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## Growth, Specialization, and Trade Liberalization

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Queen's Economics Department Working Paper No. 786

# Growth, Specialization, and Trade Liberalization

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Growth, Specialization, and Trade  
Liberalization

DISCUSSION PAPER #786

by

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Kingston, Ontario  
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## Abstract

This paper examines a two-way interaction between trade liberalization and economic growth. Through dynamic increasing returns to specialization, international trade can increase world growth rates. But growth, through specialization, alters patterns of comparative advantage, changing the incentives to levy tariffs in a dynamic tariff game between governments. Two types of equilibria are analyzed. In one, average growth rates are low, tariffs are high and rising, the ratio of exports to income (the trade ratio) is low, and falls to zero asymptotically. In the other, growth rates are high, tariffs are low and falling, the trade ratio is higher, and rises over time. The conditions under which each type of equilibrium will be observed are investigated.

## SECTION I INTRODUCTION

This paper develops a simple dynamic model of trade liberalization in which economic growth and specialization are the main driving forces. Trade liberalization is interpreted in a noncooperative sense, as an equilibrium of a dynamic tariff game between governments, in which tariff rates tend to fall over time, eventually going to zero. The central idea in the model is that the possibility for a two-way interaction between trade policy and economic growth. Trade liberalization stimulates economic growth through 'learning by doing' effects of commodity specialization. But, with imperfect international spillovers of knowledge capital across countries, growth tends to sustain lower and lower tariff rates in the dynamic game between governments. Thus, while trade policy can stimulate growth, growth in turn can lay the foundation for self-sustaining trade liberalization.

This appealing scenario need not always occur however. The model also contains another, 'tariff war', equilibrium, in which growth rates are low, and tariffs are high and rising over time.

There is substantial evidence relating economic growth, both at the world level and for individual countries, to growth in the volume of international trade (e.g. World Bank Report 1987). Table 1 gives data on export and GDP growth rates for a sample of industrial economies since the eighteenth century. In all but the period between the first and second world war, growth in exports exceeded economic growth. In the twentieth century the remarkable contrast between the growth/trade performance of the interwar and post-second world war eras is mirrored in the developments in international trade policy. The interwar era was extremely unfavourable for international trade, so much so that the writers of the time talked of 'the

law of the diminishing importance of foreign trade'<sup>1</sup>. The 1920's was characterized by high tariffs and protectionism of various other kinds, and this culminated in the trade wars of the 1930's (Kindleberger 1987). By contrast, the post-second world war period saw dramatic multilateral tariff reductions among the industrial countries, stimulated by both GATT and the European Community. Table 2 compares average US import tariffs in 1930 with those following the successful GATT rounds in the postwar period.

In the post-1973 period, growth rates of industrial countries fell significantly, as did growth in world trade. While tariffs have continued to fall since then, the momentum of trade liberalization has been slowed down by an upsurge of non-tariff barriers (Bhagwati 1988).

This evidence suggests that there may be a two-way link between economic growth and successful trade liberalization. Bhagwati (1988, p. 7) succinctly describes this view

*"If tariff cuts lead to more trade, and more trade produces more income, and more income facilitates more tariff cuts, the result is a virtuous circle that can produce the level of prosperity we saw in the glorious 1950s and 1960s."*

The model presented here attempts to capture this kind of relationship. In the model, low growth rates of income are associated with low growth of international trade volume, and high and rising tariffs. By contrast, high income growth rates are associated high growth in trade volume, and with tariffs that are low and falling. Thus trade liberalization tends to be associated with higher average growth rates of income.

The essential feature of the model is the presence of increasing returns to specialization, arising from learning by doing economies, external to

<sup>1</sup>Quoted in Viner (1950).

the firm. This is taken from the international models of 'endogenous growth' set out by Lucas (1988) and Krugman (1988)<sup>2</sup>. We focus on a symmetric version of the model in which international trade tends to increase growth rates of all countries. But trade also tends to reinforce patterns of comparative advantage over time. This can be thought of as a form of 'dynamic gains from trade'; unit costs in exportables production falls persistently relative to unit costs in importables. In this way trade can generate growing interdependence among trading partners. A trade liberalization scheme is a vehicle by which this interdependence fosters growing tariff cooperation between countries, leading eventually to self-sustaining free trade.

Two types of equilibria to the tariff game are identified. In one, strategies depend only on current state variables. These are usually called Markov-Perfect equilibria. In the second, called a Trade Liberalization, strategies may be history dependent, depending upon the actions played in the past. There are two Markov-perfect equilibrium outcomes - autarky, specifying prohibitive tariffs forever, and a tariff equilibrium that allows for trade but with imperfect specialization. The latter equilibrium is Pareto superior to autarky. It is characterized by growth rates higher than autarky, but lower than under Trade Liberalization. This equilibrium has the characteristics of a 'tariff war'. Tariffs tend to rise over time. The ratio of exports to national income (the trade ratio), may grow initially, but falls over time, asymptotically converging to zero. In this equilibrium economic growth has a distinct anti-trade bias - international trade is eventually eliminated.

<sup>2</sup>Other papers on the relationship between international trade and economic growth are Grossman and Helpman (1989), (1990), and Romer and Rivera Batiz (1989). Backus, Kehoe, and Kehoe (1990) examine the empirical support for these types of models.

The Trade Liberalization equilibrium has very different characteristics. The method of construction is to specify a sequence of tariffs which are chosen along an equilibrium path, with any defection being followed by a punishment phase. The maximal credible punishment, in the sense of Abreu (1984), is autarky forever (see Dixit 1987). This supports the maximal degree of implicit cooperation between governments. The key result of the paper is that with learning by doing effects of specialization, the threat of autarky tends to grow relative to the incentive to defect, since autarky involves diverting resources to the high-cost importable sector. This means that the lowest sustainable tariffs fall progressively, leading to free trade in finite time. In this equilibrium, growth is at its highest possible level, and the trade ratio progressively rises.

We investigate the conditions under which the Trade Liberalization equilibrium can be sustained. This is more likely the higher is the productivity of the underlying learning by doing mechanism, the lower is the extent of international spillovers of knowledge, and the lower are subjective discount rates. Initial conditions, in the form of differences between countries in the sectoral composition of knowledge capital, are also important. These differences determine initial comparative advantage. If countries are initially too 'alike', Trade Liberalization is not sustainable.

If Trade Liberalization cannot be sustained, then the best that can be attained is a 'Tariff War' equilibrium, with rising tariffs. Even in this equilibrium, however, the forces of specialization and learning by doing continue, although at a lower pace than with Trade Liberalization. The evolution of sectoral knowledge capital then implies cumulatively increasing patterns of comparative advantage. This opens up the possibility of an endogenous switch to a Trade Liberalization path at some future date.



However, with low productivity in learning by doing, this potential move to tariff cooperation will take a very long time to occur.

In a later section of the paper we investigate the effects of differences in the growth potential of different goods, a factor motivating the original Lucas (1988) paper, and much of the other literature on learning by doing<sup>3</sup>. One good can be thought of as a high-technology good, with a lot of potential for learning by doing cost reductions, while the other a primary good, with relatively little learning by doing. If a Trade Liberalization exists, then, depending upon initial comparative advantage, one country will specialize in the high growth and one in the low growth good. What does the tariff profile in the Trade Liberalization equilibrium now look like? It turns out that the answer is ambiguous. If, as is likely, the high-growth good has higher international spillovers of knowledge, tariffs will tend to be higher in the low-growth country.

The 'tariff-war' equilibrium in the asymmetric game has quite different characteristics. The high-growth country in general has the higher tariff rates. Even more striking, the combination of high tariffs and falling terms of trade may lead the country with an initial comparative advantage in the high-growth good to progressively decrease its share of labour involved in the high-growth good.

The next section sets out the basic model. Section III constructs the world competitive equilibrium for given tariff regimes. Section IV then looks at the two types of equilibria to the dynamic tariff game and examines their characteristics. Some discussion and conclusions follow.

<sup>3</sup>For a very early, and seminal analysis, see Bardhan (1970). More recently Young (1989) addresses similar issues in a learning-by-doing model much more sophisticated than that of the present paper.

## SECTION II THE MODEL

Let the two countries in the world be called Home and Foreign. Foreign variables are given an asterisk. There is an equal number of consumers (one) in each country, and they have identical preferences defined over consumption of two goods; 1 and 2. Consumers have period utility functions given by the following

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

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

As long as tariffs are not prohibitive, consumers have the option to trade in commodities with residents of the other country. We rule out international capital markets. In the symmetric model below, in equilibrium, these markets would not be used anyway<sup>4</sup>.

Let governments in each country discount their residents' future consumption at rate  $\delta$  ( $\leq 1$ ). 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.

Production technologies are Ricardian, with a fixed labour supply.

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

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

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 variables are analogous.

Labour productivity depends upon the current state of technical

<sup>4</sup>The absence of international capital markets is in line with previous literature on dynamic tariff games. See Dixit (1987) for a survey. This does not mean that the presence of international credit markets would leave the results of the paper unchanged. The reason is that the strategic tariff problem of each government is affected by these markets.

knowledge. This knowledge is sector-specific, and accrues only through production of the good - i.e. through learning by doing. Knowledge may be communicated across international borders, through either reverse engineering or direct communication<sup>5</sup>.

This is modeled as follows

$$\begin{aligned}
 (5) \quad & a_t \equiv \alpha h_{at}, \quad h_{at} = h_{at-1}(1 + \sigma l_{1t-1} + \sigma \theta l_{1t-1}^*) \\
 & a_t^* \equiv \alpha h_{at}^*, \quad h_{at}^* = h_{at-1}^*(1 + \sigma l_{2t-1}^* + \sigma \theta l_{2t-1}) \\
 & b_t \equiv \beta h_{bt}, \quad h_{bt} = h_{bt-1}(1 + \sigma l_{2t-1} + \sigma \theta l_{2t-1}^*) \\
 & b_t^* \equiv \beta h_{bt}^*, \quad h_{bt}^* = h_{bt-1}^*(1 + \sigma l_{1t-1}^* + \sigma \theta l_{1t-1}) \\
 & h_{i0}, h_{i0}^* \text{ given, } i = a, b \quad \alpha > \beta > 0, \sigma > 0, 0 \leq \theta < 1
 \end{aligned}$$

$h_{it}$  represents the aggregate stock of "specialist human capital" that has been accumulated in activity  $i$  at date  $t$ ,  $i=a,b$ . 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 tends 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

<sup>5</sup>See Lucas (1988) and Krugman (1988). According to this specification, learning-by-doing continues forever, as long as production is taking place. This is a simple way to allow for continual growth, but is counterfactual in the literal sense, since the learning curve for any individual commodity would be expected to flatten out at some point. Stokey (1988), and Young (1989) develop models in which learning by doing takes place sequentially along a continuum of goods, with goods of a lower quality or technical sophistication being produced first. Young (1989) allows for learning by doing to be bounded in any one good, but a continual move up the index of goods allows for unbounded growth. The effects of alternative assumptions about the learning-by-doing mechanism are discussed in Section V.

human capital specialized in producing that good. International spillovers of technological knowledge within a sector are allowed for through the parameter  $\theta$ . As long as  $\theta$  is between 0 and 1, an increase in world specialization always leads to increases in growth rates.

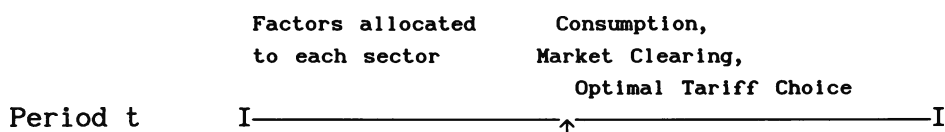
Countries are entirely symmetric; preferences are identical, and technologies are mirror images of one another. We also restrict attention to symmetric strategies in tariff game. In any equilibrium of the symmetric game, Home and Foreign residents have equal welfare. We think of this as trade liberalization between 'similar' countries, e.g. industrial countries, rather than between industrial and non-industrial economies, where learning by doing may substantially differ across goods. An extension below examines the case of differential growth rates and asymmetric strategies.

