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Gradualism in Trade Agreements with Asymmetric Countries

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This paper uses recursive methods to characterize the payoff frontier of self-enforcing trade agreements between countries of asymmetric size. We show that at points on the frontier where only one country's incentive constraint binds, the efficient agreement will be a non-stationary one that starts with a positive trade distortion but eventually reaches free trade. Our analysis illustrates how (i) relative country size, (ii) consumption smoothing incentives, and (iii) sunk investments affect the form of efficient trade agreements. In contrast to previous work on gradualism, our results are obtained from a model in which the economic environment is stationary.

1. INTRODUCTION

One of the prominent features of free-trade agreements between countries is that they do not specify immediate elimination of tariffs, but instead typically have a phase-in period during which tariffs are reduced in two or more steps to free trade. For example, the North American Free-Trade Agreement spreads tariff reductions between the U.S. and Mexico over a period of 15 years, and the accession agreement between the EU and the U.K. eliminated internal tariffs over a 5 year period. Similarly, GATT negotiations proceeded by a series of negotiating rounds, with tariffs being reduced in each round. As pointed out by Mussa (1986), immediate elimination of tariffs will be optimal when countries can commit to tariff rates and there are no distortions in goods and factor markets, because the decisions made by factor owners (even in the presence of adjustment costs) will be socially efficient.[1]

One approach that has been taken to explain gradual tariff reductions is to assume that trade agreements must be self-enforcing, and that the minimum sustainable tariff declines over time in response to changes in an economic state variable. For example, Staiger (1995*b*) examines a model in which the minimum sustainable tariff level in a trade agreement is related to the quantity of labour with skills specialized to the import-competing sector. In Staiger's model, the departure of workers from the import-competing sector as a result of trade liberalization in each (symmetric) country relaxes the incentive (*i.e.* no deviation) constraint, allowing for additional liberalization in each country over time.[2]

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[1] Mussa (1986) examines the optimal policy in the presence of various distortions, and notes that there is no presumption as to whether adjustment is too fast or too slow relative to the social optimum. The socially efficient optimal trade policy could thus be either a gradual elimination of tariffs or an initial tariff reduction that overshoots the long-run value.

[2] A similar result is obtained by Furusawa and Lai (1997), who consider a repeated game model where workers incur adjustment costs when moving out of the import-competing sector. Devereux (1997) analyses a two-country growth model in which growth increases the degree of specialization. He obtains gradual tariff reduction in the dynamic tariff game between the countries in some cases.

The purpose of this paper is to show that "gradualism" in tariff reductions can be a feature of efficient self-enforcing trade agreements between countries in models where the economic environment is stationary. The essential feature of the gradualism result in our model is an asymmetry between the two countries: the initial payoffs under the agreement are such that the incentive constraint of only one country is binding. Given this initial asymmetry, the efficient trade agreement will be non-stationary and will promise the country whose incentive constraint is binding a rising payoff over time.[3] In addition, the agreement will generally utilize a positive tariff for one country that is incentive-constrained in the initial stage to make deviation less attractive. As the payoff to the incentive-constrained country rises over time, its incentive constraint becomes less binding and the tariff can be reduced to (or asymptotically toward) zero. If the trade agreement were constrained to be stationary (*i.e.* constant tariffs and transfers), the no-deviation constraint would have to be relaxed using a permanent tariff, which would create a permanent reduction in world welfare. The efficient non-stationary contracts we examine uses a combination of tariffs and intertemporal incentives, which allows the tariff distortion to be reduced over time when the incentive constraint is binding.[4]

We make this point by characterizing the Pareto frontier of self-enforcing trade agreements between a large and small country, utilizing a recursive formulation that treats the payoff to the large country as a state variable in the problem. We show that the payoff frontier can be divided into three regions. For trade agreements offering sufficiently low (high) payoffs to the large country, immediate free-trade agreements are not incentive compatible for the large (small) country. These regions where one party is incentive constrained bound a region of intermediate payoffs to the countries in which an immediate movement to free trade is incentive compatible. In the region of the frontier in which the incentive constraint of only the large (small) country is binding, the optimal agreement will involve an increase over time in the payoff to the large (small) country until it reaches the region of the frontier where free trade is sustainable. Along this path, tariffs are reduced to zero. Our recursive formulation of the problem highlights how changes in the promised payout to the large country over time allow the agreement to evolve from the region of the frontier where production is inefficient to the region where it is efficient.

Asymmetries between countries are an important feature of many trade agreements, particularly in recent trade negotiations that Ethier (1998) describes as the "new regionalism". A common feature of the new regionalism is that small countries sign agreements with large countries in order to assure themselves access to the large-country markets. The North American Free-Trade Agreement, the Euro–Med Agreements between the European Union and Mediterranean Countries, and trade agreements between the EU and Eastern European countries all represent examples in which relatively small countries signed agreements with a large country (or customs union). The objective of the small countries in these agreements is to obtain reductions in tariffs and exemption from antidumping duties and other forms of contingent protection, which have the potential to lead to substantial terms of trade gains. For the large countries, on the other hand, the gains in terms of reduced foreign tariffs are often quite small. The main benefits to the large country from these agreements are concessions on protection of

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[3] This "backloading" of payoffs to the incentive constrained party is also a feature of the Thomas and Worrall (1994) model of "tax holidays", where countries cannot commit to a tax rate on the investment of a multinational firm. Tax payments by the multinational firm rise over time in the efficient contract, with the promise of higher future taxes being used to deter the host country from imposing confiscatory taxes on sunk investments. Similarly, Lazear (1981) examines a model in which wages of workers rise over time in order to relax the worker's no shirking constraint.

[4] Models of trade agreements with symmetric countries (*e.g.* Bagwell and Staiger, 1990) have typically focussed on symmetric trade agreements where the incentive constraints of both (or neither) country are binding, in which case stationary agreements will be optimal. However, we show that non-stationary agreements may be optimal in the symmetric country case as well if there are asymmetries in the bargaining powers that yield asymmetric payoffs to the countries.

intellectual property, laws regarding foreign investment, or other domestic policies by the small country. We model these side agreements as lump-sum transfers between the parties.

Our problem is to characterize the efficient patterns of tariffs and transfers over time, subject to the constraint that the trade agreement be self-enforcing. In particular, our emphasis is on how the tariffs and transfers are used to relax incentive constraints over time. Section 2 of the paper presents a two-country trade model with linear demands and supplies and a simple parameterization of relative country size that allows us to treat cases ranging from that of symmetric countries to the case of an infinitesimally small country. We show that for the range of payoffs in which first-best agreements are not sustainable, the efficient contracts will necessarily involve a "two-step" adjustment in which the trade agreement specifies a positive tariff for one country in the first period followed by free trade in all subsequent periods. We derive results on how the direction of the transfer and the choice of tariff will depend on the relative size of the countries and the level of payoffs promised to the countries. We also show that the tariff is used as a substitute for the transfers in this basic model.

Section 3 of the paper extends the basic model to consider the case in which an infinitesimally small country has a payoff function that is strictly concave in the level of surplus received from trade and transfers in each period, which introduces a consumption smoothing motive. We show that this consumption smoothing motive results in a many step adjustment process in which the large country has a positive tariff that is reduced gradually over time. Free trade is achieved asymptotically in this case. Since the tariff is being used as a transfer mechanism in the models of Sections 2 and 3, the gradual tariff reduction we obtain will involve an asymmetry between countries in that only one of the countries will have a positive tariff along the adjustment path.

Section 4 of the paper extends the analysis to consider the case in which supply decisions are made prior to the choice of tariffs. This introduces the role of sunk investment decisions in the small-country case that has been analysed by McLaren (1997), who argues that the existence of sunk investments that are specialized to the large-country market will worsen the bargaining position of the small country.[5] We show that the existence of sunk costs introduces an additional role for tariffs in relaxing incentive constraints in our model, since a positive tariff by the large country will result in less specialization by the small country and a lower deviation incentive for the large country. This expands the role for gradual tariff reductions in the region where the large country's incentive constraint is binding by introducing the possibility that the large country imposes a tariff at the same time that it is paying a transfer to the small country, a result which cannot occur without sunk costs.

In the various cases we present in this paper, efficient agreements involve changes in the level of transfers and gradual reductions in tariffs imposed by one country over time. However, the tariff of the other country is always eliminated immediately. This contrasts with many observed trade agreements, where the tariffs of both countries are reduced gradually over time. In the conclusion we indicate how the model can be extended to generate gradual reductions in the tariffs of both countries.

[5] McLaren assumes that transfers are determined in a Nash bargaining game that takes place after the investment decisions have been make. Since the sunk investment worsens the position of the small country in the subsequent trade negotiations over the size of transfers, the small country may actually be worse off than in the non-cooperative Nash equilibrium. In our model, the small country can never be worse off under the trade agreement because the trade agreements are self-enforcing equilibria of a repeated game and must yield payoffs no worse than those in the one-shot non-cooperative game. Park (2000) extends McLaren's model to analyse the case of an infinitely repeated game between the two countries. That analysis is limited to trade agreements where the tariff rates are constant for all time periods, and examines how the efficient frontier of self-enforcing trade agreements is affected by the existence of sunk costs and the form in which transfers are made (lump sum vs. import subsidies).

2. THE BASIC MODEL

In this section we present the basic trade model. We consider a two good, partial equilibrium model of trade between a small country, S, and a large country, L. We begin by deriving the preferences of the respective countries over trade agreements under the assumption that governments choose trade policies to maximize national welfare. We then characterize the efficient payoff frontier for the countries where trade agreements must be self-enforcing in a repeated tariff-setting game between the countries.

Demand for good i in S is $D_i^S = A - Bp_i^S$ and the supply of good i in S is $X_i^S = \alpha_i^S + \beta p_i^S$, where p_i^S is the price of good i in S. For L, demand and supply are given by $D_i^L = \lambda(A - Bp_i^L)$ and $X_i^L = \lambda(\alpha_i^L + \beta p_i^L)$, respectively, where $\lambda \geq 1$ is a measure of the relative size of country L. Letting $p_i^{jA} = (A - \alpha_i^j)/(\beta + B)$ be the autarky price of good i in country j, we assume $\alpha_1^L - \alpha_1^S = \alpha_2^S - \alpha_2^L > 0$ and $\alpha_1^L = \alpha_2^S$. This parameterization ensures that S will import good 1 and export good 2, and that the countries will be symmetric if $\lambda = 1$. By varying λ on $[1, \infty)$, we can consider the range of relative country sizes from symmetric countries to the case in which S is a price taker in world markets.

We assume that each country can impose specific tariffs on its importable, with t_j denoting the tariff imposed by country $j = S, L$. Domestic prices are $p_1^S = p_1^L + t_S$ and $p_2^L = p_2^S + t_L$ and national welfare can be expressed as

$$W_j(t_j, t_k) = \sum\nolimits_{i=1,2}\left[\int_{p_i^j}^{A/B} D_i^j(u)du + \int_{-\alpha/\beta}^{p_i^j} X_i^j(u)du\right] + t_j(D_m^j(p_m^j) - X_m^j(p_m^j)), \quad (1)$$

where $j, k = S, L (j \neq k)$ and $m = 1(2)$ when $j = S(L)$. The following properties of the national welfare functions follow from differentiation of (1), using the market clearing prices:

Lemma 1. *For non-prohibitive tariffs,* $t_L, t_S \in [0, (\alpha_1^L - \alpha_1^S)/(\beta + B))$,

(a) $W_j(t_j, t_k)$ *is concave in* t_j *for* $j, k = S, L (j \neq k)$, *with the welfare maximizing tariffs given by*

$$t_L^N = \frac{\lambda(\alpha_2^S - \alpha_2^L)}{(1 + 2\lambda)(\beta + B)}, \qquad t_S^N = \frac{(\alpha_1^L - \alpha_1^S)}{(2 + \lambda)(\beta + B)}, \quad (2)$$

(b) $W_j(t_j, t_k)$ *is decreasing and convex in* t_k *for* $j, k = S, L (j \neq k)$,

(c) $W_W(t_S, t_L) = \sum_{j=S,L} W_j(t_j, t_k)$ *is strictly concave and decreasing in* t_j *for* $j, k = S, L$ *and* $j \neq k$.

Equation (2) describes the optimal tariffs of the respective countries. Due to our partial equilibrium specification and choice of instruments, these tariffs will be dominant strategies for the respective countries and hence are the Nash equilibrium tariffs of the one-shot tariff setting game. Parts (b) and (c) illustrate the standard prisoner's dilemma of the one-shot tariff setting game: increases in one country's tariffs reduce the welfare of the other country by worsening its terms of trade, so world welfare is maximized at free trade. Lemma 1 also illustrates the effect of relative country size on the level of Nash equilibrium tariffs. t_L^N is increasing in λ and approaches the revenue maximizing tariff as $\lambda \rightarrow \infty$, while t_S^N is decreasing in λ and approaches 0 as $\lambda \rightarrow \infty$.

A trade agreement is a sequence of tariffs $t_j(i) \geq 0$ and side payments $s_j(i) \geq 0$ to be paid by country j at time $i (i = 1, \ldots, \infty)$. The transfers can be thought of as being the value of concessions made in side agreements that accompany the trade agreement.[6] Letting δ be the market discount rate and $c_j^i = \{(t_j(i), s_j(i)), (t_j(i+1), s_j(i+1)), \ldots\}$ the sequence of future actions for country j from period i onward, the payoff to country j is $V_j(c_L^i, c_S^i) = \sum_{m=0}^{\infty}(W_j(t_j(i+m), t_k(i+m)) + s_k(i+m) - s_j(i+m))\delta^m$ for $j, k = S, L$ and $k \neq j$. We do not explicitly model the bargaining game that determines the choice of a particular trade agreement between countries, but instead assume that the bargaining game results in the choice of a trade agreement that is individually rational and is not Pareto dominated.[7] Therefore, we can characterize the potential trade agreements by characterizing the agreements that are Pareto efficient.

As a benchmark, suppose that countries can make binding commitments to tariff rates. The set of Pareto optimal trade agreements can be obtained by maximizing V_S, for given V_L. These first-best agreements will specify an immediate elimination of tariffs between the countries, which maximizes world welfare, with lump-sum transfers being used to obtain the desired distribution between countries. The first-best frontier, denoted by $V_S = \Omega^*(V_L)$, is then

$$\Omega^*(V_L) = \frac{W_W(0,0)}{1-\delta} - V_L. \tag{3}$$

We assume that in the absence of a trade agreement each country chooses its optimal tariff according to (2), so individually rational agreements will be those with payoffs $V_j \geq V_j^N \equiv W_j^N(t_j^N, t_k^N)/(1-\delta)$ for $j = S, L$. This payoff frontier is illustrated by Ω^* in Figure 1, where the origin represents the payoffs (V_L^N, V_S^N) obtained in the absence of an agreement. An agreement that yields L a payoff of V_L can be achieved by a free-trade agreement with any sequence of transfers that generates a net wealth transfer to S of $(W_W(0,0) - W_S(0,0))/(1-\delta) - V_L$.

