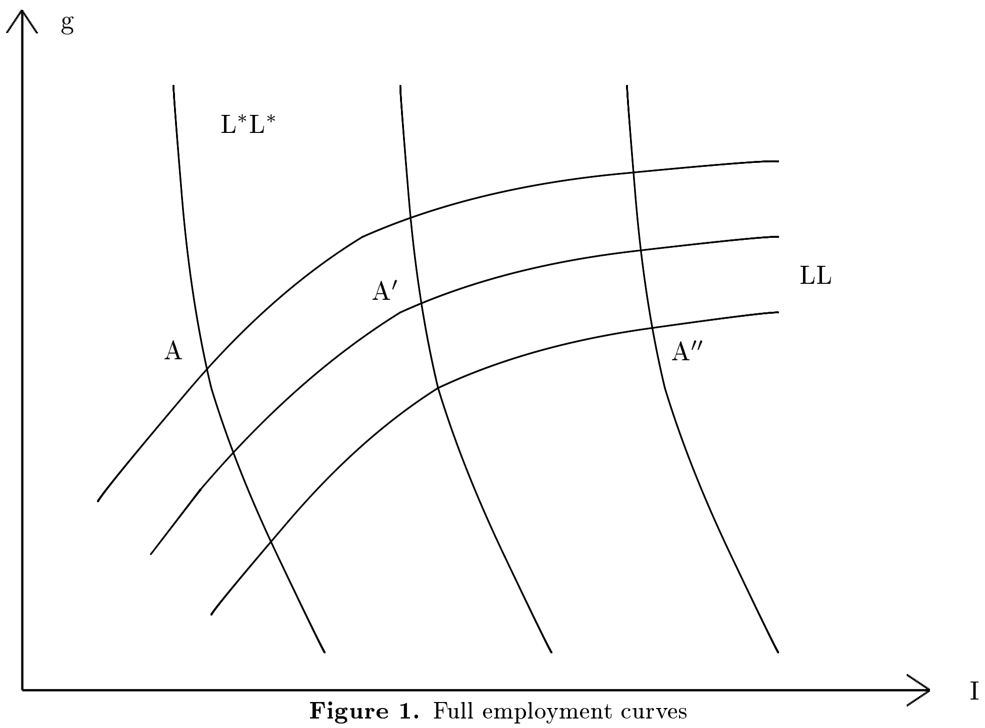


**Figure 1.** Full employment curves

**Proof** The derivative of domestic labor demand with respect to $\gamma$ is given by

$$L_\gamma := \frac{\partial L}{\partial \gamma} = -\frac{L - ag}{\gamma} < 0 \tag{23}$$

which means that a reduction of $\gamma$ increases labor demand such that higher offshoring volume is needed to keep the innovation rate constant at a given labor supply.

The derivative of foreign labor demand with respect to $\gamma$ is given by

$$\begin{aligned} L^*_\gamma := \frac{\partial L^*}{\partial \gamma} &= \frac{a^* m}{\gamma I}\left(1 + \frac{\rho + g}{g}(\sigma - 1)\right)\left(\frac{\partial m/\partial \gamma}{m} - \frac{1}{\gamma}\right) - \frac{a^*(\rho + g)(\sigma - 1)}{\gamma^2 I \left(\beta \tau(I)\Theta(I)\right)^\sigma}\beta \int_0^I \tau(i)\mathsf{d}i \\ &> 1 - \frac{\int_0^I \tau(i)\mathsf{d}i}{\beta^{\sigma-1}\left(\tau(I)\Theta(I)\right)^\sigma} > 0 \end{aligned} \tag{24}$$

which means that a reduction of $\gamma$ decreases labor demand such that a higher offshoring volume is possible at a innovation rate constant and labor supply. ∎

Moreover, it is possible to directly analyze changes of the innovation rate $g$ as reaction to changes in the intellectual property rights level. This relationship can be expressed by

$$\frac{\hat{g}}{\hat{\gamma}} = \frac{L^*_\gamma L_I - L_\gamma L^*_I}{L_g L^*_I - L^*_g L_I} \tag{25}$$

where the denominator is unambiguously larger than zero since $L_g > 0$, $L_I^* > 0$, $L_g^* > 0$, and $L_I < 0$ as shown in the proof to the existence of the equilibrium in the appendix. I define $\mathcal{N}$ as the numerator of equation (25), given by

$$\begin{aligned}\mathcal{N} := &\left(1+\frac{\rho+g}{g}(\sigma-1)\right)\left(m\Theta(I)\tau(I)-\left(g+\frac{(g+m)^2}{\rho}\right)\left(\frac{\Theta(I)\tau(I)}{(1-I)}+\sigma I(1-I)\frac{\partial}{\partial I}\tau(I)\right)\right)\\ &-\left(1+\frac{\rho+g}{g}(\sigma-1)\right)\left(g+m+\frac{(g+m)^2}{\rho}\right)\left(1+\frac{I}{\Theta(I)\tau(I)}((\sigma-1)(1-I)+\Theta(I))\frac{\partial\tau(I)}{\partial I}\right)\\ &+\frac{(g+\rho)(\sigma-1)\beta}{(\beta\tau(I)\Theta(I))^{\sigma}}\left(\Theta(I)(1-\Theta(I))\tau(I)^2+\int_0^I\tau(i)\mathrm{d}i\frac{\Theta(I)\tau(I)}{(1-I)}\right)\end{aligned} \tag{26}$$

