Perpetual Trade Liberalization[1]

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Current version, April 2001

Abstract: If the costs of going back on previously agreed tariff reductions are high relative to the terms of trade gains, then the multilateral liberalization process becomes 'perpetual'. Perpetual trade liberalization has two unique characteristics. (i) No 'efficient' tariff level exists at which liberalization stops. (ii) Some liberalization must occur in *every* period. International agreements and institutions that foster cooperation do so by making protectionist reversion costly. The theoretical model presented in this paper shows that consequently participating countries implicitly sign up to a liberalization process that must be continuously ongoing, but that this cannot achieve free trade.

Keywords. Gradualism, Perpetual trade liberalization, Trade agreement, World Trade Organization (WTO).

JEL Classification Numbers: F02, F13, F15, C73.

[1]We would like to thank Kar-yiu Wong for helpful comments and conversations about this paper. Any errors are our own. Support from the ESRC's Centre for the Study of Globalisation and Regionalisation, University of Warwick, is gratefully acknowledged.

1. Introduction

Most international agreements concerning trade liberalization are phased. Periods of time are agreed over which a set of liberalization measures are to be implemented, at the end of which the parties to the agreement reconvene to set a new timetable for further measures. For example, since the General Agreement of Tariffs and Trade (GATT) was drawn up after the war, there have been eight rounds of tariff negotiations as a result of which tariffs have fallen from an average of 50 percent, to around 5 percent today[2]. Officials working within the organizational structure of such agreements emphasize the importance of the process itself in achieving closer integration. Upon completion of the Uruguay Round, the eighth in GATT's history, the Director General, Peter Sutherland, had this to say:

> "The new agreements, the new rules and structures it sets up - all mean a commitment to a continuing process of cooperation and reform."
> (*Focus GATT Newsletter* 105, 5)

A body of literature exists that explains why liberalization may be gradual, which is grounded in economic costs of liberalization at the level of the domestic economy. The purpose of this present paper is to propose, for the first time to our knowledge, a framework in which the process is motivated by political costs at the *international* level, exhibiting its own unique set of characteristics. The result is a theory of 'perpetual trade liberalization'.

Of course, it is well known from the theory of repeated games that any efficient self-enforcing agreement to cut tariffs involves immediate adjustment to the lowest sustainable[3] level of tariffs. Since the late 1970s a literature has developed that can explain

[2] The same sort of thing occurs in regional agreements. Under the North American Free Trade Agreement (NAFTA) the market integration measures between its three members, Canada, Mexico and the US, are to be introduced over 10 years at which point, it is anticipated, more initiatives will be drawn up. And since the European Economic Community was founded with the Treaty of Rome in 1957 an ongoing process has resulted in an ever more integrated regional market. However, the present discussion focuses on the more straightforward multilateral case, where all parties are equal participants. The more complex regional case, where parties can treat one another differentially, is left to future research.

[3] By sustainable, we mean the smallest tariff where any country cannot gain by deviation to a higher tariff, knowing that this deviation will be punished by all countries reverting to the non-cooperative tariff, either temporarily or permanently.

why trade liberalization is gradual; the impossibility of jumping straight to the efficient tariff level. But this literature does not explain the feature emphasized so often in Geneva[4] that it is essential for negotiating rounds, or the implementation of measures agreed during the rounds, to be in progress at all times in order for the process to work at all. In formal terms, equilibrium paths exist in models of gradualism where trade liberalization can pause, stop permanently, or even go into reverse. Under our framework, trade liberalization must be 'perpetual'.

Perpetual trade liberalization has two characteristics that do not exist in any other theory of trade liberalization as far as we know. First, no 'efficient' tariff level exists at which liberalization stops. Therefore, participants make '...a commitment to a continuing process of cooperation...'. Second, some liberalization must occur in *every* period along the liberalization path[5].

The motivation for perpetual trade liberalization depends on the restriction of agents' ability to cheat on the agreement, and on their ability to punish deviators. The incentive to cheat, and the ability to punish are the two key factors conventionally thought to be necessary for a 'tacit' trade agreement in a repeated game. In real life, institutional constraints limit the actions of countries in both these respects. The formal approach of this paper is to ask whether an agreement is actually possible under a polemical extreme in which both the costs of cheating on an agreement and on the ability to punish are higher than the terms of trade benefits from doing so. The answer is that an agreement is possible, but that trade liberalization becomes 'perpetual' as a result.

Limiting the costs of cheating in the first place, Article 2 of GATT (1994) in the Charter of the WTO specifies that a schedule of commitments be maintained. Results of tariff negotiations are dutifully recorded as scheduled commitments in the form of tariff bindings; a permanent and irrevocable commitment that tariffs will never rise above bound levels for the product in question. Tariff bindings under GATT/WTO *de facto* have acquired the status of an international commitment comparable to that of other

[4] We refer to Geneva not just because it is home to the WTO, and the GATT before that, but because many international negotiations have taken place there, and there is a body of officials from many different organizations who reflect this basic point of view.

[5] In other theories, where trade liberalization is gradual, there are equilibrium paths in which trade liberalization can occur in every period between the initial reduction and the final efficient tariff. But unlike for perpetual trade liberalization, this is not necessarily a feature of the process.

international treaties. Bindings, if committed to, effectively slot into a box of enshrined cross country commitments comparable to military and diplomatic treaties. Violation of tariff bindings brings into question the soundness of a country's financial commitments, its trustworthiness in strategic and military matters, its diplomatic reputation. Violating tariff bindings has large costs outside the tariff area. In this spirit, we assume that the political costs of raising tariffs above agreed bindings are higher than the terms of trade gains from doing so. Consequently, deviants cannot credibly threaten to raise tariffs against other countries; the worst that they can do is to fail to implement newly agreed measures.

Limiting the ability of countries to retaliate is the GATT/WTO ruling on the 'Withdrawal of equivalent concessions' which stipulates that retaliation is not allowed to go beyond the violation by the deviating country. If the political costs incurred by deviants mean that they do not raise tariffs, the worst punishment allowable by retaliating nations is to also suspend implementation of further liberalization measures. If retaliatory action goes further than this then it is assumed to incur the same political costs as an initial violation of tariff bindings. Unlike in the traditional theory of repeated tariff games, reversion to 'optimal tariffs' may be 'too costly' as a strategy of punishment in our model.

If the worst credible action both by deviators and by retaliators is simply to halt liberalization, it turns out that any (subgame-prefect) efficient equilibrium path of tariff reductions must involve perpetual liberalization and a positive asymptotic tariff. The reasoning is as follows. Each negotiating party must not concede too much in each round of reductions. If they do, their partners in negotiation will renege on the reductions agreed in this round (and implicitly those that would have happened in the future), safe in the knowledge that they will not be punished because the costs of doing so are too high. Now, there are any number of such efficient equilibrium paths; the key point is that every single one of them exhibits perpetual trade liberalization. The most efficient tariff path is the one where the maximum possible liberalization is achieved without inducing partners to renege.

There is a very important point in this. Free trade cannot be reached in equilibrium. This is because the only mechanism to maintain currently negotiated market access concessions in the absence of a punishment is the promise of future tariff reductions. Put figuratively, countries lose the stick and have only carrots, so there must be a future supply of carrots at all times.

Our model is innovative in that the efficient tariff reduction path necessarily implies ongoing trade liberalization *ad infinitum*; tariffs are cut in *every* period. Momentum is important in the process because current liberalization is always motivated partly by the prospect of more liberalization in the future. As a result, if there is no prospect for future trade negotiations, current liberalization must cease as well. For example, suppose that a disagreement in some area not directly related to trade, such as international security or the environment, threatens a breakdown of cooperation in the future between two nations. Then under our model it may be rational to hold back on liberalization efforts not just in the future but today as well. Suspension of trade relations in response to seemingly unrelated international issues is often threatened or even enacted in the political arena[6]. But dependency of current concessions on future liberalization has not featured in previous theories of gradual trade liberalization[7].

1.1. Related Literature

Since the late 1970s, a literature has developed which tries to explain gradual trade liberalization. Early contributions tried to explain why a country would *unilaterally* (i.e. independently of behavior of other countries) wish to gradually reduce its import tariffs. The first kind of explanation for unilateral gradualism is driven by the assumption that there are costs of adjustment in moving resources out of import-competing industries to other activities (Leamer 1980, Mussa 1986). Mussa explicitly assumes convex costs of adjustment in a multi-period setting, so it follows directly that adjustment should be

[6]Some commentators suggested that the collision between a US and Chinese military aircraft threatened to decend into a new cold war. Just one week after the crisis broke, some US senators were already advocating a suspension of normal trading relations with China, and blocking their entry to the WTO. ("Seeing red" *Economist* 7^{th} April, 2001).

[7]There can be no question that the balance between the political costs imposed by protectionist reversion and the terms of trade gains varies across countries and regional blocks acting collectively. The US, European Union and Japan, as the largest buyers on world markets, may sometimes be in a position where their terms of trade gains from protectionism are greater than the political costs, in which case the reaching of agreements may be more rapid than under our characterization. We take this simplifying approach to make tractable the analysis of a relatively subtle and complex balance of opposing forces. The result is a polemical characterization of perpetual trade liberalization, which may be less severe in practice than our model suggests.

gradual, and the costs of adjustment are implicitly convex in Leamer[8].

Gradualism can also be explained by the political economy of tariff adjustment in declining industries. Cassing and Hillman (1986) have a model where, following an exogenous negative shock in the world price, the import-competing sector can lobby the government for tariff protection. The level of the tariff is assumed to depend positively on the current level of employment in the sector. However, they focus on industry collapse (with the tariff falling to zero) rather than on gradual adjustment. Brainard and Verdier(1994) endogenize the relationship between employment and tariff via an explicit model of lobbying and find that adjustment will be gradual (i.e. both the import tariff and employment in the declining industry fall gradually over time). However, the Brainard and Verdier model has strictly convex costs of adjustment, so a social planner would also choose gradualism.

