

Growth and the dynamics of trade liberalization

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Abstract

This paper develops a model of ongoing trade liberalization as a self-enforcing equilibrium in a game between governments. Economic growth is a critical ingredient in successful trade liberalization. But differences in national growth rates have profound differences on the sustainable tariff equilibria of the game. If international technology spillovers are not concentrated in high-growth sectors, faster growing countries will be more protectionist, setting higher tariffs and liberalizing trade at a later date. But with spillovers more concentrated in high-growth sectors, faster-growing countries may be less protectionist. Differences in growth rates lead the process of trade liberalization to be far from reciprocal. A sustainable trade liberalization may actually involve one country pursuing a unilateral policy of free trade, even though its trading partner imposes tariffs against it. © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

This paper explores the determine of trade liberalization in a model of endogenous world growth. While the economics profession has devoted a large amount of attention to understanding the effects of trade liberalization on economic growth (e.g. Grossman and Helpman (1991) and references therein), there has been relatively little discussion of the link running in the opposite

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direction; i.e. the effect of economic growth on the process of trade liberalization. Despite this, some writers have stressed the importance of growth in the success of trade liberalization initiatives (e.g. Bhagwati (1991)).¹

The paper develops a model that explores the dynamics of endogenous trade liberalization, where the liberalization is driven in an essential way by the process of economic growth. Trade liberalization is modeled as taking place in a repeated game between national governments. The model is used to address the following questions. How do differences in national growth rates affect the speed and pattern trade liberalization? Do fast-growing countries tend to be leaders or followers in the process of trade liberalization? How do international spillovers of technological knowledge affect the pattern of trade liberalization?

The model is one where growth and trade policy are both endogenous, and economic growth in itself tends to stimulate ongoing trade liberalization. Trade liberalization is modeled as a ‘sustainable equilibrium’ in the sense of Chari and Kehoe (1990). It is the lowest sustainable sequence of tariffs in a dynamic game between tariff setting governments.

The structure of the model is well adapted to addressing the questions set out above. First, it is shown that economic growth is a key ingredient required for a successful trade liberalization. This is because economic growth generates specialization. Specialization fosters an ongoing interdependence among countries which encourages a progressive decline in tariffs, leading to eventual free trade.

Differences in growth rates among countries will lead governments to pursue tariff reduction at different rates. Whether faster-growing countries are more or less protectionist however, depends upon the importance of international spillovers. If knowledge spillover across countries is very minor, or is balanced across all sectors, then faster-growing countries will tend to be more protectionist, setting higher import tariffs and reducing tariffs more slowly than other countries. But if knowledge spillovers are considerable, and are more concentrated in the higher growth sectors, then faster growing countries will tend to be less protectionist, and reduce tariffs at a faster rate than other countries.

Substantial differences in national growth rates will lead to an equilibrium trade liberalization that is far from reciprocal. Without spillovers, the fast-growing country may set substantially higher tariffs for a much longer time than its slower-growing trading partner. The slower growing country will, in general, completely eliminate its tariffs before those of its trading partner, and follow a policy of unilateral free trade. Finally, the trade liberalization may involve periods of increasing tariffs for the fast-growing country.

A sustainable trade liberalization is defined as the lowest sustainable sequence of tariffs, conditional on the technology differential between countries, that

¹ Ishii and Yei (1997) note that world trade volume consistently grows faster than world GDP.

satisfy dynamic incentive constraints for tariff-setting governments. These incentive constraints equate the benefit of defection in any period to the future cost of defection. To support the lowest sustainable tariffs, a defection must be followed by the worst possible equilibrium outcome. In this model, this outcome happens to be a reversion to autarky. Following Devereux (1997), the key intuition behind the process of ongoing trade liberalization is that the threat of autarky gets worse and worse over time, as economic interdependence grows. This in turn supports lower and lower tariffs.

When countries differ in their growth rates, the threat of autarky evolves at different rates. In the benchmark case, where international technological spillovers are unimportant, or similar across sectors, the autarky threat grows faster for the slower growing country. As a result, it will be less protectionist, setting lower tariffs, and even eliminating its tariffs, during a trade liberalization. But, as noted above, this pattern may be reversed if technological spillovers are high, and concentrated in the higher growth sector. In this latter case, it is in fact the higher growth country that finds the threat of autarky greater in a sustainable trade liberalization.

2. The model

There are two countries, called Home and Foreign. Foreign variables are denoted by an asterisk. There is a continuum of consumers of measure one in each country, with identical preferences defined over consumption of goods 1 and 2. Consumers have period utility functions given by

$$U_t = c_{1t}c_{2t}, \quad (1)$$

$$U_t^* = c_{1t}^*c_{2t}^*. \quad (2)$$

As long as tariffs are not prohibitive, consumers have the option to trade in commodities with residents of the other country.

Time is measured discretely. Let governments in each country discount their residents' future consumption at rate δ (< 1). Lifetime utility from period 0 onwards is then $\sum_0^\infty \delta^t U_t$ and $\sum_0^\infty \delta^t U_t^*$ for Home and Foreign, respectively.

At any given time period, production technologies are Ricardian. There is a fixed labour supply in each country, described in the following way:

$$y_{1t} = a_t l_{1t}, \quad y_{2t} = b_t l_{2t}, \quad l_{1t} + l_{2t} = 1, \quad (3)$$

$$y_{1t}^* = b_t^* l_{1t}^*, \quad y_{2t}^* = a_t^* l_{2t}^*, \quad l_{1t}^* + l_{2t}^* = 1, \quad (4)$$

where y_{it} is Home production of good i in period t and l_{it} is the fraction of the labour force, the total of which is normalized to unity, that is devoted to the production of good i . Foreign production technologies are analogous.

Labour productivity depends upon the current state of technical knowledge. This knowledge is sector-specific, and accrues only through production of the good, i.e. through learning-by-doing. Sectoral knowledge may be communicated across international borders, through either reverse engineering or direct communication.² This is modeled in the following way:

$$a_t = \alpha h_{at}, \quad h_{at} = h_{at-1}(1 + \sigma_1 l_{1t-1} + \sigma_1 \theta_1 l_{1t-1}^*), \quad (5a)$$

$$a_t^* = \alpha h_{at}^*, \quad h_{at}^* = h_{at-1}^*(1 + \sigma_2 l_{2t-1}^* + \sigma_2 \theta_2 l_{2t-1}), \quad (5b)$$

$$b_t = \beta h_{bt}, \quad h_{bt} = h_{bt-1}(1 + \sigma_2 l_{2t-1} + \sigma_2 \theta_2 l_{2t-1}^*), \quad (5c)$$

$$b_t^* = \beta h_{bt}^*, \quad h_{bt}^* = h_{bt-1}^*(1 + \sigma_1 l_{1t-1}^* + \sigma_1 \theta_1 l_{1t-1}), \quad (5d)$$

where h_{it} represents the aggregate stock of ‘specialist human capital’ that has been accumulated in activity i at date t , for $i = a, b$. A higher h_{it} raises labour productivity in activity i linearly. We distinguish between stocks of human capital by the letters a and b . In Home (Foreign), the h_{at} (h_{at}^*) represents human capital specialized in the production of good 1 (good 2) and h_{bt} (h_{bt}^*) the corresponding stock for good 2 (good 1). Initial conditions are chosen so that in a trading equilibrium, countries tend to specialize in the good corresponding to the ‘ a ’ subscripted human capital stock.

The dynamics of human capital are determined by the share of the fixed factor devoted to the production of the good. The more a country specializes in the production of a particular good, the higher is the growth rate of human capital specialized in producing that good, where the underlying growth potential is determined by the productivity factors σ_i . International spillovers of technological knowledge within a sector are introduced by the parameter θ_i , $i = 1, 2$. For instance, Eq. (5a) shows that home country productivity in sector 1 is determined by the size of both its own labour force and the foreign country’s labour force concentrated in sector 1. The size of the latter effect is dictated by the magnitude of the spillover coefficient θ_1 .

