

# The Political Economy of the International Protection Cycle

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## **Abstract**

This paper shows why and when a government responds to interest group's pressure for protection in the election period. The result explains how free trade and protectionism succeed one another. The model considered is a two country differential game with both pro-protectionist interest groups of import competing industries and anti-protectionist interest groups of export industries. If the pro-protectionist interest groups are able to obtain protection and voters are important, the level of protection is decreasing towards the end of the election period whenever the government expects losing the election with a positive probability. (JEL Classification: F13)

## **I. Introduction**

A political-economy view Buchanan/Tullock [1962], Hillman [1989] suggests that decisions on trade policies reflect the self interest of voters, organized lobbying groups and politicians. The level of protection is an equilibri-

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um yielding a politically optimal distribution of economic rents.

One feature of trade policy is that levels of protection tend to move in cycles Cassing/McKeown/Ochs [1986], Bohara/Kaempfer [1991]. Static theory predicts that the ability of interest groups to achieve protection fluctuates in response to general economic conditions, such as unemployment and GNP growth.<sup>1</sup> In periods of high unemployment, for instance, protectionist lobbies are more effective because the effect of foreign competition on domestic employment. Bohara/Kaempfer [1991] show that U.S. tariffs are Granger-caused by unemployment, real GNP, and the price level, but not by the trade balance. Rodrik [1995] proposes as a reason for these results Keynesian motives of switching demand to home products. Moreover, Takacs [1981] shows that although the pressure for protection increases in times of economic distress, the U.S. government does not necessarily respond by providing protection. The conclusion is that the equilibrium tariff cannot be explained exclusively by domestic economic conditions or by protectionist demands.

Even if economic conditions do not change, the equilibrium level of protection is not constant. Elections influence the political will to supply protection. The standard argument Tosini/Tower [1987], Stallings [1993] for an election cycle is that protection increases as the election approaches, since the political weight of interest groups is largest on election day. A politician seeking for re-election cannot afford to refuse the short term benefits of protection from interest group support. However, at the beginning of the election period, he or she can choose to neglect protectionist lobbies and pursue the aim of maximizing social welfare by free trade. Tosini and Tower [1987] base their observation on voting patterns in the U.S. Congress on the protectionist Textile bill of 1985. Their probit analysis is set up to show that the greater the time a Congressman has before he faces a re-election contest, the greater the likelihood he will vote for free trade. However, the percentage of the total term left before a Congressman confronts re-election is not statistically significant in explaining congressional voting behavior. Furthermore, there is no other convincing contribution in the literature supporting the standard view (more protection before election).

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1. Furthermore, Cassing/McKeown/Ochs [1986] show a tariff cycle for declining industries.

Further evidence regarding electoral cycles and protection is provided by Stalling [1993], who investigates anti-dumping and countervailing petitions to the International Trade Administration (ITA) between 1 January 1980 and 31 December 1988. Both the ITA and the International Trade Commission (ITC) are involved in the settlement of anti-dumping and countervailing cases. Stalling [1993] finds that the likelihood of a negative preliminary decision by the ITC is greater during the year after an election rather than in a year preceding election. On the other hand, the proportion of negative ITA decisions is higher in the year preceding an election. Furthermore, some of the negative preliminary cases ended in a positive decision in the final ITA determination. 50% of the negative preliminary decisions were eventually reversed if the preliminary decision was reached in the quarter immediately prior to an election. 32.4% of the negative decisions in the year prior to the next election eventually turned positive. In contrast, only 21.7% of the negative preliminary decisions dating back more than a year turned positive.

Von Witzke [1990] investigates price support of the U.S. government to wheat producers from 1963/64 to 1983/84. Such producer price support for an import competing good is analogous to protection and is subject to the same rent-seeking influences. His result, which is highly statistically significant, is von Witzke [1990], p. 163 : "The hypothesis that interest groups' relative power changes characteristically over the election cycle could not be rejected by the empirical analysis. All other things being equal, price support in wheat is lower in presidential election than in non-election years." To summarize, the empirical evidence is not in favor of the conventional wisdom. The empirical literature evidences that policy is more protectionist after an election than before.