Most recently, a few papers have considered the relationship between the *self-enforceability* of tariff agreements and their gradualism (Staiger(1995), Devereux(1997), Furusawa and Lai(1999)). The general idea is that initially, full liberalization cannot be self-enforcing, as the benefits of deviating from free trade are too great to be dominated by any credible punishment. But if there is partial liberalization, structural economic change reduces the benefits of deviation from further trade liberalization (and/or raises the costs of punishment to the deviator). The individual papers differ in their description of the structural change induced by partial liberalization. Staiger(1995) endows workers in the import competing sector with specific skills, making them more productive there than elsewhere in the economy. When they move out of this sector, they lose their skills with some probability. In Devereux(1997), there is dynamic learning-by-doing in the export sector. In Furusawa and Lai(1999), there are linear[9] adjustment costs incurred when labor moves between sectors[10].

[8] His adjustment cost, measured in labour units, is proportional to the number of workers who move out of the import-competing sector. But as output is a concave function of output, adjustment costs measured in units of output are convex i.e. a 1% of the number of workers moving leads to more than a 1% decrease in output.

[9] Furusawa and Lai have an Appendix where they show that with strictly convex adjustment costs, a social planner would choose gradual tariff reduction.

[10] Because of the existence of adjustment costs, adjustment is not eventually to free trade, but to a positive tariff where the marginal world benefit from tariff reduction is equal to the resulting marginal cost of adjustment (Furusawa and Lai, Section 3). Also note that an equilibrium path can be derived in their model that has tariff cutting in every period (Furusawa and Lai, Figure 2). But their concept of

Our approach, whilst also requiring self-enforceability, is clearly different to these papers just cited. We assume that there is no explicit economic linkage between time periods, just a cost of *reversing* previous tariff cuts. Our specific results are also somewhat different from the existing literature. While we have gradualism in equilibrium, the main distinguishing feature of our analysis is that tariff reductions must be *perpetual*. The implications are that neither free trade nor an efficient tariff at which liberalization stops can ever be reached[11].

We would not wish to dispute that the WTO, and the GATT that preceded it, represents a vital institutional mechanism by which postwar trade liberalization has been achieved; a principle that is widely recognized, and formally stated by Bagwell and Staiger (1999). Our point of emphasis is this. Given the ubiquitous incentive for each country to cheat unilaterally, a necessary part of the WTO's institutional mechanism is to impose limits on countries ability to act on this incentive. And it is the associated costs that have, at least partly, caused liberalization in the post-war period to be gradual. In keeping with the multilateral focus of this present argument, we depart from previous research in this area by specifying a model of n countries, and general pay-offs (subject only to the restriction that countries be symmetric).

One idea that has been associated with gradualism is that if negotiating rounds fail then there will be a collapse back to higher levels of protectionism. This idea was first discussed informally by Bergsten (1975, page 209-24), and dubbed the 'bicycle' theory by Bhagwati (1988), who borrowed the term from policy circles. The issue was first addressed formally by Staiger (1995), whose model has the property that if a round of trade liberalization fails then protectionism does indeed escalate back to the level of the previous round. The emphasis under this interpretation of the bicycle theory is on the balance of protectionist versus liberalizing pressures within the domestic economy, and the role of the negotiating rounds in helping the trade liberalizing pressures to prevail.

However, the bicycle theory has received an alternative interpretation in the WTO

equilibrium does not *necessarily* require this; alternative paths could be derived in which trade liberalization pauses, and then starts up again. Their emphasis is, instead, on the fact that liberalization must be gradual.

[11] In Staiger, adjustment is always in a finite number of periods, and the last tariff level is zero. In Furusawa and Lai, adjustment is always in a finite number of periods, and the last tariff level, although not zero, is efficient.

itself, which has been documented by Whalley and Hamilton (1996, page 131.) In their view, the bicycle theory is interpreted directly in the spirit of the above quote by Sutherland, and formalized in the way that we model it in the present paper. Under this alternative interpretation, the emphasis of the bicycle theory is placed on the importance of building up momentum behind the process of negotiating rounds, much as one builds up momentum on a bicycle. Less weight, if any, is put on the collapse back to higher protectionism if the process fails. In this respect, our model can be seen as an alternative formalization of the bicycle theory.

The layout of the rest of the paper is as follows. Section 2 formulates the economic model, and the tariff reduction game. Section 3 gives the main results. In particular, the two characteristics of perpetual trade liberalization are established in Propositions 4 and 5. Proposition 6 shows that free trade cannot be reached. The properties of perpetual trade liberalization are illustrated with an example in Section 4, where the time-path of tariffs can be explicitly computed. Section 5 concludes.

2. The Tariff Reduction Game

2.1. Tariffs and Welfare

We work with a simple and standard model of international trade. There are n countries $i \in N$ and the same number of goods. Each country i has an endowment (normalized to unity) of good i (or is endowed with a factor of production that can produce 1 unit of good i). We denote by x_j^i the consumption of good j in country i. The preferences of the representative consumer in country i over $\mathbf{x}^i = (x_j^i)_{j \in N}$ are then[12]

$$u^i(\mathbf{x}^i) = u(x_i^i, \phi(\mathbf{x}_{-i})) \tag{2.1}$$

where $\mathbf{x}_{-i} = (x_1^i, ..x_{i-1}^i, x_{i+1}^i, ..x_n^i)$. The consumer in country i faces a budget constraint

$$\sum_{j=1}^{n} p_j(1 + \tau_j^i)x_j^i = p_i + R_i \tag{2.2}$$

where p_j, τ_j^i, R_i are respectively: the world price of good j, the tariff set by country i on good j, and tariff revenue in country i, which as is usually assumed, is returned to

[12] We adopt the usual convention that bold characters denote vectors, and non-bold chracters denote scalars.

the consumer in a lump-sum. Without loss of generality, we set $\tau_i^i = 0$; also note that $-1 < \tau_j^i < \infty$.

Within a period, $t = 1, 2, \ldots$, the order of events is as follows. First, each country i simultaneously chooses an import tariff vector $\boldsymbol{\tau}^i = (\tau_j^i)_{j \in N}$. Then, given world prices $\mathbf{p} = (p_j)_{j \in N}$, and $\boldsymbol{\tau}^i$, each the consumer in country $i \in N$ chooses $\mathbf{x}^i$ to maximize u_i subject to the budget constraint, which yields the usual indirect utility function $v^i = v^i(\mathbf{p}, \boldsymbol{\tau}^i, R_i)$ and excess demands. Then, conditional on $\boldsymbol{\tau} = (\boldsymbol{\tau}^1, ..\boldsymbol{\tau}^n)$, markets clear and world prices $\mathbf{p}$ for the goods are determined[13]. These world prices will of course depend on tariffs i.e. $\mathbf{p} = \mathbf{p}(\boldsymbol{\tau})$, and so will tariff revenues i.e. $R_i = \sum_{j=1}^n p_j(\boldsymbol{\tau})\, \tau_j^i x_j^i(\mathbf{p}(\boldsymbol{\tau}))$. We suppose that equilibrium prices are unique, given tariffs, so the mapping $\mathbf{p}(.)$ is one-to-one.

So, we can write equilibrium welfare of country i, w^i, as a function of $\boldsymbol{\tau} = (\boldsymbol{\tau}^1, ..\boldsymbol{\tau}^n)$ only i.e. $w^i = w^i(\boldsymbol{\tau}^1, ..\boldsymbol{\tau}^n) \equiv v^i(\mathbf{p}(\boldsymbol{\tau}), \boldsymbol{\tau}^i, R_i(\boldsymbol{\tau}))$. Now we can define a *Nash equilibrium in tariffs* in the usual way as a $\hat{\boldsymbol{\tau}}$ such that $w^i(\hat{\boldsymbol{\tau}}^i, \hat{\boldsymbol{\tau}}^{-i}) \geq w^i(\boldsymbol{\tau}^i, \hat{\boldsymbol{\tau}}^{-i})$, all $\boldsymbol{\tau}^i \in (-1, \infty)^n$, all $i \in N$. We will focus on Nash equilibria where (i) all countries set *common tariffs* i.e. $\hat{\tau}_j^i = \hat{\tau}^i$, all $i \in N$; (ii) all these common tariffs are *equal* $\hat{\tau}^i = \hat{\tau}$, all $i \in N$. Such equilibria exist for the special cases that we consider below, due to the symmetry of the model[14].

2.2. The Tariff Reduction Game

We are interested in how fast countries can reduce tariffs from this non-cooperative Nash equilibrium, and also whether they can ever reach free trade i.e. $\tau_j^i = 0$, if the tariff reduction plan must be *self-enforcing* i.e. the outcome of a subgame-perfect equilibrium. It is convenient to impose the constraint that the cooperative tariff reductions have the same structure as does the Nash equilibrium i.e. each country sets a common tariff, τ^i. In this case, we may write country welfare as a function of common tariffs only i.e. $w^i = w^i(\tau^i, \tau^{-i})$. We now have the following very useful result[15].

Proposition 1. *$w^i = w(\tau^i, \tau^{-i})$, and if $\pi(\tau^{-i})$ is any permutation of τ^{-i}, then* $w(\tau^i, \tau^{-i}) \equiv$

[13] As this is a general equilibrium model, prices are determined only up to a scalar, and so some normalization (e.g. choice of numeraire) must be made. This technical detail, and others, are dealt with in Section ? below.

[14] More generally, it is possible to show that if all $j \neq i$ set the same common tariff, the unique best response of i is to set the same tariff on imports on all countries i.e. a common tariff.

[15] This result, and all others, are proved in the Appendix, where a proof is required.

$w(\tau^i, \pi(\tau^{-i}))$.

So, the Proposition says that countries have symmetric preferences over (common) tariffs. For example, if $n = 3$, then $w^1 = w(\tau^1, \tau^2, \tau^3)$, $w^2 = w(\tau^2, \tau^1, \tau^3)$, $w^3 = w(\tau^3, \tau^1, \tau^2)$, and $w(\tau^1, \tau^2, \tau^3) = w(\tau^1, \tau^3, \tau^2)$ etc. We can now use the function w to formulate the tariff reduction game precisely. As we are focussing on tariff reductions, we will assume throughout that $\boldsymbol{\tau} = (\tau^1..\tau^n) \in [0, \hat{\tau}]^n = F^n$. First, we assume three properties of w:

A1. $w(\boldsymbol{\tau})$ is continuous, increasing in its first argument (and strictly so if $\tau^i < \hat{\tau}^i$) and strictly decreasing in its other arguments, for all $\boldsymbol{\tau}$.