An issue of appropriate modeling is whether international spillovers take place in autarky. In autarky, no reverse engineering can be done. However, there may be other forms of indirect communication of technical knowledge. In addition, since we have modeled spillovers as being invariant to the level of international trade, the assumption that they cease under autarky would impart a discontinuity to the growth process. To avoid this, we assume therefore that there are spillovers in autarky<sup>6</sup>. It will be shown that this assumption has no important effect on any of the results.

We take these learning by doing effects to be an industry-wide phenomenon, completely external to any firm. Firms behave competitively, maximizing profits atemporally. We characterize competitive equilibrium, conditional on tariff rates, and then address the choice of optimal tariff

<sup>6</sup>One could also imagine that the force of the spillovers varied with the volume of trade, but this is probably not a good conjecture for the transfer of knowledge capital.

rates in a game between governments. An important restriction is placed on the structure of moves within a period. This is illustrated as follows



At the start of each period, workers disperse between sectors anticipating wage rates in each sector. After that, workers are in place, unable to move until the start of the next period. Given labour allocation across sectors, at the end of the period, goods markets clear, determining prices and wages, and governments choose tariff rates. Of course in equilibrium, with rational expectations, anticipated and actual wage rates will coincide. The important point about this setup is that at the time when governments choose tariffs, the sectoral allocation of resources is taken as given. This assumption builds into the model an incentive to impose tariffs which cannot be avoided by ex-post factor reallocation between sectors. It is also important for a tractable solution to the tariff game<sup>7</sup>.

### SECTION III COMPETITIVE EQUILIBRIUM FOR GIVEN TARIFFS

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, for the rest of the paper assume that  $\delta(1+\sigma)^2 < 1$ . In addition, assume that  $h_{a0} = h_{a0}^*$  and  $h_{b0} = h_{b0}^*$ , and  $\beta h_{b0} / \alpha h_{a0} < 1$ .

#### III-1) AUTARKY

Agents in Home choose consumption so that  $P_t c_{1t} = c_{2t}$ , for any time  $t$ .  $P_t$  is the relative price of good 1. If both goods are to be produced in

<sup>7</sup>The notion that with temporary fixity of factors the 'time-consistent' tariff differs from the classical 'optimal tariff' expression has been explored by Lapan (1988). In this paper, we are, in Lapan's terminology, dealing exclusively with 'time-consistent' tariffs.

autarky, wage rates must be equal in each sector, so  $P_t = (b_t/a_t)$ . 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 rates of output is  $(1+(\sigma/2)(1+\theta))$  in each sector, which is the growth rate of national income.

Autarky conditions for Foreign are exactly analogous, except that the Foreign autarky price is  $P_t = (a_t/b_t)$ . Now, using (3), (4), and (5), period 0 welfare (for each country) under autarky,

$$(6) \quad V^{AUT} = \sum_{t=0}^{\infty} \delta^t U_t = \frac{\frac{1}{4} \alpha \beta h_{a0} h_{b0}}{[1 - \delta(1 + \frac{1}{2}\sigma(1+\theta))]^2}$$

### III-2) FREE TRADE

Trade patterns will depend upon productivity, which in turn depends upon the past history of production. For the assumptions on initial conditions, opening up trade at  $t=0$  will lead Home to specialize in good 1 and Foreign to specialize in good 2. World output of each good will be  $a_t$ . Each country will consume half of this, and per period utility (of each) is  $\frac{1}{4}a_t^2$ . The equilibrium world price is unity, and the rate of growth of world income is  $(1+\sigma)$ . Again, using (3), (4), and (5), total welfare under free trade is

$$(7) \quad V^{FT} = \sum_{t=0}^{\infty} \delta^t U_t = \frac{\frac{1}{4} \alpha^2 h_{a0}^2}{(1 - \delta(1 + \sigma))^2}$$

The value of free trade is greater than that of autarky for two reasons. The first is the expression  $\alpha^2 h_{a0}^2$  in (7) compared to  $\alpha \beta h_{a0} h_{b0}$  in (6). This is the static gain from specialization. In addition, however under free trade, the effective discount factor is  $\delta(1+\sigma)^2$ , which is greater than  $\delta(1 + \frac{1}{2}\sigma(1+\theta))^2$ , the corresponding autarchic discount factor, as long as spillovers of knowledge are incomplete. This captures the 'dynamic gains from trade' effect, coming from the higher growth rates of world output.

These dynamic gains will be crucial for a successful trade liberalization.

### III-3) TARIFF DISTORTED EQUILIBRIUM

Now we analyze trading equilibria with positive, but non-prohibitory, tariffs. First we derive demands and market clearing prices for a given allocation of labour in each country and then specify the conditions governing labour supply. Since the time period is arbitrary, time subscripts are omitted for the rest of this section.

For given sectoral outputs, Home consumers face the constraints

$$Pc_1 + \tau c_2 = py_1 + \tau y_2 + R$$

where  $\tau$  is (one plus) the tariff rate,  $P$  is the world price of good 1. 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  $R = (\tau - 1)(c_2 - y_1)$ . It is easy to show that consumers' demand functions are

$$(8) \quad c_1 = (\tau / (1 + \tau) P) \{Py_1 + y_2\}, \quad c_2 = (1 / (1 + \tau)) \{Py_1 + y_2\},$$

$$(9) \quad c_2^* = (\tau^* / (1 + \tau^*)) \{Py_1^* + y_2^*\}, \quad c_1^* = (1 / (1 + \tau^*)) \{Py_1^* + y_2^*\},$$

where  $\tau^*$  is the foreign tariff rate, etc.

For a fixed labour allocation, world production of each good is given. Then without any loss of generality let Home produce a share  $k$  of total world output of good 1, ( $0 \leq k \leq 1$ ), and  $(1 - m)$  of good 2, ( $0 \leq m \leq 1$ ). Competitive equilibrium implies a world market clearing price given by

$$(10) \quad P = \frac{[\tau(1 + \tau^*)(1 - m) + (1 + \tau)m]Y_2^w}{[(1 + \tau^*)k + \tau^*(1 + \tau)(1 - k)]Y_1^w}$$

where  $Y_i^w$  is world output of good  $i$ ,  $i = 1, 2$ .

Labour supply is determined according to the inequalities<sup>8</sup>

<sup>8</sup> A tariff is defined here as a tax on the import of a good. If the good is not imported, then the tax is zero. Thus a positive tariff with imports does not translate to a subsidy in the event that the good is exported.

$$(11a) \quad \text{For (i) } Pa > b\tau, \quad l_1 = 1$$

$$(ii) \quad Pa \leq b\tau, \quad 0 \leq l_1 \leq 1 \quad l_1 + l_2 = 1$$

$$(11b) \quad \text{For (i) } Pb\tau^* < a \quad l_2^* = 1$$

$$(ii) \quad Pb\tau^* \geq a \quad 0 \leq l_2^* \leq 1 \quad l_1^* + l_2^* = 1$$

In order to determine whether specialization actually occurs we have to know the equilibrium tariff rates. Notice though, that in a symmetric equilibrium where  $P=1$ , each country specializes in its high-productivity good if tariff rates are less than  $(a/b)$ . In that case we have  $k=m=1$ .

A competitive equilibrium for a given sequence of tariff rates is then defined as the set  $\{C_{it}, C_{it}^*, P_t, l_{it}, l_{it}^*, \tau_t, \tau_t^*\}_{t=1}^{\infty}$ ,  $i=1,2$  which satisfies consumer maximization, government budget constraints, the factor market equilibrium conditions (11), and market clearing, given by (10). The equilibrium may be derived using (5) and (6) for each period  $t$  separately.

#### SECTION IV TARIFF GAMES

The determination of tariffs can be modeled as a repeated game between governments. In any time period, governments take the intersectoral allocation of labour for that period as fixed. Therefore, from equation (5), it is clear that the current tariff choice, for a fixed labour allocation, has no affect on future values of specialist human capital. The current tariff choice has no direct effect on future labour allocation either. Therefore, from the vantage point of the policy maker, there are no physical links between the actions (tariffs) of governments in period  $t$  and the state variable (human capital) in period  $t+1$ . In each period governments are faced with an identical stage game, differing only in the given values of the state variable.

This feature of the environment allows for a very simple identification of at least one subgame perfect equilibrium to the overall game - just a



repetition of a one-shot Nash equilibrium in each period. In our context we can think of these as Markov-Perfect equilibria - strategies are defined over current states only. We now characterize one-shot Nash equilibria<sup>9</sup>.

### III-1) MARKOV-PERFECT EQUILIBRIUM

Again take a representative period and ignore the subscripts. Take factor allocations as given, and substitute (10) into (8) and (9) to get the following expressions for period utility for each country,

$$(12) \quad U(\tau, \tau^*) = Y_1^w Y_2^w \frac{(k + \tau^*(1-m))^2}{(1 + \tau^*(1-m) + m)(\tau^* + \tau^* \tau(1-k) + k) \frac{\tau}{\tau}}$$

$$(13) \quad U^*(\tau, \tau^*) = Y_1^w Y_2^w \frac{(m + (1-k)\tau)^2}{(\tau + \tau \tau^*(1-m) + m)(1 + \tau(1-k) + k) \frac{\tau^*}{\tau^*}}$$

In a one-shot game tariff rates are determined by the conditions

$$(G) \quad \underset{\tau}{\text{Maximize}} U(\tau, \tau^{*N}) \quad \underset{\tau^*}{\text{Maximize}} U(\tau, \tau^{*N})$$

A One-Shot Nash equilibrium is the set  $\{C_1^N, C_1^{*N}, P^N, l_1^N, l_1^{*N}, \tau^N, \tau^{*N}\}$  which satisfies the conditions (i) government maximization, given by (G), and (ii) a competitive equilibrium for any time period. This equilibrium can be directly constructed. The construction is the subject of proposition 1.

**PROPOSITION 1** (i) Autarky is a one-shot Nash equilibrium. (ii) There will never be specialization in a one-shot Nash equilibrium.

**Proof:** (i) The first part of the proposition is quite trivial. If one country imposes a prohibitive tariff, welfare of the other country is independent of its tariff rate<sup>10</sup>. Thus a 'best response' in a weak sense is

<sup>9</sup>The results in the next few paragraphs are related to those of Kennan and Reizman (1988). They look at the equilibrium of a static tariff game and examine the effect of country size. They do not endogenize labour supply.

<sup>10</sup>Dixit (1987) emphasizes autarky as a Nash equilibrium in a Tariff Game. It is not an equilibrium of a tatonnement process in reaction curves space, such as Johnson (1953) focused on. This is probably the reason that it is often

also to impose a prohibitive tariff. Each country is in competitive equilibrium with factor allocations and consumption rates as in autarky.

(ii) There also exists an interior Nash equilibrium to the tariff game, where there is trade. Take the first order conditions for G. These are, for Home and Foreign, respectively

$$\frac{m}{\tau^2 [1+(1-m)\tau^*+m]} = \frac{(1-k)}{[1+(1-k)\tau+k]} \frac{1}{\tau}$$

$$\frac{(1-m)}{[1+(1-m)\tau^*+m]} = \frac{k}{\tau^{*2} [1+(1-k)\tau+k]} \frac{1}{\tau^*}$$

Solving these equations gives the tariff solutions

$$(14) \quad \tau = \sqrt{\frac{m}{(1-k)}} \quad \tau^* = \sqrt{\frac{k}{(1-m)}}$$

Now suppose an equilibrium with specialization exists. From (11) this entails

$$(11c) \quad Pa > b\tau \quad \text{and} \quad P\tau^*b < a$$

In addition,  $k=m=1$ <sup>11</sup>. From (10) this implies that

$$P = \frac{(1+\tau)}{(1+\tau^*)}$$

Finally (14) gives  $\tau = \tau^* = \infty$ . This violates (11c), a contradiction.

Therefore specialization cannot occur in a one-shot Nash equilibrium. □

With specialization, the demand functions (8) and (9) imply that the price elasticity of export supply is zero. From the optimal tariff formula, this implies that each country desires to set an infinite tariff. With  $P=1$ , this reduces the return to factors in the specialized sector below that of the other sector. Foreseeing this, agents will never specialize.

overlooked in the literature on optimal tariffs and retaliation.

