How to Use Industrial Policy to Sustain Trade Agreements

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Abstract

With the help of a simple Ricardian model, this paper explores the role of industrial policy in self-enforcing trade agreements. A basic version shows that the optimal self-enforcing trade agreement must include active promotion of output in inefficient, import-competing sectors. In a dynamic setting, a similar role is played by the protection of declining industries, which can be part of an efficient trade cooperation. The underlying assumptions for these results, however, are strong: heavy discounting of future gains, strong dependence on the imported goods, and a flexible industrial structure constitute preconditions for such efficiency-enhancing government interventions.

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1 Introduction

Virtually all advanced economies engage in some form of commercial and industrial policy. Huge sums are frequently spent to protect or promote sectors of comparative disadvantage and declining industries. The energy, steel, agriculture, textile and apparel sectors are among the most prominent, but by far not the only examples. In the public discourse these policies are often defended by appeals to the strategic value of the industries in question.
Economists, usually concerned about efficiency, tend to discard these claims and blame interest groups for making the economy suffer deadweight losses. The present paper argues that this view may sometimes be wrong and that the protection of comparative disadvantaged and declining sectors can be welfare improving. It shows that the correct use of industrial policy constitutes an efficient way to make countries respect trade agreements and is thus always part of the most efficient trade agreement.

At the core of the paper lies the self-enforcement constraint, which underlies any international agreement. It reflects the assumption that sovereign countries cannot be forced into international cooperation and will only respect agreements if these appear beneficial to them. Now it is well known that large countries have an incentive to unilaterally erect trade barriers since this improves their terms of trade and generates net gains. It is usually assumed that the only way to keep a country in an agreement is a credible threat of punishing any cheating or defection. The only credible punishment is a trade war in which all countries act uncooperatively. Thus, defection is followed by a trade war with all sides losing. Forward-looking policy makers weigh the transitional gains from defection against future losses from trade war.

To study this issue I develop a model of repeated trade between tow countries[2]. When now a country imports essential goods for its economy, this country's dependence and vulnerability to hostile policies is particularly high. That, in turn gives its foreign suppliers the possibility to seize large portions of its income by defecting. In other words, in such a situation the supplying country has a high incentive to defect. The importer's vulnerability and the exporter's incentive to cheat are two sides of the same coin.
What brings remedy in such situations? It is well understood that countries can use limited trade barriers in order to reduce both their own vulnerability and foreign defection incentives. This paper considers the situation where countries have two policy instruments at hand in order to reduce their dependence: commercial and industrial policies. Here, industrial policy is defined as government actions that directly target the industrial structure of a country, while commercial policy means tariffs. To reduce dependence in an efficient way, countries will choose an optimal mix of both. It will be shown that, as long as imported

[2] The conceptual framework comes from Dixit (1987), who introduces self-enforcing agreements to the literature of trade theory. The model's formal structure is like in Devereux (1997) who in turn strongly builds on Kennan and Riezman (1988).

goods are essential and when the self-enforcement constraint binds, industrial policy is always part of the most efficient trade agreement.
What is the intuition for that finding? The foreign country's market power depends on the elasticity of domestic import demand. Now, providing some of the supply domestically increases import-elasticity thereby reducing foreign market power and foreign incentives to defect. So the key to relaxing the self-enforcement constraint is to break the monopoly position of the supplying country. This is what industrial policy does by stimulating import-competing production, and this is why it helps in relaxing the self-enforcement constraint. Consequently, when industrial policy is banned altogether and tariffs constitute the only policy instrument, trade agreements will necessarily be less efficient[3].

To understand the implications of the argument, consider the energy sector. In the energy crisis' of the 1970's governments of western industrialized countries were quick to set up national programs stimulating domestic energy production to decrease dependence on imports from the countries that had just demonstrated their ability to successfully collude to form a monopolistic cartel. More than 30 years later, the same countries still subsidize inefficient energy programs motivated by the desire to reduce dependence on unreliable suppliers. A common objection to this strategy is that industrial countries should not deplete their scarce reserves but rather save them for the rainy days when oil supply slumps again. Yet, in light of the present paper's argument, the energy programs might be just the move that keeps the oil suppliers from defecting, thus avoiding rainy days in the first place.

A first extension of the model introduces dynamics in technology and provides a rationale for the protection of declining industries. The argument starts from the above statement that subsidies to import-competing sectors are part of any efficient trade agreement. When the pattern of comparative advantage deepens, the value of cooperation relative to the value of a breakdown increases and leads to a gradual reduction of tariffs and industrial policy. The liberalization is gradual, as anticipated future gains relax the self-enforcement constraint and allow a partial liberalization today. During the liberalization process, initially protected sectors are sheltered less and less and gradually shrink. The reason for a stepwise reduction of protection does not come from the desire to cushion incomes or reduce political resistance; it is an optimal policy to run because the self-enforcement constraint impedes letting them go at once.