In view of the lack of mechanisms to enforce contracts between countries, it is now a well established technique to treat trade agreements as being contained in the set of self-enforcing agreements that can be sustained in an infinitely repeated game between the countries (*e.g.* Staiger, 1995*a*). Repeated interactions between countries on trade policy issues create the potential to use the (credible) threat of future trade wars to deter countries from deviating from trade agreements. International trade organizations, such as the WTO or regional trade agreements, can then be thought of as mechanisms that allow countries to coordinate punishments and to coordinate on which of the sustainable agreements are to be chosen. Our objective in this section is to characterize the agreements that are on the incentive constrained Pareto frontier, which identifies the agreements that yield the maximum payoff to S, given V_L and the requirement that the agreement be incentive compatible for both parties.

We assume that the agreement specifies permanent reversion to the static Nash equilibrium tariffs $\{t_S^N, t_L^N\}$ with $s_L = s_S = 0$ for all future time periods following a deviation by either country.[8] If country j deviates from the agreement, it will set its tariff optimally and will not

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[6] Side agreements between countries frequently play a significant role in bilateral negotiations. For example, Whalley (1998) notes that Canada and Mexico made implicit side payments to the U.S. as part of NAFTA by adopting policies on energy and investment that were favourable to U.S. interests.

[7] With symmetric countries, the symmetric agreement is a natural one to focus on. When countries are asymmetric, however, there is no natural candidate for an agreement. One approach is to choose a particular type of bargaining solution (*e.g.* the generalized Nash bargaining solution as in Bond and Syropoulos, 1996) to choose among the agreements. Since our focus is on how dynamics of the agreement can be used to relax incentive constraints, rather than on predicting the payoffs that will result from an agreement between a particular pair of countries, a less restrictive approach requiring only Pareto optimality seems appropriate.

[8] The Nash punishments are adopted here for simplicity. Optimal punishments of the type characterized by Abreu (1988) would yield higher payoffs, since they would expand the set of incentive compatible contracts. However, the primary concern here is with the form of the contracts (*i.e.* how the tariffs and transfers vary over time) and these intertemporal aspects do not depend on the the level of the punishment payoff. Thus, the use of the term "efficient" contract here is relative to the use of the static Nash payoffs as punishment.

pay any transfers as required by the agreement (although it still receives any transfer paid by the other country). Incentive compatibility for the agreement at time i then requires that

$$(\mathrm{IC}j) \qquad V_j(c_L^i, c_S^i) \geq W_j(t_j^N, t_k(i)) + s_k(i) + \delta V_j^N \qquad \text{and for } j, k = S, L \text{ and } k \neq j. \tag{4}$$

A trade agreement will be incentive compatible if it satisfies (4) for all $i \geq 1$. The constrained efficient frontier $\tilde{\Omega}(V_L)$ will be the solution to the following optimization problem:

$$(\mathrm{P}) \qquad \tilde{\Omega}(V_L) \equiv \sup_{c_L^1, c_S^1} V_S(c_L^1, c_S^1),$$

$$\text{subject to} \qquad (\mathrm{ICL}), (\mathrm{ICS}), \text{ and } V_L(c_L^1, c_S^1) \geq V_L.$$

2.1. *Stationary and incentive compatible first-best agreements*

We begin our analysis of (P) by showing that for δ exceeding a critical value, denoted δ^C, there will exist an interval of payoffs $[V_L^*, V_L^{**}]$ for which the free-trade agreement with constant side payments (*i.e.* first-best trade agreements) will be incentive compatible. In models with symmetric countries (*e.g.* Bagwell and Staiger, 1990), it is well known that a free-trade agreement with no side payments will be sustainable if δ is sufficiently large. Our results extend this literature to show how the relative size of countries affects the direction of transfers that can be observed in an incentive compatible free-trade agreement. The interval $[V_L^*, V_L^{**}]$ is of particular interest because we will show below that when $\delta \geq \delta^C$, all trade agreements satisfying the problem (P) will eventually achieve a payoff in this interval.

With stationary transfers, (4) becomes

$$(\mathrm{IC}j) \qquad s_j - \delta s_k \leq \delta(W_j(0,0) - W_j^N) - (1-\delta)(W_j(t_j^N, 0) - W_j(0,0)), \tag{5}$$

where $W_j^N \equiv W_j(t_j^N, t_k^N)$ for $j, k = S, L$ and $j \neq k$. The asymmetry between the transfers on the left-hand side of (5) arises because when j deviates it does not pay the transfer s_j, but it receives the transfer s_k. Note that the payoffs of the countries depend only on the net transfer $s_S - s_L$, but an increase in s_j will tighten the incentive constraint of country j. Therefore, an agreement with $s_j > s_k > 0$ will be weakly dominated by the agreement with transfers $s_j' = s_j - s_k$ and $s_k' = 0$, so we can limit attention to agreements in which $\min(s_S, s_L) = 0$.

We can use (5) to define the maximum net transfer that country j is willing to pay, T_j, for a free-trade agreement,

$$T_j(\delta, \lambda) = \begin{cases} H_j(\delta, \lambda) & \text{if } H_j > 0, \\ H_j(\delta, \lambda)/\delta & \text{if } H_j \leq 0, \end{cases} \tag{6}$$

where $H_j(\delta, \lambda) \equiv \delta(W_j(0,0) - W_j^N) - (1-\delta)(W_j(t_j^N, 0) - W_j(0,0))$.

This transfer will be a constant side payment per period made (received) by country j if $T_j > 0 (< 0)$. There will exist a sustainable free-trade agreement with constant side payments iff $T_S(\delta, \lambda) + T_L(\delta, \lambda) \geq 0$.

The following properties of the maximum transfer functions can be derived from (1) and (6):

Lemma 2. *For* $\lambda \in [1, \infty)$

(a) $T_j(\delta, \lambda)$ *is increasing in* δ, *with* $T_j(0, \lambda) < 0$ *and* $T_S(1, \lambda) + T_L(1, \lambda) > 0$,
(b) $T_S(\delta, \lambda)$ *is increasing in* λ *for* $\lambda \geq 1$ *and* $T_S(1, \lambda) > 0$,
(c) $T_L(\delta, \lambda)$ *is decreasing in* λ. *There exists* $\tilde{\lambda} > 1$ *such that* $T_L(1, \lambda) < 0$ *iff* $\lambda > \tilde{\lambda}$.

Part (a) reflects the standard result that a free-trade agreement will be sustainable for δ sufficiently large. Parts (b) and (c) reflect the role of relative country size on the maximum transfer functions.

Increases in λ raise the amount that the small country is willing to pay for a free-trade agreement, since an increase in the relative size of L reduces the gains of deviating for S relative to the cost of the punishment phase. For $\delta = 1$, the small country will always be willing to pay a positive amount to obtain a first-best agreement because its payoff in the Nash equilibrium must always be less than that under free trade. In contrast, the amount that the large country will pay for a free-trade agreement is decreasing in λ, because an increase in the relative size of L raises the gains from deviation relative to the cost of punishment. The large country "wins" the tariff war for $\lambda > \tilde{\lambda}$, in the sense that it is better off in the Nash equilibrium than under free trade, so the small country will have to make a positive transfer to buy access to the large-country market for all δ in this case.[9] If $\lambda < \tilde{\lambda}$, the large country will be willing to pay to obtain a free-trade agreement if δ is sufficiently large.

Lemma 2 can be used to derive the following result on the sustainability of first-best trade agreements with constant transfers:

Proposition 1. *There will exist a critical discount parameter* $\delta^C \in (0, 1)$ *such that if* $\delta \geq \delta^C$,

(a) *a free-trade agreement with* $s_S \in [\max(-T_L(\delta, \lambda), 0), T_S(\delta, \lambda)]$ *and* $s_L = 0$ *is incentive compatible, where* $T_S(\delta, \lambda) \geq 0$,
(b) *if* $T_L(\delta, \lambda) > 0$, *a free-trade agreement with* $s_L \in [0, T_L(\delta, \lambda)]$ *and* $s_S = 0$ *is incentive compatible. If* $\lambda > \tilde{\lambda}$, *then no free-trade agreement with* $s_L > 0$ *is incentive compatible,*
(c) *these agreements sustain payoffs to the large country in the interval* $[V_L^*, V_L^{**}]$, *where*

$$V_L^* = (W_L(0,0) - T_L(\delta, \lambda))/(1 - \delta), \quad V_L^{**} = W_W(0,0)/(1 - \delta) - W_S(t_S^N, 0) - \delta V_S^N.$$

Proposition 1 illustrates the relationship between country size and the direction of transfers in sustainable agreements. If $\lambda > \tilde{\lambda}$, then all incentive compatible free-trade agreements must have $s_S > 0$ because the large country must be compensated for the fact that it wins the tariff war. If $\lambda < \tilde{\lambda}$, there will exist some discount parameters for which there are incentive compatible free-trade agreements with $s_L > 0$. Finally, we can substitute from (6) into (7) to show that $\lim_{\delta \to 1}(1 - \delta)V_L^* = W_L^N$ and $\lim_{\delta \to 1}(1 - \delta)\Omega^*(V_L^{**}) = W_S^N$. This illustrates the standard Folk Theorem result that for δ sufficiently large, any of the first-best agreements that give countries payoffs that are no less than the Nash equilibrium values can be sustained with this punishment scheme.[10]

2.2. *The incentive-constrained Pareto frontier*

Proposition 1 establishes that efficient trade agreements with payoffs to L in the interval $[V_L^*, V_L^{**}]$ can be sustained by free-trade agreements in which transfers are constant over time. For $V_L < V_L^*(V_L > V_L^{**})$, the payoff to $L(S)$ under the first-best agreement is sufficiently low that the stationary first-best agreements are not incentive compatible. In this section we characterize the constrained efficient trade agreements in these regions. In particular, we show

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[9] This phenomenon is common in trade models. Kennan and Riezman (1988) use an endowment model with Cobb Douglas preferences and show that large countries generally win tariff wars.

[10] These results can be extended to the case of costly transfers, where a side payment that has benefit s_i to the recipient country j has a cost of $(1 + \phi)s_i$ to country i, with $\phi > 0$. This case can arise when side payments are benefits in kind, or where they are financed by costly tax collection. It can be shown that the first-best frontier, Ω^*, for this case will involve the use of tariffs to transfer income between the countries up until the point where the marginal deadweight loss of the tariff imposed by the transferor is ϕ. If larger transfers are required, side payments will also be used. A result analogous to Proposition 1 can be established showing that for δ sufficiently high, an interval of the first-best frontier will be sustainable.

that the optimal trade agreements are necessarily non-stationary in the region where one incentive constraint is binding.

To characterize the solution for the incentive-constrained Pareto frontier, we will analyse the following dynamic programming problem which corresponds to the problem (P):

$$\tilde{\Omega}(V_L) = \sup_{t_L, t_S, s_L, s_S, y} W_S(t_L, t_S) + s_L - s_S + \delta\tilde{\Omega}(y), \tag{7}$$

subject to

$$\begin{aligned}
&\text{(PL)} && W_L(t_L, t_S) - s_L + s_S + \delta y \geq V_L,\\
&\text{(ICL)} && W_L(t_L, t_S) + s_S - s_L + \delta y \geq W_L(t_L^N, t_S) + s_S + \delta V_L^N,\\
&\text{(ICS)} && W_S(t_S, t_L) + s_L - s_S + \delta\tilde{\Omega}(y) \geq W_S(t_S^N, t_L) + s_L + \delta V_S^N, \qquad t_L, t_S, s_S, s_L \geq 0.
\end{aligned}$$

The variable y introduced in the programming problem is the value of the agreement to L at the end of the current period. This approach treats the payoff to L as a state variable, and a non-stationary trade agreement is one for which the value of y changes over the life of the contract.

The following result establishes that $\tilde{\Omega}$ exists and is the solution to (P) and derives some useful properties of the solution.

Lemma 3. *The optimization problem (P) has a solution $\tilde{\Omega}$ which is attained. This solution is continuous, concave, and non-increasing.*

The proof of existence involves an application of a result in Rustichini (1998) for problems in which the value function enters the incentive constraint. The result that the second-best frontier is concave will be useful in characterizing the optimal contracts below. The fact that $\tilde{\Omega}$ is monotone ensures that it will be differentiable almost everywhere, so we can characterize the optimal contract terms by analysing the necessary conditions for the Lagrangian associated with (7). We will establish below that $\tilde{\Omega}$ is differentiable in the present case.

Letting μ_j be the multiplier associated with the incentive constraint for country j and σ the multiplier associated with (PL), problem (8) yields the following necessary conditions for choice of t_L and s_L:

$$(\mu_L + \sigma - 1)\frac{\partial W_L}{\partial t_L} + \left(\frac{\partial W_S}{\partial t_L} + \frac{\partial W_L}{\partial t_L}\right) \leq 0, \quad \text{with equality if } t_L > 0, \tag{8a}$$

$$1 - \mu_L - \sigma \leq 0, \quad \text{with equality if } s_L > 0. \tag{8b}$$

Note that t_L has no effect on (ICS) in this case because W_L is additively separable in the tariff rates. It follows from the envelope theorem that $\sigma = -\tilde{\Omega}'(V_L)$ is the shadow value of an increment of payoff to L under the agreement. For $V_L \in [V_L^*, V_L^{**}]$, first-best agreements are incentive compatible and $\sigma = 1$. From the concavity of the frontier established in Lemma 3, a necessary condition for $\sigma > 1 (\sigma < 1)$ is $V_L > V_L^{**}$ $(V_L < V_L^*)$. From Lemma 1(c), an increase in t_L reduces world welfare so the second term in (8a) is negative for $t_L > 0$. It follows from Lemma 1(a) that W_L is increasing in t_L for $t_L < t_L^N$ and world welfare is maximized at $t_L = 0$, so a necessary and sufficient condition for $t_L > 0$ is that $\mu_L + \sigma > 1$. With $\mu_L + \sigma > 1$, the gains from transferring income to country L through the use of a tariff exceed the negative impact on world welfare. Note from (8b) that this condition will never be satisfied when $s_L > 0$, since it is always more efficient to transfer income to L by reducing the size of the transfer it pays rather than imposing a tariff. Note also that the t_L will never exceed t_L^N, since both terms in (8a) will be negative. A similar argument using the necessary conditions for choice of s_S and t_S yields the following result:

Lemma 4.

(a) *If* $s_j > 0$ *at time* i, *then* $t_j = 0$. *If* $t_j > 0$ *at time* i *then* $s_j = 0$ *for* $j = S, L$,
(b) *if* $\sigma > 1$, *then* $t_L > 0$. *If* $\sigma < 1$, *then* $t_S > 0$.
(c) $t_j \leq t_j^N$.