<sup>11</sup> It is easy to argue through the same reasoning that specialization cannot go the other way either, i.e. the country will not specialize in the good in which it has a comparative disadvantage.

Without specialization we have  $Pa = b\tau$  and  $P\tau^*b = a$ . Substituting (9) into these conditions and using the definitions of  $m$  and  $k$

$$(15) \quad Pa = b \left[ \frac{al_2^* Y_1^w}{bl_1^* Y_2^w} \right]^{\frac{1}{2}} \quad \text{and} \quad Pb \left[ \frac{al_1 Y_2^w}{bl_2 Y_1^w} \right]^{\frac{1}{2}} = a$$

Symmetry implies that  $Y_1^w = Y_2^w$ . Then  $P = 1$  and conditions (11) and (15) solve for equilibrium factor allocations in each country. These are

$$(16) \quad l_1 = l_1^* = a/(a+b).$$

Factor allocations here are between those of autarky and complete free trade. Using these solutions the equilibrium tariff rates are given by

$$(17) \quad \tau = \tau^* = (a/b).$$

Finally, consumption for Home, for good 1 and 2 respectively, is

$$(18) \quad c_1 = \frac{a(a^2+b^2)l}{(a+b)^2} \quad c_2 = \frac{b(a^2+b^2)l}{(a+b)^2}$$

Figure 1 illustrates the features of the Nash equilibrium. In each country, relative prices are at their autarky positions. The world price is unity. Each country incompletely specializes in its 'a'-good (high productivity good). There are some gains from trade, but less than those under complete free trade and specialization.

Now we may define a sub-game perfect equilibrium of the overall game merely as a repetition of this outcome for each time period, conditional on the states  $a_t$  and  $b_t$ . At each time period, future decisions are independent of the current tariff choice<sup>12</sup>. If the current decision maker in government accepts that her successors will play in this way, then it is optimal for her to do likewise. She cannot bind her successors in any way.

We may characterize this equilibrium using the dynamic equations for human capital accumulation. Equations (16), (17) and (18) describe the

<sup>12</sup>This equilibrium of the policy game between governments is strategically similar to the 'discretionary equilibrium' of the monetary policy game defined by Barro and Gordon (1983).

solution for each time period. In terms of Figure 1, the dynamics will lead each country's production possibilities curve to expand out asymmetrically, as it gets more and more productive in its export good. Each country will grow faster than under autarky, as the fraction  $a/(a+b)$  ( $> \frac{1}{2}$ ) of its labour force is devoted to the low cost good. Over time the fraction will tend to increase according to the dynamics of specialist human capital, so that in the limit specialization is attained. At the same time tariffs will rise progressively, as countries specialize more and more, becoming increasingly monopolistic in the the world supply of their export good. Governments engage in a progressively escalating 'tariff war'.

While international trade tends to increase growth, growth rates are less than with complete specialization. Moreover, growth itself has an anti-trade momentum. The trade ratio (for either country) is

$$(19) \quad \frac{a_t b_t (a_t - b_t)}{(a_t + b_t)(a_t^2 + b_t^2)} = \frac{(a_t/b_t)(a_t/b_t - 1)}{(a_t/b_t + 1)(a_t^2/b_t^2 + 1)}$$

Figure 2 illustrates the behaviour of (19), as a function of  $a_t/b_t$ . Starting at  $a_t/b_t=1$ , the trade ratio first rises, and then falls, approaching zero asymptotically, since (5) and (16) imply that  $a_t/b_t$  rises monotonically. Thus, depending on initial conditions, the trade ratio may rise or fall initially. If it rises, it does so temporarily, and falls monotonically thereafter. If it falls, it does so monotonically.

While countries specialize to an increasing degree, rising tariffs lead the domestic price of the importable to rise over time. Consumers progressively consume more and more of their export relative to the import good. The process of economic growth tends to eliminate international trade.

Notice that the impact of growth on tariffs depends upon the size of the international spillovers. For  $\theta=1$ , spillovers are complete. In this case,

specialization has no impact on growth at all. But then, (19) establishes that  $a_t/b_t$  is time invariant, the degree of specialization remains constant over time, and so tariffs are constant over time. In this case, growth is balanced, since each country's production possibilities curve shifts out in a parallel manner over time.

### III-2) EQUILIBRIUM WITH TRIGGER STRATEGIES

We now focus on strategies which allow for more cooperation than does the repeated one-shot Nash equilibrium. Equilibria with tariffs below those of the repeated one-shot Nash equilibrium can be thought of as endogenous, self-enforcing trade agreements. The object is to find the maximal degree of implicit cooperation between countries that can be achieved as a sub-game perfect equilibrium of the game.

Strategies are typically history dependent. Let  $\tau^t \in R_+^t$  ( $\tau^{t*} \in R_+^t$ ) denote  $(\tau_0, \dots, \tau_t)$  ( $(\tau_0^*, \dots, \tau_t^*)$ ).  $H_t = (\tau^t, \tau^{t*})$  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 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  $\Sigma = (T_i(\cdot))_{i=0}^{\infty}$ , and likewise for the Foreign government. We focus on symmetric strategies. Let  $\tilde{\tau} = (\tilde{\tau}_0, \tilde{\tau}_1, \dots)$  and  $\hat{\tau} = (\hat{\tau}_0, \hat{\tau}_1, \dots)$ . Then  $\tilde{\Sigma}$  (and  $\tilde{\Sigma}^*$ ), denoted Trade Liberalization (TL) strategies, are defined as follows

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

That is,  $\tilde{\tau}$  is 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  $\hat{\tau}$ . The punishment must constitute a sub-game perfect equilibrium. Identifying the maximal punishment allows us to characterize the greatest degree of cooperation that can arise endogenously in the tariff game.

It is clear that the maximal punishment that can be inflicted is an infinite reversion to autarky. Autarky is a subgame perfect equilibrium. If there was a sub-game perfect equilibrium which delivered payoffs worse than autarky forever, then, in this equilibrium, any country could unilaterally prohibit trade forever and by doing so make itself better off. Thus the stated punishment could not be a subgame perfect equilibrium<sup>13</sup>.

Without losing generality, we focus on tariff equilibria which allow for complete specialization, i.e. equilibria for which  $\tau_t < a_t/b_t$ . In a symmetric equilibrium, the tariff which induces diversification, at any  $t$ , is unique, i.e.,  $a_t/b_t$ . But these are equilibria of the one-shot Nash equilibrium in any case. If any cooperation in excess of this can be supported, it must involve lower tariffs and therefore specialization.

$\tilde{\tau}$  is then derived as the sequence which just removes the incentive to defect, when the punishment for defection is autarky forever.

A Trade Liberalization (TL) equilibrium is defined as a) a subgame-Perfect equilibrium in the game between governments, using the TL strategies;  $\tilde{\Sigma}$ , b) a competitive equilibrium. The requirements for b) are first that if any defection occurs, private agents will predict prohibitive

<sup>13</sup> In fact, the qualitative nature of the results would be unchanged by the use of the 'tariff war' equilibrium as a punishment. What is important is that the punishment get worse and worse over time relative to the trade liberalization equilibrium. Since the 'tariff war' equilibrium involves diversification of resources among sectors this requirement will be satisfied for this alternative punishment. Of course with this, weaker punishment, tariffs will fall at a slower rate in the Trade Liberalization equilibrium to be described below.

We also note that the equilibrium described in this section, as in all the applications of supergames to international trade e.g. Dixit (1987), Bagwell and Staiger (1988), is not necessarily 'renegotiation-proof' in the sense of Farrell and Maskin (1987) or Bergin and McLeod (1989), for instance. If governments communicate after the defection, and agree to 'forget' the punishment, they would both do better. But this restriction would then eliminate the initial equilibrium supported by the punishment threat. Renegotiation proof equilibria generally require asymmetric strategies.

tariffs for future periods, and second, that the tariff sequence actually be consistent with specialization. The first condition is clearly a rational expectation for private agents, providing governments play TL strategies<sup>14</sup>. The second condition must be checked. 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 either country can be written

$$(20) \quad U_t^{TL} = (\alpha h_{at})^2 \frac{\tilde{\tau}_t}{(1+\tilde{\tau}_t)^2}$$

The one period return to deviation is

$$(21) \quad U_t^{CHEAT/TL} = (\alpha h_{at})^2 \frac{1}{(1+\tilde{\tau}_t)}$$

Therefore the gain from cheating is

$$(22) \quad \frac{(\alpha h_{at})^2}{(1+\tilde{\tau}_t)^2}$$

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 TL equilibrium from period  $t+1$  on, evaluated in period  $t$ , can be written as

$$(23) \quad \delta \alpha^2 h_{at}^2 (1+\sigma)^2 \sum_{i=0}^{\infty} (\delta(1+\sigma)^2)^i (\tilde{\tau}_{t+1+i} / (1+\tilde{\tau}_{t+1+i})^2)$$

The discounted value of autarky forever beginning next period is

$$(24) \quad \frac{\delta \frac{1}{4} \alpha \beta h_{at} (1+\sigma) h_{bt} (1+\sigma \theta)}{(1-\delta(1+\frac{1}{2}\sigma(1+\theta))^2)}$$

Now, using the fact, from (5), that  $h_{at}=h_{a0}(1+\sigma)^t$ , and  $h_{bt}=h_{b0}(1+\sigma\theta)^t$ , the TL sequence is then defined by the conditions which ensure that the benefits from cheating, (21), are exactly offset by the future costs of cheating, i.e. (23) less (24), for every period  $t = 0, 1, 2, \dots$ . That is,

<sup>14</sup>The private sector, while acting competitively, actually participate in the punishment. This issue is discussed in Chari, Kehoe, and Prescott (1989).

$$(25) \quad \frac{1}{(1+\tilde{\tau}_t)^2} = \delta(1+\sigma)^2 \left[ \sum_{i=0}^{\infty} (\delta(1+\sigma)^2)^i \left\{ \frac{\tilde{\tau}_{t+1+i}}{(1+\tilde{\tau}_{t+1+i})^2} \right\} - \frac{1}{4} (\beta h_{b0}/\alpha h_{a0}) \frac{(1+\sigma\theta)^{t+1}}{(1+\sigma)^{t+1} (1-(1+\frac{1}{2}\sigma(1+\theta))^2 \delta)} \right]$$

It is apparent from (25) that the solution for the tariff sequence is non-stationary for  $\theta < 1$ . In order to solve for the actual sequence we make a further assumption

$$(26) \quad \delta(1+\sigma)^2 > \frac{1}{2}$$

The effective discount factor in a trade equilibrium with specialization must be greater than half. This is the common restriction put on discount factors in repeated games to allow for cooperation (e.g. Friedman 1977). To make use of (26), note that since, for  $\theta < 1$ ,  $(1+\sigma\theta)/(1+\sigma) < 1$ , so that the second term on the right hand side of (25) must tend toward zero. By (26) it must then be the case that for some  $T < \infty$ , the tariffs necessary to sustain free trade, for all  $t \geq T$ , must be zero. Thus  $(\tilde{\tau}_T, \tilde{\tau}_{T+1}, \dots) = (1, 1, \dots)$ . Moreover,  $T$  is unique, since it is determined as the smallest integer for which

$$(27) \quad 1 < \delta(1+\sigma)^2 \left[ \frac{1}{(1-\delta(1+\sigma)^2)} - (\beta h_{b0}/\alpha h_{a0}) \frac{(1+\sigma\theta)^{T+1}}{(1+\sigma)^{T+1} (1-(1+\frac{1}{2}\sigma(1+\theta))^2 \delta)} \right]$$

$T$  represents the first time period, after the trade liberalization at time 0, for which undistorted free trade can be supported by a threat to revert to autarky. The intuition behind this is quite clear. Under the Trade Liberalization, the growth effects of specialization are gained immediately. With imperfect international spillovers of knowledge, the cost of a reversion to autarky then progressively increases relative to the benefits of cheating, as time goes on, since autarky involves diversifying resources back towards the import sector, which is becoming less and less productive, in relative terms. The utility of autarky relative to free trade



tends towards zero. Then if the discount rate allows for any cooperation at all it must be the case that free trade can be supported eventually.

