Gains and Losses from International Trade in a Knowledge-driven Semi-endogenous Growth Model with Heterogeneous Firms

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Abstract

We consider a semi endogenous R&D growth model with international trade, firm heterogeneity, and local knowledge spillover in a closed economy and international knowledge spillover in a symmetric two country economy. We show that by opening trade R&D difficulty (the number of varieties produced) and welfare are ambiguously affected. When the international spillover is large (small), the former is increased (decreased). When the size of the international knowledge spillover is large (small) or the size of the international knowledge spillover is small and the size of intertemporal knowledge spillover is small (large), the latter increases (decreses). Without intertemporal and international knowledge spillovers, welfare increases.

JEL Classication: F12, F15, O30, O33

Keywords: Heterogeneous Firms, Semi Endogenous Growth, Gains and Losses from International Trade

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1. Introduction

The effects of firm heterogeneity and international trade on economic growth[2] have attracted economists' interest. Baldwin and Robert-Nicoud (2007) constructs an R&D-based growth model with firm heterogeneity, two symmetric countries, international trade, and scale effects[3]. In a knowledge driven model, further exposure to trade has a negative effect on economic growth and ambiguous effects on welfare because there are two conflicting effects: The effects of opening trade on growth are ambiguous. Unel (2010) constructs an R&D-based growth model with firm heterogeneity, two symmetry country, international trade, and scale effects.
In an endogenous international knowledge spillover model, the exposure and further exposure to trade have an ambiguous effect on economic growth and welfare.
Gustafsson and Segerstrom (2010) construct an R&D-based growth model with firm heterogeneity, two symmetry country, international trade, and no scale effects. Further exposure to trade has ambiguous effects on R&D difficulty (the number of varieties produced in each country) and ambiguous effects on welfare. Dinopoulos and Unel (2011) construct a fully endogenous growth model with firm heterogeneity, two symmetric countries, and international trade. Further exposure to trade has an ambiguous effect on economic growth and ambiguous effects on welfare. The effect of opening trade on growth is also ambiguous. But, these papers do not derive the parameter conditions for gains (losses) from international trade.

This paper constructs a semi endogenous R&D growth model with international trade, firm heterogeneity, and local knowledge spillover in a closed economy and international knowledge spillovers in a symmetry two countries economy. We show that a move from a closed economy to a restricted open economy raises or decreases R&D difficulty. When the size of international knowledge spillover is sufficiently large, it is affected positively. The intuition for the first result is the following. There are conflicting effects: the positive effect of international knowledge spillover which depends positively on the sizes of the international knowledge spillover and the negative effect of increase in the expected costs of a producing firm which does not depend on the size of international knowledge spillover. We show that a move from a closed economy to a restricted open economy raises or decreases welfare. The intuition for the second result is the following. There are conflicting effects: the positive effect of international knowledge spillover which depends positively on the sizes of the international knowledge spillover and the negative effect of increase in the expected costs of a producing firm which does not depend on the size of international knowledge spillover and depend negatively on intertemporal knowledge spillover and the positive effect of increase in the weighted average of productivities which does not depend on the size of international knowledge spillover. Thus, when international knowledge spillover is large or international spillover is small and intertemporal knowledge spillover is small (large), gains (losses) from trade occurs. Finally, we show that gains from trade occurs without knowledge spillovers because the positive effect of increase in the weighted average of productivities offsets the negative effect of increase in the expected cost of a producing firm.

The rest of the paper is organized as follows: In section 2, we describe and explain the closed and open economies. In section 3, we offer concluding remarks.

2. The Model

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[2] Melitz (2003) constructed a monopolistically competitive static model with firm heterogeneity in marginal costs of differentiated goods and Dinopoluos and Unel (2012) constructed a monopolistically competitive static model with firm heterogeneity in quality of differentiated goods.

[3] See Jones (1995, a,b), Segerstrom (1998), Dinopoulos and Syropoulos (2007), Dinopoulos and Thompson (1998), Dinopoulos and Thompson (1999), Jones (2005), and Dinopoulos and Sener (2007) for scale effect.