Lemma 4(a) shows that a country will never simultaneously make a transfer and impose a tariff, which can be interpreted as saying that tariffs serve as a substitute for the use of transfers when incentive constraints are binding in this model. If country i were simultaneously making a transfer and imposing a tariff, a reduction of both the tariff and the transfer that left i's welfare unaffected would be both feasible and welfare-improving for j. Part (b) shows that tariffs must arise in the region of the Pareto frontier where first-best agreements are not incentive compatible (*i.e.* $\sigma \neq 1$).

We will briefly sketch how Lemma 4 and the necessary conditions for the optimization problem in (7) can be used to characterize the optimal contract terms for $V_L \in [V_L^*, V_L^{**}]$, with a formal proof being provided in the appendix. For $V_L > V_L^{**}$, (ICS) is binding and (ICL) is slack, so $\mu_S > 0$, $\mu_L = 0$, and $\sigma = 1 + \mu_S$. This yields $t_L > 0$ by Lemma 4. L's tariff is used to relax (ICS) in this region because S can avoid the payment of the transfer s_S by deviating from the agreement, but it cannot avoid a transfer effected through t_L. The dynamics of the contract can be seen by taking the necessary condition for choice of y and substituting from the envelope theorem to yield

$$-\tilde{\Omega}'(y) = \frac{\mu_L - \tilde{\Omega}'(V_L)}{1 + \mu_S}. \tag{9}$$

For $V_L > V_L^{**}$, the fact that $\sigma = 1 + \mu_S$ and $\mu_L = 0$ implies that $-\tilde{\Omega}'(y) = 1$. Referring to Figure 1, suppose that the agreement negotiated between S and L calls for an initial payoff to L exceeding V_L^{**}. These results indicate that in the second period, the payoff to L will jump to a value of $y < V_L^{**}$ where free trade is sustainable in the second (and all subsequent) periods. This agreement will exhibit "gradual reduction" in tariffs for L because t_L is reduced from the Nash level to $t_L(1) \in (0, t_L^N)$ in the first period, followed by $t_L = 0$ in all subsequent periods. The frontier will be strictly concave in this region, with higher values of $t_L(1)$ being associated with larger initial values of V_L.[11]

For $V_L < V_L^*$, the payoff to L is sufficiently low under the stationary agreement that the first-best agreement violates (ICL). If the countries are sufficiently similar in size that $T_L > 0$, then $\mu_L > 0$, $\mu_S = 0$, and $\sigma = 1 - \mu_L$. The derivation of the optimal contracts is very similar to that above in this case, with the frontier for this case illustrated in Figure 1(a). Utilizing (9), we see that if the countries negotiate an agreement with the initial payoff to L below V_L^*, the agreement will call for the payoff to L to jump to $y \in [V_L^*, V_L^{**}]$ in all subsequent periods. The agreement will exhibit gradual reduction in tariffs by S in this region, with $t_S(1) > 0$ and $t_S(i) = 0$ for $i > 1$, and the frontier will be strictly concave and differentiable in this region.

If L is sufficiently large that $T_L < 0$, then the argument is slightly modified because S is paying a positive transfer to L at V_L^*. In this case, (ICL) can be relaxed by lowering s_S in the first period transfer. For $V_L \in [W_L(t_L^N, 0) + \delta V_L^N, V_L^*)$, a first-best payoff level can be obtained by setting $s_S = V_L - W_L(t_L^N, 0) - \delta V_L^N$ and $y = V_L^*$. This is illustrated by the linear segment of the

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[11] Since (ICS) binds in this region, we can use (8) to obtain the payoff to S as a function of t_L, $V_S(t_L) = W_S(t_S^N, t_L) + \delta V_S^N$. Assuming WLOG that $y = V_L^{**}$, we have from the definition of T_S and the separability of W_S that $s_S = T_S(\delta, \lambda)$ and $V_L(t_L) = W_L(t_L, 0) - W_L(0, 0) + V_L^{**}$. The properties of W_S and W_L imply that the frontier will be differentiable and strictly concave for $V_L > V_L^{**}$ as illustrated in Figure 1. Defining $V_L^{\max} = \sup\{V_L | \sigma < \infty\}$, it follows from the construction that $V_L^{\max} = V_L(t_L^N)$ and $\tilde{\Omega}(V_L^{\max}) = V_S^N$.

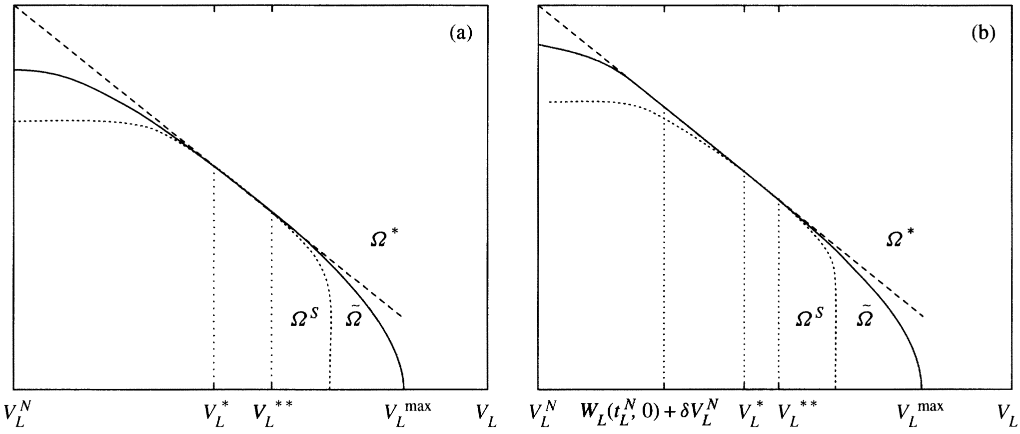

FIGURE 1

(a) Incentive-constrained frontier with $T_L(\delta, \lambda) > 0$ $\{A = 100, B = \beta = 1, \delta = 0{\cdot}65, \alpha_1^L = \alpha_2^S = -40, \alpha_2^L = \alpha_1^S = -60, \lambda = 1{\cdot}1\}$. Ω—second-best frontier—solid; Ω^*—first-best frontier—dashed; Ω^S—stationary incentive-constrained frontier—dotted. (b) Incentive-constrained frontier with $T_L(\delta, \lambda) < 0$ $\{\lambda = 1{\cdot}5 \text{ and } \delta = 0{\cdot}7\}$

frontier to the left of V_L^* in Figure 1(b). In this region, the agreement is non-stationary but tariffs are eliminated immediately. For $V_L < W_L(t_L^N, 0) + \delta V_L^N$, $t_S > 0$ is required to relax (ICL) and the frontier will be strictly concave. The agreement will exhibit both non-stationarity and gradual reduction of tariffs in this region. Note finally that as $\lambda \to \infty$, $W_L(t_L^N, 0) + \delta V_L^N \to V_L^N$ and the frontier will become linear on the interval $[V_L^N, V_L^*]$.

The following result summarizes the optimal contracts on the second-best frontier where the incentive constraints are binding.

Proposition 2. *If $\delta \geq \delta^C$, the optimal agreements have the following form in the regions where the incentive constraint binds:*

(a) *if $V_L > V_L^{**}$, then (ICS) is binding and (ICL) is slack. $\{t_L > 0, s_S \geq 0, t_S = s_L = 0\}$ in the first period followed by free trade in all subsequent periods,*

(b) *if $V_L < V_L^*$, then (ICL) is binding and (ICS) is slack:*

  (i) *if $T_L(\delta, \lambda) \geq 0$, then $\{t_S > 0, s_L \geq 0, t_L = s_S = 0\}$ in the first period followed by free trade with $y \in [V_L^*, V_L^{**}]$ in all subsequent periods,*

  (ii) *if $T_L(\delta, \lambda) < 0$ and $V_L \in [W_L(t_L^N, 0) + \delta V_L^N, V_L^*)$, the optimal contract will have $\{t_L = t_S = s_L = 0$ and $s_S \geq 0\}$ followed by free trade with $y \in [V_L^*, V_L^{**}]$. If $T_L(\delta, \lambda) < 0$ and $V_L < W_L(t_L^N, 0) + \delta V_L^N$, the contract will have the same form as in (i).*

These results illustrate the non-stationary nature of the optimal contracts when incentive constraints are binding. It is shown in Bond and Park (1998) that if one restricts attention to stationary agreements, then the incentive-constrained stationary trade agreements will call for a constant tariff pair $\{t_L > 0, t_S = 0, s_S > 0\}$ for $V_L > V_L^{**}$, and a constant pair with either $\{t_L = 0, t_S > 0, s_L > 0\}$ or $\{t_L > 0, t_S = 0, s_S > 0\}$ for $V_L < V_L^*$ to relax the respective incentive constraints. These stationary agreements require a permanent reduction in world welfare below the free-trade level. In contrast, the non-stationary agreements characterized in Proposition 2 use intertemporal incentives. Promises of higher payoffs in the future to the incentive-constrained country allow the agreement to achieve the efficient level of world welfare in all periods after the first. The inefficiency of stationary agreements is illustrated by the frontier Ω^S in Figure 1, which is the (third-best) frontier obtained when agreements must be both incentive compatible and stationary. The ability of stationary agreements to relax incentive constraints through the use of permanent changes in tariffs is limited, as reflected in the fact that Ω^S is horizontal (vertical) for much of the region below V_L^* (above V_L^{**}).

The essential element giving rise to the use of non-stationary contracts is the fact that the payoffs are such that one country's incentive constraint is binding and the other country's is not. Specifically, the country whose incentive constraint is binding accepts a lower payoff in the first period in return for a higher payoff in subsequent periods. One source of asymmetry in incentive constraints is a difference in the size of the countries. However, non-stationary agreements could arise in agreements between countries of equal size if the bargaining power of the two countries is not the same. A stationary free-trade agreement without transfers will always be sustainable between equal size countries for $\delta > \delta^C$, but if there is an asymmetry in bargaining power of the countries they might end up with an agreement whose initial payoff lies outside the range $[V_L^*, V_L^{**}]$.[12]

There are two features of the contracts derived in Proposition 2 that we will focus on in extensions of this basic model. The first is the fact that the transition to free trade involves only two steps, regardless of the value of the tariff in the initial period of the agreement. One possible explanation of this one-step adjustment is the assumption of a linear relationship between first period and future payoffs, which means that there is no cost to the countries of having large differences in consumption levels between the first period and future periods. A natural way to address this issue is to make a country's utility in each period a strictly concave function of the level of consumption in the period. We examine this extension in Section 3.

A second feature of the contracts is that the tariffs of the two countries serve primarily as substitutes for the transfers in order to relax the incentive constraints, as noted in the discussion of Lemma 4. In Section 4 we assume that suppliers must make their output choices prior to the government's choice of tariffs, and show that tariffs have an additional role to play in that case.

3. OPTIMAL CONTRACTS WITH A CONSUMPTION SMOOTHING MOTIVE

In this section we show that the introduction of a consumption smoothing motive results in multi-step reductions of tariffs in the region where only one country is incentive constrained. In light of the additional complexity introduced into the problem by the assumption of strictly concave utility functions, we will focus our attention on the version of the trade model in which S is infinitesimally small. Since S is unable to affect its terms of trade through the use of its tariff in this case, $t_S = 0$ in any optimal contract. This simplifies the maximization problem by reducing the number of contracting terms that must be solved. The consumption smoothing motive is introduced by assuming that the payoff for country S in a period is $U_S(W_S(t_S, t_L) + s_L - s_S)$, where U_S is a strictly concave and twice differentiable function. Since the impact of the small-country policy on large-country welfare is infinitesimal, we maintain the assumption that the payoff to country L is linear.[13]

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[12] A result similar to Proposition 2 would be obtained for the case of costly transfers discussed in footnote 10. In the region of the efficient frontier where one country is incentive constrained, the optimal contract will call for a jump to a contract on the portion of the frontier where a first-best contract is attainable. The difference from Proposition 2 is that the first-best contract will not necessarily involve free trade because the tariff may be used as a transfer mechanism in the first-best contract.

[13] A strictly concave utility function is likely to arise in situations where the small country has imperfect access to capital markets. An example of a trade agreement which suggests the presence of a strictly concave utility function

The properties of the payoff functions for the infinitesimally-small-country model are the limiting values of the functions derived in Lemma 1. As $\lambda \to \infty$, the free-trade prices $p_i^f(\lambda)$ approach the autarky price of the large country, $p_i^{LA} = (A - \alpha_i^L)/(B + \beta)$. The payoff to S is obtained by evaluating (1) using $p_1^S = p_1^{LA} + t_S$ and $p_2^S = p_2^{LA} - t_L$, so $W_S(t_S, t_L)$ will satisfy Lemma 1(a) and (b) with $t_S^N = 0$. Since domestic prices in the large country are unaffected by the tariff policies of either country, the payoff to L can be simply represented as tariff revenue,

$$W_L(t_L) = t_L(X_2^S(p_2^S) - D_2^S(p_2^S)). \tag{10}$$

W_L is strictly concave in t_L and achieves a maximum at $t_L^N = (\alpha_2^S - \alpha_2^L)/2(B + \beta)$, which is the limiting value from Lemma 1(a) as $\lambda \to \infty$. $W_W(t_L, t_S) = W_S(t_S, t_L) + W_L(t_L)$ is concave and decreasing in tariffs and is maximized at $t_L = t_S = 0$. In the case where the small country has a strictly concave utility function, first-best agreements will also involve immediate elimination of tariffs. The first -best frontier for this case is

$$V_S = \Omega^*(V_L) \equiv U_S(W_S(0,0) - (1 - \delta)V_L)/(1 - \delta), \tag{11}$$

which will be strictly concave in V_L from the strict concavity of U_S. The first-best agreements will necessarily be stationary in this case, because the presence of the consumption smoothing motive in S will result in constant transfers.

For purposes of comparison, the following corollary to Proposition 2 characterizes the optimal contracts for the infinitesimally small country when both countries have linear payoffs:

Corollary to Proposition 2. *If S is infinitesimally small and $\delta \geq \delta^C$, $V_L^* = V_L^N/\delta$ and $V_L^{**} = \delta(W_S(0,0) - W_S^N)/(1 - \delta)$. If $V_L > V_L^{**}$, then $\{t_L > 0, s_S \geq 0, t_S = s_L = 0\}$ in the first period followed by free trade in all subsequent periods. If $V_L \in [V_L^N, V_L^*)$ first-best payoffs can be attained by a free-trade agreement with $s_S(1) < W_L^N/\delta$ and $s_S(i) = W_L^N/\delta$ for $i > 1$.*

Since the small country has no ability to influence its terms of trade in the limiting case, its tariff will never be used to relax the incentive constraint for $V_L < V_L^*$. These agreements will be non-stationary but will not involve gradual tariff reduction when the utility functions are linear. Two-step tariff reduction in t_L will arise for $V_L > V_L^{**}$.

