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Abstract

What are the effects of the WTO's TRIPS Agreement on growth, welfare and income inequality? To analyze this question, we develop an open-economy R&D-driven endogenous-growth model with wealth heterogeneity. Under TRIPS, the North experiences higher growth and welfare at the expense of higher income inequality. As for the South, it experiences higher growth at the expense of lower welfare and higher income inequality. Also, there exists a critical degree for the domestic importance of foreign goods below which global welfare decreases under TRIPS. In light of our findings, we discuss policy implications on China's accession to the WTO in 2001.

Keywords: endogenous growth, heterogeneity, income inequality, patent policy, TRIPS

JEL classification: O34, O41, D31, F13

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1. Introduction

The WTO's Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) establishes a minimum level of protection that each member country has to provide the intellectual property of other WTO members. An important implication of this agreement is that developing countries (the South) have to increase their level of patent protection to that of developed countries (the North).[1] Given the importance of TRIPS, what are its effects on economic growth, social welfare and income inequality?

To analyze this question, we develop an open-economy quality-ladder model with heterogeneity in the initial wealth of households. In the model, both the North and the South invest in R&D, but the North is assumed to have a higher degree of innovative capability than the South. Within this framework, we derive the following results. Firstly, an increase in the level of patent protection in either the North or the South increases both countries' (a) economic growth by stimulating R&D investment and (b) income inequality by raising the return on assets. Then, following Lai and Qiu (2003) and Grossman and Lai (2004), we derive the pre-TRIPS Nash equilibrium level of patent protection. We find that the North would set a higher level of patent protection than the South. Imposing the North's level of patent protection on the South as required by TRIPS increases (decreases) social welfare of the North (South).

On one hand, this welfare analysis is consistent with Lai and Qiu (2003) and Grossman and Lai (2004). On the other hand, when comparing global welfare between the Nash equilibrium and the policy regime under TRIPS, we find that there exists a critical degree for the importance of foreign goods in domestic consumption below (above) which global welfare is lower (higher) under TRIPS while Lai and Qiu (2003) find that global welfare is always higher under TRIPS. This difference arises because we allow for varying degree for the importance of foreign goods in domestic consumption. In our model, the degree of positive externality in the Nash equilibrium is determined by the domestic importance of foreign goods. When foreign goods are not very important for domestic consumption, the two countries are almost in autarky. In this case, imposing the North's level of patent protection on the South makes the South worse off without making the North much better off.

[1] See, for example, Lai and Qiu (2003), Grossman and Lai (2004) and Lai (2005) for a discussion.

The above finding has important policy implications. Firstly, it implies that the North is not always able to compensate the South. Secondly, the condition under which global welfare would increase under TRIPS is that foreign goods are sufficiently important for domestic consumption. In other words, a sufficient degree of globalization is a necessary condition for the harmonization of intellectual property rights to improve global welfare. This finding rationalizes the fact that TRIPS, which is an international agreement on intellectual property issues rather than trade issues, is on the agenda of the WTO, an organization for liberalizing trade.

Finally, our model with heterogeneous households enables us to analyze the effects of TRIPS on income inequality in addition to growth and welfare. Under TRIPS, the North experiences higher levels of growth and welfare at the expense of higher income inequality. As for the South, it experiences higher growth at the expense of lower welfare and higher income inequality. In other words, we find that the representative-agent welfare analysis of TRIPS in previous studies can be robust to an extension with heterogeneous households. However, given the effect of TRIPS on income inequality, an analysis without considering the distributional consequences within a country may overstate the benefits and understate the costs to the society if income inequality is a social concern.

As an example of the South, China amended its patent law in 2000 in anticipation of its accession to the WTO in 2001.[2] Since this amendment, the annual growth rate of the number of applications for invention patents in China has increased to 23% (compared to less than 10% before 2000). Hu and Jefferson (2006) provide empirical evidence to show that the patent-law amendment in 2000 is a major factor for China's recent surge in patenting activities. Also, R&D as a share of GDP in China increases from an average of about 0.7% in the 90's to 1.34% in 2004. At the same time, the rising income inequality in China poses the country a serious challenge on domestic stability. In 2007, China's Gini coefficient rises to 0.47 that is above the threshold of 0.45 considered by many to indicate potential social

[2] The changes include (a) providing patent holders with the right to obtain a preliminary injunction against the infringing party before filing a lawsuit, (b) stipulating standards to compute statutory damages, (c) affirming that state and non-state enterprises enjoy equal patent rights, and (d) simplifying the patent application process, examination and transfer procedures and unifying the appeal system. See Hu and Jefferson (2006) for more details.

unrest. "The United Nations Development Programme… warned that the growing income gap between rich and poor in China could threaten its stability, saying Beijing should increase social spending, reform the fiscal system and push government reforms to narrow the gap." Our analysis suggests that increasing the level of patent protection in China as a result of TRIPS would not only lead to a reduction in China's social welfare as implied by previous studies but also exacerbates its rising income inequality.[3] Given the current situation in China, the second consequence seems to be more alarming. Therefore, our analysis supports the use of other policy tools in China, such as a more progressive income-tax system that "controls the rise in inequality by redistributing the gains from growth".[4]

Literature Review

This paper relates to Lai and Qiu (2003) and Grossman and Lai (2004). These two papers derive the Nash equilibrium level of patent protection in an open-economy variety-expanding model, in which the North and the South differ in innovative capability and analyze the welfare effects of imposing the North's level of patent protection on the South. We complement these interesting studies by also considering the effects of TRIPS on income inequality and growth and by allowing for varying degree for the importance of foreign goods in domestic consumption. To the best of our knowledge, our study is the first to analyze the effects of TRIPS on welfare, growth and income inequality simultaneously. The allowance of varying degree of domestic importance of foreign goods also yields some interesting findings.

Lai (2005) extends the model in Grossman and Lai (2004) to consider the effects of trade barrier on the Nash equilibrium level of patent protection. Lai (2005) is interested in deriving a condition under which the level of patent protection is too low before TRIPS and finds that this condition is likely to holds based on calibrated parameters. In contrast, we are interested in the change in the level of global welfare before and after TRIPS. In other words, given a suboptimally low level of patent protection before TRIPS, we want to know whether the North is able to compensate the South under TRIPS, which is a very

[3] We would like to emphasize that China's accession to the WTO carries other benefits, such as a reduction in trade barriers, which are not captured in this partial analysis of patent policy.
[4] See Piketty and Qian (2009) for a discussion.

particular policy regime that requires the harmonization of patent protection. Another difference is that Lai (2005) models trade barrier as the probability that an invention can be sold overseas while we consider the intensity of foreign goods in domestic production. We introduce a parameter for transportation costs capturing trade barrier and find that this parameter affects welfare but not the equilibrium in our model.