A1 asserts that whenever other countries' tariffs are below Nash equilibrium, any country likes an increase in its own (common) tariff, and a reduction in the tariffs of the other countries. In other words, the static tariff game has a Prisoner's Dilemma structure. Our second assumption is very weak:

A2. $w(\tau...\tau)$ is strictly decreasing in τ for all $0 < \tau \leq \hat{\tau}$.

This says that any equal reduction in all tariffs, starting from a situation of equal tariffs below the Nash level, makes any country better off. Our third assumption can be stated as follows.

A3. $w(\tau'', \hat{\tau}^{-i}) - w(\tau', \hat{\tau}^{-i}) < (\tau'', \tilde{\tau}^{-i}) - w(\tau', \tilde{\tau}^{-i})$ all $\tau'' > \tau'$, $\hat{\tau}^{-i} \gg \tilde{\tau}^{-i}$.

That is, the closer other countries' tariffs are to Nash equilibrium tariffs, the smaller the gain any country makes from increasing its own tariff towards the Nash equilibrium level[16].

Now we specify our costs of punishment. Let $\{\hat{\tau}_t\}_{t=0}^{\infty}$ be some reference tariff path. Say that i deviates at t if $\tau_t^i \neq \hat{\tau}_t$. Let τ_t^i be $i's$ common tariff at time $t = 1, 2, ...$ If $\tau_t^i \leq \tau_{t-1}^i$, country i incurs no cost. If $\tau_t^i > \tau_{t-1}^i$, country i incurs cost c_i. Payoffs over the

[16] Technically, it says that w is a *submodular* function.

infinite horizon are discounted by common discount factor δ, $0 < \delta < 1$ i.e.

$$W_i = (1-\delta)\sum_{t=1}^{\infty}\delta^t\left[w(\tau_t^i, \tau_t^{-i}) + I_t^i c_i\right] \tag{2.3}$$

where I_t^i is a dummy variable that is 1 if $\tau_t^i > \tau_{t-1}^i$ and 0 otherwise.

A *game history* at time t is defined as a complete description of past tariffs $h_t = \{(\tau_l^1, ...\tau_l^n)\}_{l=1}^{t-1}$. All countries can observe game histories. A *tariff strategy* for country $i = 1,..n$ is defined as a choice of tariffs τ_t^i in periods $t = 1, 2...$ conditional on every possible game history. A *tariff path* of the game is a sequence $\{(\tau_t^1, ...\tau_t^n)\}_{t=1}^{\infty}$ that is generated by the tariff reduction strategies of all countries. We are interested in characterizing subgame perfect Nash equilibrium tariff paths.

3. Symmetric Equilibrium Paths

Given the symmetry of the model, we restrict our attention to *symmetric* equilibrium[17] tariff paths where $\tau_t^i = \tau_t$, $t = 1, 2, \ldots$, i.e. where all countries choose the same tariff in every time period, and we denote such paths by the sequence $\{\tau_t\}_{t=1}^{\infty}$. We now wish to characterize these paths.

Because of the costs of adjustment, our game is not a repeated one, but dynamic with state variable $y_t = (\tau_{t-1}^1, ...\tau_{t-1}^n)$. However, by an adaptation of Theorem 5.6 of Fudenberg and Tirole(1991), it is easy to show that any symmetric equilibrium tariff path $\{\tau_t\}_{t=1}^{\infty}$ is generated by a strategy profile that switches to the worst (pure-strategy) present-value equilibrium payoff for player i if she unilaterally deviates from τ_t at time t. Generally, this payoff will depend on the state of the game at time t . So, denote this payoff by $\underline{W}_i(y_t)$.

We can now characterize $\underline{W}_i(y_t)$. First, note that there are two kinds of punishment that $j \neq i$ could levy on i; either to stop cutting tariffs in the future (*constrained* punishment), or to raise them (*unconstrained* punishment). In the latter case, the most severe punishment is to raise them to the Nash level $\hat{\tau}$. Of course, the cost of implementing the unconstrained punishment is that the reversal costs must be incurred.

Let $x(C)$ be the $\#C$-dimensional vector where $C \subset N$ countries choose $x \in [0, \hat{\tau}]$, and

[17] In the sequel, it is understood that "equilibrium" refers to subgame-perfect Nash equilibrium.

$\phi(\tau^{-i}) = \arg\max_{\tau} w(\tau, \tau^{-i})$ be the myopic best response by any i to τ^{-i}. So, using this notation,

$$\Delta = w(\phi(0(N/\{i\})),\ 0(N/\{i\})) - w(0(N))$$

is the gain to any country from imposing optimal import tariffs when other countries practice free trade. Then, we have;

Proposition 2. *If $c_i > \frac{\Delta}{1-\delta} = \underline{c}$, then $\underline{W}_i(y_t)$ is implemented by the constrained punishment that following a deviation τ' by i at $t-1$, all $j \neq i$ never raise their tariffs i.e. $\underline{W}_i(y_t) = w(\tau', \tau_t(N/\{i\}))/(1-\delta)$.*

Now we turn to characterize $i's$ optimal deviation τ' at t, given that his punishment payoff will be $w(\tau', \tau_t(N/\{i\}))$. There are two possible kinds of deviation for country i at t. First, it could just not cut its tariff, but leave it at τ_{t-1}, thus avoiding the lump-sum reversal cost, a *constrained* deviation. Or it could choose an *unconstrained* deviation $\phi(\tau_t(N/\{i\}))$. Given the ensuing punishment, $i's$ optimal deviation is the constrained one $\tau' = \tau_{t-1}$ if

$$\frac{w(\phi(\tau_t(N/\{i\})), \tau_t(N/\{i\}))}{1-\delta} - c_t < \frac{w(\tau_{t-1}, \tau_t(N/\{i\}))}{1-\delta},\ t = 1, 2..$$

But by the same arguments as in the Proof of Proposition 2, this holds if $c_i > \underline{c}$.

It follows immediately from Proposition 2 and the above discussion that if $c_i > \underline{c}$, the maximal present value payoff from deviation at time t from a symmetric equilibrium path is $w(\tau_{t-1}, \tau_t(N/\{i\}))$. Now for any $\tau, \tau' \in F$, let $\psi(\tau, \tau') \equiv w(\tau, \tau'(N/\{i\}))$. So, we have proved:

Proposition 3. If $c_i > \underline{c}$, $i \in N$, $\{\tau_t\}_{t=1}^{\infty}$ is an equilibrium path iff $\{\tau_t\}_{t=1}^{\infty}$ satisfies, for all $t \geq 1$, the inequalities

$$\frac{(\tau_{t-1}, \tau_t)}{1-\delta} \leq \psi(\tau_t, \tau_t) + \delta\psi(\tau_{t+1}, \tau_{t+1}) + ... \quad . \tag{3.1}$$

Let P_E be the set of non-increasing paths $\{\tau_t\}_{t=1}^{\infty}$ that satisfy (3.1), and we refer to any path in P_E as a *(symmetric) equilibrium* tariff reduction path. Note that the sequence consisting of the Nash tariff, infinitely repeated, satisfies (3.1). We call this the trivial equilibrium tariff reduction path, as no reduction takes place.

We now show that ignoring this trivial case, tariff reduction on any equilibrium path is perpetual:

Proposition 4. *If $c_i > \underline{c}$, $i \in N$, tariff reduction on any non-trivial equilibrium path is perpetual: if $\{\tau_t\}_{t=1}^{\infty}$ is an equilibrium path, then for any t, there exists an $s > t$ such that $\tau_t > \tau_s$.*

Proof. Note that if a path $\{\tau_t\}_{t=1}^{\infty}$ is non-trivial, then $\tau_t > \tau_{t-1}$ for some $t > 0$. Suppose now that there exists a $T \geq t$ with $\tau_s = \widetilde{\tau}$ for all $s \geq T$ and $\tau_s < \widetilde{\tau}$ for $s < T$. Player 1, by deviating at T, would receive $\psi(\tau_{s-1}, \widetilde{\tau})/(1-\delta) > \psi(\widetilde{\tau}, \widetilde{\tau})/(1-\delta)$, where the inequality follows from ψ decreasing in its first argument. Thus the deviation is profitable, contradicting the equilibrium assumption. □

Thus we have demonstrated the first characteristic of perpetual trade liberalization, that no 'efficient' tariff level exists at which liberalization stops.

Two comments are appropriate at this point. First, as remarked above, this result is very different from the existing literature. In other models, there are always equilibrium paths where tariff reduction can stop *permanently*, although these may not be efficient. Rather, in our setting, it is a *necessary* condition of equilibrium that tariff-cutting be perpetual. An important implication is that in our setting, free trade can never be reached except asymptotically.

Second, our perpetual tariff-cutting result formalizes the bicycle theory as discussed informally by Whalley and Hamilton (1996), and captured in the quote by Peter Sutherland in the introduction, that the achievements of each round must be seen in the context of the overall process of trade liberalization.

3.1. Efficient Equilibrium Paths

In this section we demonstrate the second characteristic of perpetual trade liberalization, that on any efficient equilibrium path there must be some liberalization in *every* period. There are an infinite number of efficient equilibrium paths, each initialized by a different (and infinite number of possible) first period tariffs $\tau_1 \leq \hat{\tau}$. We then say that the path

$\{\tilde{\tau}_t\}_{t=1}^{\infty} \in \tau_E$ is *most efficient*[18] (i.e., among symmetric equilibrium paths) if there does not exist another path $\{\tau'_t\}_{t=1}^{\infty} \in P_E$ such that

$$\sum_{t=1}^{\infty} \delta^{t-1} w(\tau'_t, ..\tau'_t) > \sum_{t=1}^{\infty} \delta^{t-1} w(\tilde{\tau}_t, ..\tilde{\tau}_t).$$

At this stage, we do not know the properties of this path, or even whether it exists and is unique. These questions are addressed in the next section, applying the results of Lockwood and Thomas(2001), henceforth LT.

