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Infant Industry Protection with Learning-by-Doing

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ABSTRACT: I use a simple two-period learning-by-doing model to examine optimal home country protection policy. In some cases, the home government will impose an import ban to protect the home firm from foreign competition. On the other hand, very often, a protective tariff provides greater welfare than when an import ban is imposed. In these cases, the first period equilibrium tariff is greater than the static Brander and Spencer "profit shifting tariff." Protection either in the form of a tariff or an import ban encourages the home firm to invest in current output which reduces future costs. Protection can be valuable because the home firm does not consider the effect of its current learning on future consumer surplus. Tariffs can thus encourage the growth of infant industries while benefiting consumers in the long run. In addition, the home firm can have an incentive to "dump" its product if the potential cost savings are sufficiently valuable.

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1. Introduction

Learning-by-Doing is significant in many high technology industries. These industries include the production of airframes, nuclear power technologies, chemical processes and semi-conductors.[1] Each of these industries can be described as being imperfectly competitive. Despite the existence of oligopolistic industries with learning-by-doing, almost all of the earlier discussions of learning-by-doing and the infant industry argument have used a perfectly competitive framework.[2] Since learning-by-doing is significant in many oligopolistic industries, the infant industry argument naturally should also be examined in such a framework.

In their paper on learning-by-doing and market structure, Dasgupta and Stiglitz (1988) examine the infant industry argument by considering the welfare effects of a temporary import ban in an imperfectly competitive learning-by-doing industry. They assume that there is a single domestic firm and that foreign production is competitive and has exhausted it's learning potential. They show that under many circumstances, a temporary import ban is welfare enhancing. One problem with their analysis is that in general, one would not typically expect an industry to have a structure where home production is undertaken by a single domestic firm while foreign production is competitive. There is no a priori reason to believe that domestic production is concentrated among a few firms and that foreign production is composed of many firms. On the contrary, one would expect that both home and foreign production would have similar characteristics. A second problem is that there is no need for the home government to impose a policy as extreme as an import ban. Indeed, it is clear that tariffs are a better instrument for promoting domestic welfare. Not only do tariffs discourage foreign production but they also extract rents from the foreign producers. Furthermore, allowing the use of tariffs does not preclude the use of an import ban - an import ban is equivalent to the imposition of a prohibitive tariff.

I extend Dasgupta and Stiglitz's analysis by considering optimal protective tariff policy when the industry is oligopolistic. I allow the use of a tariff rather than an import ban and foreign production is no longer assumed to be competitive. The model is a simple two-period model of learning-by-doing where production in the first period reduces costs in the

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[1]See Alchian (1963), Baldwin and Krugman (1988), Leiberman (1984) and Zimmerman (1983).

[2]See Bardhan (1971), Clemhout and Wan (1970) and Succar (1987).

second. In some cases, as in Dasgupta and Stiglitz, the home government will impose a prohibitive tariff (import ban) to protect the home firm from foreign competition. On the other hand, very often, a protective tariff provides greater welfare than when an import ban is imposed. In these cases, the first period equilibrium tariff is greater than the static Brander and Spencer (1984) "profit shifting tariff." Furthermore, if the discounted cost savings are sufficiently large, the home firm will dump its product, even though it is already benefiting from a protective tariff.

2. The Model

In each period t=1,2, the home government chooses a tariff to be imposed on the foreign firm. Each firm then simultaneously chooses its output level given the tariff.

Profits for firm H and firm F in period t are:

$$\pi_t^H = [p(q_t^H+q_t^F) - c_t^H]q_t^H \tag{1}$$

$$\pi_t^F = [p(q_t^H+q_t^F) - T_t - c_t^F]q_t^F \tag{2}$$

H and F denote the home and foreign firms and i denotes either H or F. Firm i's period t output is q_t^i. T_t is the period t tariff. The good is assumed to be homogeneous with linear inverse demands $p=a-b(q^H+q^F)$. Period 1 unit costs are $c_1^i=c^i$. F's period 2 unit cost is $c_2^F=c_1^F$. H's period 2 unit cost is $c_2^H=c_1^H-dq_1^H$. The foreign firm's unit cost does not change with experience and represents an established firm which has exhausted its learning potential. The home firm's unit cost is linear and downward sloping. In a two period model, a linear learning curve is a reasonable approximation of more general learning curves where the slope of the home firm's unit cost represents its current learning potential. The smaller d is, the closer the home firm is to exhausting its learning potential. Assume that $a>\max_i c^i$.