This paper also relates to the vast literature on income inequality and growth.[5] Garcia-Penalosa and Turnovsky (2006) incorporate heterogeneity in the initial wealth of households into a canonical AK endogenous-growth model and develop an approach to show that the distribution of assets is stationary on the balanced-growth path. The current study adopts a similar approach to show that the distribution of assets is also stationary on the balanced-growth path of an open-economy R&D-growth model.

Chou and Talmain (1996), Li (1998), Zweimuller (2000), Foellmi and Zweimuller (2006) and Hatipoglu (2008) also consider wealth distribution in R&D-growth models, but they do so in a closed-economy setting and focus on the effects of wealth inequality on growth. The current paper differs from these studies by considering how policy changes affect income inequality through growth given a certain degree of wealth inequality, which is independent of growth in our model. In a related study, Chu (2008) analyzes the effects of strengthening patent protection in the US on its growth and inequality in a closed-economy quality-ladder model with wealth heterogeneity. The current study differs from Chu (2008) by modeling the level of patent protection as the outcome of a policy game between countries and by considering the effects of patent policy on social welfare.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 defines the equilibrium and analyzes its properties. Section 4 considers the effects of TRIPS on growth, welfare and income inequality. Section 5 concludes with some suggestions for future research.

[5] See Aghion et al. (1999) for a recent survey.

2. The Model

We develop a quality-ladder model similar to Aghion and Howitt (1992) and Grossman and Helpman (1991a) by adding mainly two features (a) heterogeneity in the initial wealth of households and (b) incomplete patent breadth (i.e. patent protection against imitation) as in Li (2001).[6] There are two countries denoted by the North (*n*) and the South (*s*). As in Lai and Qiu (2003) and Grossman and Lai (2004), both countries invest in R&D, but they differ in innovative capability. The North is assumed to have a higher degree of innovative capability than the South. The two countries are linked through trade in intermediate goods similar to Peng et al. (2006), and trade is balanced as commonly assumed in this type of literature.

Given that quality-ladder models have been well-studied, the familiar components of the models are briefly described in Sections 2.1-2.4. To conserve space, we only present the equations for the North. However, the readers are advised to keep in mind that for each equation that we present, there is an analogous equation for the South.

2.1 Households

There is a continuum of identical households (except for the initial holding of wealth) on the unit interval $h \in [0,1]$ in each of the two countries indexed by a superscript $\in \{n, s\}$, and households are immobile across countries. In country *n*, household *h*'s utility function is given by

$$U^n(h) = \int_0^\infty e^{-\rho t} \ln C_t^n(h) dt . \tag{1}$$

$C_t^n(h)$ denotes household *h*'s consumption. $\rho > 0$ is the exogenous discount rate. Each household maximizes utility subject to a sequence of budget constraints given by

[6] Lai and Qiu (2003) and Grossman and Lai (2004) consider patent protection in the form of patent length in their variety-expanding models. Given that we have a quality-ladder model, we consider patent protection in the form of patent breadth, which is an equally important patent-policy instrument commonly discussed in the patent-design literature. See, for example, O'Donoghue and Zweimuller (2004) for a discussion. Using China as an example, its statutory length of patent has been 20 years since 1993, and the patent-law amendments before its accession to the WTO in 2001 were related to other aspects of patent protection as mentioned in footnote 2.

(2) $$\dot{V}_t^n(h) = R_t^n V_t^n(h) + W_t^n - P_t^n C_t^n(h).$$

$V_t^n(h)$ is the value of financial assets owned by household *h* in country *n* at time *t*. Household *h*'s share of financial assets at time 0 is exogenously given by $s_{v,0}^n(h) \equiv V_0^n(h)/V_0^n$ that has a general distribution function with a mean of $\int_0^1 s_{v,0}^n(h)dh = 1$ and a variance of $(\sigma_v^n)^2 \equiv \int_0^1 [s_{v,0}^n(h) - 1]^2 dh$. R_t^n is the nominal rate of return on assets in country *n*. We assume home bias in asset holding such that the shares of monopolistic firms in each country are solely owned by domestic households.[7] Household *h* inelastically supplies one unit of labor to earn a wage income W_t^n. P_t^n is the price of consumption in country *n*. From the household's intertemporal optimization, the familiar Euler equation is given by

(3) $$\frac{\dot{C}_t^n(h)}{C_t^n(h)} = r_t^n - \rho,$$

where $\dot{C}_t^n(h)/C_t^n(h)$ is the same for all *h* and $r_t^n \equiv R_t^n - \dot{P}_t^n / P_t^n$ is the real rate of return on assets.

2.2 Final Goods

Consumption in country *n* is an aggregate of domestic and foreign final goods given by

(4) $$C_t^n = \frac{(C_t^{n,n})^{1-\alpha}(C_t^{n,s})^{\alpha}}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}}.$$ [8]

$C_t^{n,s}$ refers to final goods consumed by country *n* and produced by inputs from country *s*. The parameter $\alpha \in [0,0.5]$ determines the importance of foreign goods in domestic consumption. A large number of perfectly competitive firms produce final goods using a standard Cobb-Douglas aggregator over a continuum of differentiated intermediates goods $i \in [0,1]$.

[7] Note that home bias does not eliminate the positive externality of patent protection in generating profits to be earned by foreign households. When a country raises its level of patent protection, foreign firms owned by foreign households still earn a larger amount of profits. What home bias does is to naturally link the degree of this positive externality to the share of goods traded, which is determined by the domestic importance of foreign goods.

[8] This type of Armington aggregator is commonly used in open-economy macroeconomic models for aggregating tradable goods across countries. See, for example, Obstfeld and Rogoff (2000).

(5) $$C_t^{n,n} = \exp\left(\int_0^1 \ln C_t^{n,n}(i)di\right),$$

(6) $$C_t^{n,s} = \exp\left(\int_0^1 \ln C_t^{n,s}(i)di\right).$$

$C_t^{n,s}(i)$ refers to intermediate goods *i* produced by inputs from country *s*.

2.3 Intermediate Goods

In country *n*, there is a continuum of industries indexed by $i \in [0,1]$. Each industry is dominated by a temporary monopolistic leader, who produces $X_t^{n,n}(i)$ and $X_t^{s,n}(i)$ that are the necessary inputs for $C_t^{n,n}(i)$ and $C_t^{s,n}(i)$ respectively. The leader holds a patent in each country for the industry's latest technology. Using the leader's input $X_t^{n,n}(i)$, the level of output for $C_t^{n,n}(i)$ is

(7) $$C_t^{n,n}(i) = z^{N_t^n(i)} X_t^{n,n}(i).$$

$z > 1$ is the exogenous quality improvement from each invention, and $N_t^n(i)$ is the number of inventions that has occurred in industry *i* of country *n* as of time *t*. In other words, $z^{N_t^n(i)}$ represents the quality of each unit of input produced by the leader while $X_t^{n,n}(i)$ is the quantity of input produced. Similarly, using the leader's input $X_t^{s,n}(i)$, the level of output for $C_t^{s,n}(i)$ is

(8) $$C_t^{s,n}(i) = (1-\tau) z^{N_t^n(i)} X_t^{s,n}(i),$$

where $\tau \in [0,1)$ represents transportation costs (i.e. the fraction of goods lost or damaged during transportation from one country to another) capturing the degree of trade barrier.