I first analyze a special case with a high imitation rate $m = g$. This implies that in the steady-state, each country produces half of all varieties. In this case, the expression in equation (26) is unambiguously negative. I summarize this result in the following proposition.

**Proposition 2** *A further loosening of intellectual property rights legislation has a negative effect on the global rate of innovation, when the imitation rate is alredy high $m = g$.*

**Proof** In the appendix. ■

Moreover, I can show that $\mathcal{N}$ depends negatively on the imitation rate $\partial\mathcal{N}/\partial m < 0$. This implies that the negative effect from a given incrase in $\gamma$ on the innovation rate $g$ is larger in absolute terms, the higher is the imitation rate $m$. Along the line of this argument, it might well be the case, that there exists a threshold level of the imitation rate $\tilde{m}$, at which $\mathcal{N} = 0$. This means that for rates of imitation lower than $\tilde{m}$, the innovation rate can be raised by choosing less severe intellectual property rights protection.

**Proposition 3** *The term $\mathcal{N}$ depends negatively on the imitation rate $m$. This implies that there might exist a threshold level of the imitation rate $\tilde{m}$, at which $\mathcal{N} = 0$. The existence of such a threshold level implies that $\mathcal{N} > 0$ for the range of imitation rates $m \in [0, \tilde{m})$, meaning that the innovation rate rises with a loosening of intellectual property rights. This yields an inverse U-shaped relationship between intellectual property rights $\gamma$ and innovation rate $g$, with $\tilde{m}(\tilde{\gamma})$ corresponding to the growth-maximizing level of intellectual property rights protection.*

**Proof** In the appendix. ■

Unfortunately, I cannot solve for the threshold level $\tilde{m}$ or $\tilde{\gamma}$, nor can I generally proof that $\mathcal{N}$ is positive at a low imitation rate $m$. However, in section 4 I present numerical simulations that show the existence of an inverse U-shaped relationship of $\gamma$ and $g$ for plausible paramter values.

Furthermore, I analyze how the positions of the full employment curves change with respect to exogenous changes in technological offshoring costs $\beta$. It can be shown that a reduction of $\beta$ has a qualitatively identical effect as a reduction of $\gamma$, it shifts both curves to the right. However, the effect on the foreign full employment curve is now larger since the first term of equation (22) is reduced unambiguously due to the negative effect on the imitation rate. This makes it more likely that a reduction of technological offshoring costs leads to an increase in the innovation rate. Furthermore, the offshoring volume unambiguously increases with a fall in $\beta$.

**Proposition 4** *A reduction of technological offshoring costs $\beta$ shifts the domestic and foreign labor market curve to the right. This unambiguously increases the offshoring volume $I$. The effect on the innovation rate $g$ is ambiguous.*

**Proof** The derivative of domestic labor demand with respect to $\beta$ is given by

$$L_\beta := \frac{\partial L}{\partial \beta} = -\frac{(L-ag)\sigma}{\beta} < 0 \tag{27}$$

which means that a reduction of $\beta$ increases Northern labor demand such that a higher offshoring volume is needed to keep the innovation rate constant at a given labor supply.

The derivative of foreign labor demand with respect to $\beta$ is given by

$$\begin{aligned} L^*_\beta := \frac{\partial L^*}{\partial \beta} &= \frac{a^*}{\gamma I}\left(1+\frac{\rho+g}{g}(\sigma-1)\right)\frac{\partial m}{\partial \beta} - \frac{a^*\,(\rho+g)\,(\sigma-1)}{\gamma I\,(\beta\tau(I)\Theta(I))^\sigma}\int_0^I \tau(i)\mathsf{d}i \\ &> \frac{(m+\rho+g)(m+g)\sigma}{g\rho} - \frac{\int_0^I \tau(i)\mathsf{d}i}{\beta^{1-\sigma}\,(\tau(I)\Theta(I))^\sigma} > 0 \end{aligned} \tag{28}$$

which means that a reduction of $\beta$ decreases Southern labor demand such that a higher offshoring volume is possible at a innovation rate constant and labor supply. ■

To conclude this section I look at the implications from the fact that a reduction in offshoring costs shifts the two full employment curves to the right. It means that, ceteris paribus, the lower $\beta$, the smaller the slope of the $LL$-curve at the equilibrium. However, the smaller this slope of the $LL$-curve is, the more unlikely is it that a further tightening of IPR protection can contribute to an increase in the innovation rate. This implies that for low technological offshoring costs it is more likely that loose

IPR protection is growth-maximizing.