The results summarized up to here are consistent with the empirical findings on protection and trade policy. Lee and Swagel (1997) write that "nations tend to protect industries that are weak, in decline, [] or threatened by import competition". Trefler's (1993) estimates show that a higher import penetration is associated with greater protection, and Goldberg and Maggi (1999) find

[3] The conclusion here is in line with Bagwell and Staiger (2004) who argue that strictly banning can go too far and the "WTO subsidy rules may ultimately do more harm than good to the multilateral trading system".

that "within the group of non-organized sectors, protection tends to increase with import penetration". Protectionism in general is typically explained by political economy arguments (see Grossman and Helpman (1994)).. However, Rodrik claims that "we lack a good explanation of the universal preference for trade restricting policies over trade promoting ones". Political economy has had difficulties in justifying this anti-trade bias in trade policies, and previous explanations addressing the issue are scarce and rely on very specific assumptions (see Limao and Panagariya (2002) and Fernandez and Rodrik (1991)). The present paper takes an opposite approach to this point and argues that an anti-trade bias may be precisely what is needed to make trade agreements self-enforcing.

A second extension of the simple model shows that strong rigidities in industrial structure can qualify and even reverse the basic findings. In a world where production capacities take time to build and output patterns are slow to change, countries will very much depend on imports even after an agreement breaks down. This implies that any defection is followed by an extremely harsh trade war, which will incur huge losses for all, including the defecting country. By decreasing the incentives to cheat on trade agreements, mutual dependence now proves to be beneficial. In fact, the deliberate creation of dependence constitutes a way to commit to free trade, making free trade more likely to be self-enforceable. In such a scenario, protecting import competing sectors undermines the commitment device and makes cooperation harder.
This result recalls the findings of Furusawa and Lai (1999), who find that the costs of adjusting output structures tend to relax the self-enforcement constraint because they increase the cost of returning to non-cooperation. In the present paper, the degree of irreversibility of industrial structure takes the role of adjustment costs, which create the beneficial dependence necessary to commit to free trade.

But can one reasonably expect countries to engage in the strategic creation of mutual dependence in order to enforce trade agreements? The economic cooperation on coal and steel in post World War II Europe is often read as such an event. In 1951 France, Italy, Germany Belgium, Luxemburg and the Netherlands signed the Treaty of Paris founding the European Community for Steel and Coal (ECSC). The pooling of such "strategic goods" was meant to create mutual dependence so as to make future hostile actions impossible, according to political declarations (see Gillingham (1991)). Those strategic considerations precisely reflect the last main finding of the present paper: . As it takes time to build capacities in steel production and coal mining, production patterns are rigid in the short term. Both their output rigidity and their economic importance make the coal and steel industries particularly suitable for commitment.

The rest of the paper contains five sections. Section II develops the basic model of non-cooperative trade. Section 3 then considers repeated trade and cooperative behavior, highlights the role of the self-enforcement constraint, and presents the basic finding of the paper. Section 4 introduces learning by doing to explain gradualism and the protection of declining industries. Section 5 introduces rigidities in the industrial structure of the countries. Finally, section VI concludes.

2 The Basic Model

There are two countries, Home and Foreign (Foreign variables denoted by *), and two goods x, y which are produced with constant returns to scale technologies using one single factor, labor. Countries have equal size of labor force, normalized to unity: $L = L^* = 1$. Assume that Home's (Foreign's) productivity in x- (y-) production equals b while productivity in the y- (x-) production is equal to 1. With $b > 1$, this means that Home is natural exporter of x. The technologies are disembodied and, for a start, exogenous:

$$x = bL_x \qquad y = L_y \qquad\qquad x^* = L_x^* \qquad y^* = bL^*$$

Each consumer's preference is represented by a time-separable utility function and the momentary utility (simply called utility in the following) has the Cobb-Douglas form and is symmetric in the two goods:

$$u(c_x, c_y) = \sqrt{c_x c_y} \tag{1}$$

To save notation, here and whenever there is no risk of confusion time indices are dropped.
There is no capital, no dynamic considerations on the consumers' side such that, at every point in time, individuals maximize (1) subject to their budget constraint. There are no externalities and all markets are competitive and only subject to distortions from government policies specified below.
Note that the setup is completely symmetric and the analysis will be restricted to symmetric outcomes throughout the paper.