In this paper I present a model which investigates trade (and other rent-providing) policy in an election period. In the model, voter's myopia changes the success of interest groups in the election cycle: As the election approaches, anti-protectionist interests gain a greater relative importance. If voters are ever important in influencing policy at any given time, then this has to be before an election. The relative influence of gainers and losers from protection determines the changes in trade policies during the election cycle with economic conditions and policy preferences of voters, interest

groups, and politicians exogenous and unchanged. International interdependence of protectionist policies arises because of a two country game.<sup>2</sup> Both in the non-cooperative and in the cooperative solution concepts trade policy is more protectionist after an election than before. Agreements would not result in free trade but in lower levels of protection. Free trade and protectionist policy succeed another and levels of protection move in a cycle.

## II. The Model

The model<sup>3</sup> is based on a Vote(V)-Popularity Poll(P)-function Nannestad/Paldam [1994]. A VP-function explains support for a government as a function of economic and political outcomes. I apply a dynamic version of a trade-policy political-support function as in Hillman [1982], in combination with the political capital approach of Hibbs [1982].

The policy variable is a tariff for an import competing industry in a Ricardo-Viner setting of international trade theory. I assume tariffs but the argument holds of course as well for all protectionist policies that generate the same spreading of rents, e.g. for price support to wheat producers. The tariff yields relatively large gains for small industry groups with small widely distributed losses to the public. There is a pro-protectionist interest group of import competing producers and a liberal interest group of export industries based on industry specific factor ownership. Consumers are not organized, and do not lobby. However, they vote.

Voters of country  $i \in \{1, 2\}$  evaluate their own government's policies during the election period. Their support, called popularity  $P_i$ , depends on the actual policy implemented and on the government's reputation. If voters are not fully ignorant, economic consequences of policies influences their voting decision. The sole economic influence on voters is the welfare loss due to a tariff, and hence the voting decision, i.e. the government's popularity, depends on the tariff policy. The actual tariff  $t_i$  chosen by the government is

2. See Sieg [1995] for the one country case.

3. Similar models are by Hillman/Long/Moser [1995] and Grossman/Helpman [1995].

Both do not examine the effects of regular elections. Hillman/Long/Moser [1995] explain reciprocal liberalization and Grossman/Helpman [1995] investigate the structure of protection.

compared to the individually optimal tariff of the voter Mayer [1984]. Voter's welfare depends on their ownership of specific factors. A majority of anti-protectionist voters lose from protection and therefore popularity declines if the tariff rises:  $\partial P_i / \partial t_i < 0$ .

Special interest groups influence trade policy via the amount of money they contribute, which allows the government to enhance its reputation  $R_i$ . Reputation is the accumulated stock of public support, i.e. the political capital of the government Hibbs [1982]. Reputation influences the voting decision, i.e. popularity, positively:  $P_i / R_i > 0$ . Although voters oppose protection due to economic losses, they are partly ignorant, allowing contributions for advertising, public relations, and publicity to affect the political process by increasing the probability of election Stratmann [1991]. Interest groups thereby have the opportunity to influence policy, although members of such interest groups represent only a small fraction of voters.

To summarize, the behavioral assumptions are

$$\partial P_i / \partial t_i < 0, \quad \partial P_i / \partial R_i > 0.$$

For simplicity, assume

$$P_i = q_i R_i - t_i, \quad q_i > 0 \tag{1}$$

where  $q_i$  is the weight of voter's ignorance.<sup>4</sup>

The change in reputation  $\dot{R}_i = f_i$  derives from the behavior of producers, consumers, and special interest groups:

The political support  $s_i(t_i)$  of import competing interests increases as the tariff increases.<sup>5</sup> Maximum support is at the prohibitive tariff<sup>6</sup>  $t_{i*}$ . Hence, for the import competing interest group

$$s_i(0) = 0, \quad s'_i(t_i) > 0 \quad 0 < t_i < t_{i*}, \quad s'_i(t_{i*}) = 0, \quad s''_i < 0. \tag{2}$$

4. If voters are fully ignorant, i.e. they do not care about tariffs,  $q_i$  approaches infinity and the considered model breaks down.
5. There is domestic opposition to the tariff for a sector since the tariff hurts owners of factors specific to other sectors. I consider a sector that is able to reach protection, i.e. the support for the tariff is higher than the opposition to the tariff. Therefore, the political support in the model represents net-support of import competing interest and of liberal opposition.
6. The prohibitive tariff depends on the market structure.