**Corollary 1** *A lower level of technological offshoring costs $\beta$ makes it more likely that a rather loose IPR protection maximizes the innovation rate.*

# 4 Numerical analysis

As indicated above, I proceed with a numerical analysis of the model, since the growth-maximizing level of IPR protection $\tilde{\gamma}$ cannot be solved for analytically. This numerical simulation presents a reasonable example where an inverse U-shaped relationship between IPR protection and innovation rate exists and can thereby give a better understanding of the trade offs at work in my model than a pure analytic description could possibly do.

Intuitively, the technological labor requirement for imitation with perfect knowledge spillovers $a^*$ is smaller than the labor requirement for innovation $a$. I further assume the South to be larger than the North in terms of labor endowment. To restrict the offshoring volume to values between 0 and 1, I choose a convex offshoring cost schedule $\tau(i)$ with very high offshoring costs for higher indexed tasks. With these assumptions a unique equilibrium can be identified.

Figure 2 shows the resulting innovation rate as a function of the level of IPR protection. The pattern is similar for various levels of technological offshoring costs and represents the results that I already outlined above: there exists an inverse U-shaped relationship between IPR protection and innovation rate. This result from my model reconciles the opposing theories by Glass & Saggi (2002) and Branstetter & Saggi (2009). As in the further contribution, tightening IPR protection can be harmful when it is already tight and, as in the latter contribution, a tighter level of IPR protection can further boost economic growth when IPR protection is very loose.

Having analyzed the value of optimal IPR protection for one specific parameter combination, I am furthermore interested in how these optimiality conditions react to changes in technological offshoring costs. I distinguish three different cases of optimal IPR protection. First, I assume the existence of a benevolent long-run oriented social planner who focuses on the growth rate of the economy. Second, I assume that the Northern country can force Southern authorities to implement the desired level of IPR protection to maximize Northern welfare. Or, equivalently, the North can choose between different partner countries with different levels of IPR protection to offshore production. Third, I assume that the Southern country autonomously decides on its IPR strategy to maximize own welfare and there

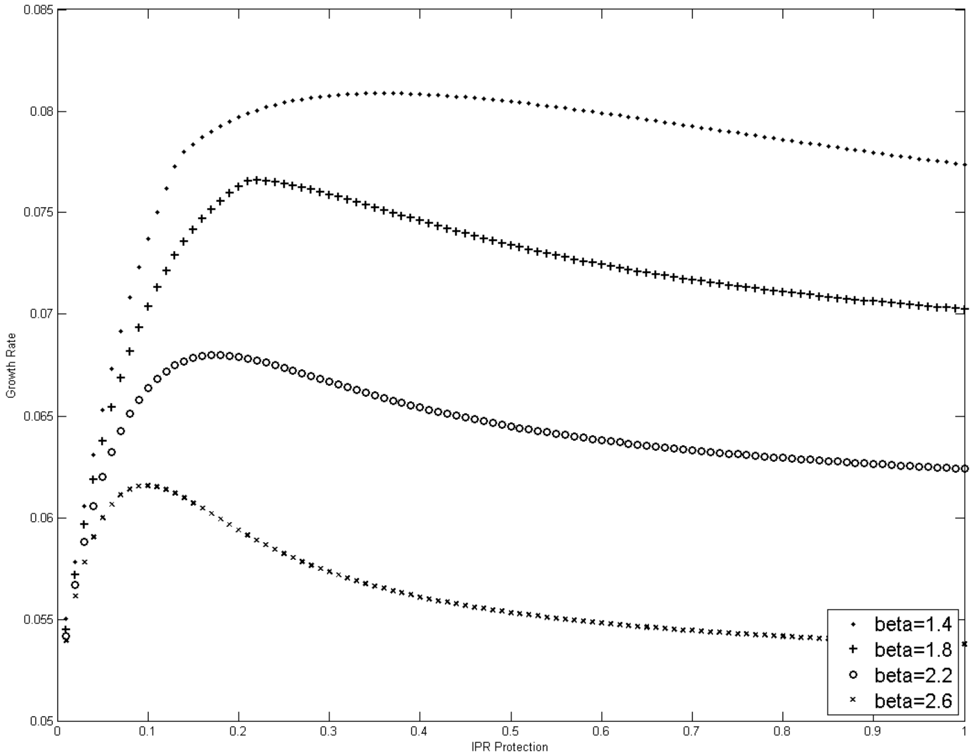


**Figure 2.** Growth Rate
Calibration: $L = 100$, $L^* = 200$, $a = 400$, $a^* = 50$, $\sigma = 2$, $\rho = 0.2$

is no other potential location for offshoring. The result for a fourth strategy, where a social planner maximizes joint welfare or where the two countries bargain over the IPR level must necessarily lie in between the second and the third outcome. In figure 3 I characterize the outcome for these three strategies depending on the level of technological offshoring costs $\beta$.