Following standard practice, I use total surplus as the measure of home welfare. Home country welfare (W) is thus the sum of home profits (π^H), consumer surplus (S) and tariff revenues (R).

$$W_t = \pi_t^H + S_t + R_t \tag{3}$$

where tariff revenue is $R_t=T_t q_t^F$ and net consumer surplus is $S_t-\int_0^{q_t} p(\hat{q})\,d\hat{q}-p(q_t)\,q_t$ when total output is q_t.

Firms and governments have common discount factor β. The assumption of a common discount factor is not crucial and I discuss later the results when discount factors are assumed to be asymmetric.

3. The Optimal Tariff

The sub-game perfect equilibrium is solved in four stages: i) the period 2 Cournot outputs, ii) the period 2 optimal tariff, iii) the period 1 Cournot outputs and iv) the period 1 optimal tariff. Each successive stage is solved using the solutions from the previous stages. Computation of the equilibrium is simplified by expressing d as a scalar multiple of b ($d=\lambda b$).

In period 2, the outputs are the standard Cournot outputs with linear demands and constant unit costs.

$$q_2^H = \begin{cases} 0 & \text{if } a+c^F+T_2 \le 2c_2^H \\ \dfrac{a-2c_2^H+(c^F+T_2)}{3b} & \text{if } a+c^F+T_2>2c_2^H \text{ and } a+c_2^H>2c^F+2T_2 \\ \dfrac{a-c_2^H}{2b} & \text{if } a+c_2^H \le 2c^F+2T_2 \end{cases} \tag{4}$$

$$q_2^F = \begin{cases} 0 & \text{if } a+c_2^H \le 2c^F+2T_2 \\ \dfrac{a-2(c^F+T_2)+c_2^H}{3b} & \text{if } a+c_2^H>2c^F+2T_2 \text{ and } a+c^F+T_2>2c_2^H \\ \dfrac{a-c^F}{3b} & \text{if } a+c^F+T_2 \le 2c_2^H \end{cases} \tag{5}$$

Notice that since c_2^H depends on q_1^H, period 1 tariff policy and output affects period 2 output, profits and welfare.

The optimal period 2 tariff can be found by maximizing

$$\begin{aligned} W_2 &= \pi_2^H + S_2 + R_2 \\ &= b(q_2^H)^2 + \frac{b(q_2^H+q_2^F)^2}{2} + T_2 q_2^F \end{aligned} \tag{6}$$

where q_2^H and q_2^F are as in (4) and (5). Solving this problem yields $T_2=(a-c^F)/3$. Substituting this into (4) and (5) yields the period 2 equilibrium outputs.

$$q_2^H = \begin{cases} 0 & \text{if } 2a+c^F \leq 3c_2^H \\ \dfrac{2(2a-3c_2^H+c^F)}{9b} & \text{if } 2a+c^F > 3c_2^H \text{ and } a+3c_2^H > 4c^F \\ \dfrac{a-c_2^H}{2b} & \text{if } a+3c_2^H \leq 4c^F \end{cases} \tag{4'}$$

$$q_2^F = \begin{cases} 0 & \text{if } a+3c_2^H \leq 4c^F \\ \dfrac{a+3c_2^H-4c^F}{3b} & \text{if } a+3c_2^H > 4c^F \text{ and } 2a+c^F > 3c_2^H \\ \dfrac{a-c^F}{3b} & \text{if } 2a+c^F \leq 3c_2^H \end{cases} \tag{5'}$$

In period 1, firms maximize total discounted profits taking into account how their choice of period 1 output affects period 2 profits.

$$\pi^i = \pi_1^i + \beta \pi_2^i \tag{7}$$

Taking into account the period 1 optimal tariff T_1 (to be derived later), there are five possible equilibrium outcomes which depend on the 'value of learning' and the initial cost configurations. These outcomes are summarized in table 1. A '+' indicates parameters are such that the firm in question produces positive output and a '0' indicates zero output. All of the other possible outcomes can be eliminated by examining the inequalities which must hold from (4′) and (5′). For example, if the home firm produces in the second period but not in the first, there are no learning effects and hence the equilibrium in each period must be the same as the static equilibrium. If the home firm does not produce in the first period then it must be that $2a+c^F \leq 3c^H$. But if the produces in the second period then $2a+c^F > 3c^H$ - a contradiction.