We begin our analysis of the strictly concave utility case by deriving the range of payoffs for which the first-best contracts are incentive compatible. The maximum transfer that S is willing to pay for a free-trade agreement is the one at which (ICS) holds with equality at free trade, which is the value $T_S(\delta)$ that solves $U_S(W_S(0,0) - T_S) - (1 - \delta)U_S(W_S(0,0)) - \delta U_S(W_S(0, t_L^N)) = 0$. The existence of a consumption smoothing motive for S raises the maximum amount that S is willing to pay for a free-trade agreement, because a free-trade agreement involves a smooth income stream whereas the deviation path does not. For the large country, $T_L(\delta) = -W_L^N/\delta$ as in the Corollary. It is straightforward to show (using an argument similar to that in Proposition 1) that there will exist a critical value $\delta^C \in (0,1)$ such that for $\delta > \delta^C$, there exists a non-empty interval $[V_L^*, V_L^{**}]$ for which first-best agreements will be incentive compatible.

for small countries is provided by the 1975 Lomé Convention, an agreement between the EU and 46 African, Caribbean, and Pacific (APC) countries. As part of the agreement, the EU agreed to a stabilization of the export earnings scheme to insure that the export earnings from particular commodities of the APC countries achieved minimum specified levels (Babarinde, 1994). The fact that this trade agreement bundles an insurance scheme with trade liberalization is consistent with the a strictly concave utility function for the APC countries arising from their inability to insure against commodity price shocks using international capital markets.

The optimal contracts for the regions where the incentive constraints bind can be derived by solving the following dynamic programming problem:

$$\tilde{\Omega}(V_L) = \sup_{t_L,t_S,s_L,s_S,y} U_S(W_S(t_L, t_S) + s_L - s_S) + \delta\tilde{\Omega}(y), \tag{12}$$

subject to (ICS) $U_S(W_S(t_S, t_L) + s_L - s_S) + \delta\tilde{\Omega}(y) \geq U_S(W_S(0, t_L) + s_L) + \delta V_S^N$, (ICL), (PL), and the non-negativity constraints given by (7). Note that in writing (ICS) we have made use of the fact that $t_S^N = 0$. Furthermore, $t_S = 0$ in any efficient contract because a reduction t_S will be both feasible and Pareto improving from a feasible contract with $t_S > 0$.

We first characterize the optimal contract for an initial value $V_L < V_L^*$ where (ICL) is binding. The following proposition shows that the optimal path will involve a positive tariff by the large country that is gradually reduced over time as the large country's payoff rises toward V_L^*.

Proposition 3. *Suppose $\delta \geq \delta^C$ and U_S is strictly concave in the case where S is infinitesimally small.*

(a) *$\tilde{\Omega}$ is concave on $[V_L^N, V_L^*)$.*

(b) *For $V_L \in (V_L^N, V_L^*)$, $\mu_L > 0$, $\mu_S = 0$, $t_S = 0$, $s_S > 0$ and $s_L = 0$. The payoff to L will be increasing over time and will satisfy $V_L < y < V_L^*$ with $\lim_{i\to\infty} V_L(i) = V_L^*$. t_L will be positive and decreasing over time with $\lim_{i\to\infty} t_L(i) = 0$ and s_S will be increasing over time.*

A detailed proof of the proposition is given in the appendix. Here we briefly sketch the arguments and provide some intuition behind the result. First, note that (ICL) binds with $\mu_L > 0$ when U_S is strictly concave. In the linear utility case described in the corollary, $\mu_L = 0$ in this region because a first-best payoff level was attainable by giving S a contract with a non-stationary consumption level. However, when U_S is strictly concave, a non-stationary contract with the same present value of consumption as the first-best contract must yield $V_S < \Omega^*(V_L)$. Therefore, we must have $\tilde{\Omega}(V_L) < \Omega^*(V_L)$ for $V_L < V_L^*$ and $\mu_L > 0$. With a binding (ICL), the transfer paid by S must be $s_S = V_L - V_L^N > 0$ for $V_L \in (V_L^N, V_L^*)$.

To see why $t_L > 0$ in this region, we can refer to the necessary conditions for the remaining contract terms.

$$\begin{aligned}
&[U_S'(W_S - s_S + s_L)(1+\mu_S) - U_S'(W_S + s_L)\mu_S - \mu_L - \sigma]\tfrac{\partial W_S}{\partial t_L} \\
&\quad + (\mu_L + \sigma)\tfrac{\partial W_W}{\partial t_L} \leq 0 \qquad \text{with equality if } t_L > 0, && \text{(13a)}\\
&-(1+\mu_S)U_S'(W_S(t_S, t_L) + s_L - s_S) + \sigma \leq 0, \qquad \text{with equality if } s_S > 0, && \text{(13b)}\\
&U_S'(W_S - s_S + s_L)(1+\mu_S) - U_S'(W_S + s_L)\mu_S \\
&-\mu_L - \sigma \leq 0, \qquad \text{with strict equality if } s_L > 0, && \text{(13c)}\\
&-(\sigma + \mu_L)/(1+\mu_S) \in \partial\tilde{\Omega}(y). && \text{(13d)}
\end{aligned}$$

Since $\tilde{\Omega}$ may not be differentiable at all points, $\partial\tilde{\Omega}(y)$ denotes the set of subgradients of $\tilde{\Omega}$ at y in condition (13d). With $s_S > 0$, (13b) ensures that the bracketed expression in (13a) will be negative when $\mu_L > 0$. It then follows from (13a) that $t_L > 0$, since $\partial W_S/\partial t_L < 0$ and the second term will be zero when evaluated at $t_L = 0$. This expression illustrates that it will be useful to trade some reduction in world welfare in order to obtain some relaxation of L's incentive constraint in this region. The result that $t_L > 0$ combined with the fact that (ICL) holds with equality at $V_L \in (V_L^N, V_L^*)$ yields $\delta(y - V_L^*) = -W_L(t_L) < 0$. Therefore, the payoff to L will remain in the region where (ICL) is binding for all time periods i.

Using (13d) and the Envelope Theorem, it can be seen that $\sigma(i)$ must be rising over time, which implies a strictly decreasing per-period payoff to S over time from (13b). The intuition here is similar to that obtained in (9) for the linear case, where a promise of higher payoff in the future to L is used to relax (ICL). Note however that in the case with strictly concave utility there is a trade-off between static distortions and intertemporal distortions when there is a consumption smoothing motive. The requirement that V_L rise over time in the optimal contract introduces an intertemporal distortion because the consumption profile of S is not stationary. Since $W_L(t_L)+\delta y = V_L^N$ when (ICL) is binding, a positive tariff can be used to slow the increase in V_L over time. The optimal trade agreement gradually reduces both of these distortions over time, with the agreement moving along the frontier toward the first-best level and the incentive constraint becoming less binding. Gradual adjustment did not arise with linear utility because there was no efficiency loss associated with a rapid increase in y. Note also that in contrast to Proposition 2 and its corollary, Proposition 3 shows a case where $t_L > 0$ when (ICL) is binding.

A similar gradualism result can be established for the region $V_L > V_L^{**}$. In the case with linear utility, this region exhibited a positive first-period tariff followed by a jump to a first-best contract. With strictly concave utility, we obtain a gradual reduction of tariffs for this region of the frontier as well.

Proposition 4. *Suppose $\delta \geq \delta^C$ and U_S is strictly concave in the case where S is infinitesimally small.*

(a) *If $V_L \in (V_L^{**}, V_L^{\max})$, $\mu_L = 0$, $\mu_S > 0$, $t_S = 0$, $t_L > 0$, $s_S > 0$ and $s_L = 0$.*

(b) *The payoff to L will be decreasing over time and will satisfy $V_L \geq y > V_L^{**}$. The large-country tariff will be positive and will decline over time, and the transfer paid by the small country will rise over time. Free trade will be reached asymptotically.*[14]

Propositions 3 and 4 illustrate that with $\delta > \delta^C$, the region where stationary free-trade agreements are sustainable is bounded on either side by regions on which the incentive constraint of one of the countries is binding and the efficient agreements are non-stationary. This feature of the frontier is similar to that obtained in Proposition 2 for the case with linear utility. The efficient trade agreements with strictly concave U_S will involve a monotonic adjustment of country payoffs along the frontier that reaches the first-best region asymptotically, rather than a one-step adjustment as obtained in the linear utility case. Proposition 3 also introduces the use of t_L in the case where (ICL) is binding, which did not happen with linear utility. Note however that Propositions 3 and 4 still have the attribute that a country that is imposing a tariff will never pay a transfer, as in Lemma 4.

4. TRADE AGREEMENTS WITH SUNK INVESTMENTS

In this section we investigate how the results of the previous sections are altered if producer decisions about output supplies are made prior to the choice of tariffs by the government. Sunk costs are potentially an important element in agreements between small and large countries, as

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[14] The major difference between this result and the one obtained in for the case where (ICL) binds is that it is not in general possible to prove that $\tilde{\Omega}$ is concave in the region. For the large country, the deviation payoff is convex in t_L, which allows concavity to be proven for the interval where (ICL) is binding. On the other hand, the deviation payoff to S, $U_S(W_S(t_L)) + \delta V_S^N$, is not necessarily a convex function of t_L Since W_S is convex in t_L, the deviation payoff will be convex in t_L when U_S is linear (or not too concave) and we obtain concavity of $\tilde{\Omega}$ as in Lemma 3. This result will not necessarily hold when the degree of risk aversion is high. However, it is possible to show that the payoff to S must be rising over time under the agreement even if $\tilde{\Omega}$ fails to be concave.

emphasized by McLaren (1997), because small-country investments that have been committed with an eye toward the large-country market are potential hostages to changes in the trade policy of the large country. In order to maintain tractability and to focus on the role of sunk investments, we maintain the parameterization of demand and supply as in the previous section for the infinitesimally small-country case but simplify intertemporal preferences by returning to the assumption that U_S is linear. Thus, we again use the corollary to Proposition 2 as a benchmark against which the role of the timing of decisions can be illustrated. We show that the existence of sunk investments introduces a new role for tariffs in efficient trade agreements. In the model without sunk costs, the role of tariffs is to relax incentive constraints by serving as an alternative transfer mechanism between countries. In contrast, we will show that in the model with sunk investments the tariff has the additional role of deterring deviation by reducing the degree of specialization by the small country, and thus reducing the deviation incentive of the large country. In particular, we show the existence of efficient trade agreements with $s_L > 0$ and $t_L > 0$. This possibility cannot arise without sunk investments, as illustrated by Lemma 4(a).

Each period is assumed to be made up of three stages. In the first stage, resource owners choose their allocation of resources between tradeable goods and the rest of the economy. Countries choose their tariff rates in the second stage, and consumers then choose their consumption bundles in the final stage. For S, the demand schedule is identical to that in the previous section. The supply schedule for good $i (i = 1, 2)$ in S is $X_i^S = \alpha_i^S + \beta p_i^{Se}$, which differs from that in the previous section only in that suppliers base their decision on the price expected to prevail at the end of the period. For L, we again analyse the limiting case in which L is arbitrarily large relative to the small country, so its internal prices are unaffected by S and are given by $p_i^{LA} = (A - \alpha_i^L)/(B + \beta)$.[15] Since world welfare is maximized at free trade in this model and payoffs are linear, the first-best frontier will be linear as in (3).[16]

4.1. *Non-cooperative equilibrium in the one-shot tariff game*

We begin by deriving the subgame perfect Nash equilibrium of the one-shot tariff-setting game with sunk investment decisions. To solve for the subgame perfect Nash equilibrium, we first derive the Nash equilibrium of the second-stage tariff game, given the output levels chosen by agents in the first stage. We then derive the supply decisions of agents in the first stage, given that they correctly anticipate the tariffs imposed by the governments in the second stage. Letting a "∧" over a variable denote a best response to a given output level, the large-country optimization problem can be expressed as

$$\begin{aligned} \hat{W}_L(X_2^S) &= \max\nolimits_{t_L} t_L(X_2^S - A + B(p_2^{LA} - t_L)), \\ \hat{t}_L(X_2^S) &= \frac{X_2^S - A + Bp_2^{LA}}{2B}; \qquad \frac{\partial \hat{W}_L}{\partial X_2^S} = \hat{t}_L(X_2^S) > 0. \end{aligned} \tag{14}$$

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[15] Note that the case we examine is the limiting case as $\lambda \to \infty$ of the model of Section 2 when firms in both countries make investments prior to the realization of the tariff vectors. Since small-country policies do not affect large-country prices in the limiting case, expected and realized returns to large-country producers will be the same regardless of the values of t_S and t_L that are chosen.

[16] Although the investments in this model are irreversible at the time tariffs are set, the economic environment is still stationary in that these investment levels do not affect the production set in subsequent periods. In contrast, Lockwood and Thomas (2002) study a model in which two players are choosing the level of an irreversible investment in a repeated prisoner's dilemma game, with the current period investment level affecting the production set in subsequent periods. In their model, irreversibility prevents a player from punishing deviations because investment levels cannot be lowered to the non-cooperative level. Deviation is deterred in their model by promises of future cooperation, which results in gradual increases in investment levels over time. Chisik (2001) examines a trade model with irreversible investments of this type with symmetric countries.

The greater is the commitment of resources by S to its export sector, the higher is the tariff imposed by L and the higher is the payoff to L. Similarly, the best response for S can be derived from

$$\hat{W}_S(t_L, X_1^S, X_2^S) = \max_{t_S} \sum\nolimits_{i=1,2} \left[\int_{p_i^s}^{A/B} D_i^S(u)du + p_i^S X_i^S - \int_0^{X_i} \frac{u - \alpha_i^S}{\beta} v du \right]$$
$$+ t_S(D_1^S(p_1^{LA} + t_S) - X_1^S),$$
$$\hat{t}_S = 0; \quad \frac{\partial \hat{W}_S}{\partial X_i^S} = p_i^S - \frac{X_i^S - \alpha_i^S}{\beta}; \quad \frac{\partial \hat{W}_S}{\partial t_L} = D_2^S(p_2^{LA} - t_L) - X_2^S < 0. \quad (15)$$

The optimal tariff for S will be 0, regardless of the initial level of X_1^S, because S obtains no terms of trade benefits from raising its tariff.