In general, the magnitude of the productivity factors σ_1 and σ_2 may differ across sectors. If $\sigma_1 > \sigma_2$, then the external learning by doing effects are more important for sector 1 than sector 2. The size of the spillover effects also can differ. If $\theta_1 > \theta_2$, then there is a greater international spillover of research knowledge from sector 1 than from sector 2. The interaction between the underlying sectoral growth rates and the spillover effects are critical for the pattern of trade liberalization.

We take these learning-by-doing effects to be an industry-wide phenomenon, external to any firm. Firms act competitively, maximizing profits. A competitive

² This specification is similar to those of Lucas (1988) and Krugman (1987).

equilibrium conditional on tariff rates is first derived, and then the determination of optimal tariff rates in the game between governments is addressed.

An important restriction is placed on the structure of moves within a period. At the start of each period, workers are allocated across sectors, anticipating wage rates in each sector. Following that, workers are in place, and cannot move until the start of the next period. For the given factor allocation across sectors, goods markets will clear, which determines equilibrium prices and wages, and governments choose tariff rates. With rational expectations, anticipated and actual wage rates will coincide. The key point is that when governments choose tariffs, the sectoral allocation of resources is fixed. This assumption builds into the model an incentive to impose tariffs which cannot be avoided by ex post factor reallocation between sectors.³

3. Competitive equilibrium for given tariff rates

In this section we derive world competitive equilibrium solutions for situations of autarky, free trade, and positive but non-prohibitive tariffs. To ensure finite levels of welfare assume that $\delta(1 + \sigma_1)(1 + \sigma_2) < 1$ holds. In addition, assume that $\beta h_{bo}/\alpha h_{ao}^* < 1$ and $\beta h_{bo}^*/\alpha h_{ao} < 1$. These conditions ensures that Home (Foreign) has an incentive to specialize in good 1 (2) at date zero, in a free trade equilibrium.

3.1. Autarky

Agents in Home choose consumption so that $P_t^A c_{1t} = c_{2t}$, for any time t , where P_t^A is the autarky relative price of good 1. If both goods are to be produced in autarky, wage rates must be equal in each sector, so $P_t^A = (b_t/a_t)$. By market clearing, $c_{1t} = a_t l_{1t}$ and $c_{2t} = b_t l_{2t}$. Combining gives $l_{1t} = l_{2t} = \frac{1}{2}$.

Period utility from autarky is $\frac{1}{4} a_t b_t$. Given $l_{it} = \frac{1}{2}$, and since the same solution holds for Foreign, the (gross) growth rate of output is $(1 + (\sigma_1/2)(1 + \theta_1))$ in sector 1 and $(1 + (\sigma_2/2)(1 + \theta_2))$ in sector 2.

Now, using Eqs. (3)–(5), period 0 welfare for the home country under autarky is

$$V^A = \sum_0^{\infty} \delta^t U_t = \frac{\frac{1}{4} \alpha \beta h_{ao} h_{bo}}{1 - \delta(1 + \frac{1}{2}\sigma_1(1 + \theta_1))(1 + \frac{1}{2}\sigma_2(1 + \theta_2))}. \quad (6)$$

³ Lapan (1988) and Staiger and Tabellini (1987) have pointed out that with temporary fixity of factors, we can define a 'time consistent' tariff that is in general higher than the classic 'optimal tariff'.

3.2. Free trade

Given the initial conditions set out above, opening up trade at $t = 0$ will lead Home to specialize in good 1 and Foreign to specialize in good 2. World output of good 1 (2) will be $a_t(a_t^*)$. The equilibrium world price of good 1 is h_{at}^*/h_{at} . Using Eqs. (3)–(5), total welfare under free trade for Home is

$$V^F = \sum_0^\infty \delta^t U_t = \frac{\frac{1}{4} \alpha^2 h_{a0} h_{a0}^*}{1 - \delta(1 + \sigma_1)(1 + \sigma_2)} \tag{7}$$

The gains from trade are twofold. First there are the static gains from specialization, revealed by comparing the expression $\alpha^2 h_{a0} h_{a0}^*$ in Eq. (7) with $\alpha \beta h_{a0} h_{b0}$ in Eq. (6). In addition, the effective discount factor under free trade, $\delta(1 + \sigma_1)(1 + \sigma_2)$, is greater than the corresponding autarky discount factor, $\delta(1 + \frac{1}{2}\sigma_1(1 + \theta_1)(1 + \frac{1}{2}\sigma_2(1 + \theta_2))$, as long as spillovers of knowledge are incomplete. This captures the ‘dynamic gains from trade’. That is, trade encourages specialization, which increases the world growth rate.

3.3. Tariff distorted equilibrium

Now, we analyse trading equilibria with positive but non-prohibitive tariffs. Without loss of generality, and to simplify notation, time subscripts are omitted for the rest of this section.

Recall that labour supply is first allocated to each sector, at the beginning of a period. With a fixed labour supply, sectoral output is fixed for that period. Then Home consumers face the constraint $Pc_1 + \tau c_2 = Py_1 + \tau y_2 + R$, where τ is the gross tariff rate P is the world price of good 1, and y_1 and y_2 represent the sectoral output levels. It is assumed that all tariff revenue is distributed back to consumers in the form of a lump-sum transfer. For Home, this is given by R , so that $R = (\tau - 1)(c_2 - y_2)$. It is easy to show that consumers’ demand functions are

$$c_1 = \left(\frac{\tau}{(1 + \tau)P} \right) (Py_1 + y_2), \quad c_2 = \left(\frac{1}{(1 + \tau)} \right) (Py_1 + y_2), \tag{8}$$

$$c_1^* = \left(\frac{1}{(1 + \tau^*)P} \right) (Py_1 + y_2), \quad c_2^* = \left(\frac{\tau^*}{(1 + \tau^*)} \right) (Py_1^* + y_2^*), \tag{9}$$

where τ^* is the foreign tariff rate, etc.

For a fixed labour allocation, world production of each good is given. Competitive equilibrium implies a world market clearing price given by

$$P = \frac{(\tau (1 + \tau^*)y_2 + (1 + \tau)y_2^*)}{((1 + \tau^*)y_1 + \tau^*(1 + \tau)y_1^*)} \tag{10}$$

Since labour supply will be allocated in response to anticipated wage rates, if tariff rates are less than Pa/b in Home, and a/Pb in the Foreign, then, with rational expectations, all Home workers will go to sector 1, and all foreign workers to sector 2. Thus, each country will specialize. With specialization, we can show that Home and Foreign utility in any period is given by

$$U(\tau, \tau^*) = \alpha^2 h_a h_a^* \frac{\tau}{(1 + \tau)(1 + \tau^*)}, \tag{11}$$

$$U^*(\tau, \tau^*) = \alpha^2 h_a h_a^* \frac{\tau^*}{(1 + \tau)(1 + \tau^*)}. \tag{11a}$$

On the other hand, if tariffs are set so that countries diversify; i.e. equal to Pa/b in the home country and a/Pb in the foreign country, then Home and Foreign utility are

$$U(\tau, \tau^*) = \frac{(y_1 y_2 (1 + \tau^*) + y_1 y_2^* + y_2 y_1^* \tau^*)^2}{(y_1 (1 + \tau^*) + y_1^* \tau^* (1 + \tau))(y_2 (1 + \tau^*) + y_2^* (1 + \tau))}, \tag{12}$$

$$U^*(\tau, \tau^*) = \frac{(y_2^* y_1^* (1 + \tau) + y_2^* y_1 + y_2 y_1^* \tau)^2}{(y_2^* (1 + \tau^*) + y_1^* (1 + \tau))(y_2 \tau (1 + \tau^*) + y_2^* (1 + \tau))}. \tag{12a}$$

Since world growth is higher with specialization, a successful trade liberalization will attempt to maintain specialization across countries. In the next section, we examine the conditions required for this.