Table 1

	Period 1		Period 2	
Case	Home Output	Foreign Output	Home Output	Foreign Output
I	+	+	+	+
II	+	0	+	+
III	+	+	+	0
IV	+	0	+	0
V	0	+	0	+

Case II is when the home government finds it optimal to impose a prohibitive import tariff (import ban) on the foreign firm in period 1 while allowing the foreign firm to compete in period 2. This corresponds to Dasgupta and Stiglitz's result showing that an import ban can enhance domestic welfare. There are other possibilities, however, which their restriction of only considering the possibility of an import ban rules out. For example, it is generally not necessary to totally restrict imports in period 1. In cases I and III a protective tariff which does not prohibit period 1 imports is optimal. It may be that as in case III, that the protection afforded to the home firm allows it to reduce its costs by enough to drive the foreign firm out of the market in period 2.

I first solve for the equilibrium outputs, prices and tariffs in case I and then present the final solutions for the other cases which are solved for in a similar fashion. Firm F's first and second order conditions are the same as in period 2 since it is assumed to have exhausted its learning potential and its period 1 output has no effect on its period 2 profits. Firm H's period 1 output affects its period 2 profits and its first and second order conditions are as follows:

$$\frac{\partial \pi_H}{\partial q_1^H} = a - c^H - bq_1^F - \left(2b - \frac{8b\beta\lambda^2}{9}\right) q_1^H + \frac{8\beta\lambda}{27}(2a + c^F - 3c^H) = 0 \qquad (8)$$

$$\frac{\partial^2 \pi^H}{(\partial q_1^H)^2} = -\frac{2b(9-4\beta\lambda^2)}{9} < 0 \tag{9}$$

The home firm's second order condition holds if and only if $\beta\lambda^2 < 9/4$. This requires that the discounted potential cost savings should not be too large.

Using the first order conditions, I solve for each firm's reaction function.

$$q_1^H = \frac{27(a-c^H-q_1^F)+8\beta\lambda[2(a-c^H)-(c^H-c^F)]}{6b(9-4\beta\lambda^2)} \tag{10}$$

$$q_1^F = \frac{a-c^F-T_1}{2b}-\frac{1}{2}q_1^H \tag{11}$$

The home firm's reaction function is always steeper than its static counterpart and if the foreign firm's cost advantage (c^H-c^F) is not too large relative the home firm's maximum profit margin (a-c^H) then the intercept is also greater (compare to when $\beta=0$).

Using the reaction functions to solve for output I get:

$$q_1^H = \frac{27(a+c^F+T_1-2c^H)+16\beta\lambda[2(a-c^H)-(c^H-c^F)]}{3b(27-16\beta\lambda^2)} \tag{12}$$

$$q_1^F = \frac{27(a-2c^F-2T_1+c^H)-8\beta\lambda[2(a-c^H)-(c^H-c^F)]-24\beta\lambda^2(a-c^F-T_1)}{3b(27-16\beta\lambda^2)} \tag{13}$$

As long as the foreign firm's cost advantage is not too large, the home firm increases its current output in order to reduce its future costs and become more competitive in period 2 (compare equation (12) to itself when there are no learning effects, $\lambda=0$). An increase in home output necessarily forces the foreign firm to restrict its output.

In period 1, the home government chooses the tariff to maximize total discounted welfare, taking into account how this choice affects the firms' period 1 output choices and period 2 welfare.

$$W = W_1 + \beta W_2 \tag{14}$$

The first and second order conditions are:

$$\frac{\partial W}{\partial T_1} = \frac{3(243+64\beta^2\lambda^4)(a-c^F)+\beta\lambda(27+64\beta\lambda^2)[2(a-c^H)-(c^H-c^F)]}{3b(27-16\beta\lambda^2)^2} - \frac{9\beta\lambda^2(23a-33c^F+10c^H)}{b(27-16\beta\lambda^2)} - \frac{3(243-267\beta\lambda^2+64\beta^2\lambda^4)}{b(27-16\beta\lambda^2)^2}T_1 = 0 \tag{15}$$

$$\frac{\partial^2 W}{(\partial T_1)^2} = -\frac{3(243-267\beta\lambda^2+64\beta^2\lambda^4)}{b(27-16\beta\lambda^2)^2} < 0 \tag{16}$$

It can be shown that both the home firm's second order condition and the government's second order condition holds if and only if $\beta\lambda^2 < (267-3\sqrt{1009})/128 \approx 1.34$. This also ensures that the denominator of (12) and (13) are always positive.