In the first stage, resource owners choose their output levels based on their expectations of second-stage prices. In the small country's importable sector, a zero tariff is anticipated and supply will equal the free-trade level, $X_1^S = \alpha_1 + \beta p_1^{LA}$. In the exportable sector, the expected price is $p_2^{LA} - \hat{t}_L(X_2^S)$ and the equilibrium output level is the solution to $X_2^S = \alpha_2^S + \beta(p_2^{LA} - \hat{t}_L(X_2^S))$. Solving this equation yields the following characterization of the subgame perfect Nash equilibrium tariff and welfare levels:

$$\hat{t}_L^N = \frac{\alpha_2^S - \alpha_2^L}{\beta + 2B}; \qquad \hat{t}_S^N = 0 : \hat{V}_L^N \equiv \frac{W_L(\hat{t}_L^N)}{1 - \delta}; \qquad \hat{V}_S^N \equiv \frac{W_S(0, \hat{t}_L^N)}{1 - \delta}. \qquad (16)$$

Note that $\hat{t}_L^N$ will exceed the tariff rate that would result if the large-country tariff could be set before the values of X_i were chosen by producers (*i.e.* t_L^N from (2)). This reflects a cost to the large country associated with its inability to commit to a tariff rate when there are sunk costs in each period.

4.2. *Incentive compatible trade agreements with sunk investments*

The objective functions in (14) and (15) can also be used to derive the payoff to the respective countries if they make the optimal deviation from a trade agreement which specifies a tariff pair (t_L, t_S). First consider a deviation by L. Since firms in the S export sector choose their output level anticipating the trade agreement will hold, their output choice can be denoted $X_2^S(t_L) = \alpha_2^S + \beta(p_1^{LA} - t_L)$. The optimal deviation for L will then be $\hat{t}_L(X_2^S(t_L))$ as defined in (15), which yields L a deviation payoff of $W_L^D(t_L) = \hat{W}_L(X_2^S(t_L))$. For S, (16) indicates that an optimal deviation will always involve the choice of a tariff of 0. The deviation payoff to S is then $W_S^D(t_S, t_L) = \hat{W}_S(t_L, X_1^S(t_S), X_2^S(t_L))$. The following results follow immediately from the definitions and the results in (15)–(17).

Lemma 5.

(a) *L's deviation payoff is a convex function of t_L, with* $\frac{\partial W_L^D}{\partial t_L} = -\beta \hat{t}_L(X_2(t_L)) < 0$. *$W_L^D(t_L) - W_L(t_L)$ is convex in t_L, with $W_L^D(\hat{t}_L^N) - W_L(\hat{t}_L^N) = 0$.*
(b) *S's deviation payoff is convex in t_L and concave in t_S, with $\partial W_S^D / \partial t_S = -\beta t_S < 0$ and $\partial W_S^D / \partial t_L = D_2^S(p_2^{LA} - t_L) - X_2^S(t_L) < 0$.*

The payoff functions for L are illustrated in Figure 2. The $W_L(t_L)$ function is from (11), which denotes the payoff to L in the case in which supply is variable. Note that the only tariff at which W_L and W_L^D are equal is $\hat{t}_L^N$, because that is the level at which the anticipated tariff is

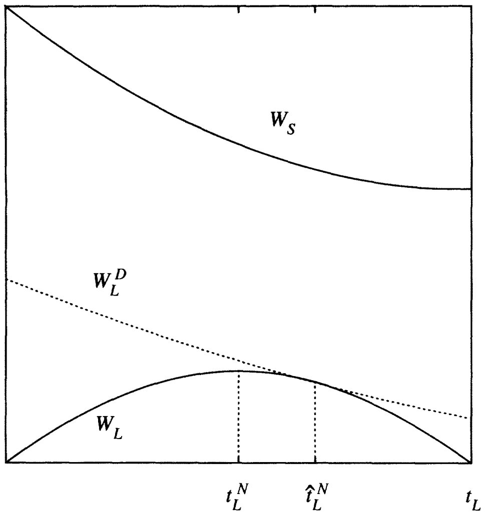

FIGURE 2
Payoffs with sunk investments

L's optimal tariff. In the previous section, the deviation payoff for L was $W_L^N \equiv W_L(t_L^N)$ for any initial t_L, because firms were assumed to observe a government's tariff choice before making their supply decisions. With investment decisions made prior to the tariff choice, there will be more specialization by the small country the lower the value of t_L specified by the agreement is and hence a greater incentive for L to deviate. Lemma 5(a) shows that a higher value of t_L will reduce the incentive for L to deviate from a free-trade agreement, which will play an important role in the subsequent analysis.

It is straightforward to show, using an argument similar to that in the case of Proposition 3, that $t_S = 0$ in any optimal trade agreement. Since an optimal deviation by S involves $t_S = 0$, it follows that $W_S^D(0, t_L) = W_S(0, t_L)$. Therefore, we can write the incentive constraints for this problem as

$$\begin{aligned}&\text{(ICL)}\quad W_L(t_L) + s_S - s_L + \delta y \geq W_L^D(t_L) + s_S + \delta \hat{V}_L^N,\\ &\text{(ICS)}\quad s_L - s_S + \delta\tilde{\Omega}(y) \geq s_L + \delta \hat{V}_S^N.\end{aligned} \tag{17}$$

An efficient trade agreement will be one that solves the dynamic programming problem

$$\tilde{\Omega}(V_L) = \sup_{t_L, t_S, s_L, s_S, y} W_S(t_L, t_S) + s_L - s_S + \delta\tilde{\Omega}(y), \tag{18}$$

subject to (17), (PL) and the non-negativity constraints in (8).

Using arguments similar to those of the previous sections, we can establish the existence of a critical discount parameter δ^C such that for $\delta > \delta^C$, there will exist an interval of payoffs $[V_L^*, V_L^{**}]$ for which stationary first-best agreements are incentive compatible.[17] For values of V_L

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[17] The upper bound of the interval is defined by the maximum transfer that S is willing to pay to maintain a free-trade agreement, which solves $(W_S(0,0) - T_S)/(1-\delta) = W_S(0,0) + \delta\hat{V}_S^N$, yielding $V_L^{**} = \delta(W_S(0,0) - W_S(0, \hat{t}_L^N))/(1-\delta)$. The maximum transfer S is willing to pay will exceed the value without sunk investments (defined in the corollary to Proposition 2) because the Nash equilibrium payoff to S is lower when investment decisions are made prior to the choice of tariffs. The lower bound of the interval is defined by the minimum payoff that L must receive to maintain a free trade agreement, which yields $V_L^* \equiv \hat{V}_L^N + W_L^D(0)\delta^{-1}$. This value may be either greater or smaller than the value without sunk costs, because the existence of sunk investments makes deviation more attractive but also makes the punishment more severe. By showing that the punishment strengthening effect dominates as δ gets higher, Park (2000) emphasizes the potential role of sunk investment in improving the small country's bargaining position.

below (above) this interval, (ICL) will be binding ((ICS) will be binding) and non-stationary trade agreements will be optimal as in the previous cases. The characterization of these agreements is obtained by solving the optimization problem (18), which yields:

Proposition 5. *Suppose that S is infinitesimally small and supply decisions are made prior to the choice of tariffs. There exists a* δ^C *such that if* $\delta > \delta^C$*, first-best payoffs are attainable if* $V_L \in [V_L^*, V_L^{**}]$*, where* $V_L^* \equiv \hat{V}_L^N + W_L^D(0)\delta^{-1}$ *and* $V_L^{**} = \delta(W_S(0,0) - W_S(0, \hat{t}_L^N))/(1-\delta)$*. The efficient agreements outside that range have the following properties:*

(a) *if* $V_L > V_L^{**}$*, then (ICS) is binding and (ICL) is slack.* $\{t_L > 0, s_S \geq 0, t_S = s_L = 0\}$ *in the first period followed by free trade in all subsequent periods,*
(b) *if* $V_L \in [W_L^D(0) + \delta\hat{V}_L^N, V_L^*)$*, first-best payoffs can be attained by a contract with* $\{t_L = t_S = s_L = 0$ *and* $s_S \geq 0\}$ *followed by free trade with* $y \in [V_L^*, V_L^{**}]$ *in all subsequent periods,*
(c) *if* $V_L \in [\hat{V}_L^N, W_L^D(0) + \delta\hat{V}_L^N)$*, then* $t_L > 0$ *and* $s_L > 0$ *in the first period followed by free trade with* $y \in [V_L^*, V_L^{**}]$ *in all subsequent periods.*

Parts (a) and (b) of Proposition 5 yield trade agreements that have the same form as in the corollary. Sunk investments play no role in the form of the contract for $V_L > V_L^{**}$ because S is too small to have an impact on the terms of trade, and hence it cannot benefit from exploiting sunk investments in L. If $V_L < V_L^*$, (ICL) will bind and $V_L = W_L^D(t_L) + s_S + \delta\hat{V}_L^N$. For $V_L \in [W_L^D(0) + \delta\hat{V}_L^N, V_L^*)$, (ICL) can be relaxed by lowering the first-period transfer paid by S as in the corollary. Reductions in s_S are a more efficient means of relaxing (ICL) than increases in t_L in this region, because they involve no reduction in world welfare.

The role of sunk investments is illustrated by part (c) of the proposition. For $V_L < W_L^D(0) + \delta\hat{V}_L^N$, free trade is not sustainable in the first period. However, (ICL) can be relaxed by having $t_L > 0$ in the first period of the agreement, because a positive tariff results in less specialization by S and hence reduces the deviation incentive of L. In this region, t_L is chosen to satisfy $V_L = W_L^D(t_L) + \delta\hat{V}_L^N$. The efficient contract can then be achieved by setting $y = V_L^*$ and $s_L = W_L(t_L) + W_L^D(0) - W_L^D(t_L) > 0$. The payoff to S under this contract will be $W_W(t_L) + W_L^D(0) - W_L^D(t_L) + \delta\Omega^*(V_L^*)$, where $W_W(t_L) = W_S(0, t_L) + W_L(t_L)$. This expression makes clear the trade-off introduced by an increase in t_L, since it allows a higher payoff to S by relaxing (ICL) but also lowers world welfare.[18] This contrasts with the case without sunk investments, where the deviation payoff of L was unaffected by t_L.

Proposition 5 illustrates that efficient trade agreements will offer higher payoffs in the future to the incentive-constrained countries, so that payoffs will move along the frontier toward the first-best region as in the previous cases analysed. The difference obtained with sunk investments is that the large country is less likely to deviate when its own tariff is raised, because the lower level of specialization by the small country makes deviation less attractive. Note that the trade agreements in Proposition 5 are characterized by two-step adjustment in the region where one of the incentive constraints binds. We show in Bond and Park (1998) that multi-step adjustment similar to those in Propositions 3 and 4 can also be obtained in the case with sunk investments if U_S is strictly concave.

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[18] The maximum payoff attainable to S occurs at $t_L^{\max} = \operatorname{argmax} W_W(t_L) - W_L^D(t_L) < \hat{t}_L^N$, which yields $V_L^{\min} = W_L^D(t_L^{\max}) + \delta\hat{V}_L^N > \hat{V}_L^N$. The second-best frontier would then be horizontal in the interval $[\hat{V}_L^N, V_L^{\min}]$. This difference from the case without sunk investments arises from the role of the tariff in reducing the amount of specialization by S.

5. CONCLUSIONS

This paper has focussed on how the variation of payoffs over time may be used to relax incentive constraints in trade agreements between asymmetric countries, and how this leads to a gradual reduction in the tariff rates over time. The introduction of an intertemporal distortion is used to reduce the static trade distortion over time, with both the intertemporal and the static distortion being reduced asymptotically in the case of strictly concave utility for the small country if the discount parameter is low enough.

The explanation of the evolution of payoffs over time in a trade agreement between asymmetric countries differs from that offered by McLaren (1997). In McLaren's model, the agreement between the small and large country is renegotiated once the small country has made its resource allocation decision. The small country's bargaining power has been reduced by the fact that it has sunk resources that are specialized to the large-country market. In the model presented in this paper, no renegotiation takes place over the life of the agreement because the payoff of the two parties is always on the utility possibility frontier. However, the particular point on the utility possibility frontier evolves over time in an optimal fashion. Thus, what might appear to be a shift in bargaining power between the two parties to the agreement is really an attempt to use variations in transfers and payoffs over time to reduce deviation incentives. Furthermore, the evolution of payoffs over time could favour either party, depending on which country's incentive constraint is binding.

One example of a trade agreement whose features are consistent with this model is the "Interim" Agreement signed in 1992 between Poland and the European Union. This agreement spelled out a process of gradual trade liberalization to be completed over a 10 year period. Since the transformation of the Polish economy from central planning to a market system would presumably involve a significant reallocation of resources toward goods that would be marketed in the European Union, the potential for exploitation of these sunk investments by changes in EU commercial policy would be large. An important feature of this agreement is the timing of concessions under the agreement. European concessions were primarily made early in the agreement, in order to stimulate the liberalization process in Poland. In contrast, the side payments to be made by Poland were primarily made late in the agreement. For example, concessions by Poland on intellectual property rights, the extension of national treatment to European companies, and liberalization of financial and insurance services were postponed for periods varying from 5 to 10 years. This pattern, with Poland the primary beneficiary in the early stages of the agreement and Europe benefitting more in the later stages, is consistent with a case in which the incentive constraint is binding for Europe.

Similar issues concerning the time profile of payments arose in the accession agreement between the U.K. and the European Community in 1971. It was generally agreed that the mutual tariff reductions associated with U.K. membership would yield a relatively greater gain to the U.K. than to the Community, because the U.K. (whose GNP was approximately 14% of Community GNP in 1973) was gaining access to a larger market. These reductions took place over a 5 year phase-in period during which both parties reduced tariffs at the same rate. However, in return for market access the U.K. would have to make a significant side payment under the agreement, because its contribution to the EC budget was expected to be substantially larger than its benefits from EC spending. Under the formula existing at the time, Britain's contribution to the budget was estimated at being 31% of the total budget for the expanded Community of 10 countries, while Britain's share of repayments from the Community was estimated to be only 6% of the community budget (Young, 1973). This disparity resulted from the nature of the contribution formula and the fact that the majority of budget payments were for the common agricultural policy, of which Britain received little because of its relatively small agricultural sector. The negotiations resulted in a transition period in which Britain's contribution would be gradually raised from a fixed percentage of 9% of the Community budget in 1973 to 19% in 1977. In the following years, the contribution would rise to the full share under the Community's allocation formula. The formula for calculating budget contributions was subsequently revised somewhat in Britain's favour when the terms of entry were renegotiated in 1974. The design of this transition agreement suggests an agreement in which Britain's incentive constraint was binding over the entry period, with gains from increased market access being accompanied by increases in transfers to the EU. The anticipation of rising benefits over time for the U.K. is reflected in the comments of Young (1973, p. 211) who noted that in subsequent negotiations "the original Six will no longer hold what is their strongest card in the entry negotiations—the ability to deny admittance to a British government plainly very anxious to enter".