To produce one unit of $X_t^{n,n}(i)$ or $X_t^{s,n}(i)$, the industry leader needs to employ one unit of workers. Therefore, the production function is

(9) $$X_t^{n,n}(i) + X_t^{s,n}(i) = L_{x,t}^{n,n}(i) + L_{x,t}^{s,n}(i) = L_{x,t}^{n}(i).$$

$L^n_{x,t}(i)$ is the number of workers in industry i of country n. The marginal cost of producing one unit of $X^{n,n}_t(i)$ or $X^{s,n}_t(i)$ is

$$MC^n_t(i) = W^n_t \, . \tag{10}$$

Implicitly, we have assumed that the industry leader must employ domestic workers to produce for both domestic and foreign markets and sidestepped the issues of foreign direct investment, licensing and overseas imitation in order to keep the model tractable.[9]

As commonly assumed in quality-ladder models, the current and former industry leaders engage in Bertrand competition, and the familiar profit-maximizing pricing strategy for the current industry leader is a constant markup over the marginal cost. The prices for $X^{n,n}_t(i)$ and $X^{s,n}_t(i)$ are respectively

$$P^{n,n}_t(i) = \mu(z,b^n)MC^n_t(i) \, , \tag{11}$$

$$P^{s,n}_t(i) = \mu(z,b^s)MC^n_t(i) \, , \tag{12}$$

where $\mu(z,b) = z^b$ for $b \in (0,1]$. b^n (b^s) captures the level of patent breadth in country n (s). In Aghion and Howitt (1992) and Grossman and Helpman (1991a), there is complete patent protection against imitation, i.e. $b = 1$. Li (2001) generalizes the policy environment to capture incomplete patent protection against imitation, i.e. $b \in (0,1]$. Because of incomplete patent protection, the former leader can imitate the current leader such that the quality of her product to be sold in country n (s) increases by a factor of z^{1-b^n} (z^{1-b^s}). In other words, the quality of the former leader's product to be sold in country n (s) can increase to $z^{N^n_t(i)-b^n}$ ($z^{N^n_t(i)-b^s}$) without infringing the current leader's patents.[10] As a result, the limit-pricing markup for the current leader is given by z^{b^n} in country n and z^{b^s} in country s respectively. An increase in b in either country enables the current leader to charge a higher markup in that country. The resulting

[9] These interesting issues have been well-studied in another strand of literature. See, for example, Grossman and Helpman (1991b), Helpman (1993), Lai (1998), Yang and Maskus (2001), Glass and Saggi (2002a, b) and Tanaka et al. (2007).

[10] $z^{N-b} = (z^{N-1})(z^{1-b})$, in which the first term on the right is the quality of the former leader's product while the second term is the increase in the quality of her product by legally imitating the current leader's product.

increases in monopolistic profits and the value of an invention improve the incentives for R&D investment. From now on, we denote patent protection as $\mu^n \equiv \mu(z,b^n)$ for convenience and consider changes in μ^n coming from changes in b^n only.

2.4 R&D

Denote the expected value of an invention for industry *i* in country *n* as $\widetilde{V}_t^n(i)$. Due to the Cobb-Douglas specification in (5) and (6), the amount of monopolistic profits is the same across industries within a country (i.e. $\pi_t^{n,n}(i) = \pi_t^{n,n}$ and $\pi_t^{s,n}(i) = \pi_t^{s,n}$ for $i \in [0,1]$). As a result, $\widetilde{V}_t^n(i) = \widetilde{V}_t^n$ for $i \in [0,1]$. Also, denote the sum of profits generated by an invention from country *n* as $\pi_t^n \equiv \pi_t^{n,n} + \pi_t^{s,n}$. Because of complete home bias in asset holding, the market value of inventions in country *n* equals the total value of assets owned by domestic households (i.e. $\widetilde{V}_t^n = V_t^n$). The familiar no-arbitrage condition for V_t^n is

(13) $$R_t^n V_t^n = \pi_t^n + \dot{V}_t^n - \lambda_t^n V_t^n .$$

The left-hand side of (13) is the nominal return on this asset.[11] The right-hand side of (13) consists of the sum of (a) the monopolistic profit π_t^n generated by this asset, (b) the potential capital gain $\dot{V}_t^n$, and (c) the expected capital loss $\lambda_t^n V_t^n$ due to creative destruction, in which λ_t^n is the Poisson arrival rate of the next invention in country *n*.

There is a continuum of R&D entrepreneurs indexed by $j \in [0,1]$ in each country, and they hire workers to create inventions. The expected profit for entrepreneur *j* in country *n* is

(14) $$\pi_{r,t}^n(j) = V_t^n \lambda_t^n(j) - W_t^n L_{r,t}^n(j) .$$

[11] As in Grossman and Helpman (1991a), the risky asset is valued at the risk-free rate because the idiosyncratic risk for any one leader is fully diversified assuming the existence of a well-functioning stock market in each country.

The Poisson arrival rate of an invention for entrepreneur j in country n is $\lambda_t^n(j) = \varphi^n L_{r,t}^n(j)$, where φ^n captures the productivity of R&D workers in country n. Without loss of generality, we assume that $\varphi^n \geq \varphi^s$. Because of free entry, the zero-profit condition from the R&D sector is given by

$$V_t^n \varphi^n = W_t^n . \tag{15}$$

This condition determines the allocation of labor between production and R&D within each country.

3. Decentralized Equilibrium

In this section, we define the equilibrium and show that the aggregate economy is always on a unique and stable balanced-growth path. Then, Section 3.1 shows that the distribution of assets is stationary on the balanced-growth path. Section 3.2 derives our measure of income inequality. Section 3.3 defines social welfare and characterizes the Nash equilibrium as well as the globally optimal level of patent protection.