I solve (15) for T_1 to get the home government's optimal period 1 tariff.

$$T_1^{**} = \frac{3(243+64\beta^2\lambda^4)(a-c^F)+\beta\lambda(27+64\beta\lambda^2)(2a+c^F-3c^H)}{9(243-267\beta\lambda^2+64\beta^2\lambda^4)} - \frac{3\beta\lambda^2(23a-33c^F+10c^H)}{243-267\beta\lambda^2+64\beta^2\lambda^4} \tag{17}$$

I substitute this into (12) and (13) to get period 1 output and then substitute the resulting outputs into period 2 output (4′), (5′).

$$q_1^H = \frac{[2(a-c^H)-(c^H-c^F)](162+147\beta\lambda-72\beta\lambda^2-64\beta^2\lambda^3)}{3b(243-267\beta\lambda^2+64\beta^2\lambda^4)} \tag{18}$$

$$q_1^F = \frac{243(a-4c^F+3c^H)-\beta\lambda(234-64\beta\lambda^2)(2a+c^F-3c^H)}{9b(243-267\beta\lambda^2+64\beta^2\lambda^4)} + \frac{64\beta^2\lambda^3(a-c^F)-9\beta\lambda^2(25a-32c^F+7c^H)}{3b(243-267\beta\lambda^2+64\beta^2\lambda^4)} \tag{19}$$

$$q_2^H = \frac{2[2(a-c^H)-(c^H-c^F)](81+54\lambda-40\beta\lambda^2-24\beta\lambda^3)}{3b(243-267\beta\lambda^2+64\beta^2\lambda^4)} \tag{20}$$

$$q_2^F = \frac{81(a-4c^F+3c^H)-\lambda(54-24\beta\lambda^2)(2a+c^F-3c^H)}{3b(243-267\beta\lambda^2+64\beta^2\lambda^4)} - \frac{\beta\lambda^2(187a-307c^F+120c^H)-64\beta^2\lambda^4(a-c^F)}{3b(243-267\beta\lambda^2+64\beta^2\lambda^4)} \tag{21}$$

In case II, the period 1 tariff is prohibitive so period 1 foreign output is zero. This results in the following equilibrium period 1 home output and period 2 home and foreign outputs:

$$q_1^H = \frac{27(a-c^H)+8\beta\lambda(2a+c^F-3c^H)}{6b(9-4\beta\lambda^2)} \tag{22}$$

$$q_2^H = \frac{2(2a+c^F-3c^H)+3\lambda(a-c^H)}{b(9-4\beta\lambda^2)} \tag{23}$$

$$q_2^F = \frac{6(a-4c^F+3c^H)-9\lambda(a-c^H)-8\beta\lambda^2(a-c^F)}{6b(9-4\beta\lambda^2)} \tag{24}$$

In case III, the period 2 profit shifting tariff is prohibitive and so period 0 foreign output is zero. This results in the following period 1 tariff, home and foreign outputs and period 2 home output:

$$T_1 = \frac{(12+\beta^2\lambda^4)(a-c^F)+\beta\lambda(3+\beta\lambda^2)(a-c^H)-\beta\lambda^2(5a-9c^F+4c^H)}{36-23\beta\lambda^2+3\beta^2\lambda^4} \tag{25}$$

$$q_1^H = \frac{(8-2\beta\lambda^2)(2a+c^F-3c^H)+\beta\lambda(13-3\beta\lambda^2)(a-c^H)}{36-23\beta\lambda^2+3\beta^2\lambda^4)} \tag{26}$$

$$q_1^F = \frac{4(a-4c^F+3c^H)-\beta\lambda(8-\beta\lambda^2)(a-c^H)-\beta\lambda^2(7a-8c^F+c^H)+\beta^2\lambda^4(a-c^F)}{b(36-23\beta\lambda^2+3\beta^2\lambda^4)} \tag{27}$$

$$q_2^H = \frac{(18-5\beta\lambda^2)(a-c^H)+\lambda(4-\beta\lambda^2)(2a+cF-3c^H)}{b(36-23\beta\lambda^2+3\beta^2\lambda^4)} \tag{28}$$

In case IV, the tariffs in both periods are prohibitive so foreign output is zero. The home outputs are:

$$q_1^H = \frac{(a-c^H)(2+\beta\lambda)}{b(4-\beta\lambda^2)} \tag{29}$$

$$q_2^H = \frac{(a-c^H)(2+\lambda)}{b(4-\beta\lambda^2)} \tag{30}$$

Finally in case V, the foreign cost advantage is too great and the home firm does not produce in either period. Foreign output is $(a-c^F)/3b$ and the tariff is $(a-c^F)/3$ in both periods.