The model we have presented has focussed on isolating the effects of country size, intertemporal preferences, and sunk investments on the form of efficient trade agreements. This work can be extended to analyse the characteristics of efficient trade agreements when there are interactions between these cases. For example, our analysis of the sunk investment case has focussed on the infinitesimally-small-country case, where the small country's tariff will never be used. In the case of finite λ, it may be optimal to have gradual reductions in both tariffs in this case, since tariffs have a role for relaxing incentive constraints through transferring income and through reducing the degree of specialization to the partner market.

APPENDIX

Proof of Lemma 1. Letting $M_k^j(p_k^j) \equiv D_k^j(p_k^j) - X_k^j(p_k^j)$ denote net imports of good k by country j, we can differentiate (1) to obtain the standard decomposition of the effects of tariff changes into terms of trade and trade volume effects:

$$\frac{\partial W_j}{\partial t_j} = M_m^j\left(1 - \frac{\partial p_m^j}{\partial t_j}\right) + t_j\left(\frac{\partial M_m^j}{\partial p_m^j}\right)\left(\frac{\partial p_m^j}{\partial t_j}\right) \quad \text{for } j = S, L;\ m = 1(2) \text{ when } j = S(L),$$
$$\frac{\partial W_j}{\partial t_k} = -M_x^j\left(\frac{\partial p_x^j}{\partial t_k}\right) \quad \text{for } j, k = S, L \text{ and } j \neq k;\ x = 1(2) \text{ when } j = L(S). \tag{A.1}$$

Substituting market clearing prices into M_k^j yields $M_1^S = \lambda(\alpha_1^L - \alpha_1^S - (B+\beta)t_S)/(1+\lambda)$ and $M_2^L = \lambda(\alpha_2^S - \alpha_2^L - (B+\beta)t_L)/(1+\lambda)$. Differentiating the equilibrium price conditions yields $\partial p_1^S/\partial t_S = \lambda/(1+\lambda) = 1 + \partial p_1^L/\partial t_S$ and $\partial p_2^L/\partial t_L = 1/(1+\lambda) = 1 + \partial p_2^S/\partial t_L$. Substituting these results into (A.1), we obtain

$$\frac{\partial W_S}{\partial t_S} = \frac{\lambda(\alpha_1^L - \alpha_1^S - (B+\beta)(2+\lambda)t_S)}{(1+\lambda)^2} \qquad \frac{\partial W_L}{\partial t_S} = -\frac{\lambda(\alpha_1^L - \alpha_1^S - (B+\beta)t_S)}{(1+\lambda)^2},$$
$$\frac{\partial W_L}{\partial t_L} = \frac{\lambda^2(\alpha_2^S - \alpha_2^L - (B+\beta)(\lambda^{-1}+2)t_L)}{(1+\lambda)^2} \qquad \frac{\partial W_S}{\partial t_L} = -\frac{\lambda^2(\alpha_2^S - \alpha_2^L - (B+\beta)t_L)}{(1+\lambda)^2}. \tag{A.2}$$

The results of Lemma 1 follow immediately from (A.2). ||

Proof of Lemma 2. Since $\partial^2 W_j/\partial t_L \partial t_S = 0$, we can define

$$\Gamma_j(\lambda) \equiv W_j(t_j^N(\lambda), 0, \lambda) - W_j(0, 0, \lambda) = \int_0^{t_j^N(\lambda)} \frac{\partial W_j}{\partial t_j} dt_j. \tag{A.3}$$

Differentiating (A.3) and using the envelope theorem yields $\Gamma'_j(\lambda) = \int_0^{t_j^N} (\partial^2 W_j/\partial t_j \partial\lambda) dt_j$. Differentiating (A.2), we obtain $\partial^2 W_L/\partial t_L \partial\lambda > 0$ for $t_L \in [0, t_L^N]$ and $\partial^2 W_S/\partial t_S \partial\lambda < 0$. This yields $\Gamma'_L(\lambda) > 0$, $\Gamma'_S(\lambda) < 0$.

Similarly, we can define

$$\Phi_j(\lambda) \equiv W_j(0, t_k^N(\lambda), \lambda) - W_j(0, 0, \lambda) = \int_0^{t_k^N(\lambda)} \frac{\partial W_j}{\partial t_k} dt_k, \tag{A.4}$$

with $\Phi'_j(\lambda) = \int_0^{t_k^N(\lambda)} (\partial^2 W_j/\partial t_k \partial\lambda) dt_i + (\partial W_j/\partial t_k)(\partial t_k^N/\partial\lambda)$ for $j, k = S, L$ and $j \neq k$. From (A.2) and (2) we have $\partial^2 W_L/\partial t_S \partial\lambda > 0$, $\partial W_L/\partial t_S < 0$, and $\partial t_S^N/\partial\lambda < 0$ which ensures $\Phi'_L(\lambda) > 0$. For the small country, we have $\partial^2 W_S/\partial t_L \partial\lambda < 0$, $\partial W_S/\partial t_L < 0$, and $\partial t_L^N/\partial\lambda > 0$ which yields $\Phi'_S(\lambda) < 0$.

Since W_j is additively separable in the tariffs, $W_j(t_j^N, t_i^N, \lambda) - W_j(0, 0, \lambda) = \Phi_j(\lambda) + \Gamma_j(\lambda)$. It then follows from the definition that $H_j(\delta, \lambda) = -(\Gamma_j(\lambda) + \delta\Phi_j(\lambda))$. Part (a) of the lemma follows from the fact that H_j is increasing in δ, that $\Gamma_j(\lambda) > 0$, and that world welfare is maximized at free trade. T_S will be increasing in λ because we have shown that Γ_S and Φ_S are decreasing in λ. $T_S(1, 1) > 0$ results from the symmetry of countries at $\lambda = 1$ and the fact that world welfare is maximized at free trade. $T_S(1, \lambda) > 0$ then follows from the fact that T_S is increasing in λ. For part (c), again note that $\Phi_L(1) + \Gamma_L(1) < 0$ from the symmetry of countries at $\lambda = 1$. T_L will be decreasing in λ because we have shown that $\Phi'_L(\lambda) > 0$ and $\Gamma'_L(\lambda) > 0$. Since $\lim_{\lambda\to\infty} t_S^N(\lambda) = 0$, we have $\lim_{\lambda\to\infty} \Phi_L(\lambda) = 0$. This yields $\lim_{\lambda\to\infty} \Phi_L(\lambda) + \Gamma_L(\lambda) > 0$. ||

Proof of Proposition 1. From the definition in (6), $H_j(\delta, \lambda)$ is continuous and increasing in δ for $\delta \in [0, 1]$ and $\lambda \in [1, \infty)$, with $H_j(0, \lambda) < 0$. From the definition of $T_i(\delta, \lambda)$ and the properties of $H_j(\delta, \lambda)$, $T_L(\delta, \lambda)$ and $T_S(\delta, \lambda)$ are both continuous and increasing in δ with $\lim_{\delta\to 0} T_L(\delta, \lambda) + T_S(\delta, \lambda) < 0$ and $T_L(1, \lambda) + T_S(1, \lambda) > 0$. Therefore, there will exist a $\delta^C \in (0, 1)$ such that $T_L(\delta^C, \lambda) + T_S(\delta^C, \lambda) = 0$. It follows from Lemma 2 that $H_S(\delta, \lambda)$ is increasing in λ and $H_L(\delta, \lambda)$ is decreasing in λ, so $T_L(\delta, \lambda) \leq T_S(\delta, \lambda)$ for $\lambda \geq 1$. This implies that for $\delta > \delta^C$, there exists a non-empty interval $[-T_L(\delta, \lambda), T_S(\delta, \lambda)] \ni$ for any $x \in [-T_L(\delta, \lambda), T_S(\delta, \lambda)]$, $\{s_S = x, s_L = 0\}$ is incentive compatible if $x \geq 0$ and $\{s_S = 0, s_L = -x\}$ is incentive compatible if $x < 0$. Lemma 2(c) ensures $T_L(\delta, \lambda) < 0$ for all $\lambda > \hat{\lambda}$, and hence $s_L = 0$ in any first-best contract.

This establishes parts (a) and (b) of the Proposition. Part (c) follows from the substitution of the payoffs $T_L(\delta, \lambda)$ and $T_S(\delta, \lambda)$ into the definition of V_L. ||

Proof of Lemma 3. In order to establish this result, we introduce the operator T which is defined on the cone of upper semicontinuous functions:

$$(Tf)(V_L) = \sup_{t_L, t_S, s_L, s_S, y \in B[f](V_L)} W_S(t_L, t_S) + s_L - s_S + \delta f(y), \tag{A.5}$$

where $B[f](V_L) = \{t_L, t_S, s_S, s_L, y | (PL), (ICL), (ICS)$, and $t_L, t_S, s_S, s_L \geq 0$ are satisfied$\}$. It is straightforward to show that this problem satisfies assumptions (A.1)–(A.5) of Rustichini (1998), so that the problem (P) will attain a maximum on the feasible set. It then follows that $\Omega_k = T^k\Omega^*$ forms a decreasing sequence of upper semicontinuous functions whose pointwise limit, Ω_∞, will be upper semicontinuous. The fact that $\Omega_\infty = T\Omega_\infty = \tilde{\Omega}$ and that $\tilde{\Omega} \geq \Omega^0$ if Ω^0 is a fixed point of T are established in Theorems 3.3 and 3.4 of Rustichini (1998).[19] Since the

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[19] Existence results for specific incentive problems where the value function enters the incentive constraint have been provided by Abreu *et al.* (1990) and Thomas and Worrall (1994). Rustichini's result is a general one that is readily applied to the present problem.

set $B[f](V_L)$ is non-increasing in V_L, $\tilde{\Omega}$ will be non-increasing in V_L and hence differentiable almost everywhere. ||

The proof of the concavity of $\tilde{\Omega}$ is obtained by an induction argument using the following result:

Lemma A.1. *If $f(V_L)$ is concave, then $T[f]$ as defined in (A.5) is concave in V_L.*

Proof. Consider V_L, V_L' such that $B[f] \neq \phi$, and let $a = (t_L, t_S, s_L, s_S, y)$ and $a' = (t_L', t_S', s_L', s_S', y')$ be the values that maximize (A.5) at V_L and V_L', respectively. Define $y^\lambda = \lambda y + (1-\lambda)y'$, $V_L^\lambda = \lambda V_L + (1-\lambda)V_L'$, $t_j^\lambda = \lambda t_j + (1-\lambda)t_j'$, and $Z^j = W_j(t_j^\lambda, t_k^\lambda) - \lambda(W_j(t_j, t_k) + s_k - s_j) - (1-\lambda)(W_j(t_j', t_k') + s_k' - s_j')$ for $j, k = L, S$ and $j \neq k$. Note that $Z^S + Z^L \geq 0$ by the concavity of world welfare in tariffs.

We have three cases to consider: (i) Z^S, $Z^L \geq 0$, (ii) $Z^L > 0$, $Z^S < 0$, and (iii) $Z^S > 0$ and $Z_L < 0$.

(i) Define $s_S^\lambda = s_L^\lambda = 0$. We first show that $a^\lambda \equiv (t_L^\lambda, t_S^\lambda, s_L^\lambda, s_S^\lambda, y^\lambda) \in B[f](V_L^\lambda)$. (PL) is satisfied because $W_L(t_L^\lambda, t_S^\lambda) + s_S^\lambda - s_L^\lambda + \delta y^\lambda \geq \lambda(W_L\ (t_L, t_S) + s_S - s_L + \delta y) + (1 - \lambda)(W_L(t_L', t_S') + s_S' - s_L' + \delta y') \geq V_L^\lambda$ by $Z^L \geq 0$ and the feasibility of a and a'. By the separability of the payoff functions, $W_j(t_j, t_k) = S_j^M(t_j) + S_j^E(t_k)$, where S_j^M is a concave function representing import sector surplus and S_j^E is a convex and decreasing function representing export sector surplus (utilizing the results of Lemma 1). Using this decomposition, (ICL) can be expressed as

$$S_L^M(t_L^\lambda) + \delta y^\lambda - S_L^M(t_L^N) - \delta V_L^N \geq \lambda(S_L^M(t_L) - s_L + \delta y) + (1-\lambda)(S_L^M(t_L') + \delta y' - s_L') \\ - S_L^M(t_L^N) - \delta V_L^N \geq 0, \tag{A.6}$$

where the first inequality follows from the concavity of S_j^M and s_L, $s_L' \geq 0$ and the second equality follows from the feasibility of a and a'. A similar argument establishes that a^λ satisfies (ICS). The non-negativity of the elements of a^λ follows immediately from the definition.

This establishes that a^λ is feasible. The payoff to S with this contract is

$$W_S(t_S^\lambda, t_L^\lambda) + s_L^\lambda - s_S^\lambda + \delta f(y^\lambda) \geq \lambda(W_S(t_S, t_L) + s_L - s_S + \delta f(y)) + (1-\lambda)(W_S(t_S', t_L') \\ + s_L' - s_S' + \delta f(y')),$$

where the inequality follows from the concavity of f and $Z^S \geq 0$. This establishes $T[f](V_L^\lambda) \geq \lambda T[f](V_L) + (1-\lambda)T[f](V_L')$ for this case.

(ii) Choose $s_L^\lambda = Z^L > 0$ and $s_S^\lambda = 0$. The fact that a^λ satisfies (PL) follows immediately from the definition of s_L^λ and the feasibility of a and a'. The non-negativity of the elements of a^λ follows from the definitions. Since $s_S^\lambda = 0$, the fact that (ICS) will be satisfied by a^λ follows from writing the constraint as in case (i). Using the definition of s_L^λ, (ICL) can be written as

$$\lambda(W_L(t_L, t_S) + s_S - s_L) + (1-\lambda)(W_L(t_L', t_S') + s_S' - s_L') + \delta y^\lambda - W_L(t_L^N, t_S^\lambda) \\ - \delta V_L^N \geq \lambda(W_L(t_L, t_S) + s_S - s_L + \delta y - W_L(t_L^N, t_S) - \delta V_L^N) \\ + (1-\lambda)(W_L(t_L', t_S') + s_S' - s_L' + \delta y' - W_L(t_L^N, t_S') - \delta V_L^N) \geq 0.$$

The first inequality follows from the convexity of W_L in t_S and the second inequality from the feasibility of a and a'. This establishes that $a^\lambda \in B[f](V_L^\lambda)$.

Substituting s_L^λ in the payoff to S yields

$$\begin{aligned} W_S(t_S^\lambda, t_L^\lambda) + s_L^\lambda - s_S^\lambda + \delta f(y^\lambda) &= W^W(t_L^\lambda, t_S^\lambda) - \lambda(W_L(t_L, t_S) + s_S - s_L) \\ &\quad - (1-\lambda)(W_L(t'_L, t'_S) + s'_S - s'_L) + \delta f(y^\lambda) \\ &\geq \lambda(W_S(t_S, t_L) + s_L - s_S + \delta f(y)) + (1-\lambda)(W_S(t'_S, t'_L) \\ &\quad + s'_L - s'_S + \delta f(y')). \end{aligned}$$

The inequality follows from the concavity of world welfare in the tariff rates and the concavity of f. This proves the concavity of $T[f]$ for this case.