$T$  is higher, the lower is the discount rate  $\delta(1+\sigma)^2$ , the lower is the initial relative productivity differential between sectors  $\beta h_{b0}/\alpha h_{a0}$ , and the higher is the extent of the spillover of learning by doing across countries  $\theta$ . The first result is obvious, the second arises because for very similar initial productivities the cost of autarky is less, and therefore a longer time must elapse in order to generate the necessary productivity differential to support free trade. The third result holds because for high knowledge spillovers the productivity wedge between sectors grows only very slowly.

To determine the tariff sequence TL, write out condition (25) for period  $T-1$ . Since tariffs are zero after  $T$ , this gives one equation in  $\tilde{\tau}_T$

$$\frac{1}{(1+\tilde{\tau}_{T-1})^2} < \delta(1+\sigma)^2 \frac{1}{(1-\delta(1+\sigma)^2)} - (\beta h_{b0}/\alpha h_{a0}) \frac{(1+\sigma\theta)^T}{(1+\sigma)^T (1-(1+\frac{1}{2}\sigma(1+\theta))^2\delta)}$$

or

$$(28) \quad \tilde{\tau}_{T-1} = -1 + \left( \delta(1+\sigma)^2 \frac{1}{(1-\delta(1+\sigma)^2)} - (\beta h_{b0}/\alpha h_{a0}) \frac{(1+\sigma\theta)^T}{(1+\sigma)^T (1-(1+\frac{1}{2}\sigma(1+\theta))^2\delta)} \right)^{-\frac{1}{2}}$$

By the definition of  $T$ ,  $\tilde{\tau}_{T-1}$  must exceed unity. The tariff rate necessary to eliminate the temptation to defect must be positive. Now moving back to time  $T-2$ , using (28), we may compute  $\tilde{\tau}_{T-2}$  in the same way. This is given by

$$(29) \quad \tilde{\tau}_{T-2} = -1 +$$

$$\left( \delta(1+\sigma)^2 \left[ \frac{4\tilde{\tau}_{T-1}}{(1+\tilde{\tau}_{T-1})^2} + \frac{\delta(1+\sigma)^2}{(1-\delta(1+\sigma)^2)} - (\beta h_{b0}/\alpha h_{b0}) \frac{(1+\sigma\theta)^{T-1}}{(1+\sigma)^{T-1} (1-(1+\frac{1}{2}\sigma(1+\theta))^2\delta)} \right] \right)^{-\frac{1}{2}}$$

This must exceed  $\tilde{\tau}_{T-1}$ , for two reasons. First, since  $\tilde{\tau}_{T-1} > 1$ , the discounted utility of remaining on the TL sequence from time  $T-1$  onwards is reduced relative to the utility of remaining on TL from time  $T$  onwards.

Second,  $((1+\sigma\theta)/(1+\sigma))^{T-1} > ((1+\sigma\theta)/(1+\sigma))^T$ . This raises the utility of autarky from time T-1 onward relative to the utility of autarky from time T onwards. Both factors reduce the implicit threat of a reversion to autarky at time T-2 relative to time T-1, and so must be offset with a higher period T-2 tariff as part of the TL sequence.

Continuing on in this manner, we can compute  $\tilde{\tau}_{T-3}$ ,  $\tilde{\tau}_{T-4}$ ,  $\tilde{\tau}_{T-5}$  etc. Moreover, by the same arguments as in the previous paragraph, these must satisfy  $\tilde{\tau}_{T-1} < \tilde{\tau}_{T-2} < \tilde{\tau}_{T-3} < \tilde{\tau}_{T-4} \dots$

While this characterizes the TL sequence we have omitted one detail. Are the tariffs consistent with international specialization? This requires only that the initial tariff in the sequence allows for specialization, i.e.  $a_0 > b_0 \tau_0$ . The condition will depend upon all the parameters of the model, and must be checked individually. If  $\tilde{\tau}_0 > a_0/b_0$ , then the TL sequence does not exist, since the maximal degree of cooperation that can be achieved is inconsistent with specialization from time 0. The effect of alternative parameter values on  $\tilde{\tau}_0$  is explored below.

The arguments of the last three pages can be summarized as follows<sup>15</sup>

*PROPOSITION 2.* (i) The sequence TL =  $\{\tilde{\tau}_t\}_0^T$  exists if  $a_0 \geq \tilde{\tau}_0 b_0$ . (ii) TL leads to eventual free trade. (iii) TL implies a declining sequence of tariffs.

The TL equilibrium sharply contrasts with the tariff war equilibrium in the previous section. Tariffs are always lower in a TL equilibrium. Tariffs fall rather than rise over time. Growth rates of income are higher. The trade ratio, is now  $1/(1+\tilde{\tau}_t)$ . Since  $\tilde{\tau}_t < a_t/b_t$ , the trade ratio exceeds (19), the trade ratio in a 'tariff war'. Moreover, the trade ratio

<sup>15</sup>It can now be verified that the assumption of continuing spillovers in autarky is not crucial to the argument. The alternative assumption; that the spillovers are eliminated under autarky, would merely entail changing the discount factor under autarky in the right-most expression of each of the equations (27), (28), and (29) from  $(1+\frac{1}{2}(1+\theta)\sigma)\delta$  to  $(1+\sigma)\delta$ . This leaves the content of proposition 2 qualitatively unchanged.

risers progressively, as tariffs fall.

In this equilibrium trade liberalization is gradual. The two countries begin trading at the beginning of the game, specializing immediately. However, free trade cannot be supported at this time because the incentives to deviate outweigh the maximal punishment. A high level of protection remains in place, so initial trade volume is relatively low. But specialization cumulatively raises the costs of a reversion to autarky. This higher punishment in turn allows for lower and lower tariffs necessary to prevent a deviation, and eventually allows for free trade. In contrast to a tariff war equilibrium, economic growth here has a distinctly pro-trade bias.

The Folk Theorem of repeated games would seem to imply that for reasonably high discount rates it would be easy to sustain free trade using a severe punishment (Fudenberg and Maskin 1986, Dixit 1987). Why does this not necessarily apply here? Take condition (25) for  $t=0$ , assuming that the TL sequence specifies zero tariffs from time 0 onwards, i.e. that free trade can be sustained initially. This implies that

$$(30) \quad \delta(1+\sigma)^2 \left[ \frac{1}{(1-(\delta(1+\sigma)^2))} - \frac{(\beta h_{b0}/\alpha h_{a0})(1+\sigma\theta)}{(1+\sigma)(1-(1+\frac{1}{2}\sigma(1+\theta)^2)\delta)} \right] \geq 1$$

First abstract from the growth process altogether, setting  $\sigma=0$ , and  $h_{b0}=h_{a0}$ . Is (30) then likely to be satisfied? This requires that  $(\delta/(1-\delta))(\alpha-\beta)/\alpha \geq 1$ . Even for high discount factors this may not be satisfied for values of  $\beta/\alpha$  very close to unity. For instance if  $\delta = 0.9$  it is satisfied only for values of  $\beta/\alpha$  below 0.89. Thus the high productivity sector must have at least a twelve percent initial cost advantage over the low productivity sector for free trade to be sustainable. If the initial forces of comparative advantage, represented by the amount by which  $\beta/\alpha$  falls below unity, are slight, then free trade is not sustainable. Including the growth

process in (30) makes the condition easier to satisfy, but for high spillovers and high values of  $\beta h_{b0}/\alpha h_{a0}$ , computations below show that it is quite possible that it fails for reasonable values of the discount rate.

The explanation for the inability to sustain free trade lies in the assumption that tariffs are determined after resource allocation taken place within a period. As explained in Lapan (1988), this gives makes the ex-post (after factors are in place) foreign offer curve less elastic than the ex-ante (before factor allocation) offer curve. In the one-shot game, taking factors of production in place, governments levy higher tariffs than would be predicted by the standard optimal tariff model. The incentive to defect on a free trade agreement is higher than in the standard model. But the cost of defecting is the same, since this cost is incurred beginning next period, after factors can relocate. If if there are only small gains from trade initially ( $\beta h_{b0}/\alpha h_{a0}$  is close to one), the cost of defecting is negligible, but given factors in place, the gains to one government from a surprise tariff are large. As a result, free trade may not be sustainable by even the maximal punishment threat. The TL equilibrium allows the gains from trade to be deepened to the point where free trade is sustainable. This makes clear why the 'dynamic gains from trade' become critical to the success of TL<sup>16</sup>.

While the TL equilibrium predicts a monotonically declining tariff path it is possible to generalize the model to allow for tariff dynamics in which tariffs decline only on average. This can be done by allowing for uncertain productivity of learning by doing. With, for instance, a persistent two-state Markov chain for  $\sigma$ , with symmetric information, tariffs are set in the game based on current and anticipated future growth rates. It is quite

<sup>16</sup>Stahl and Turunen-Red (1990) offer an alternative explanation of why free trade may not be sustainable even with severe punishment strategies, based on a model of multiple constituencies with political instability.

possible for the tariff rate to be declining on average, but for low values of  $\sigma$  to be associated with an increase in the current tariff rate.

### III-3) CHARACTERISTICS OF TARIFF GAME EQUILIBRIA

We have constructed two types of equilibria to the tariff game. Which of these equilibria is likely to be observed? Here we examine the conditions under which the TL equilibrium is sustainable. This amounts to numerically checking part (i) of proposition 2 for a range of parameter values. If this fails then only the repeated one-shot Nash equilibrium is sustainable.

Figures 3-5 present computations of tariff dynamics for various equilibria. Figure 3A presents alternative scenarios for the growth rate of learning by doing, holding the initial comparative advantage ratio  $\beta h_{b0}/\alpha h_{a0}$ , constant at 0.9. Other parameter values are given below the table. The higher is  $\sigma$ , the faster is the growth of differential cost patterns across countries and therefore the quicker is the attainment of free trade. Small changes in  $\sigma$  can have large effects on the pattern of tariffs. For a value of  $\sigma$  equal to 2.3 percent, free trade is attained very quickly - after five periods. A reduction to 2 percent raises this to five periods, and further reductions to 0.016 percent and 0.0135 percent requires 22 periods and 34 periods respectively before free trade can be sustained. For growth rates below this the TL equilibrium does not exist, since the initial tariffs exceed 21%, the maximum rates that are still consistent with specialization at the initial date (i.e.  $\tau_0 < \alpha h_{a0}/\beta h_{b0}$ ). For growth rates much above 3 percent, free trade can be sustained initially. However, with a higher  $\beta h_{b0}/\alpha h_{a0}$ , higher  $\sigma$ 's are needed for TL to exist, as shown in Figure 3B.

Figure 4 illustrates the importance of  $\beta h_{b0}/\alpha h_{a0}$ , holding  $\sigma$  constant at 2.5 percent. This represents the effects of initial conditions in the trade liberalization. The higher is this ratio, the greater is the

similarity in unit costs across countries at date 0. This will make it more difficult to sustain the TL sequence, and if TL is sustainable, will imply higher initial tariffs. Very small changes in this ratio can also have quite large effects on the tariff sequence along the TL path. For  $\beta h_{b0}/\alpha h_{a0}=0.83$ , it takes only five periods to achieve free trade. For  $\beta h_{b0}/\alpha h_{a0}=0.84$ , ten periods must elapse, and for  $\beta h_{b0}/\alpha h_{a0}=0.85$  fifteen periods are required. Increases in  $\beta h_{b0}/\alpha h_{a0}$  above this lead to a breakdown of the TL equilibrium.

These Figures illustrate that the factors which are important in ensuring the existence of the TL equilibrium also determine the maximum possible speed of tariff reduction along an equilibrium path. In addition to the parameters  $\sigma$  and  $\beta h_{b0}/\alpha h_{a0}$ , it is easily shown that higher values of  $\delta$  and lower values of  $\theta$  make it more likely that the TL equilibrium exists.

If the TL equilibrium does not exist then governments must choose tariffs according to one of the one-shot Nash equilibria. A feature of the Tariff War equilibrium is that specialization increases, despite relatively high tariffs and low growth rates. Each country is altering its pattern of comparative advantage to such an extent that the Trade Liberalization path becomes sustainable at some future date. At this date we can have an endogenous switch from the one-shot Nash equilibrium with rising tariffs to the TL equilibrium.