2.1. Basic structure of model

Consider an economy that consists of two symmetric countries, each with one factor of production (labor) and two sectors (a continuum of monopolistically competitive goods and an R&D sector). The wage rate is numeraire and normalized to unity. Each worker inelastically supplies one unit of labor, and the labor force grows at an exogenous rate n. The continuum of monopolistically competitive goods sector is monopolistically competitive and heterogeneous in marginal cost. First, firms draw marginal costs from exogenous Pareto distribution $G(B)$ after creating F_I units of knowledge (incurring start-up sunk costs $b_{It}F_I$, where b_{It} is the price of knowledge) in the R&D sector. For each firm to serve the domestic market it needs to create F_L units of knowledge (beachhead cost $b_{It}F_L$) and to serve both domestic and foreign markets it needs create F_E units of knowledge (beachhead cost $b_{It}F_E$) as well as pay iceberg costs. After the draw, they choose whether to exit, serving only the domestic market, or to serve both domestic and foreign markets. Following Unel[4] (2010), there is local knowledge spillover in the closed economy and international knowledge spillover in the open economy.

2.2. The Closed Economy

2.2.1. Consumer

The consumer is a representative agent. Each consumer supplies in-elastically one unit of labor in each period. The amount of labor supplied is same with the size of the population. Thus, the size of the population is denoted by $L_t = L_0 e^{nt}$, where n denotes the population growth rate. The consumer earns incomes from assets and labor. The consumer chooses the path of consumption expenditure and assets so as to maximize the sum of the discounted value of utility. The intertemporal utility function is given by $u(c_t^a) = \int_0^\infty \log c_t^a e^{-(\rho-n)t}\mathrm{d}t$, where c_t^a is per capita consumption index which depends on consumption of the continuum of varieties, and is given by $c_t^a = \left(\int_{\Omega_t^a} (x_t^a(i))^{\frac{\sigma-1}{\sigma}}\mathrm{d}i\right)^{\frac{\sigma}{\sigma-1}}, \sigma > 1$, where Ω_t^a is the set of varieties can be consumed, $x_t^a(i)$ is the individual demand for the *i*-th variety, and ρ is the subjective discount rate. The per capita inter-temporal budget constraint is $\dot{s}_t^a = r_t^a s_t^a + w_t^a - e_t^a$, where $s_t^a$is per capita asset, r_t^a the rate of return on asset, w_t^a wage, and e_t^a per capita expenditure. Solving the dynamic optimization problem implies $\frac{\dot{e}_t^a}{e_t^a} = r_t^a - \rho$. Static optimization derives the demand for each variety, which is given by $x_t^a(i) = \frac{p(i)^{-\sigma}}{(P_t^a)^{1-\sigma}} e_t^a L_t$, where $P_t^a = \left(\int_{i\in\Omega^a} [p_t^a(i)]^{1-\sigma}\,\mathrm{d}i\right)^{\frac{1}{1-\sigma}}$ is the price index.

2.2.2. Innovation

We next explain firm behavior. For firms to enter the market, they have to pay the sunk cost of variety creation $b_{It}^a F_I$, where $b_{It}^a \equiv \frac{1}{(m_t^a)^\phi}$, is the unit labor requirement for knowledge creation, $m_t^a$is the number of varieties produced, and $1 > \phi > 0$ is the measure of intertemporal knowledge spillover. As time goes by, R&D researchers learn how to create knowledge more efficiently; the unit labor requirement is lower. Then they learn the unit labor requirement for manufacturing from a Pareto

[4] Grossman and Helpman (1991, ch9) considered an economy where there is a knowledge spillover from the potential trade partner even when there is no international trade of goods.

distribution which is given by $G(B) = (B/\bar{B})^k$, where $1 + k - \sigma > 0$. To enter the market, each firm has to pay the domestic entry sunk cost $b_{It}^a F_L$. Firms with unit labor requirement $B > B_L^a$ exit the market immediately and firms with unit labor requirement $B_L^a \geq B$ enter the domestic market.