The political support of the interest group is independent of the time in the election period. The interest group's welfare gains depend upon the domestic price and these gains are invariant in pre-election period and post-election periods.<sup>7</sup> Therefore, interest groups are willing to pay the same price for protection at any time in the election period. In particular, they are not willing to pay more money for the same level of protection on the day before an election than on the day after an election.

Protection of import competing industries in country 1 brings about losses to export industries in country 2, and vice versa. Therefore, an export industry interest group exists in each country. Because the export lobby in country 1 receives welfare losses due to import protection in country 2, it has reason to influence the foreign government in order to reduce protection. However, the countries are defined by their endowment of "factors" in the political process, i.e. voters and interest groups of domestic industries. There is no factor movement and therefore no way for the export lobby to influence the foreign administration. The export interest group knows the retaliation and reciprocity effects Hauser [1986] of protection and tries to influence the domestic administration towards reducing protection in order to reduce the incentive for retaliation by the foreign government.<sup>8</sup> This is why domestic exporters can be seen as representatives of foreign interests in the domestic political system Moser [1990]. The GATT and the World Trade Organisation (WTO) are based on such a multilateral reciprocal exchange of market access concessions McMillan [1990].

Therefore, the domestic lobby's refusal  $r_i(t_j)$ ,  $i \neq j$  affects the domestic government's reputation. Starting with no refusal, it increases whenever foreign tariffs rise:

$$r_i(0) = 0, \quad dr_i/dt_j > 0. \quad (3)$$

Because the export lobby's negative campaign depreciates the government's popularity, the export lobby's effectiveness depends on the stock of

7. We can neglect discounting in this context.

8. See for a foundation of this argument Moser [1990, ch. 4] and Finger [1991] in a partial equilibrium framework model and Hillman/Long/Moser [1995] in a general equilibrium framework.

popularity and increases whenever the popularity grows.

Furthermore, reputation depreciates by a rate of  $\delta_i$ . This is the well-known key result of empirical voting theory called voter's myopia, i.e. in voting-functions all effects decay rapidly Nannestad/Paldam [1994], p. 217 . Thus,  $\delta_i > \beta_i$  is assumed. The reputation differential equations are:

$$\dot{R}_i = s_i(t_i(\tau)) - r_i(t_j(\tau))R_i(\tau) - \delta_i R_i(\tau), \quad i \neq j, \quad i, j \in \{1, 2\}, \quad (4)$$

where  $\tau$  is time.

The empirical evidence of the individual decision, whether to support the government or not, does not fit the results of pure decision theory. In reality voter participation does not diminish to zero. In addition, there are no rational expectations about the government's policy. Although voting should be forward oriented, i.e. the voting decision should be based upon expected future policies, past experiences work well in explaining individual voter's support or non-support of the government Fiorina [1981], Smyth/Dua/Taylor [1994] . The explanation for this is that the voter's decisions are rational but based upon static expectations. The whole theory of forward looking rational expectations turns out to be irrelevant in this framework because voting is retrospective Nannestad/Paldam [1994] . Therefore, whenever the government is interested in political pluralities it has to maximize the aggregate support based on experiences.

Voter's experiences are not only a simple average over the past, because on election day the memory of recent protectionism is more important than that of previous events.<sup>9</sup> Past experience decays with a rate of  $\beta_i$ . Therefore, the government of country  $i$  maximizes the aggregate value of votes at the election day T plus the salvage value of reputation:

$$V_i = \int_0^T \exp^{-\beta_i d} P_i(R_i(\cdot), t_i(\cdot)) d + \exp^{-\beta_i T} S_i R_i(T). \quad (5)$$

Reputation on election day has a non-negative value (i.e.  $S_i \geq 0$ ). However, it will only be useful to the administration if it carries away an election victory.