One can think of finding an efficient path by choosing a sequence $\{\tau_t\}_{t=1}^{\infty}$ to maximize (2.3) subject to the infinite number of constraints (3.1). This is a very difficult problem to tackle directly (i.e. as a programming problem), but LT present a way of characterizing this solution by indirect methods, which we now apply to the model set out above[19]. First, by Lemma 2.2 of LT, at least one tariff reduction path exists, and satisfies constraints (3.1) in every period with equality. The intuition is as follows. Equation (3.1) tells us that for the sequence of tariff reductions of a given country to be worthwhile, the gain from failing to reduce tariffs when all others proceed to do so must not be larger than the gains obtained from future symmetrical reductions. Lemma 2.2 then says that an efficient reduction path entails the largest tariff reduction (conditional upon τ_{t-1}) that gives all other partners an incentive to reduce their tariffs. A bigger reduction would induce partners to renege, but a smaller reduction would be wasteful, in that it would fail to secure beneficial reciprocal reductions from partners. Then, by Lemma 2.3 of LT, the efficient tariff reduction path must solve the following second-order difference equation

$$\psi(\tau_t, \tau_{t+1}) = \frac{1}{\delta}\left[\psi(\tau_{t-1}, \tau_t) - \psi(\tau_t, \tau_t)\right] + \psi(\tau_t, \tau_t), \ t > 1 \tag{3.2}$$

with initial conditions $\tau_0 = 0, \ \tau_1 \geq 0$. Intuitively, rearrangement of (3.1) holding with equality gives (3.2).

Let the sequence $\{\tau_t(\tau_1; \delta)\}_{t=1}^{\infty}$ solve this second-order difference equation for a fixed initial condition τ_1. From (3.1), any solution to this difference equation is non-increasing,

[18] We use the term 'first-best' to refer to unconstrained efficient outcomes.

[19] LT work with a model, where $n = 2$, and agents choose scalars measuring levels of cooperation, but these differences are inessential. They also assume reversal costs are infinite, so punishments and deviations are always (in our terminology) constrained, wheras the present analysis is more general in that it allows for finite reversal costs.

so the sequence $\{\tau_t(\tau_1;\delta)\}_{t=1}^{\infty}$ has a limit $\tau_\infty(\tau_1;\delta)$. More importantly, we can establish that any efficient solution is strictly decreasing:

Proposition 5. *If $\tau_1 < \hat{\tau}$ then an efficient tariff reduction path is strictly decreasing.*

Proof. $\tau_t < \tau_{t-1}$, $\psi(\tau_{t-1}, \tau_t) - \psi(\tau_t, \tau_t) > 0$ by A1. So, from (3.2), $\psi(\tau_t, \tau_{t+1}) > (\tau_t, \tau_t)$. But from A1, ψ is decreasing in its second argument, so $\tau_{t+1} < \tau_t$. Therefore, by induction, starting with $\tau_1 < \hat{\tau}$, it is clear that $\tau_{t+1} < \tau_t$, all $t = 1, 2, ...$ $\square$

Also note that this sequence is an equilibrium path only if $\tau_\infty(\tau_1;\delta) > 0$. Thus we have demonstrated the second characteristic of perpetual trade liberalization, that on an efficient equilibrium tariff reduction path some liberalization must occur in *every* period.

We now characterize the *optimal tariff reduction path.* Let $S(\delta)$ be the set of values of τ_1 for which $\tau_\infty(\tau_1;\delta) > 0$. By Lemma 2.5 of LT, this set contains its own infimum (lower bound), τ_1^*. Consequently, the *optimal* path is $\{\tau_t(\tau_1^*;\delta)\}_{t=1}^{\infty}$. In practice, finding the whole optimal path can only be done by numerical simulation. Presented below is an algorithm for computing the set $S(\delta)$, which is operationalized for an example in Section 4. One of the main contributions of LT, however, is to provide a very simple characterization of the limit of the optimal path $\tau_\infty^* = \tau_\infty(\tau_1^*;\delta)$. This limit has the interpretation of the minimum possible tariff that can be achieved in equilibrium in the long run. As emphasized above, for $\delta < 1$, free trade is not attainable i.e. $\tau_\infty^* > 0$. To derive the minimum possible tariff analytically, we need two more relatively weak assumptions:

A3. ψ is continuously differentiable.

Note that if A3 holds, from A1, we must have $\psi_1 < 0$, $\psi_2 > 0$. In this case, note that a small reduction Δ in region *i's* tariff will cost region i $\psi_1\Delta$ but benefit the other $n-1$ regions in total by $\psi_2\Delta$. So, the cost-benefit ratio of a small reduction in tariffs, from an initial situation where all tariffs are at $0 \le \tau \le \hat{\tau}$, is

$$\gamma(\tau) \equiv \frac{-\psi_1(\tau,\tau)}{\psi_2(\tau,\tau)} > 0,\ 0 \le \tau \le \hat{\tau} \tag{3.3}$$

Note that as the derivatives in γ are continuous, γ is continuous. Moreover, note that at $\tau = 0$ i.e. free trade, as the benefit and cost of additional tariff reduction must be equal,

$\gamma(0) = 1$. Also, note that the symmetric Nash equilibrium tariff solves $\psi_1(\hat{\tau}, \hat{\tau}) = 0$, so $\gamma(\hat{\tau}) = 0$. Then assume;

A4. $\gamma(\tau)$ is strictly decreasing in τ.

Assumption A4 says that as the tariff set by all countries becomes smaller, the cost-benefit ratio of additional tariff reductions becomes larger. As $\gamma(0) = 1$, $\gamma(\hat{\tau}) = 0 < \delta$, it follows from A4 that there is a unique solution $\tau(\delta) \in [0, \hat{\tau}]$ to the equation

$$\gamma(\tau) = \delta, \tag{3.4}$$

Clearly $\tau(\delta) > 0$, $\delta < 1$, and moreover, $\tau(.)$ is strictly decreasing in δ, with $\lim_{\delta \to 1} \widehat{\tau}(\delta) = 0$. Then (analogous to Proposition 3.1 of LT) we now have:

Proposition 6. *Assume A0-A4. Then the limit of the optimal symmetric path, τ^*_∞, is equal to $\tau(\delta)$. Consequently, for all $\delta < 1$, the efficient path of tariffs is uniformly bounded above free trade; i.e., $\tau^*_t > \tau(\delta) > 0$ for all t.*

This says that the limiting optimal equilibrium tariff reduction path is the one for which the cost-benefit ratio of further tariff reductions is equal to δ. So, when $\gamma(.)$ can be calculated analytically from the underlying economic model, the limiting tariff τ^*_∞ can easily be found for any given value of δ.

Finally, to compute the whole optimal path, rather than just its limit, the above discussion suggests the following algorithm. Let k denote the number of repetitions of the algorithm. Consider first the construction of the sets S_k, $k = 0, 1...$The kth step of the algorithm is:

1. Let $k = k + 1$.

2. Take $\tau_0 = \hat{\tau}$ and $\tau_1 = \hat{\tau} - k\varepsilon$ as initial conditions and solve (3.2) forward for T periods.

3. If $\tau_T(\tau_1, \delta) > \tau^*_\infty$, set $S_k = S_{k-1} \cup \{\hat{\tau} - k\varepsilon\}$ and go to 1.

4. If $\tau_T(\tau_1, \delta) \leq \tau^*_\infty$, stop.

This algorithm is initialized by setting $S_0 = \varnothing$. Also, note that this algorithm can only run at most for m steps, where m is the largest integer smaller than $\hat{\tau}/\varepsilon$. Intuitively, the optimal tariff reduction path cannot bring about negative tariffs, because free trade is Pareto Optimal. Let $K \leq m$ be the number of steps after which the algorithm stops. Then $S_K = S_{K-1} \cup \hat{\tau} - K\varepsilon$ and $\hat{\tau} - K\varepsilon$ is its smallest member. Note that for T large, ε small, $S(\delta)$ is well-approximated by S_K. So, $\tau_1^* \simeq \hat{\tau} - K\varepsilon$. An approximation to the optimal path is then the sequence $\{\tau_t(\hat{\tau} - K\varepsilon; \delta)\}_{t=1}^T$ given by (3.2). Note that the algorithm requires knowledge of τ_∞^*, but in the special case below, an analytical formula for this is always available.

We now apply Proposition 4 and this algorithm to a simple example.

4. An Example

We assume that the utility function (2.1) is

$$u^i = \frac{\rho}{\rho - 1}\left(x_i^i + \frac{\sigma}{\sigma - 1}\sum_{j \neq i}(x_j^i)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\rho-1}{\rho}}, \quad i = 1, ..n \tag{4.1}$$

with $\sigma, \rho > 1$, and where x_j^i is consumption of good j. So, σ measures the elasticity if substitution between different "varieties" of imported good, and ρ is the constant relative risk aversion of the consumer i.e. it is the elasticity of u^i.