The equilibrium in country n is a sequence of prices $\{R_t^n, W_t^n, P_t^n, P_t^{n,n}(i), P_t^{s,n}(i), V_t^n(h), V_t^n\}_{t=0}^{\infty}$ and a sequence of allocations $\{C_t^{n,n}(i), C_t^{s,n}(i), X_t^{n,n}(i), X_t^{s,n}(i), L_{x,t}^n(i), L_{r,t}^n(j), C_t^n(h), C_t^n, C_t^{n,n}, C_t^{n,s}\}_{t=0}^{\infty}$. Also, in each period,

a. household h chooses $\{C_t^n(h)\}$ to maximize (1) subject to (2) taking $\{R_t^n, W_t^n, P_t^n\}$ as given;

b. perfectly competitive final-goods firms maximize profit taking prices as given;

c. the leader in industry i produces $\{X_t^{n,n}(i), X_t^{s,n}(i)\}$ and chooses $\{P_t^{n,n}(i), P_t^{s,n}(i), L_{x,t}^n(i)\}$ to maximize profit according to the Bertrand competition and taking $\{W_t^n\}$ as given;

d. R&D entrepreneur j chooses $\{L_{r,t}^n(j)\}$ to maximize profit taking $\{W_t^n, V_t^n\}$ as given;

e. the market for consumption clears such that $\int_0^1 C_t^n(h)dh = C_t^n = \dfrac{[C_t^{n,n}]^{1-\alpha}[C_t^{n,s}]^{\alpha}}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}}$;

f. the market for domestic final goods clears such that $C_t^{n,n} = \exp\left(\int_0^1 \ln C_t^{n,n}(i)di\right)$;

g. the market for foreign final goods clears such that $C_t^{n,s} = \exp\left(\int_0^1 \ln C_t^{n,s}(i)di\right)$;

h. the domestic market for intermediate goods *i* clears, i.e. $C_t^{n,n}(i) = z^{N_t^n(i)} X_t^{n,n}(i)$;

i. the overseas market for intermediate goods *i* clears, i.e. $C_t^{s,n}(i) = (1-\tau) z^{N_t^n(i)} X_t^{s,n}(i)$;

j. the labor market clears such that $\int_0^1 L_{x,t}^n(i)di + \int_0^1 L_{r,t}^n(j)dj = 1$; and

k. the value of trade in intermediate goods is balanced such that $P_t^{n,s}C_t^{n,s} = P_t^{s,n}C_t^{s,n}$.[12]

Lemma 1 shows that the aggregate economy always jumps immediately to a unique and stable balanced-growth path,[13] in which all aggregate variables grow at some constant (possibly zero) rates.

Lemma 1: *The aggregate economy is always on a unique and stable balanced-growth path, in which the equilibrium allocation of labor in country n is given by*

(16) $$L_x^{n,n}(\underset{-}{\mu^n}, \underset{-}{\varphi^n}) = \left(\frac{1-\alpha}{\mu^n}\right)\left(1+\frac{\rho}{\varphi^n}\right),$$

(17) $$L_x^{s,n}(\underset{-}{\mu^s}, \underset{-}{\varphi^n}) = \left(\frac{\alpha}{\mu^s}\right)\left(1+\frac{\rho}{\varphi^n}\right),$$

(18) $$L_r^n(\underset{+}{\mu^n}, \underset{+}{\mu^s}, \underset{+}{\varphi^n}) = 1 - \left(\frac{1-\alpha}{\mu^n} + \frac{\alpha}{\mu^s}\right)\left(1+\frac{\rho}{\varphi^n}\right).$$

Proof: See Appendix A.■

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[12] These price indices will be defined in the proof for Lemma 1.
[13] As in Grossman and Helpman (1991a), the implicit assumptions behind this result are (a) at any point in time, each industry has an existing leader with a competitor one step down the quality ladder and (b) R&D entrepreneurs always implement their inventions immediately (i.e. ruling out endogenous implementation cycles).

The properties of the equilibrium labor allocation are quite intuitive. An increase in μ^n, μ^s or φ^n improves the incentive for R&D. As a result, labor is reallocated away from the production sector to the R&D sector. To ensure that $L_r^n > 0$, we impose a lower bound on R&D productivity given by

(a1) $$\varphi^n > \rho/(\Gamma^n - 1),$$

where $\Gamma^n \equiv \left(\frac{1-\alpha}{\mu^n} + \frac{\alpha}{\mu^s}\right)^{-1}$.

Given the equilibrium allocation of labor, the next lemma characterizes the equilibrium outcomes for the other aggregate variables.

Lemma 2: *On the balanced-growth path, the other aggregate variables are given by*

(19) $$\lambda^n(\underset{+}{\mu^n}, \underset{+}{\mu^s}, \underset{+}{\varphi^n}) = \varphi^n L_r^n,$$

(20) $$\frac{\dot{C}_t^n}{C_t^n} \equiv g^n(\underset{+}{\mu^n}, \underset{+}{\mu^s}, \underset{+}{\varphi^n}, \underset{+}{\varphi^s}) = [(1-\alpha)\lambda^n + \alpha\lambda^s]\ln z,$$

(21) $$C_t^n = \left(1 + \frac{\rho}{\varphi^n}\right)\frac{W_t^n}{P_t^n}.$$

Proof: See Appendix A.■

The arrival rate of an invention is increasing in domestic R&D. The growth rate of consumption in country *n* is an increasing function in the arrival rate of an invention in either country. Thus, an increase in μ^n, μ^s, φ^n or φ^s increases domestic and/or foreign R&D as well as the consumption growth rate.

3.1 Distribution of Assets

I adopt a similar approach as in Garcia-Penalosa and Turnovsky (2006) to show that the distribution of assets is stationary on the balanced growth path. The value of assets in country *n* evolves according to

(22) $$\dot{V}_t^n = R_t^n V_t^n + W_t^n - P_t^n C_t^n .$$

Combining (2) and (22), the law of motion for $s_{v,t}(h) \equiv V_t(h)/V_t$ is given by

(23) $$\frac{\dot{s}_{v,t}^n(h)}{s_{v,t}^n(h)} = \frac{W_t^n - P_t^n C_t^n(h)}{V_t^n(h)} - \frac{W_t^n - P_t^n C_t^n}{V_t^n} .$$

From (15) and (21), $s_{v,t}^n(h)$ evolves according to a simple linear differential equation given by

(24) $$\dot{s}_{v,t}^n(h) = \left(1 - s_c^n(h)\left(1 + \frac{\rho}{\varphi^n}\right)\right)\varphi^n + \rho\, s_{v,t}^n(h) .$$

(24) describes the potential evolution of $s_{v,t}^n(h)$ given an initial value of $s_{v,0}^n(h)$. $s_c^n(h) \equiv C_t^n(h)/C_t^n$ is a stationary variable from (3), so that the first term in (24) is constant. The coefficient on $s_{v,t}^n(h)$ given by ρ is constant and positive. Therefore, the only solution consistent with long-run stability is $\dot{s}_{v,t}^n(h) = 0$ for all *t*. From (24), $\dot{s}_{v,t}^n(h) = 0$ for all *t* implies that $s_{v,t}^n(h) = s_{v,0}^n(h)$ and

(25) $$C_t^n(h) = \left(1 + \frac{\rho\, s_{v,0}^n(h)}{\varphi^n}\right)\frac{W_t^n}{P_t^n}$$

for all *t*. Lemma 3 summarizes the stationarity of the wealth distribution in country *n*.