4. Tariff games

Tariffs are determined in a repeated game between governments. Within any period, governments face a fixed allocation of labour for that period. From Eq. (5), for a fixed labour allocation, the current tariff choice has no effect on future values of specialist human capital. Nor does the current tariff choice have any direct effect on future labour allocation. Therefore, from the perspective of government there are no physical links between the actions (tariffs) in period t and the state variable (human capital) in period $t + 1$. It follows that in each period, governments are faced with an identical stage game, differing only in the given values of the state variables a_t, b_t, a_t^* and b_t^* .

An sustainable equilibrium in the tariff game is defined as a sequence of tariffs which are chosen by governments subject to the conditions for a competitive equilibrium in the previous section. The time separability of the decision facing governments means that one solution to the tariff game is a repetition of a one-shot Nash equilibrium in each period. A one-shot Nash equilibrium is described by the solution to

$$\text{Max}_{\tau} U(\tau, \tau^{*N}), \quad \text{Max}_{\tau^*} U^*(\tau^N, \tau^*), \tag{G}$$

where U and U^* are given by either Eq. (11) and Eq. (11a), if tariffs are low enough to allow for specialization, or Eq. (12) and Eq. (12a), if not. We can think of G as describing Markov-Perfect equilibria – that is, strategies that are defined over current states only. The main interest of the paper however, is to determine the maximum degree of sustainable tariff cooperation that can be achieved by in a repeated game between governments. But in order to do this, we have to identify the worst possible Markov-Perfect equilibrium outcome for each country.

A simple argument leads one to conclude that any Markov-Perfect equilibrium must lead to diversification in production. From Eqs. (11) and (11a), we see that if each country specialized, a Nash equilibrium would lead to infinitely high tariff rates (since, intuitively, the foreign ‘offer curve’ is inelastic). But this would lead wages in the importables sector to exceed that in the exportables sector, and would not be consistent with factor market specialization in the first stage.

It is well known in the literature (e.g. Dixit, 1987) that autarky is always a one-shot Nash equilibrium of a tariff game.⁴ Intuitively, if one country imposes a prohibitive tariff, then the other country’s welfare is independent of its tariff. It is a weak best response for it to impose also a prohibitive tariff. But since the tariff game can be described as a series of repeated stage games, it follows that autarky forever is a Markov-Perfect equilibrium of the overall game. Moreover, it is immediately clear that autarky is the worse possible sustainable equilibrium. No country could be made to suffer a worse outcome than autarky forever, since if it was, it could simply choose autarky on its own.

4.1. Trade liberalization equilibrium

We wish to find the best sustainable equilibrium to the tariff game. Following the method of Abreu (1988) and Chari and Kehoe (1991), this can be derived by history-dependent strategies which stipulate that governments follow a prescribed sequence of tariffs as long as this sequence has been followed in the past. Otherwise both governments chose prohibitive tariff rates. Since autarky is the worst possible outcome for both countries, the threat to revert to autarky must support the best sustainable equilibrium. Equilibria with tariffs below those of the repeated one-shot Nash equilibrium can be thought of as endogenous, self-enforcing trade agreements.

More formally, we may define the strategies in the following way. Let $\tau^t \in R_+^t$ ($\tau^{*t} \in R_+^t$) denote (τ_0, \dots, τ_t) ($\tau_0^*, \dots, \tau_t^*$). $H_t = (\tau^t, \tau^{*t})$ is the tariff history up to time t . Define $T_{t+1} : R_+^t \times R_+^t \rightarrow R_+$ as the action of the home government at

⁴ Devereux (1997) shows that there are two Markov-Perfect equilibria to the one-shot tariff game in this model. One involves positive but non-prohibitive tariffs (and diversification) while the other is autarky.

time $t + 1$. That is, $T_{t+1}(\tau^t, \tau^{*t}) \rightarrow \tau_{t+1}$. A strategy of the Home government is defined as $\sum = (T_i(\cdot))_{i=0}^\infty$, and likewise for the foreign government. Let $\tilde{\tau} = (\tilde{\tau}_0, \tilde{\tau}_1, \dots)$, $(\tilde{\tau}^* = (\tilde{\tau}_0^*, \tilde{\tau}_1^*, \dots))$ and $\hat{\tau} = (\hat{\tau}_0, \hat{\tau}_1, \dots)$. $(\hat{\tau}^* = (\hat{\tau}_0^*, \hat{\tau}_1^*, \dots))$ be two alternative tariff sequences. Then \sum (and \sum^*), denoted trade liberalization (TL) strategies, are defined as follows:

$$T_{t+1} = \begin{cases} \tilde{\tau}_{t+1} & \text{if } H_t = (\tilde{\tau}^t, \tilde{\tau}^{*t}), \\ \hat{\tau}_{t+1} & \text{otherwise.} \end{cases}$$

$$T_{t+1}^* = \begin{cases} \tilde{\tau}_{t+1}^* & \text{if } H_t = (\tilde{\tau}^t, \tilde{\tau}^{*t}) \\ \hat{\tau}_{t+1}^* & \text{otherwise.} \end{cases}$$

Here, $\tilde{\tau}$ ($\tilde{\tau}^*$) are interpreted as some cooperative sequence of tariffs, played in each period as long as they have been played in the past. If not, there is a reversion to some ‘punishment’ tariffs $\hat{\tau}$ ($\hat{\tau}^*$). The punishment itself must represent a sub-game perfect equilibrium of the tariff game. By choosing the punishment to be the worst possible subgame perfect equilibrium we can characterize the greatest degree of cooperation that can arise endogenously in the tariff game. From above, we know that autarky is the worst subgame perfect equilibrium. $\tilde{\tau}$ $\tilde{\tau}^*$ are then derived as the sequences that just remove each country’s incentive to defect on the TL equilibrium, when the punishment for defection is autarky forever.⁵

Without loss of generality, we focus on tariff equilibria that allow for complete specialization, i.e. equilibria for which $\tau < Pa_t/b_t$ and $\tau^* < a_t^*/Pb_t^*$. As long as there is not too great a size difference between the countries initially, then tariffs which induce diversification are, in fact, equilibria of the one-shot Nash tariff game in every period (see Devereux, 1997). Thus, if any cooperation in excess of this can be supported, it must involve lower tariffs and therefore specialization.

A trade liberalization (TL) equilibrium is defined as (a) a subgame-perfect equilibrium in the game between governments, using the TL strategies, and (b) a competitive equilibrium. The requirements for (b) are first that if any defection occurs, private agents will predict prohibitive tariffs for future periods, and second, that the tariff sequence actually be consistent with specialization. This second condition must be checked at each time period in the TL equilibrium.

⁵ A more comprehensive definition of the TL equilibrium could be used, which defined a sequence of tariff functions, giving for each time and state, the lowest sustainable tariffs. The state of the world is represented by the size of the technology differentials between countries (the variables γ_t^i below). While this would be important in a more general model, where technology differentials depend on current and previous tariff rates, in the present example, the technology differentials move monotonically, and do not depend on tariff rates. Thus, it introduces no confusion to define the TL equilibrium as a simple sequence of tariff rates. This allows us to economize significantly on notation.