2.2.3. Product Market

If firms with unit labor requirement B enter the market, they earn profits $\pi_{Lt}^a(B) = p_{Lt}^a(B)x_{Lt}^a(B) - Bx_{Lt}^a(B)$. The profit-maximizing price is given by $p_{Lt}^a = \frac{\sigma B}{\sigma-1}$. Thus, the profit function is given by $\pi_{Lt}^a(B) = \frac{\sigma^{-\sigma}(\sigma-1)^{\sigma-1}B^{1-\sigma}e_t^a L_t}{(P_t^a)^{1-\sigma}}$. Given consumer expenditure and the price index, profit function is monotonically decreasing in the level of the unit labor requirement for manufacturing. A consumer has two means of accumulating assets: firm share and riskless bonds. The rate of return on shares comes from dividends and capital gains (losses). The rate of return on the bonds comes from the interest rate. In equilibrium, the two rates of return are equalized. Thus, the following no-arbitrage condition holds: $\frac{\pi_{Lt}^a(B)}{V_{Lt}^a(B)} + \frac{\dot{V}_{Lt}^a(B)}{V_{Lt}^a(B)} = r_t^a$. This equation determines the value of a firm serving the market as a function of the level of the unit labor requirement. The cost associated with serving the domestic market is $b_{It}^a F_L$. The profit function $\pi_{Lt}^a(B)$ monotonically decreases in the level of B. Thus, there exists a local cut off B_L^a such that

$$V_{Lt}^a(B_L^a) = \frac{\sigma^{-\sigma}(\sigma-1)^{\sigma-1}(B_L^a)^{1-\sigma}e_t^a L_t}{(P_t^a)^{1-\sigma}\left(r_t^a - \frac{\dot{V}_{Lt}^a(B_L^a)}{V_{Lt}^a(B_L^a)}\right)} = b_{It}^a F_L. \tag{1}$$

We already explained the action of firms that already enter into the domestic market. We turn to explain an incentive to enter the market. In other words, there is an incentive to create F_I units of knowledge by firms or not. There is a free entry and exit in the R&D sector. Prior to entry, a firm does not know the level of own unit labor requirement, but knows the value function of a firm serving the market and the level of the cut-off point for the unit labor requirement. Thus, comparing the expected value of the firm and the sunk cost of variety creation, they choose to produce F_I units of knowledge or not, given the fixed costs of variety creation. In other words, in equilibrium with positive entry, free entry and exit and perfect competition in the R&D sector implies the ex-ante expected present value of a winner and the aggregate sunk cost of a producing firm are equalized. Its condition is given by $\int_0^{B_L^a}[V_L^a(B) - b_{It}^a F_L]g(B)\mathrm{dB} = b_{It}^a F_I$, where the LHS is the net present value from creating a new variety and the RHS is the sunk costs of creating a new variety. Rearranging yields the ex-post free entry condition, given by

$$\frac{\sigma^{-\sigma}(\sigma-1)^{\sigma-1}\Delta_t^a e_t^a L_t}{(P_t^a)^{1-\sigma}(r_t^a + \phi g)} = b_{It}^a \bar{F}^a. \tag{2}$$

The LHS of (2) is the benefit from creating a new variety and the RHS of (2) is the associated costs, that is, the expected instantaneous costs and

$$\Delta_t^a = \int_0^{B_L^a} B^{1-\sigma}\frac{g(B)dB}{G(B_L^a)} = \frac{k(B_L^a)^{1-\sigma}}{1+k-\sigma} \tag{3}$$

is the weighted average of inverse of the marginal costs of producing firms. Hereafter, we call this the weighted average of productivities.

$$\bar{F}^a \equiv \frac{F_I}{G(B_L^a)} + F_L \tag{4}$$

is the expected costs of a producing firm for creating a new variety supplied in the market. The first term of (4) is the cost of choosing the level of unit labor requirement for manufacturing equal to or less than the cutoff level of the domestic market. The second term of (4) is the sunk domestic market entry cost.