Lemma 3: *For every household h in country n,* $s_{v,t}^n(h) = s_{v,0}^n(h)$ *for all t.*

Proof: Proven in the text.■

3.2 Income Inequality

This section derives our measure of income inequality. Income for household *h* is defined as the sum of the real return on financial assets and the wage income given by

(26) $$Y_t^n(h) = r_t^n V_t^n(h) + W_t^n .$$

From (3), (15) and Lemma 3, the share of income earned by household *h* simplifies to

(27) $$s_{y,t}^{n}(h) \equiv \frac{Y_t^n(h)}{Y_t^n} = \frac{(\rho + g^n)s_{v,0}^n(h) + \varphi^n}{\rho + g^n + \varphi^n}$$

for all t. (27) implies that the standard deviation of relative income $\sigma_y^n \equiv \sqrt{\int_0^1 [s_{y,t}^n(h) - 1]^2 dh}$ is

(28) $$\sigma_y^n = \left(\frac{\rho + g^n}{\rho + g^n + \varphi^n} \right) \sigma_v^n ,$$

where the standard deviation of relative wealth σ_v^n is exogenously given at time 0. We follow Garcia-Penalosa and Turnovsky (2006) to use the standard deviation of relative income as a measure of income inequality. Proposition 1 summarizes the effect of growth on income inequality.

Proposition 1: *Income inequality is an increasing function in the equilibrium growth rate.*

Proof: See (28).■

Intuitively, an increase in the growth rate leads to a higher real rate of asset return that increases the income of asset-wealthy households relative to asset-poor households. We now consider the effects of an exogenous increase in patent protection on growth and income inequality.

Corollary 1: *An increase in* μ^n *or* μ^s *increases growth and income inequality in both countries.*

Proof: See (20) and (28).■

A higher level of patent protection in either country increases R&D and hence economic growth as well as income inequality in both countries.

3.3 Social Welfare

Due to the balanced-growth behavior of the model, the utility of household h in country n simplifies to

(29) $$U^n(h) = \frac{\ln C_0^n(h)}{\rho} + \frac{g^n}{\rho^2}.$$

Substituting (25) into (29) yields

(30) $$\rho U^n(h) = \ln\left(1 + \frac{\rho s_{v,0}^n(h)}{\varphi^n}\right) + \ln\left(\frac{W_0^n}{P_0^n}\right) + \frac{g^n}{\rho}.$$

Note that in (30), the household-specific term is independent of patent protection.

Lemma 4: *After dropping the exogenous terms, the real wage rate in country n can be decomposed into*

(31) $$\ln(W_0^n / P_0^n) = -\ln \mu^n + \alpha \ln(1-\tau) + \alpha \ln(W^n / W^s).$$

Proof: See Appendix A.■

Lemma 4 shows that the real wage rate in country n has three components (a) the negative effect of markup pricing, (b) the negative effect of trade barrier, and (c) the relative wage rate across the two countries. An expression for the relative wage rate can be derived using the balanced-trade condition $P_t^{s,n} C_t^{s,n} = P_t^{n,s} C_t^{n,s}$, which simplifies to

(32) $$\frac{W^n}{W^s} \equiv \omega^n(\underset{+}{\varphi^n}, \underset{-}{\varphi^s}) = \frac{\mu^n}{\mu^s}\left(\frac{L_x^{n,s}}{L_x^{s,n}}\right) = \left(1 + \frac{\rho}{\varphi^s}\right) \Big/ \left(1 + \frac{\rho}{\varphi^n}\right) \geq 1.$$

Therefore, the relative wage rate is independent of patent protection. Substituting (31) and (32) into (30) and dropping the terms that are independent of patent protection yield the welfare of any household h in country n as a function of μ^n and μ^s given by

(33) $$\Omega^n(\mu^n, \mu^s) \equiv -\ln \mu^n + \frac{g^n(\mu^n, \mu^s)}{\rho}.$$

In other words, the welfare component that depends on patent protection is the same across households.

Upon deriving the welfare function, we firstly characterize the Nash equilibrium level of patent protection in the two countries denoted by $(\mu_{NE}^{n}, \mu_{NE}^{s})$. As in Grossman and Lai (2004), the policymaker in each country chooses the domestic level of patent protection once and for all at time 0 to maximize domestic households' welfare (33) taking the foreign level of patent protection as given. In other words, the policymakers in the two countries play a one-shot game at time 0. Also, we assume an interior solution for the equilibrium level of patent protection such that $\mu < z$ (i.e. $b < 1$) in each country.

Proposition 2: *The Nash equilibrium level of patent protection is given by*

(34) $$\mu_{NE}^{n}(\underset{+}{\varphi^{n}}, \underset{+}{\varphi^{s}}) = \left((1-\alpha)^2 \left(\frac{\varphi^{n}}{\rho} + 1 \right) + \alpha^2 \left(\frac{\varphi^{s}}{\rho} + 1 \right) \right) \ln z,$$

(35) $$\mu_{NE}^{s}(\underset{+}{\varphi^{n}}, \underset{+}{\varphi^{s}}) = \left((1-\alpha)^2 \left(\frac{\varphi^{s}}{\rho} + 1 \right) + \alpha^2 \left(\frac{\varphi^{n}}{\rho} + 1 \right) \right) \ln z.$$

Proof: See Appendix A.■

Consistent with Lai and Qiu (2003) and Grossman and Lai (2004), we find that the Nash equilibrium level of patent protection is stronger in the North than in the South unless either (a) $\alpha = 0.5$ or (b) $\varphi^{n} = \varphi^{s}$. For the rest of the analysis, we assume that neither (a) nor (b) hold such that $\mu_{NE}^{n} > \mu_{NE}^{s}$. Next, we derive the globally optimal level of patent protection denoted by $(\mu_{GO}^{n}, \mu_{GO}^{s}) \equiv \arg\max(\Omega^{n} + \Omega^{s})$ in Proposition 3.[14] Consistent with Lai's (2005) result on trade barrier, Corollary 2 shows that the positive externality in the Nash equilibrium is increasing in the domestic importance α of foreign goods. If and only if $\alpha = 0$, then $\mu_{NE}^{n} = \mu_{GO}^{n}$ and $\mu_{NE}^{s} = \mu_{GO}^{s}$. For the rest of the analysis, we assume that $\alpha > 0$.

[14] To be consistent with previous studies, we use this utilitarian approach to define global welfare.