As long as both home and foreign outputs are positive in both periods, the home government will not prohibit foreign imports. To see when this is true, I first examine (18) and (21). It is easy to see that as long as the second order conditions are satisfied and $2(a-c^H) \leq c^H-c^F$ then the home firm does not produce and case V is relevant. Hence the home firm will always produce in both periods as long as the foreign firm's cost advantage is not too large. Next, I examine the difference between the period 1 and 2 foreign outputs from case I in order to determine the conditions under which case II is relevant and the conditions under which case III is relevant.

$$q_1^F - q_2^F = \frac{[2(a-c^H)-(c^H-c^F)]\lambda(162-243\beta-57\beta\lambda-72\beta\lambda^2+64\beta^2\lambda^2)}{9b(243-267\beta\lambda^2+64\beta^2\lambda^4)} \tag{31}$$

Assuming that the home firm produces $(2(a-c^H)>c^H-c^F)$ then for sufficiently large β and positive λ, this expression is always negative and $q_1^F<q_2^F$. In general, $q_1^F<q_2^F$ whenever β and λ are large. This implies that as the foreign firm's cost increases, its period 1 output will be driven to zero faster than it's period 2 output. Therefore, for relatively large β and λ and moderately large c^F, case II is relevant. Similarly, for relatively small β and λ and moderately large c^F, case III is relevant. Obviously for sufficiently large c^F the foreign firm will not produce in either period and case IV pertains. These results are summarized in the following three figures. Figure 3.a is relevant for when β and λ are relatively large, figure 3.b is relevant for when β is large and λ is small and figure 3.c is relevant for when β and λ are both small. In these figures, the area above the diagonal is of the most interest since one would expect that a foreign industry which has exhausted its learning potential will have a lower cost than a domestic industry which has not exhausted its learning-potential.

{insert figures 3.a, 3.b and 3.c here}

4. Results

First, it is of interest is examine whether or not learning-by-doing increases the incentive to protect the domestic firm. The benchmark I use is the optimal tariff from the static model ($T^* = (a-c^F)/3$).[3] I compare the dynamic tariffs for the cases when both firms produce in period 1 (cases I and III). These cases are the ones of interest because in cases II and IV the tariff is not uniquely defined and in case V the home firm does not produce and hence discussion of protective policy is not relevant. The difference between the dynamic tariffs ((17) and (29)) and static tariff is:

$$T_1^{**} - T^* = \begin{cases} \dfrac{\beta\lambda(2a+c^F-3c^H)(27+90\lambda+64\beta\lambda^2)}{9(243-267\beta\lambda^2+64\beta^2\lambda^4)} & \textit{case I} \\ \dfrac{\beta\lambda((9+3\beta\lambda^2)(a-c^H)+4\lambda(2a+c^F-3c^H))}{3(36-23\beta\lambda^2+3\beta^2\lambda^4)} & \textit{case III} \end{cases} \tag{32}$$

The numerator is always positive as long as $2a+c^F > 3c^H$ (this is required for positive home production) and the denominator is positive as long as the second order conditions are satisfied. Furthermore, since the numerator is increasing in λ and the denominator is decreasing in λ (when the second order conditions are satisfied), this difference is increasing in λ.

Proposition 1: When both firms produce in period 1, $T_1^{**} > T^*$ and $d(T_1^{**}-T^*)/d\lambda > 0$.

This result depends on the fact that the foreign firm has completely exhausted its potential for learning. I discuss later how the result is affected if the foreign firm is not assumed to have exhausted its learning.

The intuition behind this result is that even though the home firm recognizes the effect of its output on its future profits, there is still an externality because it does not take into

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[3]An alternative benchmark is the optimal tariff when firms have foresight and governments behave myopically (the tariff which maximizes W_0 from (14)). This alternative benchmark is strictly smaller than the tariff for the static model and hence if the static tariff is smaller than the dynamic tariff the alternative benchmark is also smaller than the dynamic tariff.

account how its current decisions affect future consumer surplus. For example, if the home firm to expands its output sufficiently, future prices are lower and hence future consumer surplus is higher. The home firm does not consider this when maximizing profits and therefore, provides the domestic government with an incentive to protect the domestic firm.