2.2.4. R&D technology

The production function for variety is given by $\dot{m}_t^a = \frac{L_{Rt}^a}{b_{It}^a \bar{F}^a}$, where L_R^a are researchers devoted to R&D. Rearranging, it becomes $\frac{\dot{m}_t^a}{m_t^a} = \frac{1}{z_t^a \bar{F}^a} \frac{L_{Rt}^a}{L_t}$, where

$$z_t^a \equiv \frac{(m_t^a)^{1-\phi}}{L_t} \tag{5}$$

is R&D difficulty because the short run growth rate, $\frac{\dot{m}_t^a}{m_t^a}$ depends negatively on z_t^adue to diminishing returns to knowledge in the R&D production function. In the steady-state equilibrium, z_t^a must be constant, and the steady-state growth rate is $g = \frac{g_L}{1-\phi}$. This growth rate depends only on population growth rate and the level of inter-temporal knowledge spillover, as in Jones (1995a).

2.2.5. Equilibrium condition

Each worker supplies one unit of labor in each period, and the total population size is given by L_t. Labor is used for R&D or manufacturing. Because the labor market is perfectly competitive, the full-employment condition is $L_t = L_{Rt}^a + L_{xt}^a$ where $L_{xt}^a = \int_0^{B_L^a} B x_L^a(B) m_t^a \frac{g(B)\mathrm{dB}}{G(B_L^a)}$is the manufacturing work force because firms with unit labor requirement B require Bx units of labor and the equilibrium Pareto distribution is given by $\frac{g(B)\mathrm{dB}}{G(B_L^a)}$. The price index is given by $(P_t^a)^{1-\sigma} = \int_0^{B_L^a} p_{Lt}^a(B)^{1-\sigma} m_t^a \frac{g(B)\mathrm{dB}}{G(B_L^a)} = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} m_t^a \Delta_t^a$

2.2.6. Steady state in closed economy

Substituting the free entry condition, costs of creating a new variety, and the Pareto distribution into the local cut-off condition yields the unique solution for the cutoff level of the local market such that $\frac{1+k-\sigma}{k} = \frac{F_L}{F_I\left(\frac{\bar{B}}{B_L^a}\right)^k + F_L}$. The autarkic local market cut-off level is given by

$$B_L^a = \left(\frac{(1+k-\sigma)F_I}{(\sigma-1)F_L}\right)^{\frac{1}{k}} \bar{B} \tag{6}$$

An increase in the start-up cost implies an increase in the expected instantaneous costs, but the benefit from creating new variety does not change. Thus, higher domestic cutoff levels are derived. On the other hand, an increase in beachhead cost leads to higher sunk domestic market entry cost as well as higher expected instantaneous costs. The former effect always dominates the latter one. Thus, the domestic cutoff level B_L^a shifts down so as to satisfy the cutoff condition.

We turn to determining R&D difficulty and per capita expenditure by the labor market condition and the zero profit cutoff condition. The labor market clearing condition is a downward-sloping curve in the (e_t^a, z_t^a) plane because an increase in e_t^a implies a larger number of manufacturing workers and a smaller number of researchers. The free entry condition is an upward sloping curve in the (e_t^a, z_t^a) plane because an increase in e_t^a implies a larger benefit from creating a new variety and associated costs. Thus, there is a unique solution of these variables.

The full employment condition becomes $1 = \frac{kF_L}{1+k-\sigma} g z_t^a + \frac{\sigma-1}{\sigma} e_t^a$. On the other hand, the free entry condition is $\frac{e_t^a}{\sigma(r_t^a+\phi g) z_t^a} = \frac{kF_L}{1+k-\sigma}$, where $g \equiv \frac{g_L}{1-\phi}$ and the constancy of e_t^a in the steady state equilibrium from two conditions implies $r_t^a = \rho$ in the steady-state equilibrium from the Euler equation. The closed form solutions of these are given by $e_t^a = \frac{\sigma(\rho+\phi g)}{g+(\sigma-1)(\rho+\phi g)}$ and $z_t^a = \frac{1+k-\sigma}{kF_L[g+(\sigma-1)(\rho+\phi g)]}$.