Proposition 3: *The globally optimal level of patent protection is given by*

(36) $$\mu_{GO}^{n}(\underset{+}{\varphi^{n}},\underset{+}{\varphi^{s}})=\left((1-\alpha)\left(\frac{\varphi^{n}}{\rho}+1\right)+\alpha\left(\frac{\varphi^{s}}{\rho}+1\right)\right)\ln z>\mu_{NE}^{n},$$

(37) $$\mu_{GO}^{s}(\underset{+}{\varphi^{n}},\underset{+}{\varphi^{s}})=\left((1-\alpha)\left(\frac{\varphi^{s}}{\rho}+1\right)+\alpha\left(\frac{\varphi^{n}}{\rho}+1\right)\right)\ln z>\mu_{NE}^{s}.$$

Proof: See Appendix A.■

Corollary 2: *An increase in* α *increases* $\mu_{GO}^{n}-\mu_{NE}^{n}$ *and* $\mu_{GO}^{s}-\mu_{NE}^{s}$.

Proof: See Appendix A.■

4. Effects of TRIPS

In this section, we analyze the effects of TRIPS on growth, welfare and income inequality simultaneously. We follow Lai and Qiu (2003) and Grossman and Lai (2004) to define the policy regime under TRIPS as $\mu_{TRIPS}^{s}=\mu_{TRIPS}^{n}=\mu_{NE}^{n}$. Under TRIPS, the North experiences higher levels of growth and welfare at the expense of higher income inequality. As for the South, it experiences higher growth at the expense of lower welfare and higher income inequality.

Under TRIPS, the South's level of patent protection increases from μ_{NE}^{s} to μ_{TRIPS}^{s}. This higher level of patent protection increases growth in both countries (i.e. $g_{TRIPS}^{n}>g_{NE}^{n}$ and $g_{TRIPS}^{s}>g_{NE}^{s}$). (28) shows that higher growth increases income inequality (i.e. $\sigma_{y,TRIPS}^{n}>\sigma_{y,NE}^{n}$ and $\sigma_{y,TRIPS}^{s}>\sigma_{y,NE}^{s}$). Also, (33) shows that the higher growth in the North unambiguously increases its welfare (i.e. $\Omega_{TRIPS}^{n}>\Omega_{NE}^{n}$). As for the South, the increase in μ^{s} leads to two opposing effects on its welfare. One is the positive growth effect, and the other is the negative effect of markup pricing. However, from the definition of the

Nash equilibrium, a unilateral deviation from the best response must render the South worse off (i.e. $\Omega^s_{TRIPS} < \Omega^s_{NE}$). Proposition 4 summarizes these findings.

Proposition 4: *In the North, the effects of TRIPS on growth, welfare and income inequality are (a)* $g^n_{TRIPS} > g^n_{NE}$, *(b)* $\Omega^n_{TRIPS} > \Omega^n_{NE}$, *and (c)* $\sigma^n_{y,TRIPS} > \sigma^n_{y,NE}$. *In the South, the effects of TRIPS on growth, welfare and income inequality are (a)* $g^s_{TRIPS} > g^s_{NE}$, *(b)* $\Omega^s_{TRIPS} < \Omega^s_{NE}$, *and (c)* $\sigma^s_{y,TRIPS} > \sigma^s_{y,NE}$.

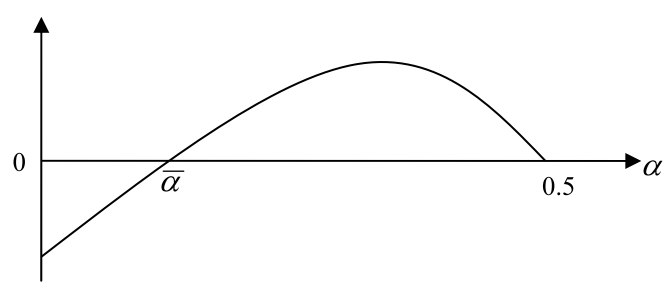
Proof: Proven in the text.■

Finally, we compare the level of global welfare between the Nash equilibrium and the policy regime under TRIPS. It turns out that there exists a critical degree for the importance of foreign goods in domestic consumption below which global welfare is lower under TRIPS. Proposition 5 and Figure 1 summarize this result.

Proposition 5: There exists a cutoff value $\overline{\alpha} \in (0,0.5)$ such that if and only if $\alpha \in (0,\overline{\alpha})$, then $\Omega^n_{TRIPS} + \Omega^s_{TRIPS} < \Omega^n_{NE} + \Omega^s_{NE}$.

Proof: See Appendix A.■

Figure 1: Difference in Global Welfare between TRIPS and the Nash Equilibrium



Firstly, note that as $\alpha \to 0$, $\Omega^n_{TRIPS} + \Omega^s_{TRIPS} < \Omega^n_{NE} + \Omega^s_{NE}$ because the two economies are in autarky and the South's optimal level of patent protection is lower than that of the North. Forcing the South to adopt the North's level of patent protection causes the South to experience a welfare loss while the North's welfare is unchanged. When α is slightly above 0, $(\Omega_{TRIPS}^{n}+\Omega_{TRIPS}^{s})-(\Omega_{NE}^{n}+\Omega_{NE}^{s})$ must be increasing in α because the positive externality in the Nash equilibrium reduces the welfare loss in the South and leads to a small welfare gain for the North under TRIPS. As $\alpha \to 0.5$, $\Omega_{TRIPS}^{n}+\Omega_{TRIPS}^{s}=\Omega_{NE}^{n}+\Omega_{NE}^{s}$ because the Nash equilibrium is the same as the policy regime under TRIPS, such that $\mu_{NE}^{s}=\mu_{TRIPS}^{s}$. When α is slightly less than 0.5, $\Omega_{TRIPS}^{n}+\Omega_{TRIPS}^{s}>\Omega_{NE}^{n}+\Omega_{NE}^{s}$ because $\mu_{NE}^{s}<\mu_{TRIPS}^{s}<\mu_{GO}^{s}$. In other words, the South's level of patent protection under TRIPS is moving towards the globally optimal level. For intermediate values of α, there exists a critical degree $\overline{\alpha}$ below (above) which global welfare under TRIPS is lower (higher) than in the Nash equilibrium.

5. Conclusion

This paper analyzes the effects of TRIPS on growth, welfare and income inequality simultaneously. In summary, strengthening patent protection in developing countries as a result of TRIPS increases global economic growth but also worsens global income inequality. Whether it increases global welfare depends on the importance of foreign goods in domestic consumption. To derive these results, this paper incorporates heterogeneity in the initial wealth of households into an open-economy quality-ladder model. Our model belongs to the class of first-generation R&D-growth models that exhibit scale effects,[15] in which a larger economy experiences faster growth and an economy with growing population experiences an increasing growth rate rather than a balanced-growth path. We avoid these problems by normalizing each country's population size to one. Possible extensions for future research include (a) analyzing the effects of TRIPS on growth and income inequality in later vintages of R&D-growth models, and (b) calibrating an R&D-growth model to quantitatively evaluate the effects of the patent reform in China on its rising income inequality.

[15] See, for example, Jones (1999) for a discussion on scale effects in R&D-growth models.