We proceed by examining directly the conditions necessary to ensure that no government would ever wish to defect from TL. Under the proposed strategies, given no defection, period utility of the home country can be written as

$$U_t^{TL} = a_t a_t^* \frac{\tilde{\tau}_t}{(1 + \tilde{\tau}_t)(1 + \tilde{\tau}_t^*)}. \tag{13}$$

The one-period return to deviation for the home country is⁶

$$U_t^{CH} = a_t a_t^* \frac{1}{(1 + \tilde{\tau}_t^*)}. \tag{14}$$

Therefore, the gain from cheating is

$$\frac{a_t a_t^*}{(1 + \tilde{\tau}_t)(1 + \tilde{\tau}_t^*)}. \tag{15}$$

The cost of cheating at any time t is the discounted welfare from the TL equilibrium less the discounted welfare from autarky, both starting in period $t + 1$. The discounted welfare of the home country in the TL equilibrium from period $t + 1$ on, evaluated in period t , can be written as

$$\delta a_t a_t^* \sum_{i=0}^{\infty} (\delta(1 + \sigma_1)(1 + \sigma_2))^i \frac{\tilde{\tau}_{t+1+i}}{(1 + \tilde{\tau}_{t+1+i})(1 + \tilde{\tau}_{t+1+i}^*)}. \tag{16}$$

The discounted value of autarky forever for the home country, beginning next period, is

$$\frac{\delta a_t b_t (1 + \sigma_1)(1 + \sigma_2 \theta_2)}{1 - \delta(1 + \frac{1}{2} \sigma_1(1 + \theta_1))(1 + \frac{1}{2} \sigma_2(1 + \theta_2))}. \tag{17}$$

From Eq. (5) we can use the fact that $a_t \equiv \alpha h_{at}$, etc., and that $h_{at} = h_{a0}(1 + \sigma_1)^t$, and $h_{bt} = h_{b0}(1 + \sigma_2 \theta_2)^t$. If the TL equilibrium is to be attained, it must satisfy an incentive constraint which ensures that the benefits from cheating, given in Eq. (15), are no greater than the future costs of cheating (i.e. Eq. (16) less Eq. (17)) for every period beginning at time-0. That is,

$$\frac{1}{(1 + \tilde{\tau}_t)(1 + \tilde{\tau}_t^*)} \leq \delta_1 \left[\sum_{i=0}^{\infty} \delta_1^i \frac{\tilde{\tau}_{t+1+i}}{(1 + \tilde{\tau}_{t+1+i})(1 + \tilde{\tau}_{t+1+i}^*)} - \frac{1}{4} \frac{\beta h_{b0}}{\alpha h_{a0}^*} \gamma^{t+1} \frac{1}{(1 - \delta_2)} \right]. \tag{18}$$

⁶ If it cheats, the home country sets an arbitrarily high tariff rate to exploit all the gains from trade.

In Eq. (18), we simplify notation by letting $\delta_1 = \delta(1 + \sigma_1)(1 + \sigma_2)$, $\delta_2 = \delta(1 + \frac{1}{2}\sigma_1(1 + \theta_1))(1 + \frac{1}{2}\sigma_2(1 + \theta_2))$, and $\gamma_2 = ((1 + \sigma_2\theta_2)/(1 + \sigma_2))$.

Using exactly the same arguments as before, the analagous incentive constraint for the foreign country is

$$\frac{1}{(1 + \tilde{\tau}_t)(1 + \tilde{\tau}_t^*)} \leq \delta_1 \left[\sum_{i=0}^{\infty} \delta_1^i \frac{\tilde{\tau}_{t+1+i}^*}{(1 + \tilde{\tau}_{t+1+i})(1 + \tilde{\tau}_{t+1+i}^*)} - \frac{1}{4} \frac{\beta h_{b0}^*}{\alpha h_{a0}} \gamma_1^{t+1} \frac{1}{(1 - \delta_2)} \right], \tag{19}$$

where $\gamma_1 = ((1 + \sigma_1\theta_1)/(1 + \sigma_1))$.

Eqs. (18) and (19) represent the conditions under which both countries will be content to remain on the TL path, rather than cheat, at each time period. But we wish to use these conditions to define the TL path itself. That is, we wish to discover the maximal degree of cooperation that can be sustained in the face of the threat to revert to autarky. The way to approach this is to derive the tariff sequence $\tilde{\tau} \tilde{\tau}^*$, if it exists, which leads the inequality constraints (18) and (19) to bind. It is apparent that the solution for the tariff sequence is non-stationary when $\theta_1 < 1$ and $\theta_2 < 1$. If spillovers are imperfect, the relative importance of the autarky threat is changing over time since γ_2 and γ_1 are less than unity. When spillovers are imperfect, the more time countries have specialized in the past, the worse that autarky looks, relative to specialization and trade.

In order to analyse the path of trade liberalization, we make a further assumption, given in Eq. (20)

$$\delta_1 > \frac{1}{2}. \tag{20}$$

This ensures that free trade is eventually sustainable for both countries. To see this, note from Eqs. (18) and (19) that as $t \rightarrow \infty$, these constraints are satisfied with zero tariffs if Eq. (20) is met.

4.2. Trade liberalization with identical countries

It is instructive to first summarize the main results of the tariff game with complete symmetry, i.e. when $h_{a0} = h_{a0}^*$ and $h_{b0} = h_{b0}^*$, and also $\sigma_1 = \sigma_2, \theta_1 = \theta_2$. In this case, Eqs. (18) and (19) are identical, and a single dynamic incentive constraint fully characterizes the TL tariff sequence.⁷ The following proposition can be established

⁷This case is explored in Devereux (1997).

Proposition 1. (a) *There is a unique integer T and a unique tariff sequence $S = \{\tilde{\tau}\}_0^T$ such that free trade is sustainable after time T . Moreover, T satisfies*

$$\frac{\log(\omega)}{\log \gamma} \leq T \leq \frac{\log(\omega)}{\log \gamma} - 1,$$

$$\omega = \frac{(2\delta_1 - 1)(1 - \delta_2)}{(1 - \delta_1)\beta}.$$

(b) *S is a TL equilibrium if and only if $a_0 \geq \tilde{\tau}b_0$.*

With complete symmetry, tariffs are identical across countries in a symmetric equilibrium. Moreover, tariffs decline gradually over time. At the beginning of a trade liberalization experience (when countries first enter into a trading relationship), free trade is not sustainable, since the gains from trade may be very slight (if $\beta b_0/\alpha b_0$ is close to one), while with fixed factors within a period, the gains from cheating on free trade for any one country are large (intuitively, fixed factors make the ex post offer curves very inelastic). But countries specialize at the beginning of the trading relationship, and the ongoing sector-specific growth leads the gains from trade to become locked in. With continual growth in productivity in the export sector and less than perfect spillovers of sector-specific knowledge, the option of not trading becomes worse and worse over time. As a result, the costs of cheating on the cooperative path of tariffs (the TL equilibrium) progressively rise relative to the benefits of cheating, leading to a relaxation in the incentive constraint (18) over time. The consequence is that the symmetric path of tariffs that just discourages cheating in the game shows a downward trend, eventually leading to full free trade. Essentially, gradual trade liberalization is a vehicle for countries to harness the growing interdependence that trading involves, in order to progressively reduce barriers to trade over time.

From Proposition 1, T is lower, the higher is the underlying rate of productivity growth σ , and T is higher, the higher is the international spillover of technological knowledge. The first result comes from the fact that the gains from trade become locked in faster, the higher is the rate of growth. When growth is high, the disadvantage of moving back to autarky in any period gets worse and worse at a faster rate, thus leading to a faster rate of trade liberalization.