A standard analysis, given in the Appendix, shows that the unique symmetric Nash equilibrium is where every country sets a common tariff of

$$\hat{\tau} = \frac{1}{\sigma - 1}$$

for the optimal tariff[20]. Next, we can obtain a formula for $\psi(\tau, \tau')$. This is simply

$$\psi(\tau, \tau') \equiv \frac{\rho}{\rho - 1}\left(I(\tau, \tau')\right))^{(\rho-1)/\rho}$$

where

$$I(\tau, \tau') = (n - 1)\left[\frac{1}{\sigma - 1}(1 + \tau)^{1-\sigma} + \tau(1 + \tau)^{-\sigma}\right]\left(\frac{1 + \tau}{1 + \tau'}\right)^{\frac{\sigma(1-\sigma)}{(1-2\sigma)}}$$

[20] Alternatively the *ad valorem* tariff is expressed as a percentage of the price, in which case we get the very familiar inverse-elasticity formula $\frac{\hat{\tau}}{1+\hat{\tau}} = \frac{1}{\sigma}$

is the real income of the household in country i at competitive equilibrium with tariffs, given that i sets τ and all other countries set τ'. Again, in the Appendix, it is shown that (3.4) is

$$\frac{(1-(\sigma-1)\tau)}{(1+\sigma\tau)}=\delta$$

Solving, we get

$$\tau(\delta)=\frac{1-\delta}{\sigma(1+\delta)-1} \tag{4.2}$$

Notice that $\tau(0)=\hat{\tau}=1/(\sigma-1)$, and $\tau(1)=0$, but $0<\tau(\delta)<\hat{\tau},\ 0<\delta<1$. That is, when agents place a very high weight on future outcomes, tariff rates close to zero can be achieved through the process of gradual reciprocal reductions, whereas when agents are relatively impatient, the solution is closer to that of the one-shot Nash equilibrium.

Intuitively, the optimal reduction path is the one that entails the biggest possible tariff reduction in the first and all subsequent periods, whilst still giving trade partners an incentive to participate in reciprocal reductions. A bigger reduction by any country would induce partners to renege if the costs of punishment are prohibitive. A smaller reduction would waste reciprocal gains from market access that could be secured through liberalization by all negotiating partners. The algorithm finds the set of all equilibrium paths, starting with one given by the smallest possible initial tariff reduction (given ε). The set is expanded, increasing the initial reduction by ε each time, and checking that the path is an equilibrium. The procedure is continued until the initial reduction leads to a path that fails the equilibrium criterion. Then the previous - last surviving - path, involving the largest initial reduction, is the optimal reduction path; the most efficient. Thus the set of perpetual tariff reduction paths is defined.

The optimal tariff reduction path for quasi-linear preferences can be computed using the algorithm set out towards the end of Section 4, after Proposition 5. The preference function (4.1) is substituted into the second order difference equation that defines an equilibrium tariff reduction path (3.2). The resulting expression is used to solve sequentially for the equilibrium tariff level τ_{t+1}, given levels in τ_{t-1} and τ_t. Recall that the algorithm requires the size of the steps between simulations ε and the total number of periods T to be determined. We use, respectively, $\varepsilon=0.0001$ and $T=10000$. A smaller value of ε and a larger value of T would yield greater accuracy in computation of the equilibrium reduction path, but take longer.

The technical details are as follows. The procedure is begun with $k = 0$, so in calculating S_0 the procedure is initialized using $\tau_1 = \hat{\tau} - 0.0001 = 1/(\sigma - 1) - 0.0001$. Let K be the highest value of k for which $\tau_T(\tau_1, \delta) > \tau^*_\infty$. Steps $K-1$ and K are illustrated in Figure 1, for $\rho = \sigma = 2$ and $\delta = 0.5$, where the path corresponding to step K is the approximation to the optimal tariff reduction path. The tariff level is shown on the vertical axis, with simulation periods on the horizontal. Only the first 1000 periods of the simulation are presented. We also show what happens for $k = K+1$ and $k = K+2$. Note that no value for the number of countries is specified. The reason is that n has no impact whatever on the equilibrium path under the quasi-linear preference specification[21].

A horizontal line shows the limit to tariff reductions $\tau^*_\infty = \tau(\delta) = 0.25$ (by 4.2). Given $\sigma = 2$, we have $\tau_1 = 0.9999$ for $k = 1$, $\tau_1 = 0.9998$ for $k = 2$ and so on. Figure 1 shows $k = K - 1 = 4746$, for which $\tau_1 = 0.5254$ and $k = K = 4747$; $\tau_1 = 0.5253$. In fact the resulting reduction paths are so close together than they are graphically indistinguishable.

Now see what happens when we let $k = K + 1 = 4748$. The path diverges sharply downwards such that τ_{10000} - were it to be displayed - would be significantly below τ^*_∞, failing the criterion for that path to be an equilibrium. At $t = 300$, $\{\tau_{300}(\hat{\tau} - (K+1)\,\varepsilon; \delta)\} > \tau(\delta)$, and is close to $\{\tau_{300}(\hat{\tau} - K\varepsilon; \delta)\}$. However, as t increases further the path of the sequence $\{\tau_t(\hat{\tau} - (K+1)\,\varepsilon; \delta)\}_{t=1}^T$diverges downwards sharply from $\{\tau_t(\hat{\tau} - K\varepsilon; \delta)\}_{t=1}^T$, such that $\tau_T(\tau_1, \delta) \leq \tau^*_\infty$ for $K + 1$. Figure 1 also shows that for $K+2$, this divergence takes place at an even lower value of t.

Figure 1 also shows the trivial liberalization path, embodying no liberalization at all, with the tariff remaining at the static Nash equilibrium level, and the 'region of efficient equilibrium liberalization paths', which (in the limit) fills the area between the trivial path and the optimal tariff reduction path.

On a cautionary note, the algorithm may pick a path that appears to approximate the equilibrium path for a given value of T, but fails for some larger T. In view of this possibility the value of K and corresponding τ_1 for the optimal path given here by $\tau_1 = 0.5253$ was checked for robustness by setting $T = 100000$ and verifying that $\tau_T(\tau_1, \delta) > \tau^*_\infty$ continued to hold. The same robustness check was also performed on all

[21] To put this another way, if a closed form solution for the reduction path could be found, then n would cancel from the expression.

other computed optimal paths presented below.

Focusing on the characteristics of the optimal reduction path, we see that the majority of liberalization takes place in the first 25 or so periods, with the rate of liberalization slowing significantly after that. This profile depends partly on the quasi-linear specification of preferences, and could be slowed down using an alternative specification.

Figures 2 and 3 illustrate optimal tariff reduction paths that result from comparative dynamics exercises carried out using the quasi-linear preference function on the same format as Figure 1, except that the latter figures present only the first 250 of 10000 periods. Figure 2 shows how the optimal reduction path varies with the substitution elasticity σ, whilst Figure 3 indicates the impact of variation in the discount factor δ. Results for variations in ρ are presented in Table 1.

Look at Figure 2 first. There are optimal reduction paths for three substitution elasticities $\sigma = 2$, 5 and 10 with the other parameters held fixed at $\rho = 2$, $\delta = 0.5$. The key data and results for these simulations are presented in boxes on the far right hand side of the figure. As in Figure 1, for each value of σ we already know $\hat{\tau}$ and $\tau(\delta)$ from the analysis. Both are decreasing in σ, and the figure shows that the optimal reduction paths are monotonically decreasing in σ as well.

The discount rate δ only affects the reduction path, and not $\hat{\tau}$, explaining why the optimal reduction paths in Figure 3 start at the same point and decline towards different limits. Simulations for $\delta = 0.1$, 0.5 and 0.9 are shown, holding $\rho = \sigma = 2$. We already know from (4.2) that when agents are relatively patient, an outcome closer to free trade can be achieved. Here we see that not only the limit but the path towards it exhibits greater liberalization at each point in time t.

The results for comparative dynamics of variations in ρ are presented in a table because the variation is so small that it cannot be discerned graphically. But simulations varying ρ are interesting to consider because reductions are not monotonic in ρ for given t. Table 1 shows that whilst for $\rho = 2$ the symmetrical tariff reduction is initially smaller than for $\rho = 10$, for higher values it is larger; that is, for $t = 1, .., 17$ we have $\tau_t|_{\rho=2} > \tau_t|_{\rho=10}$, but for $t = 18, .., 10000.$, the size of reductions switches so that $\tau_t|_{\rho=2} < \tau_t|_{\rho=10}$. To see why, recall that the parameter ρ reflects the elasticity of marginal utility of extra income made available by multilateral trade liberalization. The higher the parameter value, the more the marginal utility of income falls as income rises. Therefore, as liberalization proceeds further tariff concessions matters less to the representative consumer for higher values of ρ, and this is reflected in lower overall reductions in the longer run. The paths cross because $\hat{\tau}$ and $\tau(\delta)$ do not vary with ρ. For lower values of ρ less liberalization takes place in the short term so that more can be promised in the future when it will be more highly valued.

5. Conclusions

The purpose of this paper has been to present a new theory of trade liberalization that is perpetual, in that liberalization never stops in equilibrium, and that consequently free trade can never be reached. These features of the liberalization process are motivated by a polemical characterization of the restrictions that international institutions, principally the WTO, place on countries' abilities to raise protectionism against one another.

Our model sets up an extreme environment in which, once market access concessions have been agreed upon, countries may not be able to raise protectionism against one another at all. We then ask whether it would be possible for a trade agreement to be reached. The answer was that it would be, but that trade liberalization becomes perpetual; there is no efficient tariff at which trade liberalization stops, and some trade liberalization must take place in every period.

Inevitably, the theoretical framework simplifies the situation in a number of key respects. First, all countries are assumed to be symmetrical, and small in terms of their purchasing power on world markets relative to the political costs of raising protectionism. In actual fact, the variation in country size and purchasing power across different markets is likely to make the actual dynamics of perpetual liberalization considerably more subtle and complex, with more rapid progress achieved in areas where countries receive greater gains from protectionism relative to the political costs incurred. Second, attention is restricted to tariffs. In practice, rather than focusing entirely on one area, the liberalization process continually seeks out new areas where markets can be opened up, at the moment focusing on agriculture and services. Another simplifying assumption in this respect is that all countries only export a single good, with all countries equally open at a given time. In practice all countries export a number of goods, with levels of openness varying across sectors. Finally, regionalism has recently been a very important issue in terms of determining differential rates of trade liberalization between close neighboring countries relative to those further away. By defining a symmetrical modelling framework this issue is completely suppressed in our present paper.

There may be many other competing pressures other than the standard terms-of-trade motive working against further liberalization, and these are also suppressed in our model. One area that has attracted significant attention recently is the incentive for politicians to be protectionist in order to gain financial backing from industrialists (Grossman and Helpman 1995) and for electorates to elect politicians who signal that they will adopt protectionist measures in order to increase their chances of being elected (Riezman 2001). These protectionist forces may be outweighed at an early stage by the phased gains that we describe, but not later once the potential gains from phased liberalization become relatively small. A study of the interplay between these forces might shed light on why there appears to be insufficient political will to launch another (Millennium) round of world trade talks.