(iii) This case follows by defining $s_S^\lambda = Z^S$ and $s_L^\lambda = 0$ and using the same arguments as for case (ii). ||

The first-best frontier Ω^* is concave in V_L, so it follows from Lemma A.1 that $T^n\Omega^*$ is concave in V_L for all n. Therefore, the pointwise *limit* $\Omega_\infty = \tilde{\Omega}$ will be concave. The fact that $\tilde{\Omega}$ is concave and bounded will also imply continuity.

Proof of Proposition 2. (a) Suppose $V_L > V_L^{**}$, which requires $\tilde{\Omega}(V_L) < \tilde{\Omega}(V_L^{**})$. We first establish that $t_L > 0$ and $s_L = 0$ in this region. The fact that (ICS) binds at V_L^{**} implies $\tilde{\Omega}(V_L^{**}) = W_S(t_S^N, 0) + \delta V_S^N$. In order for (ICS) to be satisfied at V_L it follows that we must have $W(t_S^N, t_L) + s_L < W(t_S^N, 0)$. In light of Lemma 4 and the fact that W_S is decreasing in t_L, we must have $t_L > 0$ and $s_L = 0$ for $V_L > V_L^{**}$.

We next show that we must have $\sigma = 1 + \mu_S$ in this region. The necessary condition for choice of s_S ensures that $\sigma \leq 1 + \mu_S$, so we prove the result by assuming $\sigma < 1 + \mu_S$ (which requires $s_S = 0$) and showing a contradiction. The fact that (ICL) is satisfied at V_L^{**} ensures that $V_L^{**} \geq W_L(t_L^N, 0) + T_S + \delta V_L^N$, so (ICL) cannot be binding for $V_L > V_L^{**}$ with $s_S = 0$. Substituting $\mu_L = 0$ and $\sigma < 1 + \mu_S$ in (9) yields the requirement that $-\sigma/(1+\mu_S)$ be contained in the subgradient of $\tilde{\Omega}$ at y (which we denote by $\partial\tilde{\Omega}(y)$), since we have not established that $\tilde{\Omega}$ is differentiable everywhere. It then follows that $y < V_L^*$ by the concavity of $\tilde{\Omega}$. Since (ICL) is slack in this contract it must be the case that (ICS) is binding. However, $y < V_L^*$ is not consistent with the fact that (ICS) is binding at V_L with $s_S = 0$. To see this note that (ICS) binding implies $0 = W_S(t_S, t_L) - W_S(t_S^N, t_L) + \delta(\tilde{\Omega}(y) - V_S^N) < W_S(0,0) - W_S(t_S^N, 0) + \delta(\tilde{\Omega}(V_L^{**}) - V_S^N)$, where the inequality follows from the fact that (ICS) binds at V_L^{**} with $T_S > 0$. By the separability of W_S and the fact that W_S is increasing in t_S over the feasible range, this inequality implies $\tilde{\Omega}(y) < \Omega^*(V_L^{**})$. However, this contradicts the requirement that $y < V_L^*$. Therefore, we have established that $\sigma = 1 + \mu_S$. Substituting this result in the necessary condition for choice of t_S, it can be seen that we must have $t_S = 0$.

The fact that $\sigma = 1 + \mu_S$ can be substituted into the necessary condition for choice of y to obtain the result that $-(1 + \mu_L) \in \partial\tilde{\Omega}(y)$. We now show that $\mu_L = 0$, which ensures that y will be in the efficient region of the frontier with $-\tilde{\Omega}'(y) = 1$. Suppose to the contrary that $\mu_L > 0$, which requires that (ICL) bind at V_L. The fact that (ICL) binds at V_L and is satisfied at V_L^{**} implies $0 = W_L(t_L, 0) - W_L(t_L^N, 0) + \delta(y - V_L^N) \leq W_L(0,0) - W_L(t_L^N, 0) + \delta(V_L^{**} - V_L^N)$. Since W_L is increasing in t_L for the relevant range this requires $y < V_L^{**}$ and hence $x \geq -1$ for all $x \in \partial\tilde{\Omega}(y)$. However, the necessary condition for choice of y requires that the subgradient of $\tilde{\Omega}$ contain an element less than -1 if $\mu_L > 0$. This yields a contradiction so we must have $\mu_L = 0$ and $-\tilde{\Omega}'(y) = 1$.

These results allow us to characterize the optimal contracts for $V_L > V_L^{**}$ in the manner discussed in the text.

(bi) Suppose $V_L < V_L^*$ and $T_L \ge 0$. In this case the argument proceeds exactly as in the previous case to establish that the optimal contract will have $t_L = s_S = \mu_S = 0$, $t_S > 0$, $\mu_L + \sigma = 1$, and $-\tilde{\Omega}'(y) = 1$. An explicit relationship between V_L and t_S in this region can then be attained from (ICL), which requires that $V_L = W_L(t_L^N, t_S) + \delta V_L^N$. Using the separability of W_L, it follows that (s_L, y) must satisfy $s_L \ge 0$, $y \in [V_L^*, V_L^{**}]$, and $-s_L + \delta y = W_L(t_L^N, t_S) - W_L(0, t_S) + \delta V_L^N = W_L(t_L^N, 0) - W_L(0, 0) + \delta V_L^N = -T_L + \delta V_L^*$.

(bii) If $T_L < 0$, then $V_L^* = W_L(t_L^N, 0) - T_L + \delta V_L^N$. For $V_L \in [W_L(t_L^N, 0) + \delta V_L^N, V_L^*)$, a first-best payoff level is attainable by setting $s_S = V_L - W_L(t_L^N, 0) - \delta V_L^N$ and $y = V_L^*$. The former condition ensures that (ICL) is satisfied with equality, and the latter yields the desired payoff to L.

For $V_L < W_L(t_L^N, 0) + \delta V_L^N$, satisfaction of (ICL) will require $t_S > 0$ and $s_S = 0$. The argument then proceeds as in (bi) to establish that $t_L = s_S = \mu_S = 0$, $\mu_L + \sigma = 1$, and $-\tilde{\Omega}'(y) = 1$. As in (bi), the terms (s_L, y) must satisfy $s_L \ge 0$, $-s_L + \delta y = \delta V_L^*$, and $y \in [V_L^*, V_L^{**}]$. ||

Proof of Proposition 3. For the case of concave U_S, we introduce the operator $\hat{T}$ which is defined on the cone of upper semicontinuous functions:

$$(\hat{T}f)(V_L) = \sup\nolimits_{t_L, t_S, s_L, s_S, y \in B[f](V_L)} U_S(W_S(t_L, t_S) + s_L - s_S) + \delta f(y), \qquad \text{(A.7)}$$

where $B[f](V_L) = \{t_L, t_S, s_S, s_L, y \mid (PL), (ICL), (ICS)$ *and* $t_L, t_S, s_S, s_L \ge 0$ *are satisfied*$\}$. The argument in Lemma 3 can be used to establish that $\tilde{\Omega}$ is a fixed point of $\hat{T}$, and that $\tilde{\Omega}$ will be upper semicontinuous. Since the set $B[f](V_L)$ is non-increasing in V_L, $\tilde{\Omega}$ will be non-increasing in V_L and hence differentiable almost everywhere. Furthermore, we show in Bond and Park (1998) that $\tilde{\Omega}$ is differentiable at V_L^* and V_L^{**} with $\tilde{\Omega}'(V_L^*) = \Omega^{*\prime}(V_L^*)$ and $\tilde{\Omega}'(V_L^{**}) = \Omega^{*\prime}(V_L^{**})$.

The following result, which uses the operators $\hat{T}$ and $B[f]$ defined in (A.7), will be useful in establishing the properties of $\tilde{\Omega}$:

Lemma A.2. *Suppose that $f(V_L)$ is an upper semicontinuous, non-increasing function with the following properties:*
(I) $\tilde{\Omega} \le f \le \Omega^*$ for all V_L such that $B[f](V_L) \ne \phi$. (II) f concave on $[V_L^N, V_L^*]$. If U_S is strictly concave, then

- (A) *The solution to the optimization problem* (A.7) *has the properties that* (ICL) *binds on* $[V_L^N, V_L^*)$, (ICS) *is slack on* $[V_L^N, V_L^*)$, $s_L = 0$, $t_L > 0$, *and* $y < V_L^*$.
- (B) $\hat{T}f(V_L)$ *is an upper semicontinuous, non-increasing function that satisfies properties* (I)–(II).

Proof. (A) We prove (A) by showing that these properties hold for the solution to the optimization problem $\hat{T}_g$, where $g = f$ for $V_L \le V_L^*$ and $g = \Omega^*$ for $V_L > V_L^*$. Since we will show that $y < V_L^*$ for the problem $\hat{T}_g$, the contract terms that solve $\hat{T}_g$ will also solve $\hat{T}_f$ because $f \le g$ for $V_L > V_L^*$.

(ICS slack). If $s_L = 0$, the fact that $\hat{T}[g](V_L) > \tilde{\Omega}(V_L^{**}) \ge U_S(W_S(t_L)) + \delta V_S^N$ implies that (ICS) is slack for $V_L < V_L^*$. Suppose that $s_L > 0$ and (ICS) is binding, which requires $g(y) = V_S^N$. It follows from (13c) and (13d) that $U_S'(W_S(t_L) + s_L)/(1 + \mu_S) = -g'(\Omega^{*-1}(V_S^N)) = U_S'(W_S^N)$, and hence $W_S(t_L) + s_L \le W_S^N$ by the strict concavity of U_S. This would imply $\hat{T}[g](V_L) \le V_S^N$, which is a contradiction since $\hat{T}[g](V_L) > \tilde{\Omega}(V_L^{**})$.

(ICL binds). If (ICL) is slack, then the necessary conditions for optimization (given by (13a)–(13d) with $\mu_S = \mu_L = 0$) require that $t_L = 0$ and

$$-U_S'(W_S(0) - s_S + s_L) \in \partial g(y)\cdot \tag{A.8}$$

If (ICL) is slack with $t_L = 0$ we have $-s_L + \delta y \geq W_L^N + \delta V_L^N = \delta V_L^*$, where the equality follows from the fact that (ICL) holds with equality at V_L^*. This implies $y \geq V_L^*$. The payoff to L will satisfy $V_L = s_S - s_L + \delta y < V_L^* = -T_L + \delta V_L^*$, so $s_S - s_L + T_L < \delta(V_L^* - y) \leq 0$ and $U_S'(W_S(0) - s_S + s_L) < U_S'(W_S(0) + T_L) = -g'(V_L^*)$. Therefore, for (A.8) to be satisfied we must have $y < V_L^*$ by the concavity of g. However, this contradicts our result that $y \geq V_L^*$ if (ICL) is slack. Therefore, (ICL) must bind.

($s_L = 0$). Suppose $s_L > 0$. This will require $t_L = 0$, as can be seen by substituting (13c) into (13a). With (ICL) binding, $V_L = V_L^N + s_S$ and $s_L > 0$ implies $V_L = V_L^N$. Substituting this result into (PL) yields $s_L = \delta(y - V_L^*)$. The payoff to S under this contract is given by $U_S(W_S(0) + s_L) + \delta g(V_L^* + s_L/\delta)$. However, the payoff under this contract is maximized by choosing $s_L = 0$, since $U_S'(W_S(0) + s_L) < U_S'(W_S(0) + T_L) \leq -g'(V_L^* + s_L/\delta)$ by the strict concavity of U_S, the definition of g, and $y > V_L^*$. Therefore, we have a contradiction with the assumption that $s_L > 0$.

($t_L > 0, y < V_L^*$). From (13a) and (13b), it follows that $s_S > 0$ and $\mu_L > 0$ are sufficient to ensure $t_L > 0$. If $s_S = 0$, the fact that (ICL) is binding requires that the choices of t_L and y satisfy $V_L^N = W_L(t_L) + \delta y$. Substituting this result into the payoff for S yields $U_S(W_S(t_L)) + \delta g((V_L^N - W_L(t_L))/\delta)$. Differentiating this expression with respect to t_L and evaluating at $t_L = 0$ yields $U_S'(W_S(0))(\partial W_S/\partial t_L) + U_S'(W_S(0) + T_L)(\partial W_L/\partial t_L)$. This expression must be positive from the fact that $\partial W_W/\partial t_L = 0$ at $t_L = 0$, U_S is strictly concave, and $T_L < 0$. Therefore, we must have $t_L > 0$. The fact that (ICL) binds at V_L and V_L^* yields $\delta(y - V_L^*) = -W_L(t_L) < 0$. Therefore, $y < V_L^*$.

This establishes that the solution to $\hat{T}[g]$ satisfies (A) of the Lemma. It then follows that the solution to $\hat{T}[f]$ has the same properties by the above argument.

(B) $\hat{T}f$ satisfies (I): From the definition of $\hat{T}f$, the fact that it is non-decreasing in f, and the fixed point property of $\tilde{\Omega}$, we have $\Omega^* \geq \hat{T}\Omega^* \geq \hat{T}f \geq \hat{T}\tilde{\Omega} = \tilde{\Omega}$.

$\hat{T}f$ satisfies (II): Choose $V_L, V_L' \in [V_L^N, V_L^*]$ and let $a = \{t_L, s_S, s_L, y\}$ and $a' = \{t_L', s_S', s_L', y'\}$ be the associated actions that maximize the objective function. Defining $V_L^\lambda = \lambda V_L + (1 - \lambda)V_L'$, we define the action a^λ to be $y^\lambda = \lambda y + (1 - \lambda)y'$, $t_L^\lambda = \lambda t_L + (1 - \lambda)t_L'$, $s_S^\lambda = \max(0, -Z)$, and $s_L^\lambda = \max(0, Z)$ where $Z = W_L(t_L^\lambda) - \lambda[W_L(t_L) + s_S - s_L] - (1 - \lambda)[W_L(t_L') + s_S' - s_L']$. It can then be shown that a^λ is feasible and yields a payoff exceeding $\lambda T[f](V_L) + (1 - \lambda)T[f](V_L')$ using an argument identical to that in the proof of Lemma A.1. ||

Since the first-best frontier is continuous, decreasing, and concave it satisfies the conditions of Lemma A.2. It then follows by induction that the function $T^n\Omega^*$ is concave on $[V_L^N, V_L^*)$ for all n by Lemma A.2. The limit of this sequence, which is $\tilde{\Omega}$ by Lemma 3, will also be concave on $[V_L^N, V_L^*)$, which proves part (a) of the proposition.