We derive the closed form solution for the autarkic welfare[5] to be

$$c_t^a = \frac{(\rho+\phi g)(\sigma-1)(m_t^a \Delta_t^a)^{\frac{1}{\sigma-1}}}{g+(\sigma-1)(\rho+\phi g)}, \tag{7}$$

where the weighted average of the unit labor requirements of producing firms is given by $\Delta_t^a = \frac{k\left(\frac{(1+k-\sigma)F_I}{(\sigma-1)F_L}\right)^{\frac{1-\sigma}{k}} (\bar{B})^{1-\sigma}}{1+k-\sigma}$.

2.3. Open Economy

The model of the open economy is exactly same as in Gustafsson and Segerstrom (2010) and we do not explain the model explicitly. We use superscript o to represent an open economy. The consumer maximization problem is given by the equations for a closed economy but with superscript o.

2.3.1. Innovation

We next explain firm behavior. For firms to enter the market, they have to pay the sunk cost of variety creation $b_{It}^o F_I$, where $b_{It}^o \equiv \frac{1}{(m_t^o+\lambda m_t^o)^\phi}$ is the unit labor requirement for creating knowledge and $1 > \lambda > 0$ measures the international knowledge spillover. We follow Unel (2010) in that trading goods between countries conveys knowledge about R&D between countries. This assumption has an important role in the result about gains (losses) from international trade in this paper. Then entrants pick up the level of unit labor requirement for manufacturing from a Pareto distribution as defined in the closed economy. For a firm to enter the market, thus

pay the local and foreign beachhead costs, given by $b_{It}^o F_L$ and $b_{It}^o F_E$. For one unit of good to arrive to the domestic (foreign) market, 1 (τ) units of the good must be produced. Firms with unit labor requirement $B > B_L$ exit the market immediately. Firms with unit labor requirement $B_L > B > B_E$ enter the domestic market. Firms with unit labor requirement $B_E > B$ enter both markets. The value of serving the domestic market is given by (6) with superscript o. Similarly, the cutoff point for the export market is determined such that

[5] The derivation of welfare in a closed economy is given in an Appendix.

$$V_E^o(B_E^o) = \frac{\tau^{1-\sigma}\sigma^{-\sigma}(\sigma-1)^{\sigma-1}(B_E^o)^{1-\sigma}e_t^o L_t}{(r_t^o+\phi g)(P_t^o)^{1-\sigma}} = b_{It}^o F_E, \tag{8}$$

Using the cutoff condition (3) with superscript o and (8), the cut-off ratio is given by $\frac{B_E^o}{B_L^o} = \left(\frac{\tau^{1-\sigma}F_L}{F_E}\right)^{\frac{1}{\sigma-1}} < 1$. The free entry condition is given by (2) with superscript o or

$$\frac{\sigma^{-\sigma}(\sigma-1)^{\sigma-1}\Delta_t^o e_t^o L_t}{(r_t^o+\phi g)(P_t^o)^{1-\sigma}} = b_{It}^o \bar{F}^o. \tag{9}$$