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9. This is the well-known "cost of ruling" Nannestad/Paldam [1994], Paldam/Skott [1995] : An administration governing for one legislative period loses an average of about 1.7 per cent of the popularity during that period, even if it acts exactly as the rational voter expects.

Because the pro-protectionist interest group is able to obtain protection,

$$q_i s'_i(0) > \delta_i - \beta_i \quad (6)$$

is assumed. The effect of the first monetary unit spent on supporting the government is larger than the difference of depreciation rates.

To summarize, governments are monopolistic protection suppliers faced with dynamic political demand and political cost functions. The politically optimal tariffs are the solution of the following differential game:

$$\max_{t_1(\cdot)} V_1 = \int_0^T \exp^{-1} P_1(R_1(\cdot), t_1(\cdot)) d\tau + \exp^{-1} S_1 R_1(T) \quad (7)$$

$$\max_{t_2(\cdot)} V_2 = \int_0^T \exp^{-2} P_2(R_2(\cdot), t_2(\cdot)) d\tau + \exp^{-2} S_2 R_2(T) \quad (8)$$

$$\text{s.t. } \dot{R}_1 = s_1(t_1(\cdot)) - r_1(t_2(\cdot)) R_1(\cdot) - \gamma_1 R_1(\cdot) \quad (9)$$

$$\dot{R}_2 = s_2(t_2(\cdot)) - r_2(t_1(\cdot)) R_2(\cdot) - \gamma_2 R_2(\cdot) \quad (10)$$

Several solution concepts may be appropriate to determine the optimal tariff policy. If the game is non-cooperative, since the countries are not able to achieve binding commitments, I use the Nash solution concept. Because no politician can commit himself to a tariff policy, the Stackelberg approach does not reach an equilibrium. Both countries unsuccessfully try to take the leading position. In this dynamic game the Stackelberg solution is not sub-game perfect. If the countries are able to arrange binding commitments, e.g. under an organisation like the WTO, the cooperative solution concept determines the optimal policy.

### III. The Solutions of the Game

In this section the necessary conditions for an open-loop Nash solution of the trilinear differential game (7)-(10) (Feichtinger [1983]) are provided by a Pontryagin-type maximum principle. The current value Hamiltonian  $H^i$  of player  $i$  is defined as

$$H^i = q_i R_i - t_i + \lambda_i^1 (s_1(t_1) - r_1(t_2) R_1 - \gamma_1 R_1) + \lambda_i^2 (s_2(t_2) - r_2(t_1) R_2 - \gamma_2 R_2) \quad (11)$$

where  $\lambda_j^i$  is the current-value adjoint variable of country  $i$  with respect to country  $j$ , measuring the current-value shadow price of an additional mar-

ginal unit of reputation  $R_j$  evaluated by the government of country  $i$ . The adjoint equation, i.e.  $\dot{\lambda}_i^j = -\beta_i \lambda_i^j - H_{R_j}^i$ , yields for  $i \neq j \in \{1, 2\}$ :

$$\dot{\lambda}_i^j = (r_i(u_j) + \delta_i - \beta_i) \lambda_i^j - q_i \quad (12)$$

$$\dot{\lambda}_j^i = (r_j(u_i) + \delta_j - \beta_j) \lambda_j^i. \quad (13)$$

The transversality conditions are

$$\lambda_i^i(T) = S_i, \quad \lambda_j^j(T) = 0. \quad (14)$$

**Lemma 1:** The Nash-optimal controls satisfy the following system of two non-linear differential equations

$$\dot{t}_1 = \frac{s_1'(t_1)}{s_1(t_1)} (q_1 s_1'(t_1) + r_1 - r_1 - r_2(t_2)) \quad (15)$$

$$\dot{t}_2 = \frac{s_2'(t_2)}{s_2(t_2)} (q_2 s_2'(t_2) + r_2 - r_1 - r_2(t_1)). \quad (16)$$

**Proof:** See appendix.

Lemma 1 implies, that the optimal tariffs  $(t_1^*, t_2^*)$  are independent of the initial reputation. The proof of Lemma 1 shows, that also the  $\lambda_i$  are independent of the initial reputation. Furthermore, tariff and reputation equations are uncoupled and hence the optimal tariffs are closed-loop equilibria. To summarize, the Nash solution is subgame perfect. Thus, even if the government has no ability to commit itself to specific policies, the announced policy is time consistent and credible Staiger/Tabellini [1991].<sup>10</sup>

A phase portrait analysis shows the qualitative behavior of the optimal tariffs.