But when spillovers are large, trade liberalization is harder to sustain. In the limit, as $\theta = 1$, then $\gamma = 1$. This means that the disadvantage of moving back to autarky is constant.⁸ Technological spillovers allow for a country to reap the productivity benefits of foreign learning by doing, even though it may not be producing the good directly. As these become more important therefore, it

⁸ Note however that there are still static gains from trade in this case, as long as $\alpha \geq \beta$.

becomes harder and harder to sustain trade liberalization, since the threat of autarky is growing much more slowly over time.

4.3. Trade liberalization with differences in growth rates

When sectors differ in terms of potential growth rates, and the degree of spillover of technological knowledge, trade liberalization is more problematic, since the incentive constraints will differ across countries. This is because the countries experience different gains from trade. We now explore this case. To simplify the algebra we continue to maintain the assumption $h_{a0} = h_{a0}^*$ and $h_{b0} = h_{b0}^*$, and we set $\alpha = 1, \beta < 1$. For concreteness, we assume for the remainder of the paper that $\sigma_1 \geq \sigma_2$, so that sector 1 is the high growth sector.

The TL equilibrium is determined by the two incentive constraints (18) and (19). Eq. (18) ensures that Home has no incentive to deviate on a free trade equilibrium, while Eq. (19) does the same for foreign. In addition there is an additional constraint that must be satisfied at any time period. Tariffs and world relative prices must be such that neither country has an incentive to diversify in production; i.e. the TL equilibrium must support specialization. To ensure this, the following two conditions must be met at any time t :

$$p_t a_t \geq \tilde{\tau}_t b_t,$$

$$a_t^* \geq p_t \tilde{\tau}_t^* b_t^*.$$

From condition (20), we know that eventually, free trade is sustainable. To derive the TL sequence, we must determine the earliest date at which this is so. This requires that we find the smallest integer; T , for which either Eq. (18) or Eq. (19) or both are satisfied as equalities when $\tilde{\tau}_{T+i} = \tilde{\tau}_{T+i}^* = 1$, for all $i \geq 1$. Since the right-hand side of both incentive constraints is unambiguously increasing in t when tariffs are zero (or constant), it immediately follows that for all $t \geq T$, free trade is sustainable.

A glance at constraints (18) and (19) however tells us that it is not, in general, possible for both to be satisfied as equality conditions when $\tilde{\tau} = \tilde{\tau}^* = 1$. This is because the costs of defection on TL grows at different rates in the two countries. The dynamics of the autarky threat point for the home country is governed by

$$\gamma_2 = \frac{1 + \sigma_2 \theta_2}{1 + \sigma_2},$$

while the dynamics of the autarky threat for the foreign country are governed by

$$\gamma_1 = \frac{1 + \sigma_1 \theta_1}{1 + \sigma_1}.$$

Thus, whether the right-hand side of Eq. (18) rises faster or slower than the right-hand side of Eq. (19), (if tariff rates were equal or constant in the two countries) depends upon the condition

$$\sigma_2 + \sigma_1\theta_1 + \sigma_1\sigma_2\theta_1 \geq \sigma_1 + \sigma_2\theta_2 + \sigma_1\sigma_2\theta_2.$$

If, for instance, $\theta_1 = \theta_2 = 0$, i.e. there were no international spillovers at all, then it is clear that the right-hand side of Eq. (19) rises faster than the right-hand side of Eq. (18), (when $\sigma_1 > \sigma_2$), and the threat of autarky grows faster for the foreign country, since $\gamma_2 > \gamma_1$. Intuitively, the foreign country is specializing in a low growth sector. It is trading with the home country and reaping the benefits by consuming some of the high growth good (good 1), whose terms of trade will be falling over time. If it was forced back into autarky, it would be forced to produce good 1 itself at a cost disadvantage proportional to the amount that sector 1 in the home country has grown during the TL, $(1 + \sigma_1)^t$. This is greater than the equivalent threat for the home economy, which, in the event of a breakdown of trade, would have to produce good 2 at a cost disadvantage of $(1 + \sigma_2)^t$.

But in the event of spillovers that differ across sectors, the condition can go the other way. In particular, if $\theta_1 > \theta_2$, we can have $\gamma_2 < \gamma_1$, and the threat of autarky grows faster for the home country. Intuitively, in this case, even though the home country is producing with the faster growing technology, the international technological spillovers in this sector are so much greater that the foreign country's relative cost disadvantage in its import sector evolves at a slower rate than does that of the home country. While the foreign country continues to produce good 2 along the TL path, the technological spillovers maintain the efficiency of sector 1 in its country at a relatively high rate. Conversely, while the home country continues to produce the high growth good 1, its relative cost disadvantage in its import sector grows faster because it receives less international spillovers of technological knowledge from abroad.

The relative magnitude of γ_1 and γ_2 critically determines T , the first date that free trade is sustainable, because this determines which of incentive constraints (18) and (19) will be the last satisfied as an equality, at $\tilde{\tau}_{T+i} = \tilde{\tau}_{T+i}^* = 1$. Since both constraints must be satisfied with zero tariffs to ensure free trade, then T must be determined by the incentive constraint of Home (Foreign) if $\gamma_2 > \gamma_1$ ($\gamma_1 > \gamma_2$), as it is then Home's (Foreign's) incentive constraint that will be the last one to be satisfied, when tariffs are zero.

Let us look first at the case where technological spillovers are the same in each sector; thus $\theta_1 = \theta_2$. Therefore, $\gamma_2 > \gamma_1$. T is then defined by the incentive constraint of the home country. T is given by the smallest integer

$$1 \leq \delta_1 \left[\frac{1}{(1 - \delta_1)} - \beta \gamma_2^{T+1} \frac{1}{(1 - \delta_2)} \right]. \quad (21)$$

It is obvious to see that if Eq. (21) is satisfied, so will be the incentive constraint of the foreign country at time T , for zero tariffs. For T and every period beyond, free trade is sustainable. For dates $t < T$, however, free trade is not sustainable, since it will violate condition (18), although the foreign country's incentive constraint (19) may be satisfied. Therefore, some tariffs must be applied at date $T - 1$, and (as we will show) for all dates before that.

How can we construct this tariff sequence? The aim is to identify the maximal degree of cooperation between countries. This is characterized by the lowest tariff sequence $\tilde{\tau}, \tilde{\tau}^*$ which satisfies the constraints (18) and (19) for $t = 0 \dots T - 1$. We construct the sequence in the following way. Given T , backwards recursion on Eqs. (18) and (19) produce the conditions for period $T - 1$

$$\frac{1}{(1 + \tilde{\tau}_{T-1})(1 + \tilde{\tau}_{T-1}^*)} \leq \frac{\delta_1}{4} \left[\frac{1}{(1 - \delta_1)} - \beta \gamma_2^T \frac{1}{(1 - \delta_2)} \right], \tag{22}$$

$$\frac{1}{(1 + \tilde{\tau}_{T-1})(1 + \tilde{\tau}_{T-1}^*)} \leq \frac{\delta_1}{4} \left[\frac{1}{(1 - \delta_1)} - \beta \gamma_1^T \frac{1}{(1 - \delta_2)} \right]. \tag{23}$$