It becomes clear that for an archaic offshoring technology with high offshoring costs, all strategies demand high levels of IPR protection. However, as the offshoring technology improves, IPR protection should be reduced and finally might be completely abolished. This confirms the result from corollary 1. The growth-maximizing level of IPR protection is always tighter than the optimal IPR strategy for the other two concepts. This is due to the fact that a tight IPR protection creates a distortion in the firms' offshoring decision, driving up offshoring volumes towards tasks with high coordination costs where lots of resources are lost in the offshoring process. This has a negative effect on real wages that is welfare-relevant but not considered by the growth-maximizing policy maker.

The fact that Southern politicians also find it optimal to choose a positive level of IPR protection is

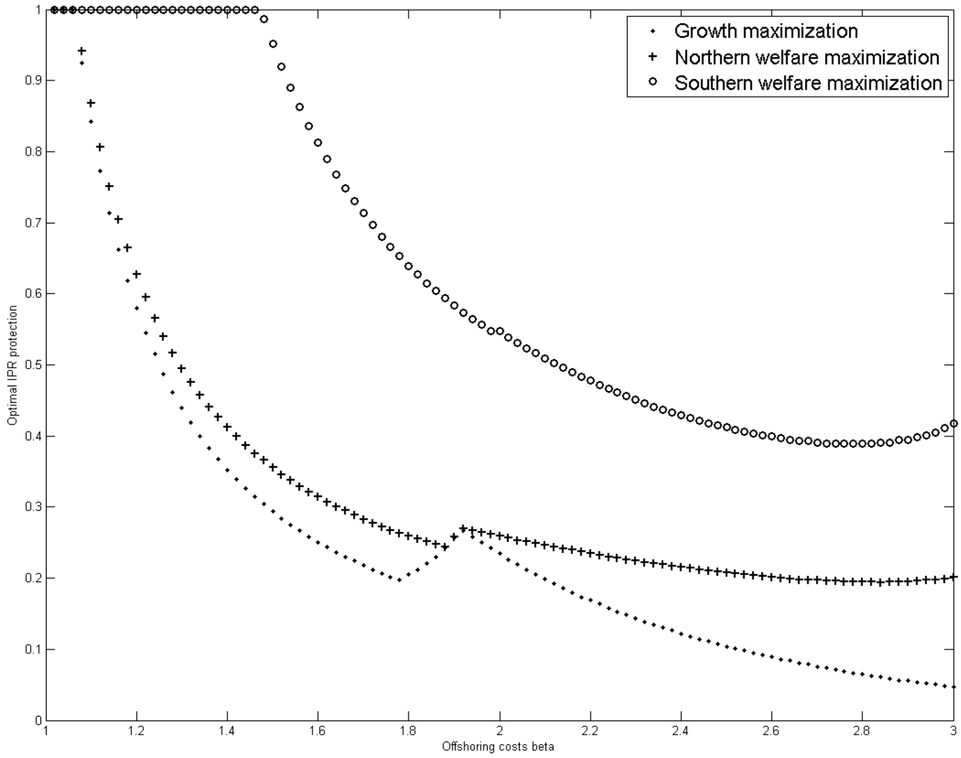


**Figure 3.** Optimal IPR protection
Calibration: $L = 100$, $L^* = 200$, $a = 400$, $a^* = 50$, $\sigma = 2$, $\rho = 0.2$

due to the fact that utility from more variety in consumption increases at the rate $g$, also for consumers in the South. Hence, it is only the shift in the relative wage from a reduction in the offshoring volume that makes a less rigorous IPR policy desirable from a Southern point of view.

Interestingly, the three scenarios all yield a (more or less pronounced) non-monotonicity in the optimal IPR level. This is due to the fact that relaxing IPR protection leads to a convergence of wages in the two countries. With an exogenous reduction of offshoring costs $\beta$ it seems worthwhile to accelerate the movement towards similar wages that makes Southern imitators hit the price constraint determined by their Northern competitor's production costs as described in footnote 1. A further improvement in offshoring technology allows for a tightening of IPR protection while keeping producers in the South just marginally price constrained. Only if $\beta$ is reduced even more, a more liberal IPR strategy can increase growth and welfare.