Figure 5A gives an example of such dynamics. For  $\sigma=0.15$  and  $\beta h_{b0}/\alpha h_{a0} = 0.85$ , the TL sequence does not exist, since it would require initial tariffs above the prohibitory rate. Assuming that instead the Pareto-superior one-shot Nash equilibrium is chosen, countries will trade initially but subject to low growth rates and rising tariffs. After 8 periods however, specialization has increased to such a degree that a trade liberalization can be sustained. Tariffs fall in period 9, and then converge towards free

trade. But for very low growth rates, it takes an extremely long time to achieve sustainable free trade. This is exacerbated by the fact that under the tariff war outcome the growth of 'interdependence' is slower than under the TL equilibrium, since countries incompletely specialize.

An alternative reason for the failure of the TL equilibrium may be very similar initial cost conditions. An illustration of this is given in Figure 5B. Even though  $\sigma$  is relatively high, at 3 percent, the high initial  $\beta/\alpha$  ratio implies that in order to attain free trade, a tariff war of almost thirty periods is required. Once on the TL equilibrium, free trade is achieved after four periods.

#### III-4) DIFFERENCES IN GROWTH RATES

If goods have different potential for learning by doing, specialization will lead countries to grow at different rates. Now we alter the model by letting good 1 have a higher potential for learning by doing, leaving the structure of comparative advantage as before. Now (5) becomes

$$\begin{aligned}
 (5') \quad & a_t \equiv \alpha h_{at}, & h_{at} &= h_{at-1} (1 + \sigma_1 l_{1t-1} + \sigma_1 \theta_1 l_{1t-1}^*) \\
 & a_t^* \equiv \alpha h_{at}^*, & h_{at}^* &= h_{at-1}^* (1 + \sigma_2 l_{2t-1}^* + \sigma_2 \theta_2 l_{2t-1}^*) \\
 & b_t \equiv \beta h_{bt}, & h_{bt} &= h_{bt-1} (1 + \sigma_2 l_{2t-1} + \sigma_2 \theta_2 l_{2t-1}^*) \\
 & b_t^* \equiv \beta h_{bt}^*, & h_{bt}^* &= h_{bt-1}^* (1 + \sigma_1 l_{1t-1}^* + \sigma_1 \theta_1 l_{1t-1}^*) & \alpha > \beta \\
 & h_{i0}, h_{i0}^* \text{ given, } i = a, b & \sigma_1 > \sigma_2 > 0, & 1 > \theta_1 > \theta_2 > 0
 \end{aligned}$$

The faster growing good is assumed to have a higher spillover parameter. Improvements in producing high technology goods such as computers are probably more readily applicable in foreign contexts than developments in primary goods, which might be climate- or culture-specific, for instance.

How does this asymmetry in growth rates alter the results of the tariff game? Take first the one-shot Nash equilibrium. For the same initial conditions the time 0 outcome is as described in equations (16)-(18). But

from time 1 on the ratio  $a_t/b_t$  exceeds  $a_t^*/b_t^*$ . Equations (15) now become

$$P_t a_t = b_t \left[ \frac{a_t^* l_{2t}^* (a_t l_{1t} + b_t^* (1 - l_{2t}^*))}{b_t^* (1 - l_{2t}^*) (a_t^* l_{2t}^* + b_t (1 - l_{1t}))} \right]^{\frac{1}{2}}$$

$$(15') \quad P_t b_t^* \left[ \frac{a_t l_{1t} (a_t^* l_{2t}^* + b_t (1 - l_{1t}))}{b_t (1 - l_{1t}) (a_t^* l_{2t}^* + b_t^* (1 - l_{2t}^*))} \right]^{\frac{1}{2}} = a_t^*$$

where the term  $(a_t l_{1t} + b_t^* (1 - l_{2t}^*))$  represents world output of good 1, etc. Together with (10), (15') determines equilibrium values of  $l_{1t}$ ,  $l_{2t}^*$ , and  $P_t$  for each  $t$ . The actual tariff rates can then be obtained using (14).

In the presence of this asymmetry, an analytical solution to the one-shot game cannot be obtained. Approximate numerical solutions can easily be calculated for however, taking each period in isolation, and the dynamics of human capital accumulation can then be computed from (5'). Table 3 gives solutions for growth rates, factor allocations, and tariffs for 14 periods.<sup>17</sup> In this example, Home has an initial comparative advantage in good 1, and  $\sigma_1=0.02$ , with  $\theta_1=0.9$ , while Foreign has comparative advantage in good 2, with  $\sigma_2=0.01$  and  $\theta_2=0$ <sup>18</sup>. Under free trade Home would permanently specialize in good 1 and Foreign in good 2. In the tariff war, as before, neither specializes completely. The relative price of good 1 falls progressively, and both countries tariff rates rise, with Home having the higher rate. A striking feature of this example is that both countries tend to increase the share of labour going into the low-growth good as time goes on. With both growth and spillovers associated with good 1 being high, in this equilibrium

<sup>17</sup> The solution procedure works by first picking some arbitrary values of  $l_1$  and  $l_2^*$  for the first period. With these we may determine estimates for the price  $P$  from the two equations in (15') and from equation (10). A grid search is then performed over values of  $l_1$  and  $l_2^*$  so as to minimize the squared difference between the three different  $P$  values. This is then repeated for every period, updating with the human capital accumulation equations.

<sup>18</sup> The importance of these parameter assumptions is discussed below.



both countries tend to become more efficient in the production of good 1. But under the tariff distorted equilibrium world demand for good 1 tends to grow too slowly to match the expanded supply. As a consequence, supply must contract through falling factor allocations towards good 1 in both countries. Hence world growth rates actually fall progressively as both countries increase the share of employment in the low growth good<sup>19</sup>.

We now turn to the analysis of the Trade Liberalization sequence in the presence of asymmetric growth rates. As before, we wish to characterize the maximal degree of cooperation that can be achieved in the face of the threat of a reversion to autarky. To economize on space, we omit the formal definition of strategies, as this is a simple generalization of the previous case. Equation (25) is now replaced by two incentive conditions, one for each country. These are

$$(31) \quad \frac{1}{(1+\tilde{\tau}_t)(1+\tilde{\tau}_t^*)} \leq \delta(1+\sigma_1)(1+\sigma_2) \left[ \sum_{i=0}^{\infty} (\delta(1+\sigma_1)(1+\sigma_2))^i \left\{ \frac{\tilde{\tau}_{t+1+i}}{(1+\tilde{\tau}_{t+1+i})(1+\tilde{\tau}_{t+1+i}^*)} \right\} - \frac{1}{4} (\beta h_{b0}/\alpha h_{a0}) \frac{(1+\sigma_2\theta_2)^{t+1}}{(1+\sigma_2)^{t+1} (1-(1+\frac{1}{2}\sigma_1(1+\theta_1))(1+\frac{1}{2}\sigma_2(1+\theta_2))\delta)} \right]$$

$$(32) \quad \frac{1}{(1+\tilde{\tau}_t)(1+\tilde{\tau}_t^*)} \leq \delta(1+\sigma_1)(1+\sigma_2) \left[ \sum_{i=0}^{\infty} (\delta(1+\sigma_1)(1+\sigma_2))^i \left\{ \frac{\tilde{\tau}_{t+1+i}^*}{(1+\tilde{\tau}_{t+1+i})(1+\tilde{\tau}_{t+1+i}^*)} \right\} \right]$$

<sup>19</sup>For  $\sigma_1+\sigma_2\theta_2 > \sigma_2+\sigma_1\theta_1$  dynamics similar to subsection III-1 occur.

$$- \frac{1}{4} (\beta h_{b0} / \alpha h_{a0}) \left[ \frac{(1 + \sigma_1 \theta_1)^{t+1}}{(1 + \sigma_1)^{t+1} (1 - \delta (1 + \frac{1}{2} \sigma_1 (1 + \theta_1)) (1 + \frac{1}{2} \sigma_2 (1 + \theta_2)))} \right]$$

Condition (31) ensures that Home has no incentive to deviate from the TL strategy, while (32) does the same for Foreign. To derive the TL sequence, it is again necessary to determine the earliest date at which free trade is sustainable. Now however, the dynamics constraints are not the same for Home and Foreign. The critical condition is whether  $(\sigma_1 + \sigma_2 \theta_2) > (\sigma_2 + \sigma_1 \theta_1)$ . This determines whether the threat of autarky grows faster for the home or Foreign. Take the case  $\theta_1 = \theta_2 = 0$ . Then it is clear that the right hand side of (31) rises faster. The foreign country, in assessing the threat of autarky, stands to lose relatively more than Home, because it must diversify in production with a knowledge base in good 1 that is unchanged since date 0, and a base in good 2 that has grown relatively slowly. For  $\theta_1 > \theta_2 > 0$  however, it is plausible that  $\sigma_1 + \sigma_2 \theta_2 < \sigma_2 + \sigma_1 \theta_1$ . Then the threat of autarky grows faster for Home, since the spillovers of the high technology knowledge to Foreign dampen the autarky threat for that country, while the spillovers from the low technology good to Home are small.

How does this condition affect the determination of the TL sequence? For concreteness, assume that  $\sigma_1 + \sigma_2 \theta_2 < \sigma_2 + \sigma_1 \theta_1$ . In that case the analogous condition to (27) is satisfied for Home for a time T below that for which it is satisfied for Foreign. Since both (31) and (32) must be satisfied for the TL sequence to exist, the date T\* after which free trade is sustainable must then be determined by the incentive constraint of Foreign. T\* is defined as the smallest integer for which

$$1 \leq \delta (1 + \sigma_1) (1 + \sigma_2) \left[ \frac{1}{(1 - \delta (1 + \sigma_1) (1 + \sigma_2))} - \frac{(1 + \sigma_1 \theta_1)^{T^* + 1}}{(1 + \sigma_1)^{T^* + 1} (1 - \delta (1 + \frac{1}{2} \sigma_1 (1 + \theta_1)) (1 + \frac{1}{2} \sigma_2 (1 + \theta_2)))} \right]$$

For  $T^*$  onwards, the TL sequence allows for complete free trade. For  $t < T^*$ , however, free trade cannot be sustained since it will violate condition (32), although (31) may still be satisfied. Therefore some tariffs must be positive at date  $T^*-1$ , and using the same arguments as in section III-2, for dates before this. Can these tariffs be constructed? Recall that we are attempting to identify the maximal degree of cooperation between governments. In the asymmetric game this requires making utility comparisons between countries. We simply take as a welfare index the sum of utilities along the TL sequence. Thus the maximal degree of cooperation would imply the tariff rates which satisfy both (31) and (32), and maximize  $\sum_{t=0}^{\infty} \delta^t (U_t^* + U_t)$ , where

$$U_t + U_t^* = \alpha^2 (\tau_t + \tau_t^*) h_{at}^2 / ((1 + \tau_t)(1 + \tau_t^*)).$$

To construct the tariff sequence, take (31) and (32) for period  $T^*-1$

$$(33) \quad \frac{1}{(1 + \tilde{\tau}_{T^*-1})(1 + \tilde{\tau}_{T^*-1}^*)} \leq \delta(1 + \sigma_1)(1 + \sigma_2) \left[ \frac{1}{(1 - \delta(1 + \sigma_1)(1 + \sigma_2))} \right. \\ \left. - \frac{(1 + \sigma_1 \theta_1)^{T^*}}{(1 + \sigma_1)^{T^*} (1 - \delta(1 + \frac{1}{2}\sigma_1(1 + \theta_1))(1 + \frac{1}{2}\sigma_2(1 + \theta_2)))} \right]$$

$$(34) \quad \frac{1}{(1 + \tilde{\tau}_{T^*-1})(1 + \tilde{\tau}_{T^*-1}^*)} = \delta(1 + \sigma_1)(1 + \sigma_2) \left[ \frac{1}{(1 - \delta(1 + \sigma_1)(1 + \sigma_2))} \right. \\ \left. - \frac{(1 + \sigma_2 \theta_2)^{T^*}}{(1 + \sigma_2)^{T^*} (1 - \delta(1 + \frac{1}{2}\sigma_1(1 + \theta_1))(1 + \frac{1}{2}\sigma_2(1 + \theta_2)))} \right]$$