One less than satisfactory aspect of our analysis is that the political costs of tariff reversals are not firmly micro-founded. However, it is clear that such costs exist and are very important in the international arena. And no theory exists of which we are aware that enables such costs to be taken into account. Therefore, in the absence of such a theory, we believe that it is worthwhile to simply assume that such costs exist in order to examine their consequences, rather than ignore their impact because they cannot be fully motivated.

A current example appears to highlight the potential importance of perpetual trade liberalization. Recall that a key consequence of perpetual trade liberalization is that liberalization today depends critically on future promises of increased market access. When countries lose the ability to raise protectionism, all they have to keep current liberalization on track is the promise of future concessions. Consequently, if factors exogenous to trade threaten future international relations, then trade talks stop immediately. This seems to be a particularly important observation at the time of writing. Some commentators have suggested that a crisis provoked between China and the US by the collision between military aircraft may provoke a descent into cold war. Consequently, trade relations appear to have been the first (not directly related) area to be threatened as a result. Perpetual trade liberalization can explain why. If cold war were to result in the future, putting a halt to trade liberalization, then it is rational to suspend current negotiations as well. This appears to be a very promising research area for the future.

Another promising direction for future research in this area would involve a weakening of the symmetry assumptions we have made, to allow trade block formation to be considered. The theory of repeated games has been used to study trade block formation, where a preferential trade agreement is supported by the credible threat of punishment. In a recent paper using a repeated game framework Bond, Syropoulos and Winters (2001) point out that trade liberalization within the European Union has been very slow. It may be that our framework provides a way of understanding gradualism between members.

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A. Appendix

A.1. Proofs of Propositions

Proof of Proposition 1. Fix $i \in N$, and normalize prices by setting $p_i = 1$, so $\mathbf{p} = (p_1, ..p_{i-1}, p_{i+1}, ..p_n)$. Then, by the symmetry of the model, and taking τ_i as fixed,

$$\mathbf{p}(\tau^i, \pi(\tau^{-i})) = \pi(\mathbf{p}(\tau^i, \tau^{-i})),\ R^i(\tau^i, \tau^{-i}) = R^i(\tau^i, \pi(\tau^{-i})) \tag{A.1}$$

where $\pi(.)$ is any permutation function i.e. a permutation in tariffs of other countries leads to the same permutation in their equilibrium prices, as tariffs are the only variables affecting excess demands that differ across countries. Now note that by definition,

$$w^i(\tau^i, \tau^{-i}) \equiv v^i(\mathbf{p}(\tau^i, \tau^{-i}), \tau^i, R^i(\tau^i, \tau^{-i})) \tag{A.2}$$

Also, by the symmetry of ϕ,

$$v^i(\pi(\mathbf{p}(\tau^i, \tau^{-i})), \tau^i,) = v^i(\mathbf{p}(\tau^i, \tau^{-i}), \tau^i, R^i) \tag{A.3}$$

i.e. country utility is the same if the world prices of imports are permuted. So we have

$$\begin{aligned} w^i(\tau^i, \pi(\tau^{-i})) &= v^i(\mathbf{p}(\tau^i, \pi(\tau^{-i})), \tau^i,\ R^i(\tau^i, \pi(\tau^{-i}))) \\ &= v^i(\pi(\mathbf{p}(\tau^i, \tau^{-i})), \tau^i,\ R^i(\tau^i, \tau^{-i})) \\ &= v^i(\mathbf{p}(\tau^i, \tau^{-i}), \tau^i,\ R^i(\tau^i, \tau^{-i})) \\ &= w^i(\tau^i, \tau^{-i}) \end{aligned} \tag{A.4}$$

where the first line of (A.4) is from (A.2), the second is from (A.1), the third is from (A.3), and the fourth is from (A.2) again. This proves the second part of the Lemma. To prove the first part, note that as all countries are identical up to a permutation of the indices of the goods, $w^j = w^i(\tau^j, \tau^{-j})$, all i, j so $w^i = w(\tau^i, \pi(\tau^{-i}))$ as required. □

Proof of Proposition 2. (i) Consider the following constrained penal code (in the sense of Abreu). If any i deviates at t, the constrained punishment is initiated i.e. all $j \neq i$ stop lowering tariffs. If any j deviates from the constrained punishment, the constrained punishment is also initiated. We show that this penal code is itself a subgame-perfect equilibrium. It is sufficient to show that given a constrained deviation by j at time $t-1$ of

$\tau' \in [0, \hat{\tau}]$, and constrained punishments by $k \neq i, j$, $i's$ best response is a constrained punishment also. So, a one-shot deviation from the constrained punishment of j must not pay for i.

Deviation is a choice of $\tau'' \neq \tau_t$. Clearly, a deviation $\tau'' < \tau_t$ can never benefit i by Assumption 1. So, the optimal deviation is $\tau'' = \phi(\tau', \tau_t(N/\{i,j\}))$,which incurs a cost c_i. So, a one-shot deviation from the constrained punishment of j must not pay for i if;

$$\frac{w(\tau_t, \tau', \tau_t(N/\{j\}))}{1-\delta} > \frac{w(\phi(\tau', \tau_t(N/\{i,j\})), \tau', \tau_t(N/\{i,j\}))}{1-\delta} - c_i \tag{A.5}$$

where the LHS is the present value payoff from adhering to the punishment, and the RHS the payoff from deviating once, bearing in mind that following the deviation, the constrained penal code says that tariff levels do not change thereafter. For (A.5) to hold, we require

$$c_i > \frac{w(\phi(\tau', \tau_t(N/\{i,j\})), \tau', \tau_t(N/\{i,j\})) - w(\tau_t, \tau', \tau_t(N/\{i,j\}))}{1-\delta}, \ t = 1, 2.. \tag{A.6}$$

But then

$$\begin{aligned} & w(\phi(\tau', \tau_t(N/\{i,j\})), \tau', \tau_t(N/\{i,j\})) - w(\tau_t, \tau', \tau_t(N/\{i,j\})) \\ < \ & w(\phi(\tau', \tau_t(N/\{i,j\})), 0(N/\{i\})) - w(\tau_t, 0(N/\{i\})) \\ < \ & w(\phi(0(N/\{i\})), \ 0(N/\{i\})) - w(0(N)) \end{aligned}$$

where the second line follows from $\phi(\tau', \tau_t(N/\{i,j\})) > \tau_t$ and A3, and the third from A2 (implying $w(0(N)) < w(\tau_t, 0(N/\{i\}))$) and the definition of ϕ. So, for (A.6) to hold, it is sufficient that

$$c_i > \frac{w(\phi(0(N/\{i\})), \ 0(N/\{i\})) - w(0(N))}{1-\delta}$$

(iii) The only other possible kind of penal code is where punishers increase tariffs. In this case, they can inflict the maximal punishment by all increasing tariffs to the Nash level immediately, and keeping them there. So, define the unconstrained penal code to be one where following any deviation (including deviations from the penal code), all players immediately increase their tariffs to the Nash level and keep them there. So, we only need show that this penal code is not itself a Nash equilibrium. This will be the case if, following a deviation at time $t-1$, it pays i to deviate at time $t+1$ by not raising her tariff but keeping at τ_t for ever:

$$\frac{w(\hat{\tau},\hat{\tau}(N/\{i\}))}{1-\delta}-c_i<\frac{w(\tau_t,\hat{\tau}(N/\{i\}))}{1-\delta}$$

which requires

$$c_i>\frac{w(\hat{\tau},\hat{\tau}(N/\{i\}))-w(\tau_t,\hat{\tau}(N/\{i\}))}{1-\delta} \tag{A.7}$$

But now by similar arguments to above, it is possible to show that

$$w(\hat{\tau},\hat{\tau}(N/\{i\}))-w(\tau_t,\hat{\tau}(N/\{i\}))<\Delta$$

So, (A.7) is certainly satisfied if $c_i >\underline{c}$. □

A.2. Analysis of the quasi-linear example

Maximization of (4.1) subject to (2.2) gives demands for the two goods;

$$x_j^i = \left[\frac{p_j(1+\tau_j^i)}{p_i}\right]^{-\sigma},\ j\neq i \tag{A.8}$$

$$x_i^i = 1+\frac{R_i}{p_i}-\sum_{j\neq i}\frac{p_j(1+\tau_j^i)x_j^i}{p_i}=1+\frac{R_i}{p_i}-\sum_{j\neq i}\left[\frac{p_j(1+\tau_j^i)}{p_i}\right]^{1-\sigma} \tag{A.9}$$

where the demand for good i, x_i^i is determined residually via the budget constraint.

Indirect utility for the representative household in i is therefore derived by substituting (A.8) ,(A.9), back into (4.1) to get

$$v^i=\frac{\rho}{\rho-1}\left(\frac{1}{\sigma-1}\sum_{j\neq i}\left[\frac{p_j(1+\tau_j^i)}{p_i}\right]^{1-\sigma}+\frac{R_i}{p_i}\right)^{\frac{\rho-1}{\rho}} \tag{A.10}$$

Also, tariff revenue is

$$R_i=\sum_{j\neq i}p_j\tau_j^i x_j^i=\sum_{j\neq i}\frac{p_j\tau_j^i}{p_i}\left[\frac{p_j(1+\tau_j^i)}{p_i}\right]^{-\sigma} \tag{A.11}$$

It is convenient to work with indirect real income

$$I^i=\frac{1}{\sigma-1}\sum_{j\neq i}\left[\frac{p_j(1+\tau_j^i)}{p_i}\right]^{1-\sigma}+\sum_{j\neq i}\frac{p_j\tau_j^i}{p_i}\left[\frac{p_j(1+\tau_j^i)}{p_i}\right]^{-\sigma} \tag{A.12}$$

which is the argument of (A.10), using (A.11) to substitute out R_i.