Since $\gamma_2 > \gamma_1$, if Eq. (22) is binding, then Eq. (23) must be satisfied as a strict inequality. Thus, Eq. (22) gives the lowest function of tariff rates $(1 + \tilde{\tau}_{T-1})(1 + \tilde{\tau}_{T-1}^*)$, that can be sustained in a TL equilibrium. But the actual values of $\tilde{\tau}_{T-1}$ and $\tilde{\tau}_{T-1}^*$ are (as yet) undetermined. Moving back to period $T - 2$ however, we have

$$\frac{1}{(1 + \tilde{\tau}_{T-2})(1 + \tilde{\tau}_{T-2}^*)} \leq \frac{\delta_1}{4} \left[\frac{\delta_1}{(1 - \delta_1)} + \frac{4\tilde{\tau}_{T-1}}{(1 + \tilde{\tau}_{T-1})(1 + \tilde{\tau}_{T-1}^*)} - \beta \gamma_2^t \frac{1}{(1 - \delta_2)} \right], \tag{24}$$

$$\frac{1}{(1 + \tilde{\tau}_{T-2})(1 + \tilde{\tau}_{T-2}^*)} \leq \frac{\delta_1}{4} \left[\frac{\delta_1}{(1 - \delta_1)} + \frac{4\tilde{\tau}_{T-1}^*}{(1 + \tilde{\tau}_{T-1})(1 + \tilde{\tau}_{T-1}^*)} - \beta \gamma_1^t \frac{1}{(1 - \delta_2)} \right]. \tag{25}$$

Assume for a moment that $\tilde{\tau}_{T-1} = \tilde{\tau}_{T-1}^*$ held; i.e. country's levied identical tariffs. Then the lowest function of tariffs $(1 + \tilde{\tau}_{T-2})(1 + \tilde{\tau}_{T-2}^*)$ would be defined by Eq. (24) as an equality, and again, Eq. (25) would hold as a strict inequality. Moving back in this manner for periods $T - 3$ and beyond, the tariff sequence would be determined fully by equality in the home country incentive constraint.

However, it is possible to reduce $(1 + \tilde{\tau}_{T-2})(1 + \tilde{\tau}_{T-2}^*)$ even further than this, and thus reducing average tariffs in a TL equilibrium even more than that, by having tariff rates differ across countries. In particular, if, beginning at the

symmetric case $\tilde{\tau}_{T-1} = \tilde{\tau}_{T-1}^*$, the home tariff $\tilde{\tau}_{T-1}$ rose, while the foreign tariff $\tilde{\tau}_{T-1}^*$ declined, given the fixed value of $(1 + \tilde{\tau}_{T-1})(1 + \tilde{\tau}_{T-1}^*)$, then average tariffs in previous periods can be reduced. By allowing tariffs to differ between countries, the foreign incentive constraint may be made more nearly binding, thus allowing for a lower path of tariffs.

Intuitively, allowing the home country a higher tariff at time $T - 1$ raises the cost of a defection at time $T - 2$, thus allowing for time $T - 2$ tariffs to fall in the TL path without engendering a defection. At the same time, since the foreign country's constraint is not binding at all when $\tilde{\tau}_{T-1} = \tilde{\tau}_{T-1}^*$, reducing its tariff in the TL equilibrium at time $T - 1$ will not affect its incentive to defect.⁹

How much can $\tilde{\tau}_{T-1}^*$ be reduced, relative the symmetric case? In the limit $\tilde{\tau}_{T-1}^* = 1$, tariffs cannot be negative. Thus, if this limit is met, that is, if Eq. (25) is non-binding when $\tilde{\tau}_{T-1}^* = 1$, the foreign country may be required to follow a policy of free trade as part of the TL equilibrium, while at the same time the home country imposes positive tariffs.

The sequence of TL equilibrium tariff rates for all other periods can be obtained by recursive use of Eqs. (18) and (19) in the same manner. The general formulation for the determination of the TL equilibrium, from time $T - 1$ onwards, is given by the conditions

$$\tilde{\tau}_{T+i} = \tilde{\tau}_{T+i}^* = 1, \quad i \geq 0, \tag{26}$$

$$\frac{1}{(1 + \tilde{\tau}_{T-i})(1 + \tilde{\tau}_{T-i}^*)} = \frac{\delta_1}{4} \left[V_{T-i} - \beta \frac{\gamma_2^{T-i}}{(1 - \delta_2)} \right], \tag{27}$$

$$V_{T-i} = \delta_1 V_{T+1-i} + \frac{4\tilde{\tau}_{T+1-i}}{(1 + \tilde{\tau}_{T+1-i})(1 + \tilde{\tau}_{T+1-i}^*)}, \tag{28}$$

$$V_T = \frac{1}{(1 - \delta_1)}, \tag{29}$$

$$\frac{1}{(1 + \tilde{\tau}_{T-i})(1 + \tilde{\tau}_{T-i}^*)} \leq \frac{\delta_1}{4} \left[V_{T-i}^* - \beta \frac{\gamma_1^{T-i}}{(1 - \delta_2)} \right], \quad \tilde{\tau}_{T+1-i} \geq 1, \tag{30}$$

$$V_{T-i}^* = \delta_1 V_{T+1-i}^* + \frac{4\tilde{\tau}_{T+1-i}^*}{(1 + \tilde{\tau}_{T+1-i})(1 + \tilde{\tau}_{T+1-i}^*)}, \tag{31}$$

$$V_T^* = \frac{1}{(1 - \delta_1)}. \tag{32}$$

⁹ There is another, welfare-based interpretation of this procedure. If we are trying to identify the maximal degree of cooperation, then the tariff sequence must be efficient in the sense that it maximizes some utility index. It is easy to show that, taking a simple sum of utilities as a welfare criterion, the asymmetric tariff sequence described here and below raises welfare relative to the symmetric, equal tariff, outcome.

Conditions (27)–(29) give the dynamics of the incentive constraint and value function for the home government. Conditions (30)–(32) give those for the foreign government. In condition (30), there must be at least one equality. Thus, if the foreign tariff is strictly positive, the incentive constraint must be binding. If the incentive constraint is non-binding, the foreign tariff must be zero.

With the aid of conditions (26)–(32), we can establish the following proposition.

Proposition 2. When sectoral growth rates differ, and $\sigma_1 > \sigma_2$,

(a) *If $\theta_1 < 1$ and $\theta_2 < 1$, there is a unique T after which free trade can be sustained. If $\theta_1 = \theta_2$, T is determined by the home country incentive constraint. But if $\theta_1 > \theta_2$, T may be determined by the foreign country incentive constraint.*

(b) *There is a unique sequence $S = \{\tilde{\tau}_{T-i}, \tilde{\tau}_{T-i}^*\}_{i=1}^T$ which solves conditions (26)–(32).*

(c) *The average tariff function $(1 + \tilde{\tau}_t)(1 + \tilde{\tau}_t^*)$ in S is declining monotonically.*

(d) *When $\theta_1 = \theta_2$, the home country (the faster growing country) will eliminate tariffs at a later date, and/or has higher tariffs at the end of the trade liberalization, than the slower growing country. When $\theta_1 > \theta_2$, however, this may be reversed.*

(e) *S is a TL equilibrium if and only if it satisfies the conditions $p_t a_t \geq \tilde{\tau}_t b_t$ and $a_t^* \geq p_t \tilde{\tau}_t^* b_t$.*

Proof. (a) This has been proven in the discussion above.

(b) The sequence S can be constructed by recursing backwards in the manner described above.