Since $\tilde{\Omega}$ satisfies the conditions of Lemma A.2, Lemma A.2 (A) yields $\mu_L > 0$, $t_L > 0$, $\mu_S = t_S = s_L = 0$, and $y < V_L^*$. (ICL) will be slack with $s_S = 0$ for $V_L > V_L^N$, so $s_S > 0$. With $y < V_L^*$, we must have $\mu_L(i), \mu_L(i + 1) > 0$ and $\mu_S(i) = \mu_S(i + 1) = 0$. Since (13b) must hold at i and $i + 1$, it follows that $\mu_L(i) = U_S'(W_S(t_L(i + 1)) - s_S(i + 1)) - U_S'(W_S(t_L(i)) - s_S(i)) > 0$. By the strict concavity of U_S, $W_S(t_L(i)) - s_S(i)$ is a decreasing sequence. It then follows that $V_S(i)$ is a decreasing sequence on the interval $[\tilde{\Omega}(V_L), \Omega^*(V_L^*))$, and hence will have a limit in $[\tilde{\Omega}(V_L), \Omega^*(V_L^*)]$. Note that $V_L(i)$ will then be an increasing sequence on $[V_L, V_L^*)$, since $\tilde{\Omega}$ must be decreasing in V_L for $V_L > V_L^{\min}$. The sequence $W_S(t_L(i)) - s_S(i)$ must be bounded below by $W_S(0) + T_L$ and will be convergent, so the sequence $U_S'(W_S(t_L(i)) - s_S(i))$ will be bounded above by $U_S'(W_S(0)) + T_L)$ and will be convergent. Since this sequence must be a Cauchy sequence, it follows that $\lim_{i\to\infty} \mu_L(i) = U_S'(W_S(t_L(i+1)) - s_S(i+1)) - U_S'(W_S(t_L(i)) - s_S(i)) = 0$. Since $\mu_L > 0$ for all $V_L < V_L^*$, we must have $\lim_{i\to\infty} V_L(i) = V_L^*$.

Since (ICL) binds at i and $i+1$, $s_S(i+1) - s_S(i) = V_L(i+1) - V_L(i) > 0$. A binding (ICL) also implies that $W_L(t_L(i)) + \delta y(i) = V_L^N$, which when combined with the previous result yields $W_L(t_L(i)) - W_L(t_L(i+1)) = \delta(y(i+1)) - y(i)) > 0$ and $t_L(i)$ will be a decreasing sequence. Rewriting (13a) using $\partial W_W/\partial t_L = -t_L(B+\beta)$ and $\partial W_S/\partial t_L = -\alpha_2^S + \alpha_2^L + (B + \beta)t_L$, we obtain $t_L = \mu_L(\alpha_2^S - \alpha_2^L)/[(B+\beta)(\sigma + 2\mu_L)]$. Therefore, $\lim_{i\to\infty} \mu_L(i) = 0$ implies $\lim_{i\to\infty} t_L(i) = 0$. ‖

Proof of Proposition 4. ($s_S > 0$). Suppose $s_S = 0$. (ICS) requires $\tilde{\Omega}(y) \geq V_S^N$ in this case, so (ICS) must be slack if $\tilde{\Omega}(y) > V_S^N$. Suppose $\tilde{\Omega}(V_L) \leq V_S^N$. (ICS) can only be satisfied in this case if $t_L \geq t_L^N$. However, (13a) can be rewritten as $[U_S'(W_S - s_S + s_L)(1 + \mu_S) - U_S'(W_S + s_L)\mu_S](\partial W_S/\partial t_L) + (\mu_L + \sigma)(\partial W_L/\partial t_L) \leq 0$. This expression must be strictly negative when evaluated at $t_L \geq t_L^N$ because the first term will be negative and the second term will be non-positive with $\sigma > 0$. Therefore, we must have $t_L < t_L^N$ in the negatively sloped region of the efficient frontier and hence $\tilde{\Omega}(V_L^{\max}) > V_S^N$. This establishes that (ICS) is slack if $s_S = 0$. Similarly, (ICL) requires $V_L \geq V_L^N + s_S$, which must be satisfied if $s_S = 0$. With $\mu_S = \mu_L = 0$, (13a)–(13c) implies $t_L = 0$ and (13b), (13c) imply $U_S'(W_S(0) + s_L) = \sigma$. Denote the time at which $s_S = 0$ as time 1, and let time i denote the first time $i > 1$ at which $s_S(i) > 0$. Since $\mu_S(j) = \mu_L(j) = 0$ for $j < i$, repeated application of (13d) yields $\sigma(i) = \sigma(1)$. We have from (13b) that $(1 + \mu_S(i))U_S'(W_S(t_L) - s_S(i)) = U_S'(W_S(0) + s_L(1))$, which requires $W_S(t_L(i)) - s_S(i) > W_S(0) + s_L(1)$ by the strict concavity of U_S. This yields a contradiction since W_S is decreasing in $t_L = 0$, so $s_S(i) = 0$ and $t_L(i) = 0$ for all $i > 0$. However, such an agreement would imply a first-best outcome with a payoff to L of at most V_L^N, which contradicts $V_L > V_L^{**}$. Therefore we must have $s_S(i) > 0$ for all i.

($y > V_L^{**}$ and $\mu_L = 0$) with $s_S > 0$, we can use (13b) and (13d) to obtain

$$U_S'(w_S - s_S) + \frac{\mu_L}{1 + \mu_S} \in -\partial\tilde{\Omega}(y), \tag{A.9}$$

where (A.9) allows for the possibility that $\tilde{\Omega}$ is not differentiable at y. Suppose that U_S is strictly concave and $y \leq V_L^{**}$. $\tilde{\Omega}$ is concave on $[V_L^N, V_L^{**}]$ and differentiable at V_L^{**}, so (A.9) yields $U_S'(W_S(t_L) - s_S) \leq -\tilde{\Omega}(V_L^{**}) = U_S'(W_S - T_S)$. With U_S strictly concave, $U_S(W_S(t_L) - s_S) \geq U_S(W_S(0) - T_S)$. Furthermore, $y \leq V_L^{**}$ yields $\tilde{\Omega}(y) \geq \tilde{\Omega}(V_L^{**})$. Together these inequalities imply $\tilde{\Omega}(V_L) \geq \tilde{\Omega}(V_L^{**})$, which is a contradiction because $\tilde{\Omega}(V_L) < \Omega^*(V_L) < \tilde{\Omega}(V_L^{**})$ for $V_L > V_L^{**}$ from the properties of the first-best frontier. Therefore, $y > V_L^{**}$. With $s_S > 0$, (ICL) requires that $W_L(t_L) + \delta y V_L^N$. The fact that (ICL) is satisfied at V_L^{**} with $t_L = 0$ yields $\delta V_L^{**} > V_L^N$, so $y > V_L^{**}$ and the fact that $W_L(t_L) \geq 0$ is sufficient to ensure $\mu_L = 0$ and $t_L > 0$.

($\mu_S > 0$). Suppose that $\mu_S = 0$, which would require $t_L = 0$ from (13a)–(13c). The fact that (ICS) binds at V_L^{**} yields $\Omega^*(V_L^{**}) = U_S(W_S(0) - T_S(\delta)) + \delta\Omega^*(V_L^{**}) = U_S(W_S(0)) + \delta V_S^N$. For $V_L > V_L^{**}$ we have $\tilde{\Omega}(V_L) < \Omega^*(V_L) < \Omega^*(V_L^{**})$ which would be a violation of (ICS) with $t_L = 0$. This yields a contradiction, so $\mu_S > 0$.

With $s_S > 0$ and $\mu_L = 0$, the necessary condition (13b) for choice of s_S at time i is $(1 + \mu_S(i))U_S'(W_S(t_L(i)) - s_S(i)) = \sigma(i)$. Since $y(i) > V_L^{**}$, we must also have

$(1+\mu_S(i+1))U_S'(W_S(t_L(i+1))-s_S(i+1)) = \sigma(i+1)$. Since $-\sigma(i+1) \in \partial\tilde{\Omega}(y)$ by the envelope condition, it follows from (13d) and these two necessary conditions that $(1+\mu_S(i+1))U_S'(W_S(t_L(i+1))-s_S(i+1)) = U_S'(W_S(t_L(i))-s_S(i))$. With strictly concave U_S this implies that $W_S(t_L(i))-s_S(i) < W_S(t_L(i+1))-s_S(i+1)$. Since this holds for all i, we have $\tilde{\Omega}(i) < \tilde{\Omega}(i+1)$. The fact that (ICS) binds at i and $i+1$ with $s_S > 0$ implies $U_S(W_S(t_L(i+1)) > U_S(W_S(t_L(i))$, so $t_L(i)$ will be a decreasing sequence. A binding (ICS) also implies that $\delta(\tilde{\Omega}(i+2)) - \tilde{\Omega}(i+1)) = (U_S(W_S(t_L(i+1))) - U_S(W_S(t_L(i+1) - s_S(i+1))) - (U_S(W_S(t_L(i))) - U_S(W_S(t_L(i) - s_S(i))) > 0$, which requires $s_S(i)$ be an increasing sequence.

The sequence $W_S(t_L(i)) - s_S(i)$ is increasing and is bounded above by $W_S(0) - T_S(\delta)$, so it must achieve a limit, as will the decreasing sequence $U_S'(W_S(t_L(i)) - s_S(i))$. Since $U_S'(W_S(t_L(i)) - s_S(i))$ is a Cauchy sequence, the sequence $U_S'(W_S(t_L(i)) - s_S(i)) - U_S'(W_S(t_L(i+1))-s_S(i+1)) = \mu_S(i+1)U_S'(W_S(t_L(i+1)) - s_S(i+1))$ must converge to zero, which requires that μ_S converge to zero. The necessary condition for choice of t_L in (13a) can be expressed as $t_L(i) = [\mu_S(i)U_S'(W_S(t_L(i)))(\alpha_2^S - \alpha_2^L)]/[(\sigma + \mu_S(i)U_S'(W_S(t_L(i)))(B+\beta)]$, which will converge to zero as $\mu_S(i)$ converges to zero. ||

Proof of Proposition 5. The major difference between the optimization problem in (18) and that in (7) for the infinitesimally-small-country case is that the deviation payoff for L is a function of t_L. It is straightforward to prove Lemma A.1 for this case. Specifically, the fact that $W_L^D(t_L)$ is convex in t_L (Lemma 5) ensures that inequality in (A.6) will hold in this case. This result can then be used to prove that $\tilde{\Omega}$ is continuous, concave, and non-increasing as in Lemma 3.

Since $\tilde{\Omega}$ is differentiable almost everywhere, we can characterize the contract terms by forming the Lagrangian for (18). The necessary conditions for t_L and s_L become

$$(\mu_L + \sigma - 1)\frac{\partial W_L}{\partial t_L} + \left(\frac{\partial W_S}{\partial t_L} + \frac{\partial W_L}{\partial t_L}\right) - \mu_L \frac{\partial W_L^D}{\partial t_L} \leq 0, \quad \text{with equality if } t_L > 0, \tag{A.10a}$$

$$1 - \mu_L - \sigma \leq 0, \qquad \text{with equality if } s_L > 0. \tag{A.10b}$$

Since $\partial W_L^D/\partial t_L < 0$, we have both $\mu_L > 0$ and $\mu_L + \sigma > 1$ as sufficient conditions for $t_L > 0$. Note that in contrast to the result of Lemma 4, $s_L > 0$ is not sufficient to ensure $t_L = 0$. It can be shown using the same arguments as in the proof of Proposition 2(a) that for $V_L > V_L^{**}$, we will have $\sigma = 1 + \mu_S > 1$, $\mu_L = 0, s_S \geq 0$, and $t_L > 0$. This yields a two step adjustment as in Proposition 2a, and the frontier in this region can be derived as in footnote 11. Part (b) can be proven by noting that if $V_L \in [W_L^D(0) + \delta\hat{V}_L^N, V_L^*)$, a first-best payoff level can be constructed by setting $s_S(1) = V_L - W_L^D(0) - \delta\hat{V}_L^N$ and $y = V_L^*$.

For $V_L < W_L^D(0) + \delta\hat{V}_L^N$, (ICL) will be violated for any agreement with $t_L = 0$ and payoffs to S must be below the first-best level. It then follows from the concavity of $\tilde{\Omega}$ that $\sigma < 1$ in this region, which can be substituted into the necessary condition for choice of s_S to establish that $s_S = 0$. Condition (A.10b) requires $\sigma + \mu_L \geq 1$, so $\mu_L > 0$ and (ICL) will hold with equality in this region. We will derive the remaining contract terms under the assumption that $\mu_S = 0$, and then show that (ICS) is slack in the resulting contract. With $s_S = 0$, we must choose $t_L \ni V_L = W_L^D(t_L) + \delta\hat{V}_L^N$ for (ICL) to be satisfied. Let $V_L^{\min} = \inf\{V_L | \sigma > 0$ for all $\sigma \in -\partial\tilde{\Omega}(V_L)\}$. For $V_L \in (V_L^{\min}, W_L^D(0) + \delta\hat{V}_L^N)$, (PL) and (ICL) will hold with equality which requires $s_L = W_L(t_L) - W_L^D(t_L) + \delta(y - \hat{V}_L^N)$ and $s_L \geq 0$. In this region, we can find the optimal contract by substituting this expression for s_L into V_S and choosing y to maximize V_S. The necessary condition for choice of y yields $-\tilde{\Omega}'(y) = 1$ if $s_L > 0$. This necessary condition is satisfied for $y \in [V_L^*, V_L^{**}]$, since these contracts are first-best and will satisfy $s_L > 0$. WLOG choose $y = V_L^*$ and $s_L = W_L(t_L) + W_L^D(0) - W_L^D(t_L) > 0$ for $t_L > 0$. This contract satisfies (ICS) because $\Omega^*(V_L^*) > \hat{V}_L^N$. The payoff to S under this agreement is $V_S(t_L) = W_S(t_L) + W_L(t_L) - W_L^D(t_L) - \delta(V_W(0) - V_L^N)$, where $V_W(0) = W_S(0)/(1-\delta)$ is the discounted world surplus under free trade. Since $\psi(t_L) \equiv W_S(t_L) + W_L(t_L) - W_L^D(t_L)$ is concave in t_L with $\psi'(0) > 0$ and $\psi'(\hat{t}_L^N) < 0$, there will exist a value $V_L^{\min} \in (\hat{V}_L^N, W_L^D(0) + \delta\hat{V}_L^N)$ at which the payoff to S is maximized. For $V_L < V_L^{\min}$, (PL) will be slack and hence $\tilde{\Omega}'(V_L) = 0$. Thus, for $V_L \in [\hat{V}_L^N, W_L^D(0) + \delta V_L^N)$ the optimal contract will have a positive tariff in the first period followed by a jump to a payoff in the first-best region in subsequent periods. ||

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