Now, in Nash tariff equilibrium, a given country will always set the same tariff on all imported goods. So, we may suppose that all countries $j \neq i$ set a tariff $\tau' = \tau_k^j$ on imports from all countries $k \neq j$, and country i sets tariff $\tau = \tau_k^i,\ k \neq i$. Then, we only need to find the best response τ to τ' to characterize the Nash equilibrium in tariffs. If $\tau' = \tau_{jk},\ k \neq j, ..n,\ \tau = \tau_k^i,\ k \neq i$ in equilibrium, $p_j = p$, all $j \neq i$. So, we may choose p_i as the numeraire. Using these simplifications, we may rewrite (A.12) as

$$I(\tau, p) = \frac{n-1}{\sigma-1}\left[p(1+\tau)\right]^{1-\sigma} + (n-1)p\tau\left[p(1+\tau)\right]^{-\sigma} \tag{A.13}$$

Finally, we need to calculate how the (reciprocal of) terms of trade for country i, p, changes with τ', τ.Evaluating (A.8) ,(A.9) at $\tau' = \tau_{jk},\ k \neq j, ..n,\ \tau = \tau_k^i,\ k \neq i,\ p_j = p$, $j \neq i, p_i = 1$, we get;

$$\begin{aligned} x_i^i &= 1 + (n-1)p\tau\left[p(1+\tau)\right]^{-\sigma} - (n-1)\left[p(1+\tau)\right]^{1-\sigma} && \text{(A.14)} \\ x_i^j &= \left[\frac{(1+\tau')}{p}\right]^{-\sigma} && \text{(A.15)} \end{aligned}$$

So, substituting (A.14),(A.15) into the market-clearing condition for good i, namely that supply of unity equals the sum of country demands$1 = \sum_{i \in N} x_i^j$, we have

$$(n-1)p\tau\left[p(1+\tau)\right]^{-\sigma} - (n-1)\left[p(1+\tau)\right]^{1-\sigma} + (n-1)\left[\frac{(1+\tau')}{p}\right]^{-\sigma} = 0 \tag{A.16}$$

Solving (A.16) for p, we get:

$$p(\tau, \tau') = \left(\frac{1+\tau}{1+\tau'}\right)^{\sigma/(1-2\sigma)}$$

Note that as $\sigma > 0.5$ by assumption, $p_\tau < 0$ i.e. an increase in $i's$ tariff always improves $i's$ terms of trade. So, we may write country $i's$ real income as $I\left(p(\tau, \tau'), \tau\right)$. So, a (symmetric) Nash equilibrium in tariffs is a τ^* such that $I(\tau^*, p(\tau^*, \tau^*)) \geq I(\tau, p(\tau, \tau^*))$, all $\tau \neq \tau^*$. As I is continuously differentiable, we can characterize τ^* as the solution to

$$I_\tau(\tau^*, p(\tau^*, \tau^*)) + I_p(\tau^*, p(\tau^*, \tau^*))p_\tau(\tau^*, \tau^*) = 0 \tag{A.17}$$

where I_τ, I_p denote partial derivatives of I. Now,

$$\begin{aligned} I_\tau(\tau, p) &= -\sigma(n-1)\tau p^{1-\sigma}(1+\tau)^{-\sigma-1} && \text{(A.18)} \\ I_p(\tau, p) &= -(n-1)p^{-\sigma}(1+\tau)^{1-\sigma} + (n-1)(1-\sigma)p^{-\sigma}\tau(1+\tau)^{-\sigma} \\ p_\tau &= \frac{\sigma}{1-2\sigma}\left(\frac{1+\tau}{1+\tau'}\right)^{(\sigma/(1-2\sigma))-1}\frac{1}{1+\tau'} \end{aligned}$$

So, using (A.18) and the fact that $p(\tau^*, \tau^*) = 1$, we have from (A.17) that

$$-\sigma(n-1)\tau^*(1+\tau^*)^{-\sigma-1}+[-(n-1)(1+\tau^*)^{1-\sigma}+(n-1)(1-\sigma)\tau^*(1+\tau^*)^{-\sigma}]\frac{\sigma}{1-2\sigma}\frac{1}{1+\tau^*}=0$$

Eliminating common terms, we get

$$-\tau^* + [-(1+\tau^*) + (1-\sigma)\tau^*]\frac{1}{1-2\sigma} = 0$$

Solving, we get

$$\tau^* = \frac{1}{\sigma - 1}$$

for the optimal tariff.

Next, denote by $\psi_1 = \partial\psi(\tau,\tau')/\partial\tau,\ \psi_2 = \partial\psi(\tau,\tau')/\partial\tau'$. Now by inspection,

$$\frac{-\psi_1(\tau,\tau)}{\psi_2(\tau,\tau)} = \frac{-I_1(\tau,\tau)}{I_2(\tau,\tau)}$$

and also

$$\begin{aligned} I_1 &= (n-1)\left(\frac{1+\tau}{1+\tau'}\right)^{\frac{\sigma(1-\sigma)}{(1-2\sigma)}}\left(-\sigma\tau(1+\tau)^{-\sigma-1}\right) + (n-1)\frac{(1-\sigma)\sigma}{(1-2\sigma)(1+t)}\left(\frac{1+\tau}{1+t}\right)^{\frac{\sigma(1-\sigma)}{(1-2\sigma)}-1}\Psi \\ I_2 &= (n-1)\frac{(1-\sigma)\sigma}{(1-2\sigma)}\frac{(1+\tau)}{(1+t)^2}\left(\frac{1+\tau}{1+t}\right)^{\frac{\sigma(1-\sigma)}{(1-2\sigma)}-1}\Psi \end{aligned}$$

where $\Psi = \left[\frac{1}{\sigma-1}(1+\tau)^{1-\sigma} + \tau(1+\tau)^{-\sigma}\right]$. From these facts, we have

$$\frac{-\psi_1(\tau,\tau')}{\psi_2(\tau,\tau')} = \frac{1+\tau'}{1+\tau}\left(\frac{(1-(\sigma-1)\tau)}{1+\sigma\tau}\right)$$

So, $\hat{\tau}$ solves

$$\frac{-\psi_1(\tau,\tau)}{\psi_2(\tau,\tau)} = \frac{(1-(\sigma-1)\tau)}{1+\sigma\tau} = \delta$$

from which we can solve for the tariff rate in the limit of the reduction path

$$\widehat{\tau} = \tau(\delta) = \frac{1-\delta}{\sigma(1+\delta)-1}$$

Notice that for $\delta = 0$ we have that $\widehat{\tau} = \tau^* = 1/\sigma$, whilst when $\delta = 1$, $\widehat{\tau} = 0$, and that in general this solution implies $0 < \widehat{\tau} < \tau^*$, as required (with strict inequalities because we have assumed $0 < \delta < 1$). That is, when agents place a very high weight on future outcomes, tariff rates close to zero can be achieved through the process of gradual reciprocal reductions, where as when agents are relatively impatient, the solution is closer to that of the one-shot Nash equilibrium.

Figure 1; Approximating the Optimal Tariff Reduction Path

$r = 2 \quad s = 2 \quad d = 0.5 \quad \hat{t} = 1$

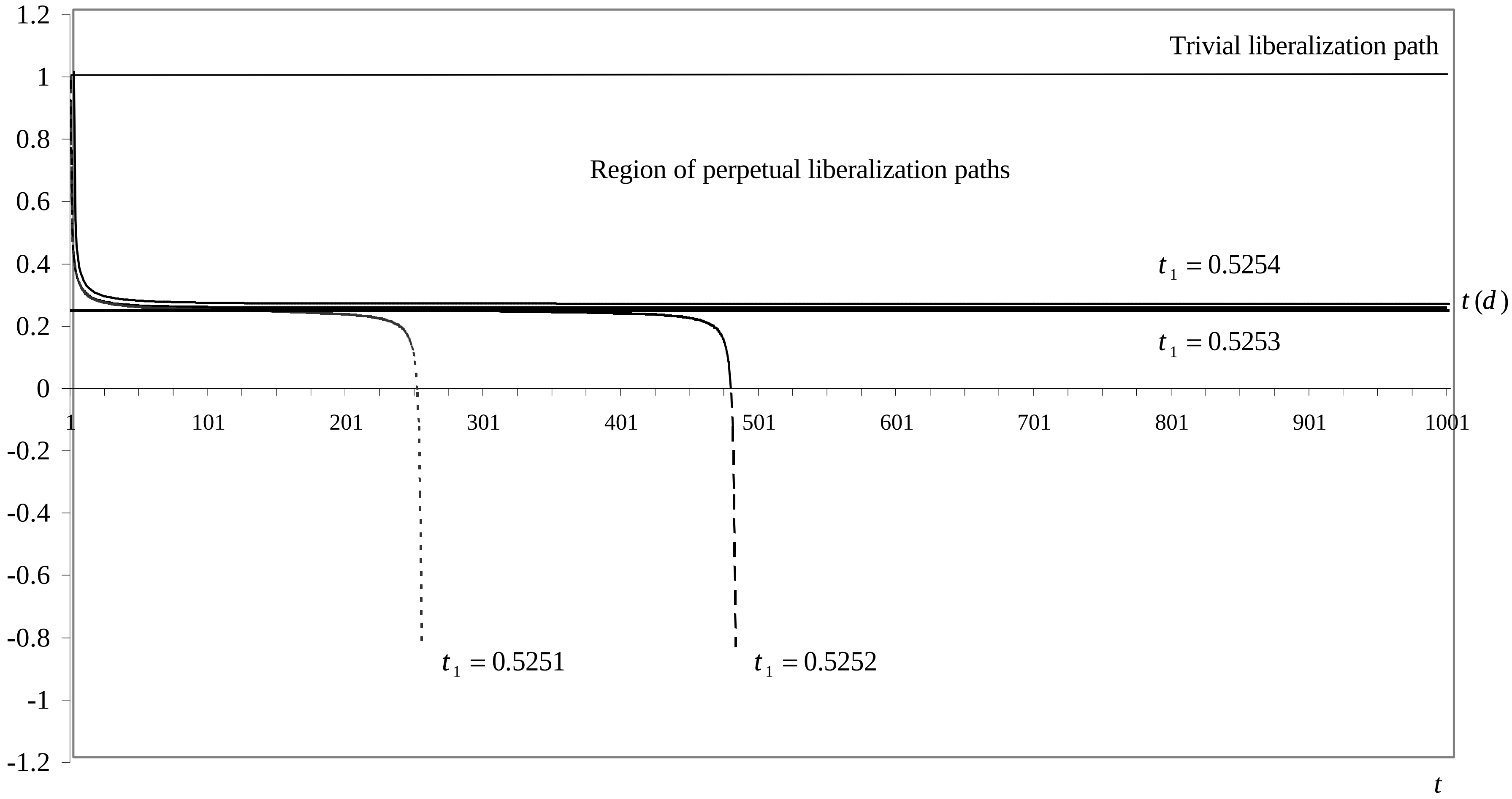

Figure 2: The approximate optimal tariff reduction path for various substitution elasticities