(c) This can be shown in two stages. First, when the first part of condition (30) is satisfied with an equality, we may add the two incentive constraints together to get, at time $T - 1$, the condition

$$\frac{1}{(1 + \tilde{\tau}_{T-1})(1 + \tilde{\tau}_{T-1}^*)} = \frac{\delta_1}{4} \left[\frac{1}{(1 - \delta_1)} - \beta \frac{\gamma_1^T}{(1 - \delta_2)} - \beta \frac{\gamma_2^T}{(1 - \delta_2)} \right]. \tag{33}$$

This uniquely defines $(1 + \tilde{\tau}_{T-1})(1 + \tilde{\tau}_{T-1}^*)$. Now move back to $T - 2$, we have

$$\begin{aligned} & \frac{1}{(1 + \tilde{\tau}_{T-2})(1 + \tilde{\tau}_{T-2}^*)} \\ &= \frac{\delta_1}{4} \left[\frac{\delta_1}{(1 - \delta_1)} + 4 \frac{\tilde{\tau}_{T-1} + \tilde{\tau}_{T-1}^*}{(1 + \tilde{\tau}_{T-1})(1 + \tilde{\tau}_{T-1}^*)} - \beta \frac{\gamma_1^{T-1}}{(1 - \delta_2)} - \beta \frac{\gamma_2^{T-1}}{(1 - \delta_2)} \right]. \end{aligned} \tag{34}$$

This uniquely defines $(1 + \tilde{\tau}_{T-2})(1 + \tilde{\tau}_{T-2}^*)$. Moreover, $(1 + \tilde{\tau}_{T-2})(1 + \tilde{\tau}_{T-2}^*)$ must exceed $(1 + \tilde{\tau}_{T-1})(1 + \tilde{\tau}_{T-1}^*)$, since the right-hand side of (34) must be less than the right-hand side of Eq. (33). There are two reasons this must be so. First,

as we move back one period, the autarky threat is less (the last two expressions in (34) are greater than those in Eq. (33)). Second, tariffs are higher in period $T - 1$ than in period T , so that total utility on the continuation path of the TL equilibrium in period $T - 1$ is less than utility in period T . Thus, average tariffs in period $T - 2$ exceed those in period $T - 1$. Continuing in this fashion, we may show that average tariff rates are higher as we go back to period $t = 0$.

In the second case, the right-hand side of condition (31) applies, and foreign tariffs are zero. Then tariffs are determined only by the home country incentive constraint. We must then show that the home tariff is falling over time. To show this, begin at time T . The home tariff at time $T - 1$ is described by

$$\frac{1}{(1 + \tilde{\tau}_{T-1})} = \frac{\delta_1}{2} \left[\frac{1}{(1 - \delta_1)} - \beta \frac{\gamma_2^T}{(1 - \delta_2)} \right], \quad (35)$$

while the home tariff at time $T - 2$ is described by

$$\frac{1}{(1 + \tilde{\tau}_{T-2})} = \frac{\delta_1}{2} \left[\frac{\delta_1}{(1 - \delta_1)} + 2 \frac{\tilde{\tau}_{T-1}}{(1 + \tilde{\tau}_{T-1})} - \beta \frac{\gamma_2^{T-1}}{(1 - \delta_2)} \right]. \quad (36)$$

To show that $\tilde{\tau}_{T-2} \geq \tilde{\tau}_{T-1}$ rearrange Eq. (36) and use Eq. (35) to get

$$\frac{1}{(1 + \tilde{\tau}_{T-2})} - \frac{1}{(1 + \tilde{\tau}_{T-1})} = \frac{\delta_1}{2} \left[\frac{2\tilde{\tau}_{T-1}}{(1 + \tilde{\tau}_{T-1})} - 1 + \beta \frac{\gamma_2^T - \gamma_2^{T-1}}{(1 - \delta_2)} \right]. \quad (37)$$

The right-hand side of Eq. (37) can be shown to equal

$$1 - \delta_1 \left(\frac{1}{(1 - \delta_1)} - \beta \frac{\gamma^{T-1}}{(1 - \delta_2)} \right) + \beta \frac{(\gamma^T - \gamma^{T-1})(1 - \delta_1 \gamma)}{(1 - \delta_2)}. \quad (38)$$

The first two expressions are negative by the definition of T (i.e. the incentive to defect is greater than the benefit to free trade at time $T - 1$). The second expression is negative since $\gamma < 1$. Thus, we have established that $\tilde{\tau}_{T-2} \geq \tilde{\tau}_{T-1}$. The same procedure can be used for time $T - 3$ and on so as to show that the sequence of home tariffs is falling over time, when the foreign country pursues a zero tariff policy.

(d) This has been shown in the discussion above; with equal technological spillovers, $\gamma_2 > \gamma_1$, and since T is determined by Home's incentive constraint, it will be the last to eliminate tariffs, and/or have higher tariffs at time $T - 1$.

(e) Once the sequence S is constructed, the conditions given in part (e) of the proposition must be checked to ensure that relative prices are still consistent with specialization. If this condition fails, then there is no TL equilibrium that allows for free trade. In this case, the only sustainable equilibrium is the repeated one-shot Nash equilibrium.

What are the characteristics of the trade liberalization equilibrium? In the case without spillovers, the model implies that the fastest growing country will have the highest tariff rate. While overall tariffs will tend to decline over time, starting at the point that countries enter into a trading relationship, the slower growing country's tariff will decline faster, and it may actually eliminate its tariff altogether, following a period of unilateral free trade, even though the other country continues to levy positive tariffs against it! Essentially, it is worthwhile for the slow-growing country to suffer a period of high tariffs levied by its trading partner, in order to reap the benefits of importing the higher growth good, and moving towards full free trade.

4.4. Numerical simulations

We now illustrate the dynamics of tariffs during a trade liberalization, for different assumptions about sector-specific productivity, technological spillovers, and discount rates. In Fig. 1 it is assumed that $\delta_1 = 0.6$, $\beta = 0.5$, and $\theta_1 = \theta_2 = 0$. Thus, there are no technological spillovers across countries. Fig. 1(a) represents the case where $\sigma_1 = \sigma_2 = 0.02$. Trade liberalization then takes 8 years, and tariffs are the same in each country, falling monotonically along the TL path. In Fig. 1(b), $\sigma_1 = 0.025 > \sigma_2 = 0.015$. In this case, trade liberalization takes 10 years, and Home tariffs exceed Foreign tariffs. Foreign tariffs fall to zero after only 8 years. In Fig. 1(c) and (d), the σ_1 is raised (to 0.03 and 0.035 respectively), while σ_2 is reduced (to 0.01 and 0.0075, respectively). In this case a sharp difference opens up between Home and Foreign tariffs. The foreign country initially levies tariffs just below those of the home country. But then Foreign tariffs fall sharply, and go to zero. Home tariffs initially fall, but then rise for one period, before the foreign country eliminates its tariff.

The intuition for the one period increase in the home tariff along the TL path in Fig. 1(c) and (d) is as follows. Since the home country is specializing in the high-growth sector (sector 1), and the foreign country the low growth sector, the foreign country is gaining greater 'dynamic gains from trade'. In order to ensure that the home country has a continued incentive to stay on the TL path, Foreign tariffs must be expected to fall sharply at the beginning of trade. But after foreign tariffs are eliminated, this can no longer occur. To maintain the home country incentive constraint, there must be a shift upwards in the path of (declining) Home country tariffs.

We can draw two conclusions from Fig. 1. First, a TL equilibrium may involve one country following a lengthy period of unilateral free trade. Secondly, tariff rates may not be monotonic in a TL equilibrium.¹⁰

¹⁰The non-monotonicity of Home tariffs in Fig. 1 is still consistent with Proposition 2c. While Home tariffs may rise for one period, the tariff function $(1 + \tau)(1 + \tau^*)$ is still falling.