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Appendix A

Proof for Lemma 1: In this proof, we first show that aggregate expenditure on consumption $E_t^n \equiv P_t^n C_t^n$ in country *n* always jumps immediately to a unique and stable steady-state value. Then, we show that this steady-state value determines a unique and stationary equilibrium allocation of labor in country *n*. Choosing labor as the numeraire in country *n* (i.e. $W_t^n = 1$ for all *t*) implies that $V_t^n \varphi^n = 1$ for all *t* from (15). Given that φ^n is constant, $\dot{V}_t^n = 0$. Integrating (2) over $h \in [0,1]$ and then setting $\dot{V}_t^n$ to zero yield

(A1) $$E_t^n = W_t^n + R_t^n V_t^n = 1 + R_t^n / \varphi^n .$$

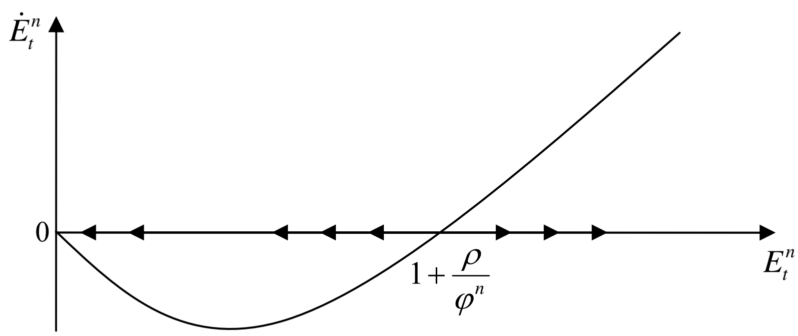
Using its definition, the law of motion for aggregate expenditure on consumption is given by

(A2) $$\frac{\dot{E}_t^n}{E_t^n} = \frac{\dot{P}_t^n}{P_t^n} + \frac{\dot{C}_t^n}{C_t^n} = R_t^n - \rho$$

from (3) because $\dot{C}_t^n / C_t^n = \dot{C}_t^n(h) / C_t^n(h)$ for all $h \in [0,1]$. Substituting (A1) into (A2) yields

(A3) $$\dot{E}_t^n / E_t^n = \varphi^n (E_t^n - 1) - \rho ,$$

which is plotted in the following figure.



For any initial value of E_t^n below $1 + \rho / \varphi^n$, E_t^n eventually converges to zero violating the households' utility maximization. For any initial value of E_t^n above $1 + \rho / \varphi^n$, E_t^n eventually increases to a point in which all the workers are allocated to production. A zero allocation of R&D workers violates the R&D

entrepreneurs' profit maximization. Therefore, to be consistent with long-run stability, E_t^n must always jump to its unique non-zero steady state given by

(A4) $$E^n = 1 + \rho / \varphi^n .$$

From (A2), $\dot{E}_t^n = 0$ implies that $R_t^n = \rho$ for all *t*.

Next, we derive the equilibrium allocation of labor. The price index for $C_t^n = \dfrac{(C_t^{n,n})^{1-\alpha}(C_t^{n,s})^{\alpha}}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}}$ is $P_t^n \equiv (P_t^{n,n})^{1-\alpha}(P_t^{n,s})^{\alpha}$. The price index for $C_t^{n,n}$ is $P_t^{n,n} \equiv \exp\left(\int_0^1 \ln\left(\dfrac{P_t^{n,n}(i)}{z^{N_t^n(i)}}\right)di\right) = \dfrac{\mu^n W_t^n}{Z_t^n}$, where $Z_t^n \equiv \exp\left(\int_0^1 N_t^n(i)di \ln z\right)$. Similarly, the price index for $C_t^{n,s}$ is $P_t^{n,s} = \dfrac{\mu^n W_t^s}{(1-\tau)Z_t^s}$. From (5), (7) and (9), the aggregate production function for $C_t^{n,n} = Z_t^n L_{x,t}^{n,n}$. Similarly, from (6), (8) and (9), the aggregate production function for $C_t^{n,s} = (1-\tau)Z_t^s L_{x,t}^{n,s}$. For country *n*, the value of export is $P_t^{s,n}C_t^{s,n}$ while the value of import is $P_t^{n,s}C_t^{n,s}$. The balanced-trade condition is

(A5) $$P_t^{s,n}C_t^{s,n} = P_t^{n,s}C_t^{n,s} \Leftrightarrow L_{x,t}^{s,n} = \left(\frac{\mu^n}{\mu^s \omega_t^n}\right)L_{x,t}^{n,s},$$

where $\omega_t^n \equiv W_t^n / W_t^s$ denotes the relative wage rate. The conditional demand functions in country *n* for domestic and foreign final goods are $P_t^{n,n}C_t^{n,n} = (1-\alpha)P_t^n C_t^n$ and $P_t^{n,s}C_t^{n,s} = \alpha P_t^n C_t^n$. Combining these two conditions yield

(A6) $$\frac{P_t^{n,n}C_t^{n,n}}{(1-\alpha)} = \frac{P_t^{n,s}C_t^{n,s}}{\alpha} \Leftrightarrow L_{x,t}^{n,s} = \left(\frac{\alpha}{1-\alpha}\right)\omega_t^n L_{x,t}^{n,n}.$$

Substituting (A6) into (A5) yields

(A7) $$L_{x,t}^{s,n} = \left(\frac{\mu^n}{\mu^s}\right)\left(\frac{\alpha}{1-\alpha}\right)L_{x,t}^{n,n}.$$

Substituting $E_t^n = P_t^{n,n}C_t^{n,n}/(1-\alpha) = \mu^n L_{x,t}^{n,n}/(1-\alpha)$ into (A4) yields (16). Then, substituting (16) into (A7) yields (17). Finally, substituting (16) and (17) into the labor-market clearing condition yields (18). A similar exercise yields the unique, stable and stationary equilibrium allocation of labor in country *s*.■

Proof for Lemma 2: The arrival rate of an invention in country *n* is

(A8) $$\lambda_t^n = \varphi^n L_{r,t}^n .$$

The growth rate of $Z_t^n = \exp\left(\int_0^1 N_t^n(i)di \ln z\right) = \exp\left(\int_0^t \lambda_\tau^n d\tau \ln z\right)$ is given by

(A9) $$\frac{\dot{Z}_t^n}{Z_t^n} = \lambda_t^n \ln z .$$

The balanced-growth rate of consumption in country *n* is

(A10) $$\frac{\dot{C}_t^n}{C_t^n} = (1-\alpha)\lambda^n \ln z + \alpha \lambda^s \ln z .$$

Finally, aggregating (2) over $h \in [0,1]$ yields the level of consumption in country *n* given by