The weighted average of productivities is given by

$$\Delta_t^o \equiv \int_0^{B_L^o} B^{1-\sigma}\frac{g(B)\mathrm{dB}}{G(B_L^o)} + \tau^{1-\sigma}\int_0^{B_E} B^{1-\sigma}\frac{g(B)\mathrm{dB}}{G(B_L^o)} = \frac{k(B_L^o)^{1-\sigma}\Xi}{1+k-\sigma}, \tag{10}$$

where the effects of globalization on the economy through the weighted average of levels of unit labor requirements, the expected instantaneous costs, and R&D difficulty which are given by $\Xi \equiv 1 + \tau^{-k}\left(\frac{F_L}{F_E}\right)^{\frac{1+k-\sigma}{\sigma-1}} > 1$. The expected instantaneous costs is given by

$$\bar{F}^o \equiv \frac{F_I}{G(B_L^o)} + \int_0^{B_L^o} F_L\frac{g(B)\mathrm{dB}}{G(B_L^o)} + \int_0^{B_E} F_E\frac{g(B)\mathrm{dB}}{G(B_L^o)} = F_I\left(\frac{\bar{B}}{B_L^o}\right)^k + F_L\Xi. \tag{11}$$

Using (8)-(11), the domestic cutoff level is uniquely determined so as to satisfy following condition, and it is $\frac{1+k-\sigma}{k\Xi} = \frac{F_L}{F_I\left(\frac{\bar{B}}{B_L^o}\right)^k + F_L\Xi}$.

$$B_L^o = \left(\frac{(1+k-\sigma)F_I}{(\sigma-1)F_L}\right)^{\frac{1}{k}}\Xi^{\frac{-1}{k}}\bar{B}. \tag{12}$$

We compare an autarkic cutoff point level with the cutoff level in the open economy. In an open economy, productive firms export their good. Thus, they demand more labor for manufacturing as well as beachhead costs. To satisfy the labor constraint, the cutoff point for the domestic market is decreased because labor is the numeraire. Thus, less productive firms shut down because the amount of labor supplied is the same. The price index in an open economy is given by $(P_t^o)^{1-\sigma} = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} m_t^o \Delta_t^o$.

2.3.2. Steady state in open economy

The free entry condition and the full employment condition constitute a system of two equations in the two unknowns: per capita expenditure and R&D difficulty. They are $\frac{e_t^o}{\sigma(\rho+\phi g)} = \frac{\bar{F}^o z_t^o}{(1+\lambda)^\phi}$ and $1 = \frac{\sigma-1}{\sigma}e_t^o + \frac{g z_t^o \bar{F}^o}{(1+\lambda)^\phi}$, where $\bar{F}^o = \frac{kF_L\Xi}{1+k-\sigma}$ is the expected instantaneous cost. Solving these conditions, the closed form solution of per capita expenditure and R&D difficulty are given by $e_t^o = e_t^a$ and $z_t^o = \frac{(1+k-\sigma)(1+\lambda)^{\phi}}{kF_L[g+(\sigma-1)(\rho+\phi g)]\Xi}$.

We turn to explaining difference in per capita expenditure and R&D difficulty between the closed and open economies. Compared with the closed economy, the costs of a producing firm are ambiguously affected through two channels: a positive effect of the international knowledge spillover and a negative effect of the increase in costs through the added beachhead costs for the foreign market plus the increased probability of shut down. The international knowledge spillover affects the labor demands in both sectors by the same amount. Thus, international knowledge spillover does not affect the division of labor. Finally, per capita expenditures in the closed and open economies are exactly the same. The condition for an increase in R&D difficulty or the number of varieties produced between the closed and open economies is given by $(1+\lambda)^{\phi} > \Xi$. We define $\gamma(\phi,\lambda)$ as $\gamma(\phi,\lambda) \equiv (1+\lambda)^{\phi}$.The function $\gamma(\phi,\lambda)$ is monotonically increasing in ϕ and λ. The function Ξ does not depend on ϕ and λ. For any given $1 > \phi > 0$, there is a level of $\bar{\lambda}$ such that $\gamma(\phi,\bar{\lambda}) = \Xi$. If international knowledge spillover is greater (less) than $\bar{\lambda}$, R&D difficulty (the number of variety) is increased (decreased). The intuition behind this result is that gains from opening trade depends positively on the international knowledge spillover and intertemporal knowledge spillover while costs from opening trade do not depends on them. Thus, R&D difficulty increases when they are too large

These results contrast with the results about further exposure to trade on R&D difficulty by Gustafsson and Segerstrom (2010). A further exposure to trade always decreases the number of varieties produced because there is only the negative channel of the increase in R&D costs by decreasing the cutoff point for the domestic market.