**Lemma 2:** Assume that one isocline of the equation system (15) and (16) is always steeper than the other and

$$s_i'^{-1}((r_i - r_i)/q_i) > r_j^{-1}(q_j s_j'(0) + r_j - r_j). \quad (17)$$

10. It is important to the model to assume that the governments retain full discretion in tariff-setting policy. Institutional constraints, such as the WTO, affect this discretion and change the results.

Then a unique interior optimal tariff equilibrium exists. The stationary point is an unstable node (case A) if in (17)  $<$  holds (see Figure 1) and a saddle point (case B) if in (17)  $>$  holds (See Figure 2).

**Proof:** See appendix.

The phase portraits of the Nash-optimal solutions are described in Figures 1 and 2.

Consider the case that the static tariff equilibrium is not prohibitive. The terminal values of the Nash tariffs are determined by the salvage values  $S_i$ . Therefore, an optimal tariff is described by a trajectory ending in the point  $(t_1^*(T), t_2^*(T))$  (cf. (21)) and corresponding to the election period T.

**Theorem 1:** In the Nash equilibrium the optimal tariff decreases towards end of the legislative period, whenever the administration expects losing the election with a positive probability.

**Proof:** If the time horizon is not finite, the salvage values are zero and the equilibria are the saddle-point, respectively, the unstable node. If the governments expect losing the election with a positive probability, the salvage values on election day T are smaller than the values on the infinite horizon

Figure 1  
Tariff Phase Diagram (Case A)

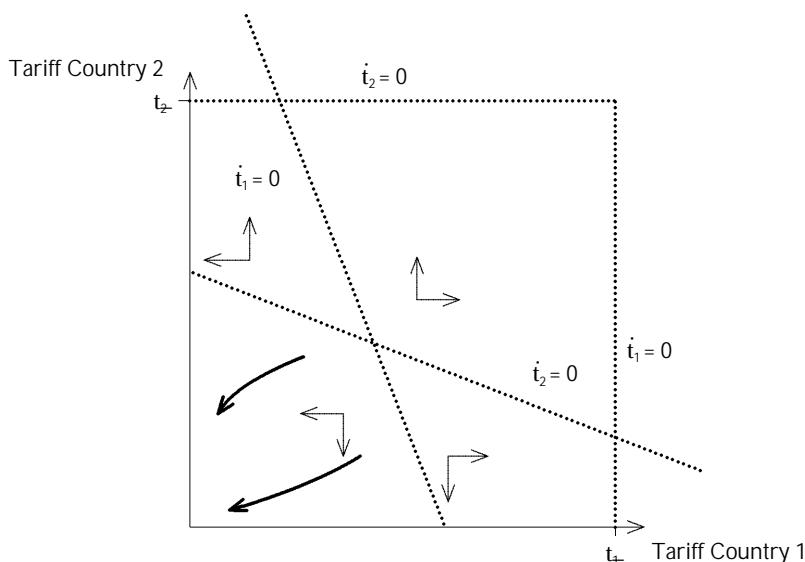
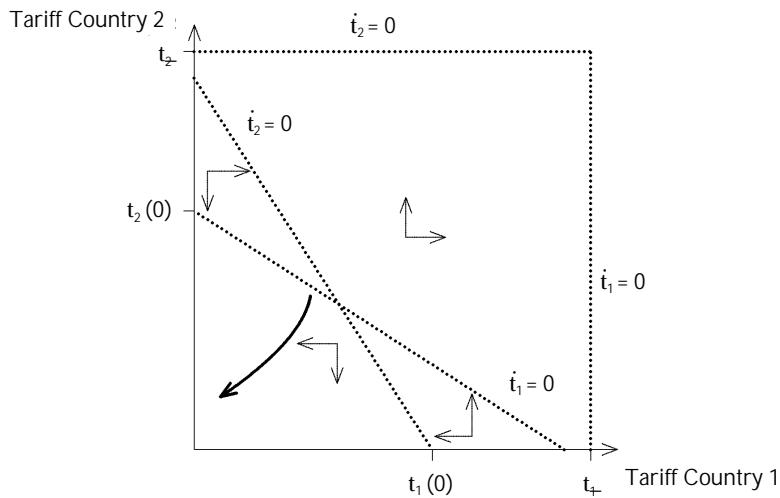