(A11) $$C_t^n = \frac{W_t^n + R_t^n V_t^n}{P_t^n} = \left(1 + \frac{\rho}{\varphi^n}\right)\frac{W_t^n}{P_t^n}$$

because $\dot{V}_t^n = 0$, $R_t^n = \rho$ and $V_t^n \varphi^n = W_t^n$.■

Proof for Lemma 4: Firstly, normalize W_0^n to one. Then, the price index for consumption at time 0 is $P_0^n \equiv (P_0^{n,n})^{1-\alpha}(P_0^{n,s})^{\alpha}$, where $P_0^{n,n} = \mu^n W_0^n / Z_0^n$ and $P_0^{n,s} = \mu^n W_0^s / [(1-\tau)Z_0^s]$ from the proof for Lemma 1. The initial levels of technology $Z_0^n \equiv \exp\left(\int_0^1 N_0^n(i)di \ln z\right)$ and $Z_0^s \equiv \exp\left(\int_0^1 N_0^s(i)di \ln z\right)$ are exogenous. After dropping the exogenous terms, $\ln(W_0^n / P_0^n)$ simplifies to (31).■

Proof for Proposition 2: After dropping the terms that are independent of patent protection, the welfare of any household h in country n is

$$\Omega^n = -\ln\mu^n + \frac{g^n}{\rho}. \tag{A12}$$

The arrival rates of inventions in the two countries are

$$\lambda^n = \varphi^n - \left(\frac{1-\alpha}{\mu^n} + \frac{\alpha}{\mu^s}\right)(\varphi^n + \rho), \tag{A13}$$

$$\lambda^s = \varphi^s - \left(\frac{1-\alpha}{\mu^s} + \frac{\alpha}{\mu^n}\right)(\varphi^s + \rho). \tag{A14}$$

Substituting (A13) and (A14) into (A10) yields

$$g^n = \left((1-\alpha)\left(\varphi^n - \left(\frac{1-\alpha}{\mu^n} + \frac{\alpha}{\mu^s}\right)(\varphi^n + \rho)\right) + \alpha\left(\varphi^s - \left(\frac{1-\alpha}{\mu^s} + \frac{\alpha}{\mu^n}\right)(\varphi^s + \rho)\right)\right)\ln z. \tag{A15}$$

Substituting (A15) into (A12) and then dropping the exogenous terms yield

$$\Omega^n = -\ln\mu^n - \left((1-\alpha)\left(\frac{1-\alpha}{\mu^n} + \frac{\alpha}{\mu^s}\right)(\varphi^n + \rho) + \alpha\left(\frac{1-\alpha}{\mu^s} + \frac{\alpha}{\mu^n}\right)(\varphi^s + \rho)\right)\frac{\ln z}{\rho}. \tag{A16}$$

Differentiating (A16) with respect to μ^n yields

$$\frac{\partial\Omega^n}{\partial\mu^n} = -\frac{1}{\mu^n} + \left(\left(\frac{1-\alpha}{\mu^n}\right)^2(\varphi^n + \rho) + \left(\frac{\alpha}{\mu^n}\right)^2(\varphi^s + \rho)\right)\frac{\ln z}{\rho} = 0. \tag{A17}$$

Solving (A17) yields (34), and (35) can be obtained using a similar derivation.■

Proof for Proposition 3: Combining (A16) and the analogous condition for country s yields

$$\Omega^n + \Omega^s = -\ln\mu^n - \ln\mu^s - \left(\left(\frac{1-\alpha}{\mu^n} + \frac{\alpha}{\mu^s}\right)(\varphi^n + \rho) + \left(\frac{1-\alpha}{\mu^s} + \frac{\alpha}{\mu^n}\right)(\varphi^s + \rho)\right)\frac{\ln z}{\rho}. \tag{A18}$$

Differentiating (A18) with respect to μ^n yields

(A19) $$\frac{\partial(\Omega^n+\Omega^s)}{\partial\mu^n}=-\frac{1}{\mu^n}+\left(\left(\frac{1-\alpha}{(\mu^n)^2}\right)(\varphi^n+\rho)+\left(\frac{\alpha}{(\mu^n)^2}\right)(\varphi^s+\rho)\right)\frac{\ln z}{\rho}=0.$$

Solving (A19) yields (36), and (37) can be obtained using a similar derivation.■

Proof for Corollary 2: Subtracting (34) from (36) and differentiating $\mu_{GO}^n-\mu_{NE}^n$ with respect to α show that the sign of $\partial(\mu_{GO}^n-\mu_{NE}^n)/\partial\alpha$ is given by the sign of $(1-2\alpha)>0$ for $\alpha<0.5$. Similarly, from (35) and (37), differentiating $\mu_{GO}^s-\mu_{NE}^s$ with α shows that the sign of $\partial(\mu_{GO}^s-\mu_{NE}^s)/\partial\alpha$ is also given by $1-2\alpha$.■

Proof for Proposition 5: As $\alpha\to 0$, $\Omega_{TRIPS}^n+\Omega_{TRIPS}^s<\Omega_{NE}^n+\Omega_{NE}^s$ because the two countries are in autarky so that $\mu_{GO}^s<\mu_{TRIPS}^s$. As $\alpha\to 0.5$, $\Omega_{TRIPS}^n+\Omega_{TRIPS}^s=\Omega_{NE}^n+\Omega_{NE}^s$ because the Nash equilibrium is the same as the policy regime under TRIPS such that $\mu_{NE}^s=\mu_{TRIPS}^s$. The rest of the proof shows that there must exist an intermediate range of α, in which $\Omega_{TRIPS}^n+\Omega_{TRIPS}^s>\Omega_{NE}^n+\Omega_{NE}^s$. From (34) and (37), $\mu_{GO}^s-\mu_{TRIPS}^s$ is an increasing function in α. As $\alpha\to 0.5$, $\mu_{GO}^s>\mu_{TRIPS}^s$. Therefore, there must exist a threshold denoted by $\tilde{\alpha}\in(0,0.5)$ above which $\mu_{NE}^s<\mu_{TRIPS}^s<\mu_{GO}^s$. When $\alpha\in[\tilde{\alpha},0.5)$, it is sufficient for $\Omega_{TRIPS}^n+\Omega_{TRIPS}^s>\Omega_{NE}^n+\Omega_{NE}^s$ to hold, and there exists a lower critical value $\bar{\alpha}\in(0,\tilde{\alpha})$ above which $\Omega_{TRIPS}^n+\Omega_{TRIPS}^s>\Omega_{NE}^n+\Omega_{NE}^s$ still holds. In this case, the South's level of patent protection moves from one suboptimal level to another suboptimal level (i.e. $\mu_{NE}^s<\mu_{GO}^s<\mu_{TRIPS}^s$). In summary, for low values of α, $\Omega_{TRIPS}^n+\Omega_{TRIPS}^s<\Omega_{NE}^n+\Omega_{NE}^s$. As α increases above $\bar{\alpha}$, the reverse is true.■