The offshoring technology is a crucial factor in the determination of the optimal IPR protection. Figure 4 illustrates that the driving force behind this result is the offshoring volume. When offshoring is

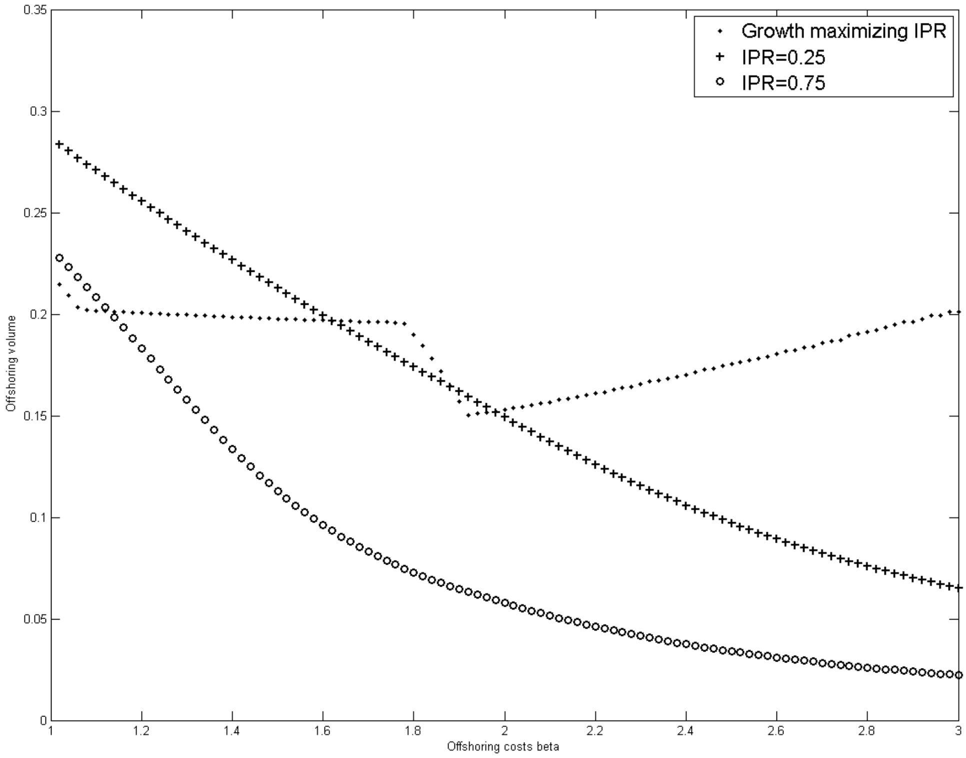


**Figure 4.** Offshoring Volume
Calibration: $L = 100$, $L^* = 200$, $a = 400$, $a^* = 50$, $\sigma = 2$, $\rho = 0.2$

technologically difficult, tight IPR protection is chosen to disrupt earnings prospectives from imitation in the South. Hence, wages in the Southern production sector can be reduced, which allows for a higher offshoring level. On the other hand, when offshoring is rather cheap, low IPR protection increases incentives for research in the South. This implies a flow of workers into the imitative research sector, higher wage pressure and less offshoring. The offshoring volume is kept on a low level compared to the technological possibilities.

Moreover, figure 4 reveals that my model is consistent with recent empirical evidence, suggesting a positive relationship of the quality of intellectual property legislation and the offshoring activity. For example Branstetter et al. (2006, 2010) find that multinational firms significantly increase their scale of oversea activities, following a reform that improves a country's intellectual property rights system. Canals and Sener (2011) suggest that especially high-tech-intensive industries expand their volume of offshore sourcing.

Somehow surprisingly, the growth-maximizing IPR protection does not yield an offshoring volume that monotonously increases as offshoring costs fall. However, this result must be seen in the light of a generally lower innovation rate when offshoring costs are high. Driving down the imitation rate by the same proportion leads to an increased movement of Southern workers into offshore production. To make this possible with increasing offshoring costs, incentives for imitation must be reduced over-proportionally which leads to further increases in the offshoring volume. Hence, the offshoring volume moving monotously with offshoring costs is not as intuitive as it seems on the first glance as soon as IPR protection is chosen optimally.

Summarizing, intermediate levels of offshoring seem to be an optimal choice for the long-run benefit of North and South. This is due to two opposing forces. On the one hand, a high share of offshored production means higher profits, increasing the leverage of a given research effort and leading to more innovative effort. On the other hand, a high share of offshored production increases the risk of imitation, which destroys profits from Northern innovation and thus reduces incentives for innovation. Balancing these two forces, the growth rate is maximized at intermediate levels of offshoring.

In other words, a tight IPR policy has a direct discouraging effect on imitation, a channel to increase the growth rate and welfare. However, it also is a source of distortion by *increasing* the offshoring volume above its original level. The cost of this distortion is lower, and thus the incentive for a tight IPR policy more persuasive when the initial offshoring volume is low or, in other words, technological offshoring costs are high. Although with a different intuition, the same result has already been identified in static models with a traditional trade policy instrument. Zissimos (2011) finds that incentives for positive distortionary tariffs that *decrease* trade volumes are higher between countries, where bilateral transport costs are lower, featuring a higher ex ante trade volume. This is due to the fact that costly transport destroys rents and if rents are lower, the rent-shifting motive of unilateral tariff setting is less important.