Figure 2  
Tariff Phase Diagram (Case B)



equilibrium trajectories. Depending on expectations, a part of the reputation stock is depreciated on election day. From (21) it follows that the optimal terminal tariffs are smaller than the equilibrium tariffs. Thus the phase diagram shows the decreasing tariffs in some period near election day.

Although the importance of interest groups is maximal on election day, the success of the lobbies decreases during the term of office. The explanation for this is as follows. Both policy and reputation are most important on election day, since there are costs of ruling. Thus, both lobbies and voters are most important on election day. The tariff level is determined by the absolute and the relative influence of voters and lobbies. The absolute influence determines a level of protection as in the static model Hillman [1982] , but since preferences do not change, this level is constant. However, the lobby's relative influence changes during the election period. The amount of revenues to the lobbies, i.e. their welfare gains, are independent of when they originate. Therefore, the support of the lobbies depends on the received tariff level and does not depend on the time in election period. However, voters forget about the policy pursued at the beginning of the election period. Therefore, voters are unimportant in this period of time. If voter's evaluation of the tariff policy is important at any time, then it is important at the end of

the election period. At the election the relative importance of voters is maximal and the relative power of interest groups, especially pro-protectionist lobbies, minimal.

To summarize, the optimal policies are lower tariffs in election years than in non-election years. Changes in the governments trade policies are caused by variations in the relative power of pro- and anti-protectionist voters and are not caused by absolute high levels of pressure by interest groups. As an anonymous referee remarks, elections are beneficial because they weakens the influence of interest groups and force the government policy towards the position of the median – albeit myopic – voter.<sup>11</sup> This is in contrast to the traditional Political Business Cycle literature that assumes, that the reelection chances can be improved by misleading voters.

If  $s_i'(0) < \dots$  and  $S_i < s_i'^{-1}$  then (21) has no admissible solution. In this case a terminal interval  $[\tilde{\tau}, T]$  with free trade exists, i.e. the optimal tariff is zero.

For some combinations of salvage values and terms of office the tariff paths are non-monotonic. This holds true for maximally one country, whereas the tariff in the other country decreases monotonously. Furthermore, maximally one interval with increasing tariffs exists at the beginning of the term of office. Subsequently, the tariff decreases until the next election.

Each tariff harms foreign exporters. In response, they build an anti-protectionist interest group and influence their domestic government Moser [1990, ch. 4], Finger [1991], Hillman/Long/Moser [1995]. Whereas in the Nash solution no government cares about this decrease of the foreign government's popularity, this effect is internalized in the cooperative solution. Because of this externality an institution like the WTO attains some significance by guaranteeing observance of the agreements.

If  $s_i(t_i) = 1/2c_i t_i^2$ ,  $\beta_1 = \beta_2 = \beta$ , and  $r_i(t_j) = k_i t_j$ , the following theorem holds: (see appendix)

**Theorem 2:** If the negotiation power of both countries is equal, the cooperative tariff is lower than the Nash tariff. The tariff cycle appears in the cooperative game as well.