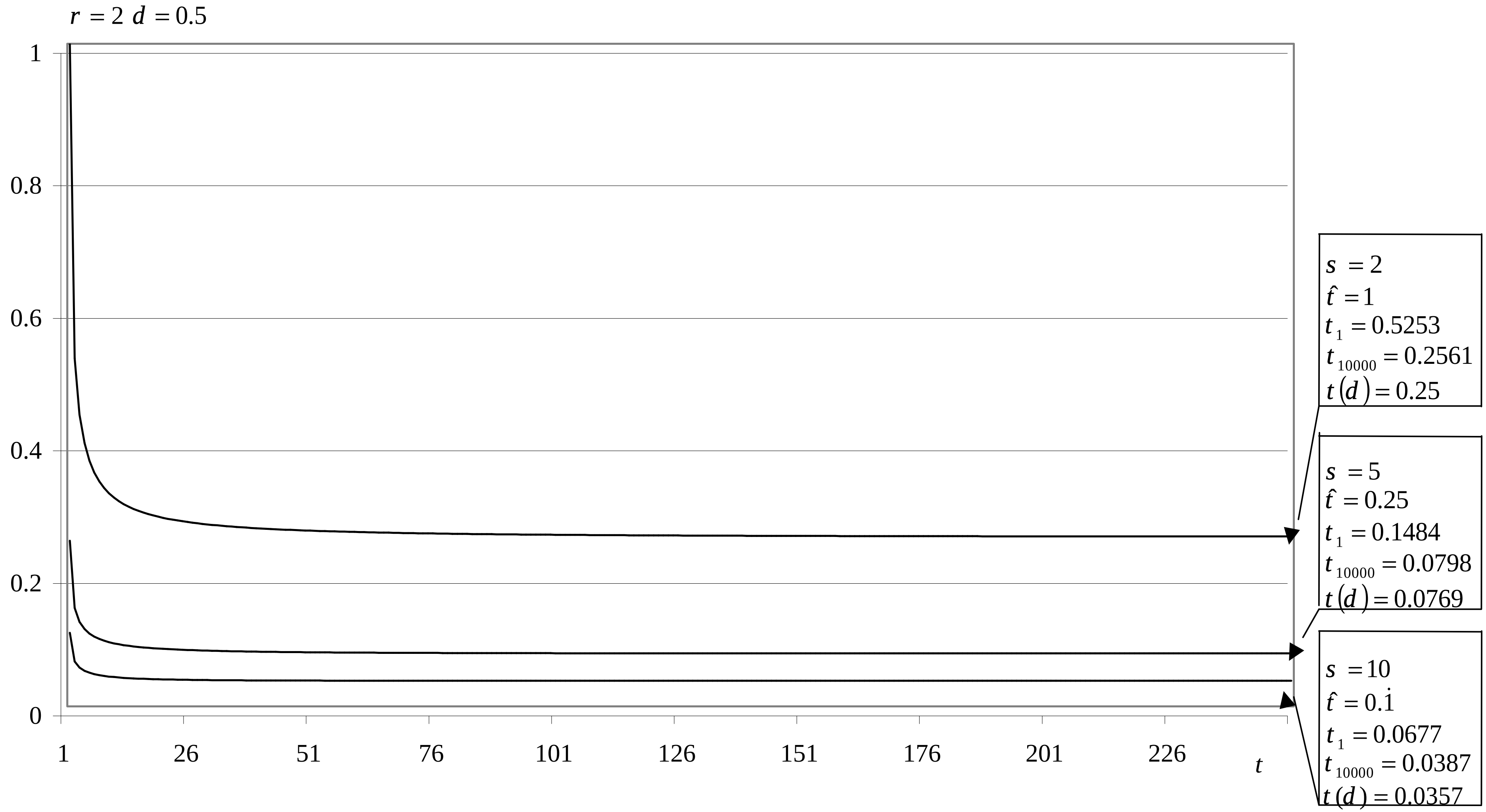

Figure 3: The approximate optimal tariff reduction path for various discount rates

$r = 2 \quad s = 2 \quad \hat{t} = 1$

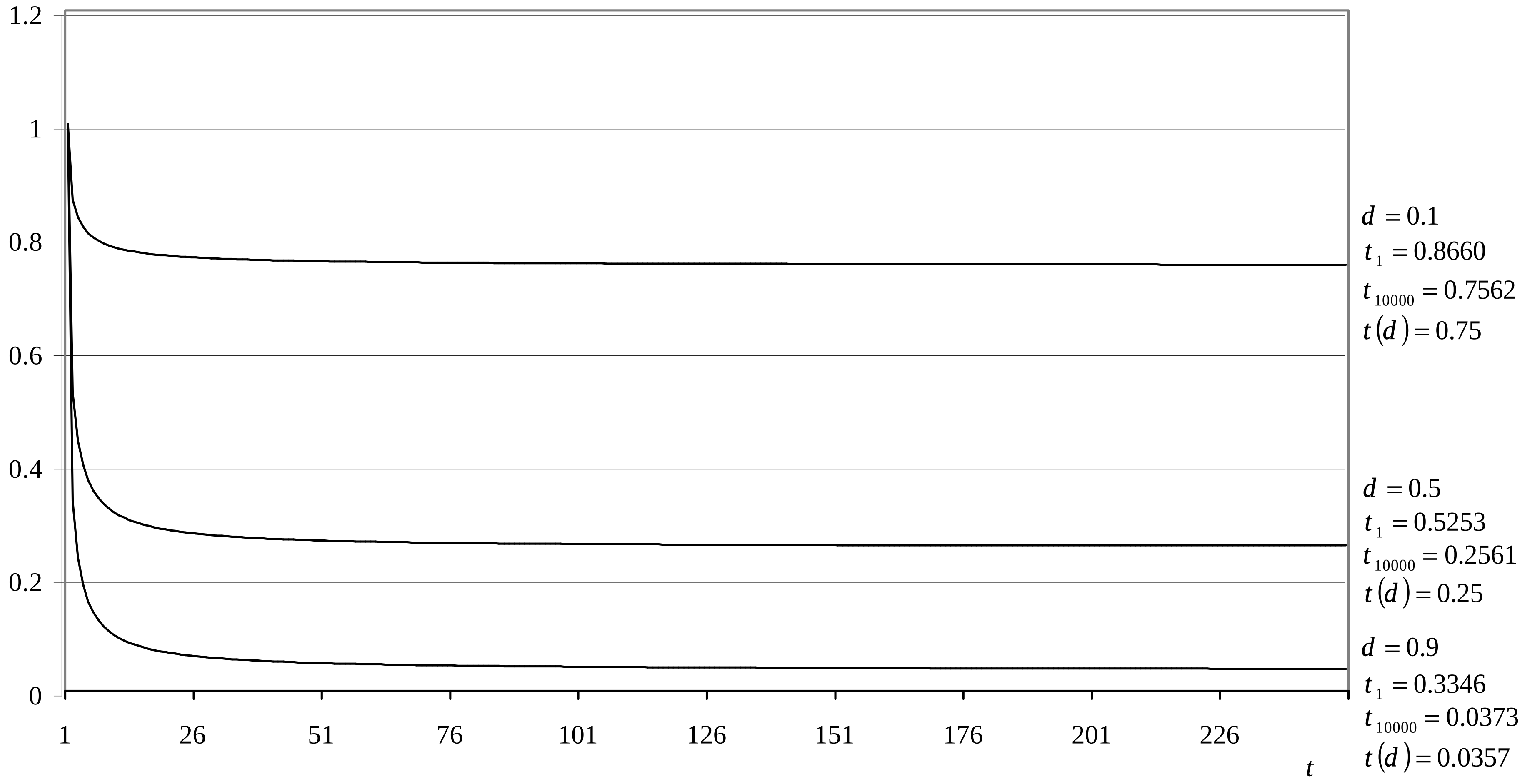

Table 1; Optimal tariff reductions for various elasticities of the marginal utility of income

t	$\rho = 2$	$\rho = 10$	Difference
1	0.5253	0.5248	0.0005
2	0.440298	0.439921	0.000377
3	0.397464	0.397177	0.000287
4	0.371056	0.370832	0.000224
5	0.352977	0.352798	0.000179
6	0.339759	0.339615	0.000144
7	0.329646	0.329528	0.000118
8	0.321643	0.321547	9.6E-05
9	0.315145	0.315066	7.9E-05
10	0.309759	0.309695	6.4E-05
11	0.30522	0.305168	5.2E-05
12	0.30134	0.301299	4.1E-05
13	0.297985	0.297954	3.1E-05
14	0.295055	0.295032	2.3E-05
15	0.292473	0.292457	1.6E-05
16	0.29018	0.290171	9E-06
17	0.28813	0.288127	3E-06
18	0.286287	0.28629	-3E-06
19	0.28462	0.284629	-9E-06
20	0.283106	0.283119	-1.3E-05
21	0.281724	0.281742	-1.8E-05
22	0.280459	0.280481	-2.2E-05
23	0.279295	0.279322	-2.7E-05
24	0.278221	0.278252	-3.1E-05
25	0.277228	0.277262	-3.4E-05