It is also of interest to consider whether or not there is an incentive for the domestic firm to dump, even though it is benefiting from protective domestic policies. Dick (1991) and Gruenspecht (1988) examine a duopoly trade model of learning-by-doing where there is no government intervention. They find that firms dump their product in the first period in order to reduce their future costs and to be more competitive in the second period. This can turn out to be true for the home firm even when it benefits from a protective tariff.

Again I examine the case when both firms produce in period 1. I substitute the outputs ((12) and (13) and (18) and (19)) into the inverse demand function to get the period 1 price. I then compute the period 1 profit margin.

$$p_1 - c^H = \begin{cases} \dfrac{(2a+c^F-3c^H)](486-207\beta\lambda-648\beta\lambda^2+128\beta^2\lambda^3+192\beta^2\lambda^4)}{9(243-267\beta\lambda^2+64\beta^2\lambda^4)} & \text{case } I \\ \dfrac{(8-6\beta\lambda^2+\beta^2\lambda^4)(2a+c^F-3c^H)-\beta\lambda(5-2\beta\lambda^2)(a-c^H)}{36-23\beta\lambda^2+3\beta^2\lambda^4} & \text{case } III \end{cases} \tag{33}$$

These expressions are negative, when the foreign firm's cost advantage is not too large and when β and λ are sufficiently large yet satisfy the second order condition. This is most easily demonstrated by considering the case when $\beta=\lambda=1$. Hence the following proposition:

Proposition 2: When both firms produce in period 1, $p_1 < c^H$ *if and only if* β *and* λ *are sufficiently large.*

The home firm prices below its unit cost if the discounted cost savings are valuable enough and if the foreign firm has exhausted its learning potential. Many countries define this type of behavior as dumping. The result is striking because, even though the home government imposes a protective tariff, the home firm still has an incentive to dump its product when the discounted cost savings are sufficiently large. Dick (1991) and Gruenspecht's (1988) dumping result occurs in a model where the home government does not impose a protective tariff.

5. Concluding Remarks

This paper provides support for the infant industry argument when the industry is oligopolistic and when there is learning-by-doing. If the home firm's potential for learning is relatively large compared to the foreign firm and the foreign firm's cost advantage is not too large then the home government can improve welfare by imposing some type of protective policy. The protective policy that the home government uses can be either an import ban or a protective tariff. This protection result is due to the fact that the home firm does not internalize the affect of its first period decision on future consumer surplus.

Although protection may be beneficial to the home country, under some circumstances joint welfare of the two countries will be reduced. In particular, if the foreign firm has a cost advantage and the value of the home firm's potential for learning is small, joint optimal policy would not be to encourage home production since the foreign firm is the more efficient producer. In a general equilibrium setting where there is trade going in both directions, agreements to ban trade restrictions may be beneficial to both parties.

On the other hand, when one of the countries is an LDC, it may be that the foreign country would want to allow the home country to protect its infant industries in order to aid in the LDC's development, even though total world surplus is lower. This would help home country develope industries which can compete on the world market and would act as a North-South welfare transfer. A pure monetary transfer may not suffice if self-sufficiency is the eventual goal and development depends on some learning industries.

One of my assumptions is that the foreign firm has completely exhausted its learning potential. This is not crucial to my results. For example, the much more complicated equilibrium can be computed for the more general case where the foreign firm is still learning ($c_2^F=c^F$-$d^Fq_1^F$ and $c_2^H=c^H$-$d^Hq_1^H$). The equilibrium tariffs and prices will be continuous functions of d^F. Since propositions 1 and 2 are true when $d^F=0$ they also hold as long as d^F is not too large. Hence with foreign learning, the propositions can be amended with the condition that the foreign firm should have sufficiently exhausted its learning potential.

Another assumption is that the government and firms have identical discount factors. With asymmetric discount factors, the dynamic tariff can be smaller than the static tariff if the government's discount factor is sufficiently small.[4] In this case, the home firm is more patient than the government and from the government's point of view, the home firm requires no further incentives to increase output.