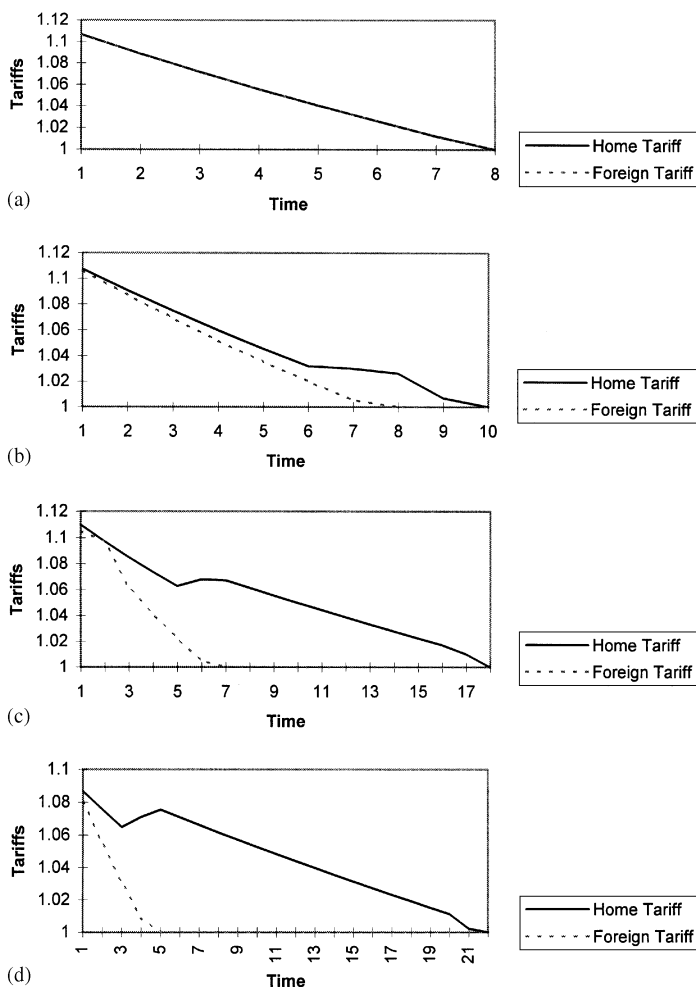


Fig. 1. Tariff paths with no spillovers.

Fig. 2 investigates the role of international technological spillovers in the trade liberalization game. Fig. 2(a) illustrates the case of Fig. 1(c), but now assuming that there are identical spillovers in each sector, where $\theta_1 = \theta_2 = 0.4$. The path of tariffs has the same shape as before, but the length of the trade liberalization now increases considerably. As discussed above, the presence of spillovers reduces the threat of autarky, and by doing so, prolongs the trade liberalization episode. Fig. 2(b) illustrates the same example, but now with higher spillovers. As expected, the trade liberalization is prolonged even further.

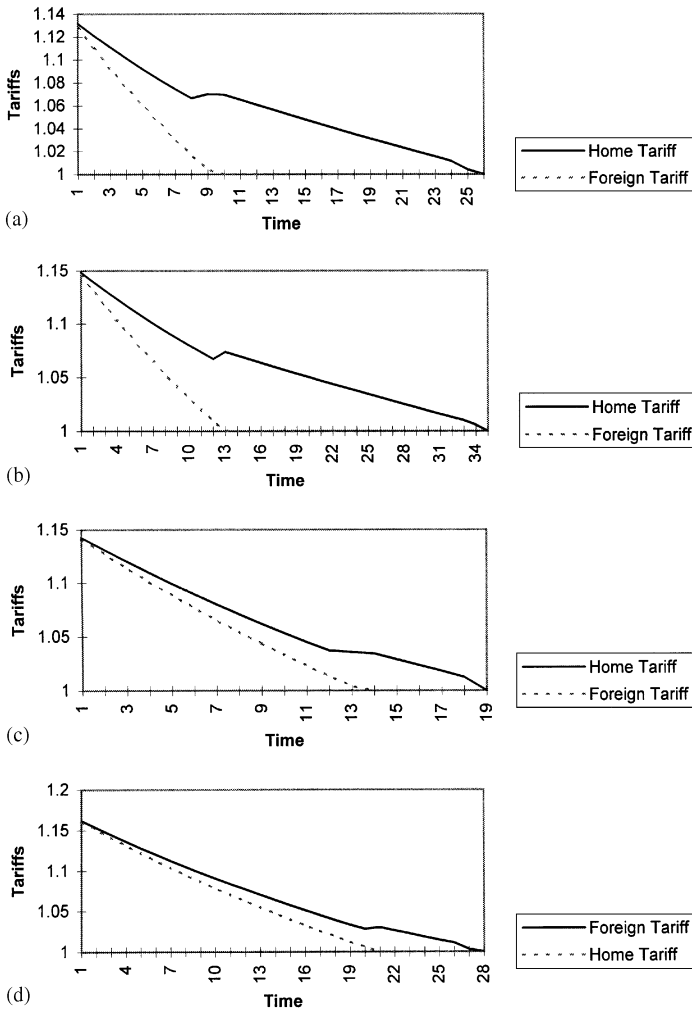


Fig. 2. Tariff paths with spillovers.

Fig. 2(c) and (d) allow for asymmetric technological spillovers, again for the case $\sigma_1 = 0.03$, and $\sigma_2 = 0.01$. In Fig. 2(c), $\theta_1 = 0.7$, and $\theta_2 = 0$. Here we see that, relative to Fig. 1(c), there is a much smaller gap between Home and Foreign tariffs. In Fig. 2(d), θ_1 is increased to 0.8. Now the tariff dynamics are reversed. The Foreign country will be the more protectionist. It will set a path of tariffs higher than the home country. The home country will eliminate its tariffs before the foreign country.

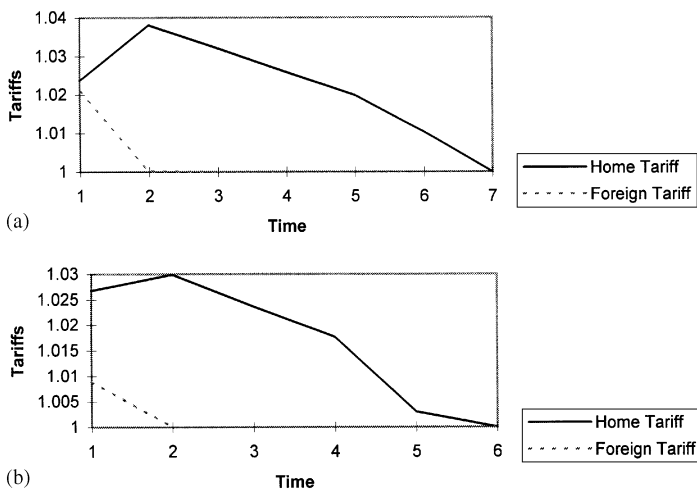


Fig. 3. Tariff paths with high government discount factor.

Finally, Fig. 3 illustrates the effect of a rise in the government discount factor (for the growth rates of Fig. 1(c) again). We see a number of effects. First of all, the length of trade liberalization is dramatically shortened – to 7 periods in Fig. 3(a). Second, a trade liberalization may involve *rising* Home tariffs right at the beginning of the game. Finally, the foreign country may effectively eliminate all protection at the outset of the TL game, when the home country is increasing its tariffs!

These examples show that the path of trade liberalization may be quite complex. Even though we have derived the maximum possible degree of self-enforcing trade liberalization in the game between governments, the differences in growth rates may mean that tariff reduction is far from reciprocal. When technological spillovers are either symmetric or absent, the fast-growing country will be more protectionist, and will be the last to eliminate its tariffs. The slower growing country may wish to follow a policy of unilateral free trade. But when there are high spillovers concentrated in the fast-growing sector, these dynamics may actually be reversed. In that case, the process of trade liberalization will be dictated by the slower growing countries.

5. Conclusions

While it is by now well known that international trade can have important implications for patterns of growth, this paper has demonstrated that growth differences between countries has important effects on the patterns of

self-enforcing trade liberalization. When countries engage in mutual trade liberalization, tariffs must be set so as to maintain each country's incentive to remain on the trade liberalization path. But the presence of differences in national growth rates and the degree of international technological spillovers may imply that the most efficient trade liberalization path is very far from the ideal of reciprocity. Tariffs may differ considerably between countries, and may move in different directions. Despite this, the paper does imply that economic growth provides a powerful stimulus for trade liberalization.

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