From the assumption that  $\sigma_1 + \sigma_2 \theta_2 < \sigma_2 + \sigma_1 \theta_1$ , if (34) is binding then (33) is a strict inequality. Thus (34) gives the lowest value of the function of national tariff rates;  $(1 + \tilde{\tau}_{T^*-1})(1 + \tilde{\tau}_{T^*-1}^*)$ , that can be sustained in a TL equilibrium. If individual tariff rates are non-negative, welfare,  $U_{T^*-1} + U_{T^*-1}^*$ , is maximized when this function is as low as possible,

From these two conditions alone the actual value of Home and Foreign tariffs are undetermined. Moving back to period  $T^*-1$  however, we have

$$(33') \frac{1}{(1+\tilde{\tau}_{T^*-2})(1+\tilde{\tau}_{T^*-2}^*)} \leq \delta(1+\sigma_1)(1+\sigma_2) \left[ \frac{4\tilde{\tau}_{T^*-1}}{(1+\tilde{\tau}_{T^*-1})(1+\tilde{\tau}_{T^*-1}^*)} + \frac{\delta(1+\sigma_1)(1+\sigma_2)}{(1-\delta(1+\sigma_1)(1+\sigma_2))} \right. \\ \left. - \frac{(1+\sigma_1\theta_1)^{T^*-1}}{(1+\sigma_1)^{T^*-1}(1-\delta(1+\frac{1}{2}\sigma_1(1+\theta_1))(1+\frac{1}{2}\sigma_2(1+\theta_2)))} \right]$$

$$(34') \frac{1}{(1+\tilde{\tau}_{T^*-2})(1+\tilde{\tau}_{T^*-2}^*)} = \delta(1+\sigma_1)(1+\sigma_2) \left[ \frac{4\tilde{\tau}_{T^*-1}^*}{(1+\tilde{\tau}_{T^*-1})(1+\tilde{\tau}_{T^*-1}^*)} + \frac{\delta(1+\sigma_1)(1+\sigma_2)}{(1-\delta(1+\sigma_1)(1+\sigma_2))} \right. \\ \left. - \frac{(1+\sigma_2\theta_2)^{T^*-1}}{(1+\sigma_2)^{T^*-1}(1-\delta(1+\frac{1}{2}\sigma_1(1+\theta_1))(1+\frac{1}{2}\sigma_2(1+\theta_2)))} \right]$$

For arbitrary values of  $\tau_{T^*-1}$  and  $\tau_{T^*-1}^*$ , (34') defines the smallest function  $(1+\tilde{\tau}_{T^*-2})(1+\tilde{\tau}_{T^*-2}^*)$  that can be sustained along the TL path. Note again that if the time  $T^*-1$  tariff rates are equal, then (33') is again a strict inequality. But it is possible to do better than that. By letting  $\tau_{T^*-1}$  fall until (33') is met with equality, given the fixed value of  $(1+\tilde{\tau}_{T^*-1})(1+\tilde{\tau}_{T^*-1}^*)$  derived from (33) and (34), the function  $(1+\tilde{\tau}_{T^*-2})(1+\tilde{\tau}_{T^*-2}^*)$  can be minimized. This raises the value of  $U_{T^*-2}+U_{T^*-2}^*$ , while for equal initial  $\tau_{T^*-1}$  and  $\tau_{T^*-1}^*$ , leaves  $U_{T^*-1}+U_{T^*-1}^*$  unaffected. It thus clearly maximizes the welfare index.

In this way we derive unique values of  $\tau_{T^*-1}$  and  $\tau_{T^*-1}^*$  along a TL path. Furthermore it is the case that  $\tau_{T^*-1} < \tau_{T^*-1}^*$ ; Home, the fastest growing country in this example, has the lowest tariff rate. Continuing on in this manner, it is easy to show that (i) the Home tariff rate will be lower than the Foreign tariff rate for all  $t \in [0, T^*-1]$ , and (ii), both tariffs are declining over time. Part (i) is established by using the same logic as in the above paragraphs, and part (ii) by following the same procedure as in

section III-2.

Thus, with optimal trade liberalization both country's tariffs fall progressively, but those of the fast-growing country are lower and fall faster. Home, while growing faster, becomes relatively more 'vulnerable' along the TL path, since its utility of autarky declines faster than that of Foreign. But if alternatively  $\sigma_1 + \theta\sigma_2 > \sigma_2 + \theta\sigma_1$ , the direction of the argument is reversed. In that case Home has the higher tariff rates.

#### SECTION V DISCUSSION AND CONCLUSIONS

This paper has tried to give a political economic explanation of the dynamics in trade policy in the industrial world. There is substantial, but by no means universal, evidence that trade liberalization tends to stimulate growth rates. But the viability of trade liberalization depends upon the outcome of a strategic interaction between sovereign governments in a world economy. Periods of low productivity tend to produce low growth rates, which is compounded by higher tariff levels. We should then expect see the coincidence of low growth and 'Tariff Wars'; rising protectionism and a low growth of international trade.

This seems to capture the interwar experience with growth and tariffs. Relative to the second half of the nineteenth century, the period between the wars saw a progressive decline in the importance of international trade. Following World War I, many European countries maintained tariffs to protect industries that had grown up during the conflict. Income growth rates were considerably lower than in the postwar period - even the 1920's postwar recovery in the US was not generally experienced in Europe. During the 1920's, a series of international conferences attempted to generate support for tariff reduction. Following the 1929 stock market crash, the Smoot-Hawley bill in the US, and the onset of the Great Depression, any

support completely evaporated, and tariffs were universally escalated in the 1930's (Kindleberger 1987). We could interpret this evidence as indicating that two preconditions for TL; differences in initial conditions, and high growth of productivity, were absent during the interwar period.

By contrast, with high underlying productivity of learning by doing, international specialization allows for maximal growth rates. Trade Liberalization is self-fulfilling, as initial trade and specialization allow for continued tariff reduction, with very high growth in international trade volume. This scenario closely resembles the post-war experience of trade liberalization, nurtured under the auspices of GATT and the European community. Tariffs fell dramatically during this time, especially after the Kennedy round of GATT negotiations. Bhagwati (1988), as cited above, argues that high economic growth rates were central to the success of postwar liberalization.

In the 1970's and 1980's, the decline in tariff rates were countered by a growth in non-tariff barriers. While our model is not rich enough to explain this, it does imply that periods of low growth will tend to arrest the momentum of trade liberalization. According to Bhagwati (1988), the slowdown of the process of liberalization in the post 1973 period was intimately connected with the slowdown in growth rates following the oil shocks and recessions of the mid 1970's.

While the model may capture some of the key economic forces involved in trade liberalization, it is counterfactual in some respects. In particular, trade liberalization tends to be irreversible. This comes from the particular specification of learning by doing of Krugman (1988) and Lucas (1988). Learning-by-doing goes on forever, and tends to progressively entrench national comparative advantage. As suggested by Lucas (1988), the

linear specification for learning by doing might be thought of as capturing the essential features of a model in which learning by doing in any particular product died away after some time, but knowledge accumulation continually switches to new, more sophisticated, products. Models in this vein have been developed by Stokey (1988) and Young (1989). In these richer models, however, it is not necessarily true that specialization 'digs itself in' over time. Endogenous product cycles can occur. Incorporating these features into a tariff game setup, as in the present paper, we would no longer expect that the dynamics of trade liberalization are all in one direction. Instead, it might be expected that there would be cycles in protectionism, with periods of specialization and learning by doing associated with declining tariffs, but periods of high product relocation associated with increasing tariffs.

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TABLE 1 GDP and Export Growth 1720-1985  
 (Japan Germany Italy France U.K. U.S.)

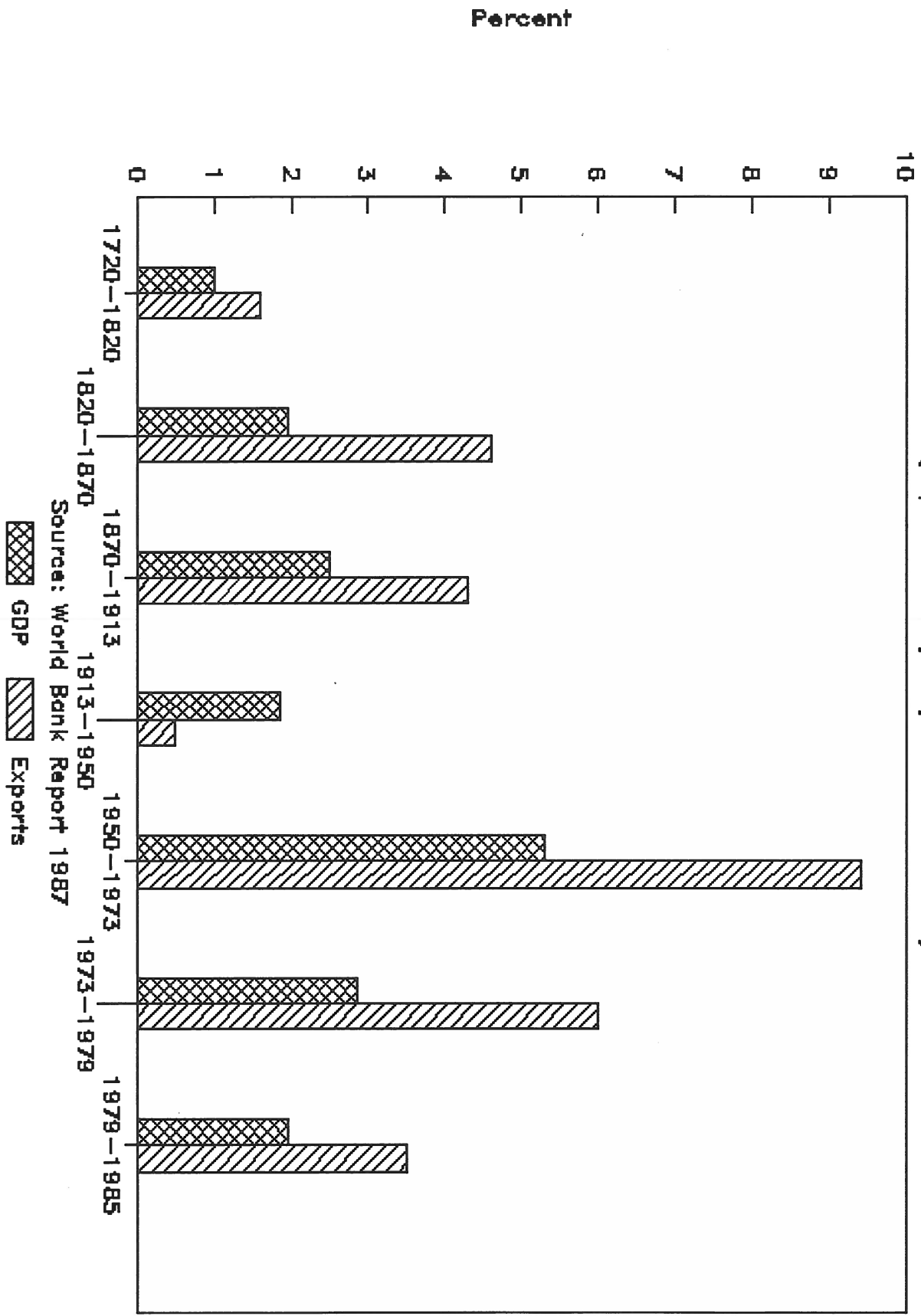


TABLE 2

*US Import Tariffs: 1930 and Postwar*

Year	<i>Percentage ad valorem equivalent tariff rate on US imports</i>	
	<i>Dutiable Imports</i>	<i>Total Imports</i>
1930	53	18
1947-56	25	9
1967	12	7
1979	8.3	6.2
1987	5.8	4.3

Source: Whalley 1985, Table 1.3, World Bank Report 1987

TABLE 3

THE TARIFF WAR EQUILIBRIUM WITH ASYMMETRIC GROWTH RATES

$\sigma_1=0.02$   $\sigma_2=0.01$   $\theta_1=0.9$   $\theta_2=0$   $\delta=0.8$   $\beta/\alpha=0.5$