We analyze the effects of opening trade on welfare. Welfare in an open economy is given by

$$c_t^o = \frac{(\sigma-1)e_t^o}{\sigma(m_t^o\Delta_t^o)^{\frac{1}{1-\sigma}}}, \tag{13}$$

where $\Delta_t^o = \frac{k}{1+k-\sigma}\left(\frac{(1+k-\sigma)F_I}{(\sigma-1)F_L}\right)^{\frac{1-\sigma}{k}} \Xi^{\frac{k+\sigma-1}{k}} (\bar{B})^{1-\sigma}$ and $m_t^o = \left(\frac{(1+k-\sigma)(1+\lambda)^{\phi}L_t}{kF_L[g+(\sigma-1)(\rho+\phi g)]\Xi}\right)^{\frac{1}{1-\phi}}$. Likewise in a closed economy, welfare depends positively on the level of the weighted average of productivities and the R&D difficulty (the number of varieties produced).

Using (7) and (13), we can derive the condition for the gains (losses) from international trade which is given by $\gamma(\phi,\lambda) \equiv (1+\lambda)^{\phi} \geq \Xi^{\frac{(\phi-1)[k+\sigma-1]+k}{k}} \equiv F(\Xi,\phi)$. The function $\gamma(\phi,\lambda)$ is the benefit of opening international trade which comes from international knowledge spillover that is increasing in both the levels of intertemporal knowledge spillover ϕ and international knowledge spillover λ. The function $F(\Xi,\ \phi)$ measures the total net negative effects through opening international trade which is also increasing in the level of inter-temporal knowledge spillover ϕ. The total net negative effects are the increases in the expected instantaneous R&D cost minus gains from increases in the weighted average of productivities.

We summarize our results about gains from international trade: Without knowledge spillovers, that is, when $\phi = \lambda = 0$, there are gains from international trade because the increase in the expected instantaneous costs through added sunk costs of the foreign market and changes in cutoff points is outweighed by the positive effects of the higher weighted average of productivities.

We turn next to deriving the condition for gains (losses) from international trade. The following are two cases for gains from international trade. The first case is that international knowledge spillovers, λ, are small. That is, we first consider the following case: $\gamma(\phi,\lambda)^{1/\phi} < F(\Xi,\ \phi)^{1/\phi}$. In this case, under small (large) levels of intertemporal knowledge spillover ϕ, the benefits (resp. costs) of opening international trade dominates its costs (benefits) and gains (losses) from international trade occur. We next consider the second case where large knowledge spillover from the foreign country occurs. That is,

$\gamma(\phi, \lambda)^{\frac{1}{\phi}} - 1 \geq F(\Xi, \phi)^{\frac{1}{\phi}} - 1$. In this case, whether there is a small or large level of intertemporal knowledge spillover ϕ, the benefits (costs) of opening international trade always dominates its costs from increasing the negative effects of an increase in the expected instantaneous costs. This result is different from Gustafsson and Segerstrom.

3. Conclusions

We analyze the effects of moving from autarky to restricted trade on R&D difficulty and welfare in a semi endogenous R&D based-growth model with firm heterogeneity. We first show that it has an ambiguous effects on R&D difficulty. This is because there are two conflicting effects: international knowledge spillover and an increase in expected instantaneous costs through added beachhead costs for exporting and changes in cutoff points. The sign of this effect depends on the size of the international knowledge spillover. We second show that it has an ambiguous affects on welfare. This is also because there are two conflicting effects: international knowledge spillover and an increase in expected instantaneous costs through added beachhead costs for exporting and changes in cutoff points. If the size of the international knowledge spillover is large (small), welfare is positively (negatively) affected or the size of the international knowledge spillover is small and the intertemporal knowledge spillover is small (large), welfare is positively (negatively) affected.

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