# 5 Conclusion

In this paper I analyze the role of intellectual property rights on the rate of innovation when production can be sliced into tasks that are potentially performed offshore and Northern varieties are at the risk of being imitated. There are several mechanisms that link these variables within the model. Incentives for innovation in the North lead to more offshoring through the full employment conditions. There are backward linkages from offshoring to innovation since leverage of the research activity is increased. Furthermore, on the one hand, offshoring facilitates the leakage of knowledge to the South and thereby raises the imitation rate of Northern inventions. On the other hand, the number of workers employed in imitative research is reduced since the full employment conditions must hold in the South.

I show that intermediate levels of IPR protection are required to maximize the steady-state growth rate, Northern welfare, or Southern welfare. The reason is a trade off between benefits from increased leverage of innovation and the costs of an increased imitation risk. This yields an interior solution for the optimal IPR protection level which is sensitive to the level of technological offshoring costs. With high offshoring costs that induce only a small offshoring volume, IPR protection should be tight to reduce profits from imitation and induce Southern workers to move into the offshoring production sector. With low offshoring costs, however, offshoring levels are already high and policy makers want to reduce them choosing less IPR protection and making the offshore production jobs relatively less attractive for Southern labor compared to imitative activity.

The resulting inverse U-shaped relationship of IPR protection and the innovation rate reconciles opposing theories from the existing literature. A sharpening of IPR protection raises the innovation rate when IPR protection is loose, as described by Brannstetter and Saggi (2009). However, when protection is already tight a further increase can be harmful as in Glass & Saggi (2002).

# Appendix

**Proof to proposition 2** Assuming $m = g$, the sign of $\mathcal{N}$ is equal to the sign of

$$\begin{aligned}
&\frac{(g+\rho)(\sigma-1)\beta}{(\beta\tau(I)\Theta(I))^{\sigma}}\left(\Theta(I)(1-\Theta(I))\tau(I)^2-\int_0^I \tau(i)\mathrm{d}i\frac{\Theta(I)\tau(I)}{(1-I)}\right)\\
&-\frac{(2g)^2}{\rho}\left(1+\frac{\rho+g}{g}(\sigma-1)\right)\left(\frac{\Theta(I)\tau(I)}{(1-I)}+\sigma I(1-I)\frac{\partial\tau(I)}{\partial I}+1+I\frac{((\sigma-1)(1-I)+\Theta(I))}{\Theta(I)\tau(I)}\frac{\partial\tau(I)}{\partial I}\right)\\
&-(g+(\rho+g)(\sigma-1))\left(\frac{I\Theta(I)\tau(I)}{(1-I)}+\sigma I(1-I)\frac{\partial\tau(I)}{\partial I}+2+2I\frac{((\sigma-1)(1-I)+\Theta(I))}{\Theta(I)\tau(I)}\frac{\partial\tau(I)}{\partial I}\right)\\
&<\frac{\beta}{(\beta\tau(I)\Theta(I))^{\sigma}}\left(\Theta(I)(1-\Theta(I))\tau(I)^2-\int_0^I \tau(i)\mathrm{d}i\frac{\Theta(I)\tau(I)}{(1-I)}\right)\\
&-\left(\frac{I\Theta(I)\tau(I)}{(1-I)}+\sigma I(1-I)\frac{\partial}{\partial I}\tau(I)+2+\frac{2I}{\Theta(I)\tau(I)}((\sigma-1)(1-I)+\Theta(I))\frac{\partial\tau(I)}{\partial I}\right)<0
\end{aligned} \tag{29}$$

since

$$\frac{1-\Theta(I)}{(\beta\Theta(I))^{\sigma-1}\tau(I)^{\sigma-2}}<2 \tag{30}$$

for a reasonable lower bound of the elasticity of substitution $\sigma \geq 2$. ■

**Proof to proposition 3** The partial derivative of $\mathcal{N}$ with respect to $m$ is given by

$$\begin{aligned}\frac{\partial \mathcal{N}}{\partial m} &= \Theta(I)\tau(I) - 2\frac{g+m}{\rho}\left(\frac{\Theta(I)\tau(I)}{1-I} + \sigma I(1-I)\frac{\partial \tau(I)}{\partial I}\right) \\ &\quad - (1+2(g+m))\left(1 + I\frac{(\sigma-1)(1-I)+\Theta(I)}{\Theta(I)\tau(I)}\frac{\partial \tau(I)}{\partial I}\right) \\ &< \Theta(I)\tau(I) - 2\frac{g+m}{\rho}\frac{\Theta(I)\tau(I)}{1-I} - 1 < 0 \end{aligned} \tag{31}$$

if the growth rate is not too low

$$2(g+m) > \frac{\Theta(I)\tau(I)-1}{\Theta(I)\tau(I)}(1-I)\rho \quad \blacksquare \tag{32}$$