	$l_1$	$l_2^*$	$\tau$	$\tau^*$	$P$
1	0.667	0.667	.15	0.1	1
2	0.666	0.669	.79	0.5	0.99
3	0.665	0.671	1.4	0.9	0.98
4	0.665	0.673	2.3	1.7	0.97
5	0.664	0.675	2.9	2.1	0.96
6	0.663	0.677	3.6	2.5	0.95
7	0.663	0.679	4.5	3.2	0.94
8	0.662	0.681	5.1	3.7	0.93
9	0.661	0.683	5.8	4.0	0.92
10	0.661	0.685	6.7	4.7	0.91
11	0.66	0.687	7.4	5.1	0.90
12	0.659	0.689	8.1	5.5	0.89
13	0.659	0.691	9.0	6.2	0.88

2

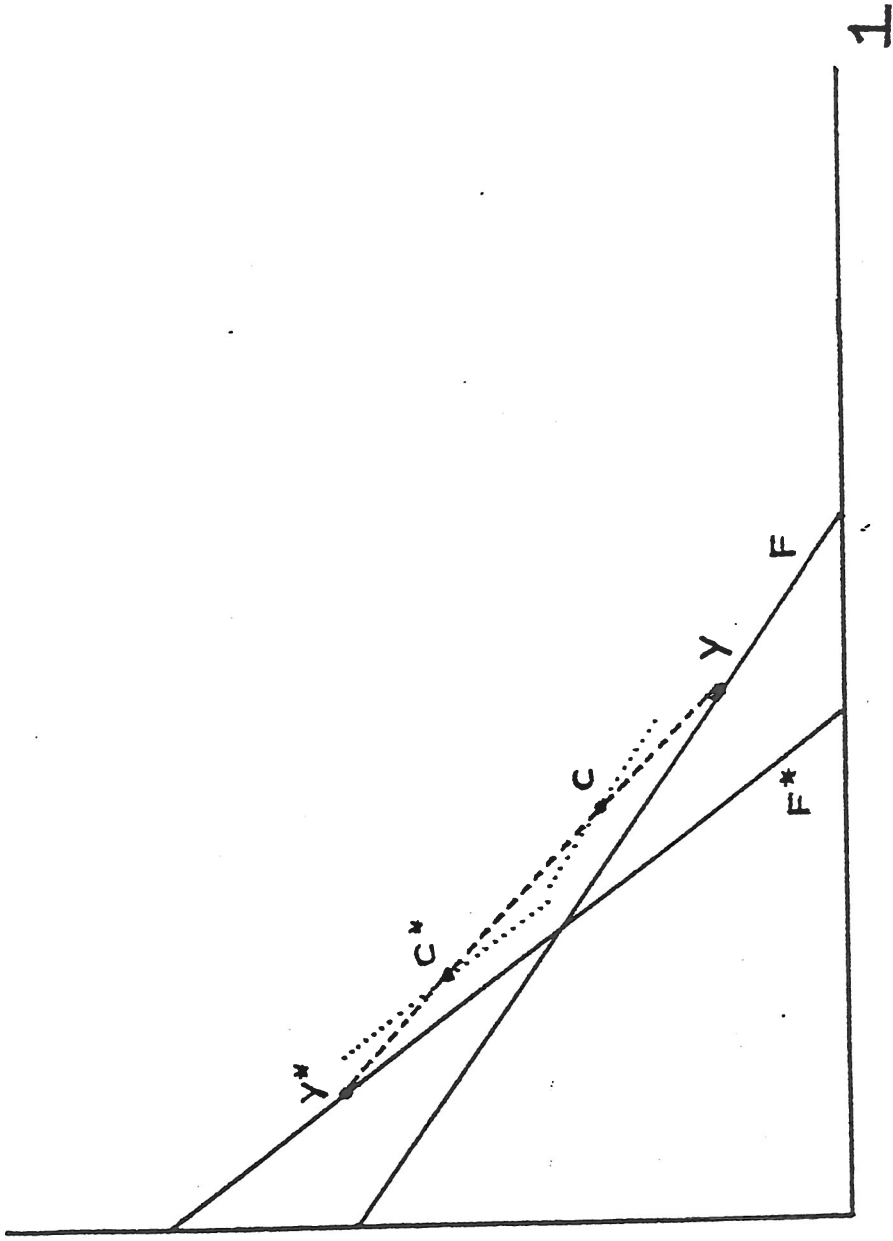
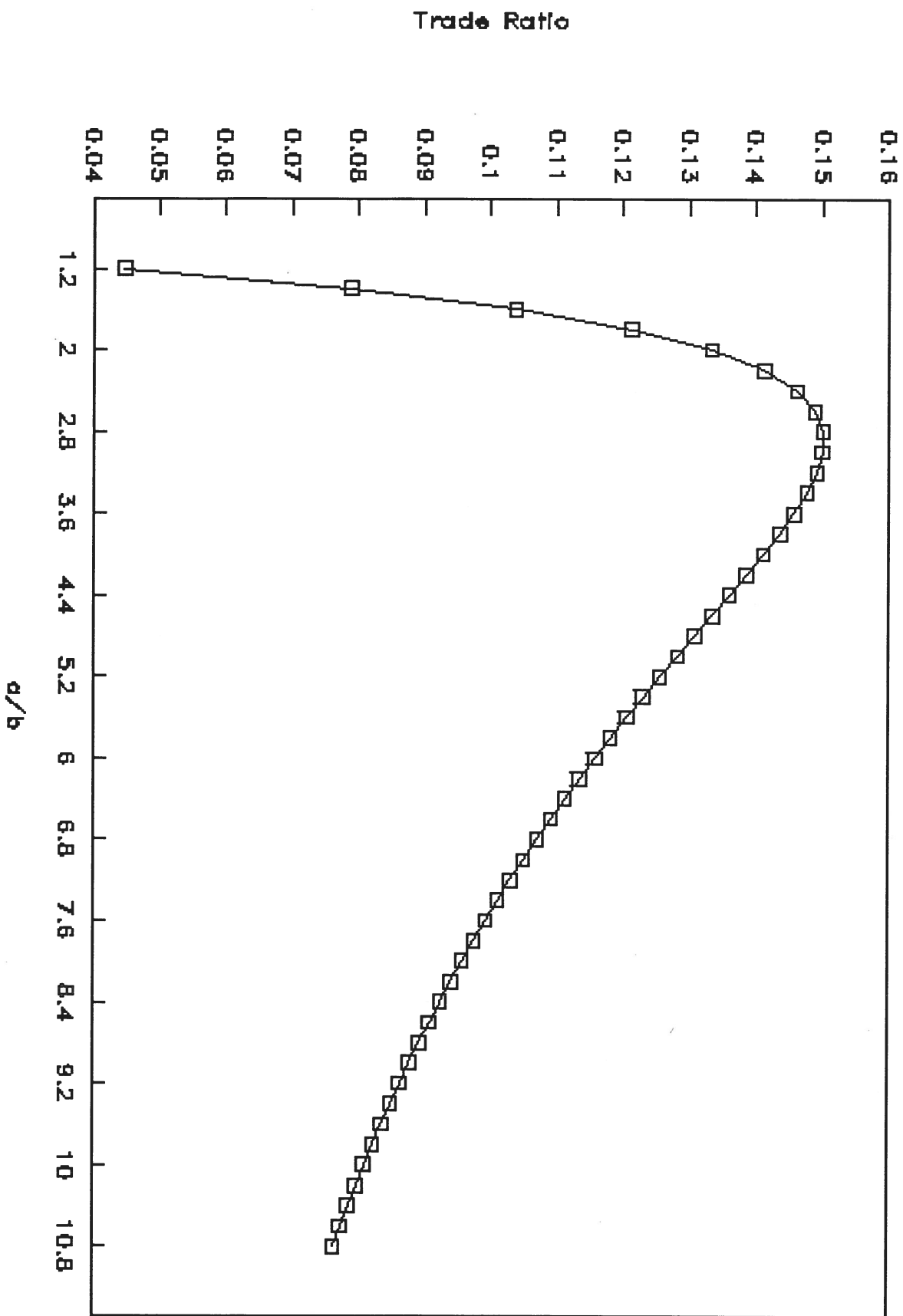


Figure 1

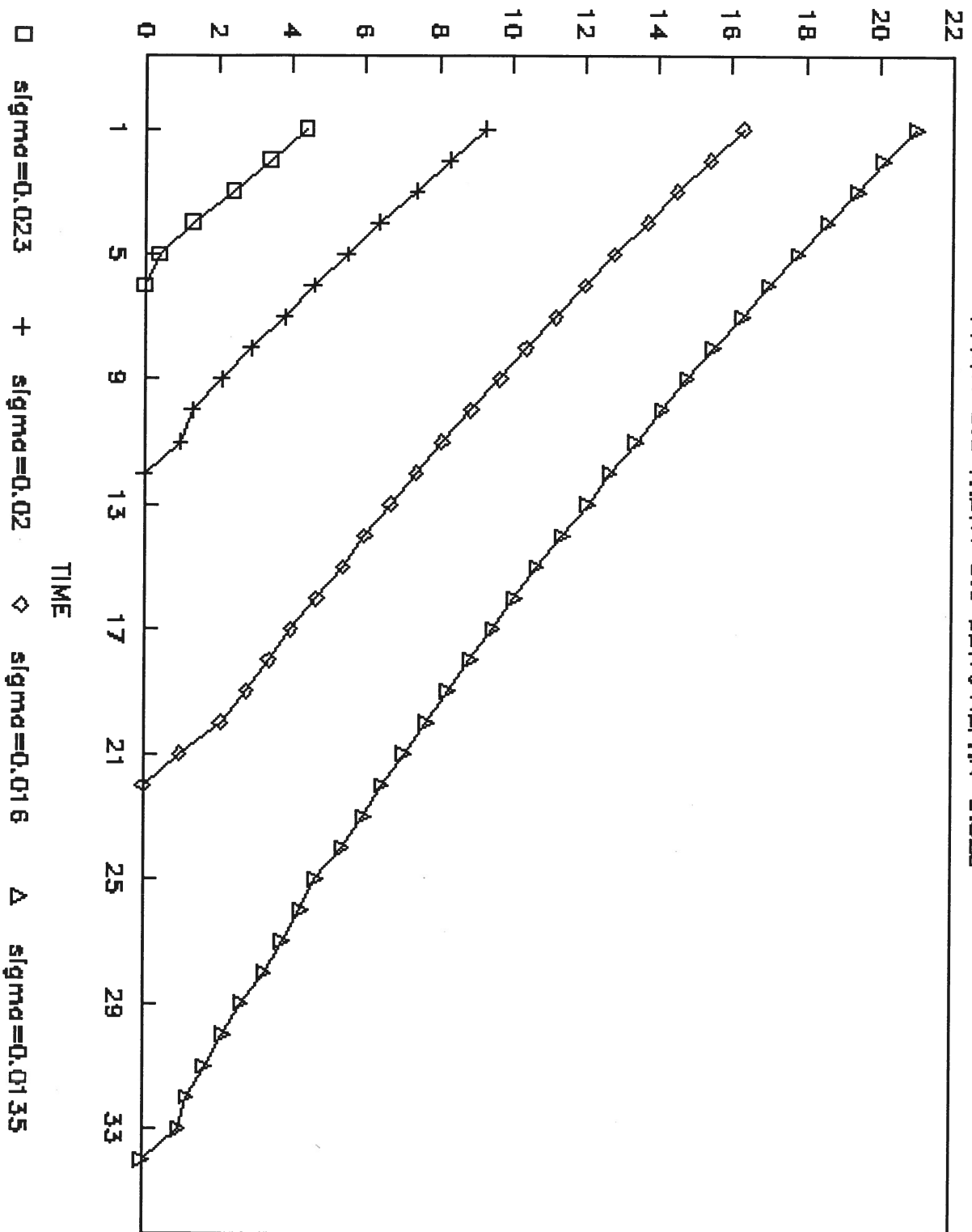
- F: Home Production Frontier
- Y: Home Production Point
- C: Home Consumption Point
- F\*: Foreign Production Frontier
- Y\*: Foreign Production Point
- C\*: Foreign Consumption Point