Since the cooperative tariff is smaller than the Nash tariff, the Nash tariff

11. Empirical evidence for this argument provides Pommerehne [1978].

is not Pareto optimal. The outcome of negotiations on trade policy such as GATT negotiations, is a reduction of the tariff but not free trade.<sup>12</sup> Furthermore, it is dynamically optimal for the governments to increase the level of protection in the post election year. Therefore, any agreement reached should not prohibit increases in the level of protection. For example, the GATT is founded on the principle of national property rights to market access. Consequently, in the United States six legal procedures (escape clauses, anti-dumping petitions, countervailing duty cases, section 301, section 337, and section 406) have been created which permit raising protection Finger [1988].

At the end of this section I discuss the sensitivity of the results to changes in the assumptions. The dynamics of the tariff policy is completely changed if the voting decision and the expectations are rational. In this case no tariff cycle occurs. However, as discussed in detail in chapter 2, the empirical evidence shows that voting is retrospective Nannestad/Paldam [1994]. The tariff cycle disappears also if reputation depreciates at a slower rate than voter's experiences. In this case, voter's myopia of trade policies is irrelevant and the interest groups affect the protection level. Therefore, if the consumer's welfare determines the voting decision in any way, the reputation must depreciate faster than voter's experiences, as I assumed in the model. Assuming identical election days in both countries is no restriction. The theorems remain unchanged if election days differ in both countries.<sup>13</sup>

#### **IV. Conclusion**

von Witzke [1990] shows, that price support in wheat is lower in election than in non-election years. This paper presents a theoretical argument for this hypothesis. The static interest group approach to protection shows why protectionist interest groups are able to receive protection even when there

12. The forming of lasting free trade areas cannot be explained by regular elections and the resulting tariff cycle but by the change of interest group's power Hillman/Long/Moser [1995].
13. A way to incorporate different election days  $T_1 < T_2$  is to define  $T = T_1$  and the salvage value of the country 2 suitable. The solutions of the new game correspond to the solutions presented in this paper.

is a majority of voters and interest groups of export industries preferring free trade. In a dynamic perspective the following effect occurs additionally: during election campaigns the influence of interest groups is larger than at the beginning of the legislative period, but at this time voters gain their maximum of importance, too. During the incumbency the importance of anti-protectionist voters rises and the power of interest groups shrinks. Therefore, the government increases the level of protection, for example the producers price support, at the beginning and cuts it towards the end of its term of office, i.e. trade policy moves in a political cycle.

Elections bring about a protection cycle even if foreign countries retaliate against rising levels of protection. Binding agreements reached, for example, in the World Trade Organization do not result in free trade but in lower levels of protection than without international coordination of policies. Politicians do not give up the national property rights to market access, i.e. their right to raise protection.

## Appendix

### *Proof of Lemma 1*

The adjoint equation and the transversality condition yield  $\lambda_i^j(\tau) = 0 \quad \tau \in [0, T]$ . Thus, only  $\lambda_1^1 = \lambda_1$  and  $\lambda_2^2 = \lambda_2$  are relevant to the following analysis. Because  $S_i > 0$  we obtain  $\lambda_i(\tau) > 0 \quad \tau \in [0, T]$ . Furthermore,

$$H_{t_i}^i = -1 + s_i'(t_i) \quad (A1)$$

$$H_{t_i t_i}^i = s_i''(t_i). \quad (A2)$$

If the solution  $t_i^*$  lies in the interior of the admissible interval  $[0, t_i]$ , the first order condition  $H_{t_i}^i = 0$  is fulfilled, yielding

$$\lambda_i = (s_i'(t_i^*))^{-1}. \quad (A3)$$

Substituting the transversality condition we get

$$s_i'(u_i(T)) = S_i^{-1}. \quad (A4)$$

Thus we obtain a unique pair  $(t_1^*(T), t_2^*(T))$  of terminal tariffs, if the equa-

tion (A4) is solvable. The tariff on election day is high if  $S_i$  is high, and vice versa. If (A4) is not solvable, the optimal tariff is zero in some terminal subinterval. Differentiation (A3) with respect to time yields

$$\dot{\lambda}_i = -\dot{s}_i''(\dot{s}_i)^{-2} \dot{t}_i.$$

Substituting this and (A3) into the adjoint equation yields Lemma 1.  $\square$

### **Proof of Lemma 2:**

The isocline

$$\dot{t}_1 = q_1 s_1'(\dot{t}_1) + \beta_1 - \delta_1 - r_1(\dot{t}_2) = 0 \quad (\text{A5})$$