Another possible policy tool for the domestic government would be domestic production subsidies. It can be argued that subsidies may be a superior tool because they would benefit first period consumer surplus as well as encouraging expanded domestic production. On the other hand, although tariffs decrease current consumer surplus, they also serve the purpose of protecting the home firm as well as extracting rents from the foreign firm. Without a detailed analysis, the conditions under which a subsidy is superior and those under which a tariff is superior cannot be determined, however, it is clear that a superior policy tool would be for the government employ both tariffs and production subsidies. Inclusion of these analysis might be interesting but would not alter the result that some form of protection might enhance the welfare of an individual country.

Finally, another possibility would be if the home government could initially commit to a long-term policy. It can be shown that, in this case, the protection result is even stronger. In case I (when both firms produce in both periods), the tariffs in both periods are strictly greater than the static tariff. The intuition is that the promise of protection in both periods, induces the home firm to further expand its first period output. Protection in the second period is more effective if second period costs are lower. This, however, raises the question of whether or not the home government can credibly commit to a long-term policy.

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[4]To demonstrate, consider case I. With asymmetric discount factors, the difference in the dynamic and static tariffs is:

$$T_1^{**} - T^* = \frac{[2(a-c^H)-(c^H-c^F)]\lambda(243\beta^g - 216\beta^f + 162\beta^g\lambda - 72\beta^f\lambda + 64(\beta^f)^2\lambda^2)}{9(243 - 27\beta^g\lambda^2 - 240\beta^f\lambda^2 + 64(\beta^f)^2\lambda^4)}$$

where β^g and β^f are the government and firm discount factors. This is positive as long as β^g is not too small.

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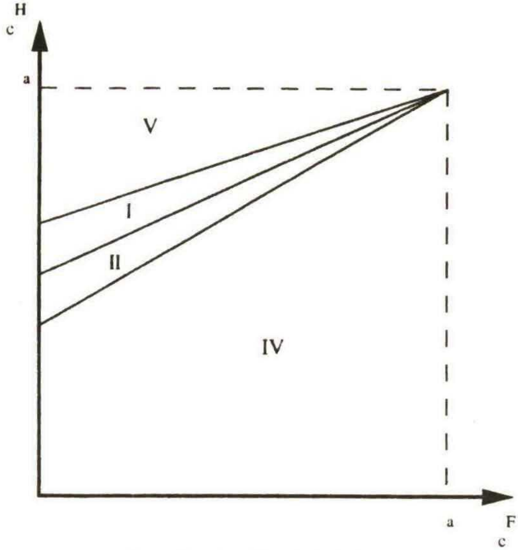

Figure 3.a - β and λ relatively large

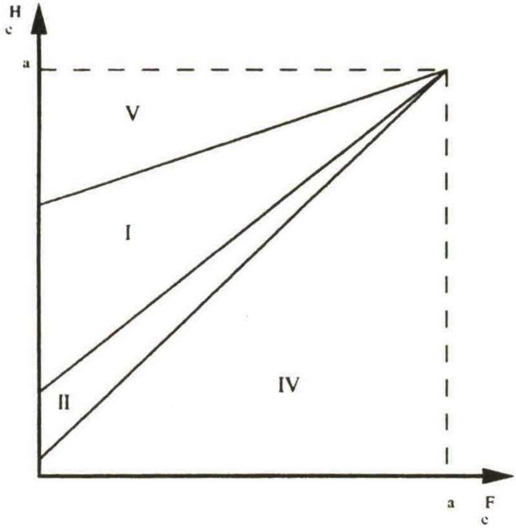

Figure 3.b - β large and λ small.

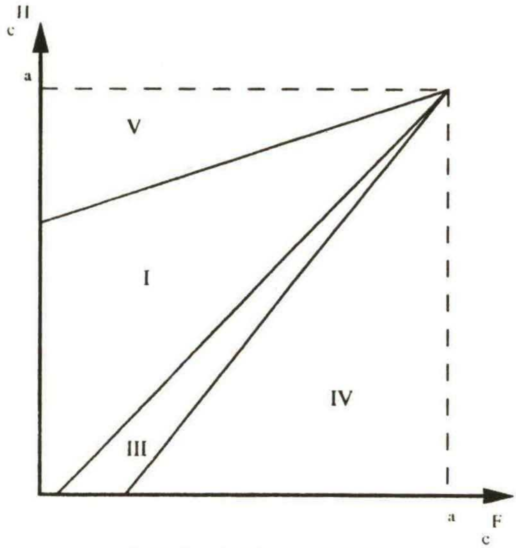

Figure 3.c - β and λ relatively small.

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