FIGURE 2  
TRADE RATIO: TARIFF WAR EQUILIBRIUM



TARIFF RATES

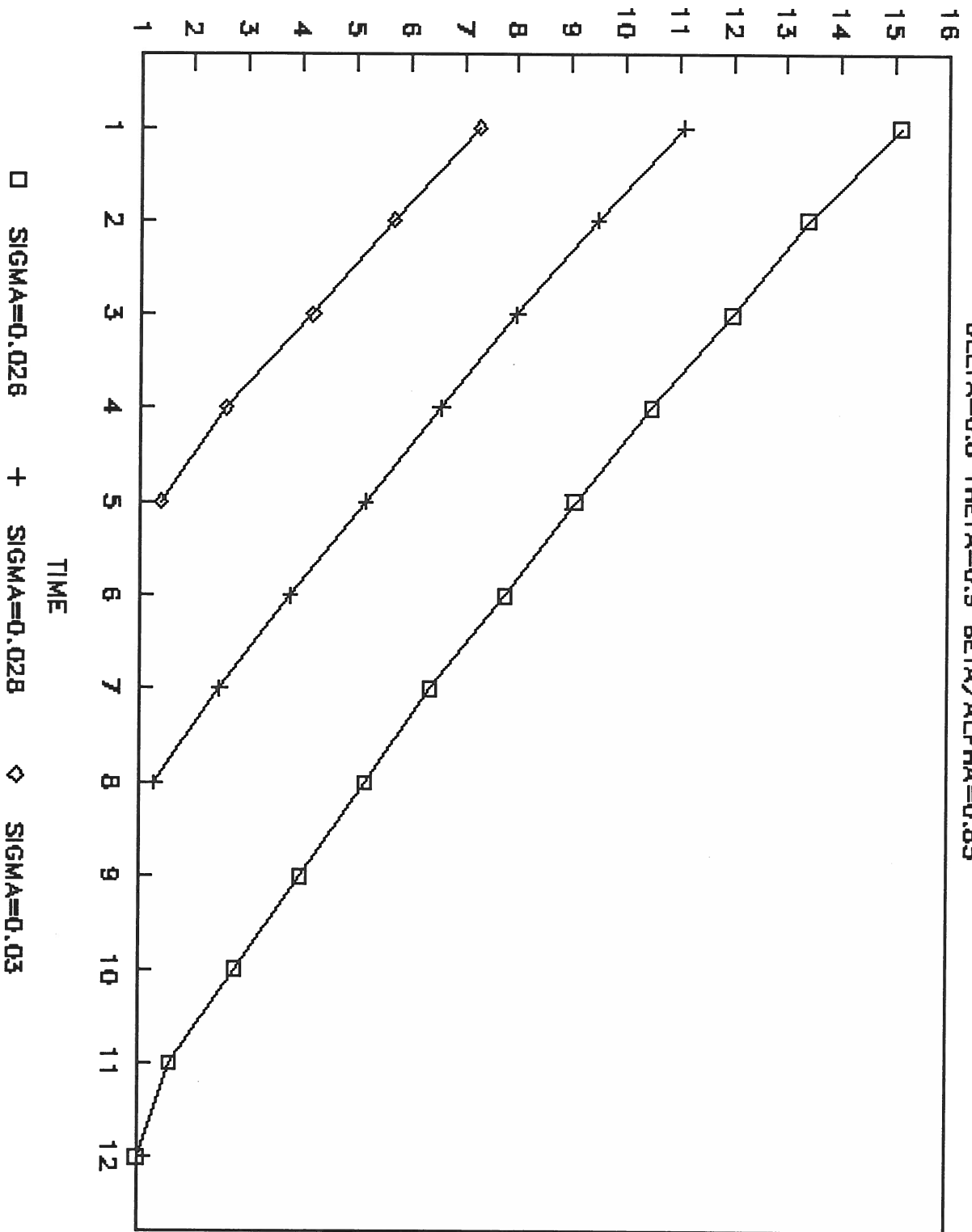
FIGURE 3A  
DELTA=0.8 THETA=0.9 BETA/ALPHA=0.825



TARIFF RATES

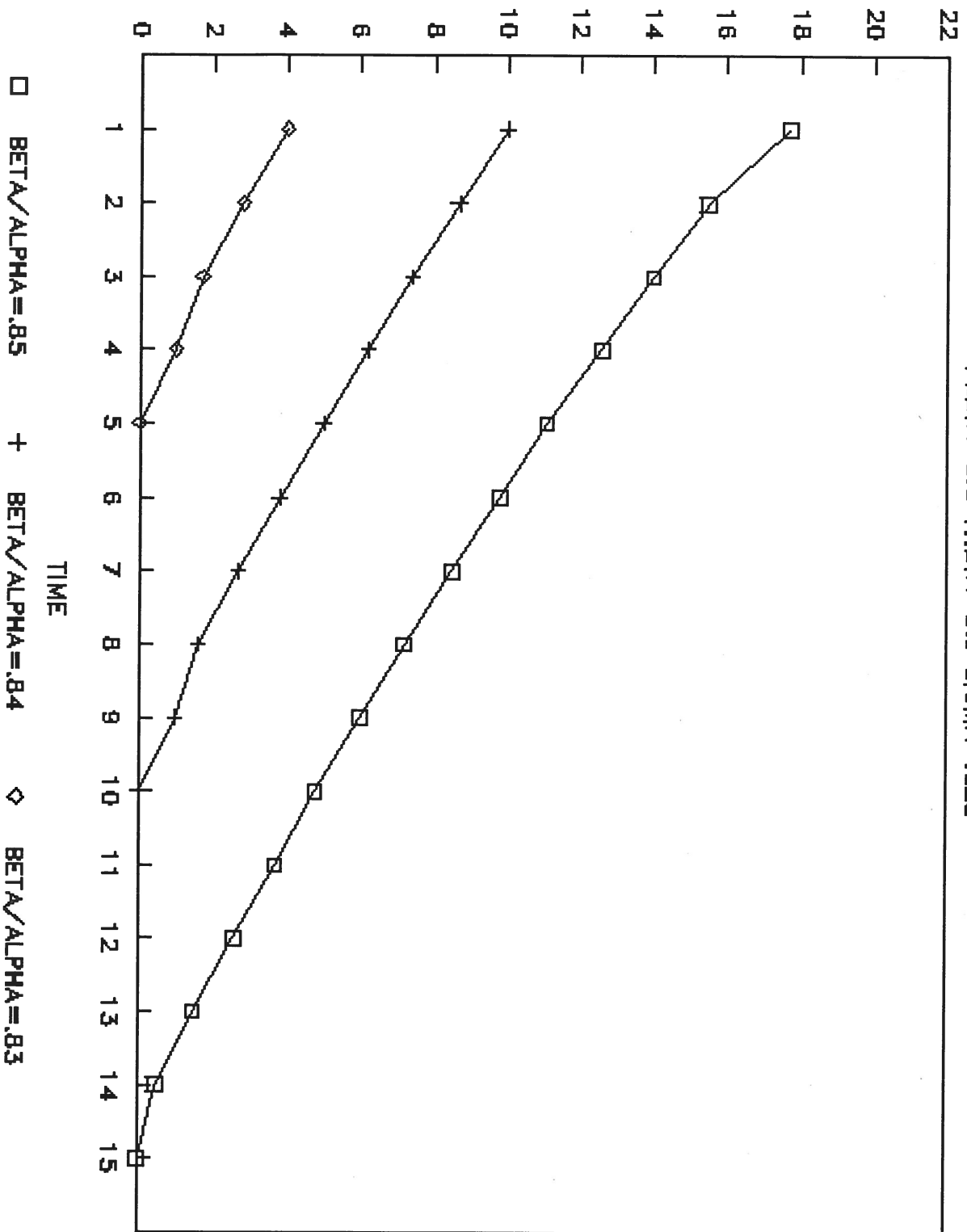
FIGURE 3B

DELTA=0.8 THETA=0.9 BETA/ALPHA=0.85



TARIFF RATES

FIGURE 4  
DELTA=0.8 THETA=0.9 SIGMA=.025

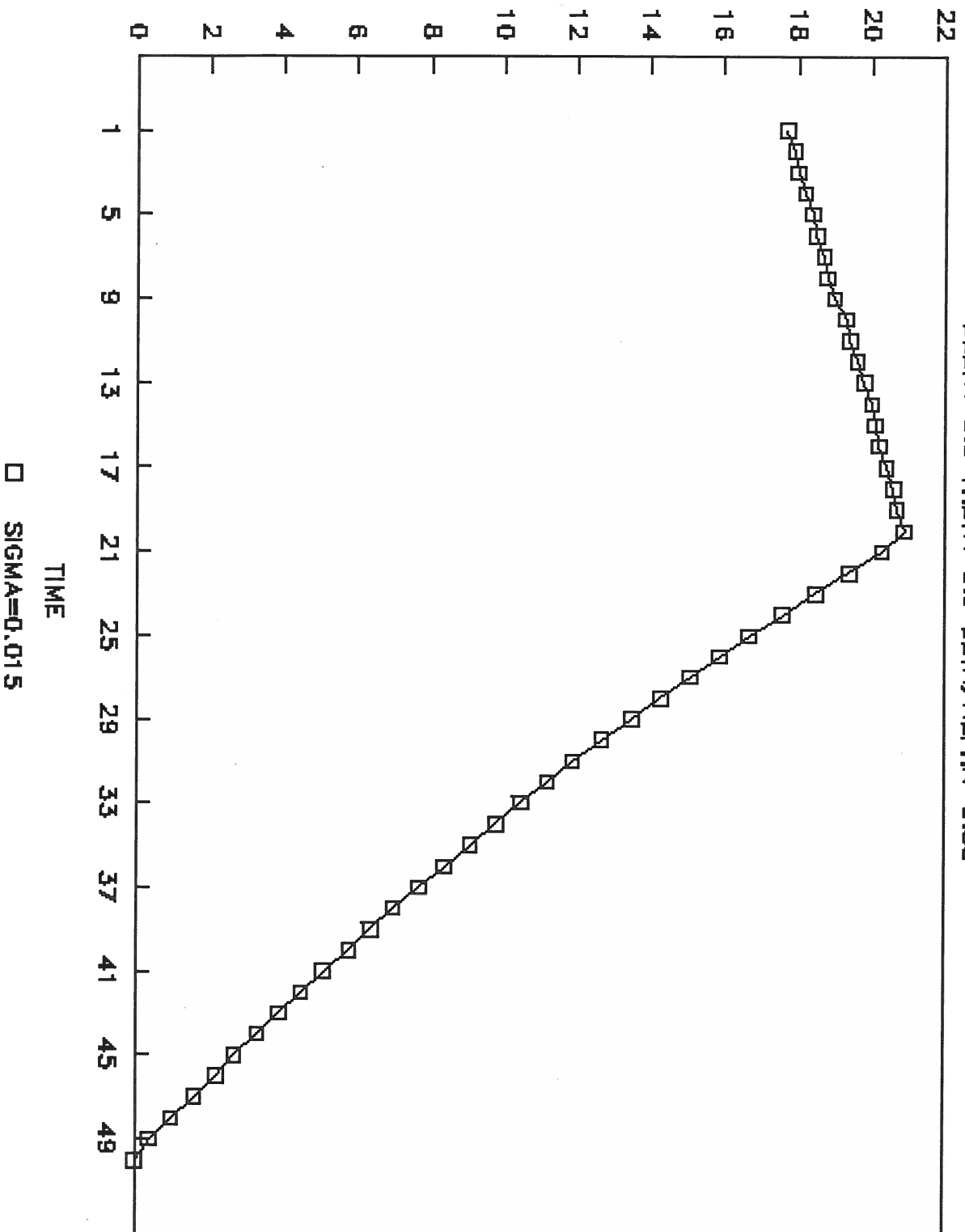




TARIFF RATES

FIGURE 5A

DELTA=0.8 THETA=0.9 BETA/ALPHA=0.85



TARIFF RATES

FIGURE 5B  
DELTA=.85 THETA=.9 BETA/ALPHA=.95