is denoted as  $\dot{t}_2 = \phi_2(\dot{t}_1)$ . The slope of the  $\dot{t}_1 = 0$  curve

$$\frac{dt_2}{dt_1|_{t_1=0}} = \frac{\dot{t}_1 / \dot{t}_1}{\dot{t}_1 / \dot{t}_2} = -\frac{q_1 s_1''(\dot{t}_1)}{-r_1'(\dot{t}_2)} < 0 \quad (\text{A6})$$

is negative. For  $t_1 = t_+$  follows  $r_1(t_2) = \beta_1 - \delta_1$ , and thus  $\phi_2(t_+) \in [0, t_+]$ . Because of (6) and (A5) a unique  $\tilde{t}_1 \in (0, t_+)$  exists with  $\phi_2(\tilde{t}_1) = 0$ , i.e.,

$$s_1'(\tilde{t}_1) = (\delta_1 - \beta_1) q_1^{-1}. \quad (\text{A7})$$

Furthermore,  $\phi_2(0)$  is given by

$$r_1(\phi_2(0)) = q_1 s_1'(0) + \beta_1 - \delta_1$$

provided that

$$q_1 s_1'(0) + \beta_1 - \delta_1 = r_1(t_2). \quad (\text{A8})$$

The isocline  $\dot{t}_2 = 0$  denoted as  $t_1 = \phi_1$  has analogous properties. Therefore the stationary point  $(\hat{t}_1, \hat{t}_2)$  lies in the region  $0 < \hat{t}_i < \tilde{t}_i$ , provided that it exists. The existence in the first quadrant of the phase plane is guaranteed, if

$$\tilde{t}_1 < \phi_1(0) \quad \text{and} \quad \tilde{t}_2 < \phi_2(0) \quad (\text{A9})$$

or

$$\tilde{t}_1 > \phi_1(0) \quad \text{and} \quad \tilde{t}_2 > \phi_2(0). \quad (\text{A10})$$

Considering (A7) and (A9) these conditions are (17).

If one isocline  $\phi_1$  or  $\phi_2$  has a larger slope than the other for all  $t_1$ , the equilibrium is unique. Differentiating (15) and (16) yields

$$\dot{t}_i / t_{i|t_1=\hat{t}_1} > 0 \text{ and } \dot{t}_j / t_{j|t_1=\hat{t}_1, t_2=\hat{t}_2} > 0. \quad (\text{A11})$$

Therefore, the trace of the Jacobian is positive and the determinant of the Jacobian is positive if in (17)  $<$  holds and negative if in (17)  $>$  holds. Thus  $<$  yields an unstable node and  $>$  a saddle point.

### **Proof of Theorem 2:**

If we specify  $s_i(t_i) = 1/2c_i t_i^2$  and  $r_i(t_j) = k_i t_j$  and consider the Nash equilibrium, the equations for the adjoint variables are  $\lambda_i^j = 0$  for  $i \neq j$  and

$$\dot{\lambda}_i^i = \lambda_i(\delta_i - \beta_i + k_i t_i) - q_i. \quad (\text{A12})$$

The optimal tariff is  $t_i = 1/c_i - 1/(c_i \lambda_i)$ . In the cooperative game the problem is to maximize

$$\begin{aligned} & \int_0^T [P_1(R_1(\cdot), t_1(\cdot)) + P_2(R_2(\cdot), t_2(\cdot))] d \\ & + \exp^T (S_1 R_1(T) + S_2 R_2(T)). \end{aligned} \quad (\text{A13})$$

The equations for the adjoint variables are the same as in the Nash case. The optimal tariff is

$$t_i = \frac{1}{c_i} - \frac{1}{c_{i-i}} - \frac{\sum_j R_j k_j}{\sum_i c_i}. \quad (\text{A14})$$

Thus the cooperative tariff is lower than the Nash tariff and the Nash tariff is not Pareto optimal.

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