**Lemma 1** *The partial derivative* $\partial m/\partial I > 0$

**Proof** The derivative is given by

$$\frac{\partial m}{\partial I} = \frac{\partial \Phi}{\partial I}\frac{\rho}{(1-\Phi)^2} \tag{33}$$

since we know that

$$0 < \Phi = \frac{g+m}{\rho+g+m} < 1 \tag{34}$$

and

$$\frac{\partial \Phi}{\partial I} = \Phi\left(\frac{1}{I} + \frac{((\sigma-1)(1-I)+\Theta(I))}{\Theta(I)\tau(I)}\frac{\partial \tau(I)}{\partial I}\right) > 0 \quad \blacksquare \tag{35}$$

**Lemma 2** *Under the conditions that* $g > 0$, $m > 0$, $I \in [0;1]$, $g \geq m$, *and an additional loose upper limit on the elasticity of substitution the domestic full employment curve is upward sloping in the I-g-space, while the foreign full employment curve is downward sloping. This means that a unique equilibrium exists.*

**Proof** The domestic full employment curve is upward sloping

$$\frac{\mathsf{d}g}{\mathsf{d}I}_{|\mathsf{d}L=0} = -\frac{\partial L/\partial I}{\partial L/\partial g} > 0 \tag{36}$$

since

$$L_g := \frac{\partial L}{\partial g} = a + \frac{a^*(\sigma-1)(1-I)}{I\gamma(\Theta(I)\tau(I)\beta)^\sigma} > 0 \tag{37}$$

and

$$L_I := \frac{\partial L}{\partial I} = -\frac{a^*(g+\rho)(\sigma-1)}{I^2\gamma(\beta\Theta(I)\tau(I))^\sigma} - \frac{a^*\sigma(g+\rho)(\sigma-1)(1-I)^2\beta\frac{\partial\tau(I)}{\partial I}}{I\gamma(\beta\Theta(I)\tau(I))^{\sigma+1}} < 0 \tag{38}$$

while the foreign full employment curve is downward sloping

$$\frac{\mathsf{d}g}{\mathsf{d}I}_{|\mathsf{d}L^*=0} = -\frac{\partial L^*/\partial I}{\partial L^*/\partial g} < 0. \tag{39}$$

since

$$
\begin{aligned}
L_g^* := \frac{\partial L^*}{\partial g} &= \frac{a^*(\sigma-1)\int_0^I \tau(i)\,\mathrm{d}i\beta}{I\gamma(\Theta(I)\tau(I)\beta)^\sigma} - \frac{a^*\rho(\sigma-1)}{g^2 I\gamma}\left(\frac{\rho\Phi}{1-\Phi}-g\right) + \frac{a^*((g+\rho)(\sigma-1)+g)}{gI\gamma}\left(\frac{\rho\frac{\partial\Phi}{\partial g}}{(1-\Phi)^2}-1\right) \\
&= \frac{a^*(\sigma-1)\int_0^I \tau(i)\,\mathrm{d}i\beta}{I\gamma(\Theta(I)\tau(I)\beta)^\sigma} - \frac{a^*\rho(\sigma-1)m}{g^2 I\gamma} + \frac{a^*\left(g^2\sigma+g\rho(\sigma-1)\right)}{g^2 I\gamma}\left(\frac{m(2g+m+\rho)}{g(g+\rho)}\right) \\
&> \frac{a^*(\sigma-1)\int_0^I \tau(i)\,\mathrm{d}i\beta}{I\gamma(\Theta(I)\tau(I)\beta)^\sigma} - \frac{a^*\rho(\sigma-1)m}{g^2 I\gamma} + \frac{a^*(\sigma-1)g(g+\rho)}{g^2 I\gamma}\left(\frac{m(2g+m+\rho)}{g(g+\rho)}\right) \\
&= \frac{a^*(\sigma-1)\int_0^I \tau(i)\,\mathrm{d}i\beta}{I\gamma(\Theta(I)\tau(I)\beta)^\sigma} + \frac{a^*(\sigma-1)m(2g+m)}{g^2 I\gamma} > 0
\end{aligned} \tag{40}
$$

Moreover,

$$
\begin{aligned}
L_I^* := \frac{\partial L^*}{\partial I} &= \frac{a^*\frac{\rho\frac{\partial}{\partial I}\Phi(I,g)}{(\Phi(I,g)-1)^2}\left(\frac{(g+\rho)(\sigma-1)}{g}+1\right)}{I\gamma} - \frac{a^*\left(\frac{(g+\rho)(\sigma-1)}{g}+1\right)}{I^2\gamma}\left(\frac{\rho\Phi}{1-\Phi}-g\right) \\
&+ \frac{a^*(g+\rho)\left(I\tau(I)-\int_0^I\tau(i)\,\mathrm{d}i\right)(\sigma-1)\beta}{I^2\gamma(\beta\Theta(I)\tau(I))^\sigma} - \frac{a^*\sigma(g+\rho)\int_0^I\tau(i)\,\mathrm{d}i(\sigma-1)(1-I)\frac{\partial}{\partial I}\tau(I)\beta^2}{I\gamma(\beta\Theta(I)\tau(I))^{\sigma+1}} \\
&= \frac{a^*((g+\rho)(\sigma-1)+g)\left(\frac{\partial\Phi}{\partial I}\frac{I\rho}{(1-\Phi)^2}-m\right)(\beta\Theta(I)\tau(I))^{\sigma+1}}{gI^2\gamma(\beta\Theta(I)\tau(I))^{\sigma+1}} \\
&+ \frac{a^*g(g+\rho)(\sigma-1)\beta^2}{gI^2\gamma(\beta\Theta(I)\tau(I))^{\sigma+1}}\left(\left(I\tau(I)-\int_0^I\tau(i)\,\mathrm{d}i\right)\Theta(I)\tau(I)-\sigma\int_0^I\tau(i)\,\mathrm{d}i(1-I)\frac{\partial\tau(I)}{\partial I}I\right)
\end{aligned} \tag{41}
$$

which is larger than zero since

$$
I\tau(I) - \int_0^I \tau(i)\,\mathrm{d}i > 0 \tag{42}
$$

and using equation (35) it is possible to derive a sufficient condition for the first term being larger than the remainder of the second term as

$$
\sigma < 4\Theta(I)^{\sigma+1}(\beta\tau(I))^{\sigma-1} \tag{43}
$$

which constitutes a loose upper bound for the elasticity of substitution between varieties. ■

**Lemma 3** *The domestic full employment curve is concave in the I-g-space.*

**Proof** The curvature of the implicit function $L = L(I,g)$ in the I-g-space is given by

$$
\frac{\mathrm{d}^2 g}{\mathrm{d}I^2} = -\frac{L_{II}L_g^2 + L_{gg}L_I^2 - 2L_{Ig}L_I L_g}{L_g^3} \tag{44}
$$

where the subscripts denote first and second partial derivatives. The denominator is positive since $\frac{\partial L}{\partial g} > 0$ as shown above. Moreover, the second term of the numerator vanishes due to $\frac{\partial^2 L}{\partial g^2} = 0$, so that concavity is proven by

$$
L_{II}L_g^2 > 2L_{Ig}L_I L_g. \tag{45}
$$

The term on the left-hand side is positive

$$\frac{\partial^2 L}{\partial I^2} = \frac{a^* (g+\rho)(\sigma-1)\, 2}{I^3 \gamma(\beta\Theta(I)\tau(I))^{\sigma}} + \frac{a^*\sigma(g+\rho)(\sigma-1)\beta\left((2-I-I^2)\frac{\partial\tau(I)}{\partial I} - I\left(1-2I+I^2\right)\beta\frac{\partial^2\tau(I)}{\partial I^2}\right)}{I^2\gamma(\beta\Theta(I)\tau(I))^{\sigma+1}}$$
$$+\frac{a^*\sigma(g+\rho)(\sigma-1)(\sigma+1)(1-I)^3\beta^2\left(\frac{\partial\tau(I)}{\partial I}\right)^2}{I\gamma(\beta\Theta(I)\tau(I))^{\sigma+2}} > 0 \tag{46}$$

if the offshoring cost schedule is not too convex

$$\frac{\partial^2\tau(I)}{\partial I^2} < \frac{\partial\tau(I)}{\partial I}\frac{2-I-I^2}{I(1-2I+I^2)} \tag{47}$$

and the term on the right-hand side is positive since $\frac{\partial L}{\partial g} > 0$ and $\frac{\partial L}{\partial I} < 0$ as shown above and the cross derivative

$$\frac{\partial^2 L}{\partial I\partial g} = -\frac{a^*(\sigma-1)}{I^2\gamma(\beta\Theta(I)\tau(I))^{\sigma}} - \frac{a^*\sigma(\sigma-1)(1-I)^2\beta\frac{\partial\tau(I)}{\partial I}}{I\gamma(\beta\Theta(I)\tau(I))^{\sigma+1}} < 0 \tag{48}$$

However, I can show that a sufficient condition for equation (45) to hold is

$$\left(1+\Theta(I)\frac{\sigma}{\sigma-1}-I\right)\left(1+\frac{1}{2}\frac{\sigma(\sigma+1)I^2(1-I)^3}{(\Theta(I)\tau(I))^2}\left(\frac{\partial\tau(I)}{\partial I}\right)^2\right) > \left(1+\frac{\sigma I(I-1)^2\frac{\partial\tau(I)}{\partial I}}{\Theta(I)\tau(I)}\right)^2 \tag{49}$$

which constitutes a very loose upper limit to the feasible offshoring volume. An extended version of the proof is available upon request. ■

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