2.1 The Integrated Economy

The integrated economy is a world where goods and factors can cross borders without costs. In such a world the relative price of goods must be unity because of symmetry ($p_x/p_y = 1$). All goods are produced competitively using the most efficient technology available, i.e. productivity in both sectors is b. Individuals face the budget constraint $c_x + c_y \leq I = b$, which implies that utility of a representative consumer in either of the two countries is

$$u^F = b/2 \tag{2}$$

This utility level reflects the efficient outcome of the integrated economy. It is replicated by a world economy in which there is free and costless trade in goods but factors - that is labor - is bound to stay within national borders. In this

world of free trade there is complete international specialization, relative goods price is unity, and the citizens utility function under free trade is (2) again.
Yet in this model economy countries have an incentive to distort the world economy by erecting trade barriers and thereby manipulate the terms of trade to their favor. When there is no credible way to commit to the optimal free-trade outcome, both countries will start to set tariffs, which triggers a trade war. This will be discussed next.

2.2 Trade War

When two large countries cannot commit to free trade, they will try to manipulate the terms of trade to their favor, which results in a trade war with typically all sides loosing. So it happens in the symmetric setting assumed here, where the net effect of the terms of trade manipulation entirely cancels out and the world economy is left with the distortions only.

Consider first the production side of, say, Home's economy[4]. Normalizing the international price for good x to 1 and denoting the one of good y with p the production pattern in Home without any government intervention is

$$y \in \begin{cases} \{0\} & if \quad p < b \\ [0,1] & if \quad p = b \\ \{1\} & if \quad p > b \end{cases} \qquad \text{and} \qquad x \in \begin{cases} \{b\} & if \quad p < b \\ [0,b] & if \quad p = b \\ \{0\} & if \quad p > b \end{cases}$$

But countries can engage in commercial and industrial policies that distort this production pattern. Here, the commercial policy is an ad valorem import tariff that drives a wedge between local and international prices of the imported good: $p^{Home} = Tp$. Industrial policy will be understood as government's actions that directly distort the domestic production structure. In particular, assume that Home's government can guarantee a minimum level of production y (x) in the y-sector (x-sector) and distort production. There are various ways to implement such a policy. To keep the matter simple, assume that the government levies lump-sum taxes to finance subsidies, which are given to workers engaging in production of y (x) up to the respective target level. If the subsidy is high enough (e.g. equal to b per unit of output), the subsidized labor will produce the good y (x) independently of price changes[5].
When the government sets tariffs and subsidies, output in the two countries and

[4] The following formulas describe the case for Home, the counterparts for Foreign are symmetric.

[5] Note that when the per-unit subsidy is equal to b, there is an unequal income distribution in the country. Since consumer's utility is linear in income I, however, a government with a utilitarian welfare function does not care about distributional effects and still takes (1) as the representative agent's utility.

sectors is

$$y \in \begin{cases} \{\bar{y}\} & if\ pT < b \\ [\bar{y}, 1-\frac{\bar{x}}{b}] & if\ pT = b \\ \{1-\frac{\bar{x}}{b}\} & if\ pT > b \end{cases} \qquad x \in \begin{cases} \{b(1-\bar{y})\} & if\ pT < b \\ [\bar{x}, b(1-\bar{y})] & if\ pT = b \\ \{\bar{x}\} & if\ pT > b \end{cases}$$
$$x^* \in \begin{cases} \{\bar{x}^*\} & if\ T^* < pb \\ [\bar{x}^*, 1-\frac{\bar{y}^*}{b}] & if\ T^* = pb \\ \{1-\frac{\bar{y}^*}{b}\} & if\ T^* > pb \end{cases} \qquad y^* \in \begin{cases} \{b(1-\bar{x}^*)\} & if\ T^* < pb \\ [\bar{y}^*, b(1-\bar{x}^*)] & if\ T^* = pb \\ \{\bar{y}^*\} & if\ T^* > pb \end{cases} \tag{3}$$

In this way, governments can set a minimum output in each sector that is independent of prices and therefore independent of foreign policies.
A benevolent government will engage in commercial and industrial policy whenever it increases the own citizens' utility (1).

The next step is to determine consumers' incomes and utilities.
With tariff revenues distributed lump sum, Home's average income is $I = x + pTy + (T-1)p(c_y - y)$. Using the equal expenditure shares, i.e. $pT \cdot c_y = I/2$ and $c_x I/2$, Home's income becomes

$$I = \frac{2T}{T+1}(x + py)$$

With the same calculations for Foreign and with the trade balance $x - c_x = p(c_y - y)$ one solves for the world price for good y

$$p = \frac{x^*T^*(T+1) + x(T^*+1)}{yT(T^*+1) + y^*(T+1)} \tag{4}$$

Home's utility then becomes

$$u = \frac{x + py}{\sqrt{p}} \cdot \frac{\sqrt{T}}{T+1} \tag{5}$$

Note that in the case of symmetry (the important one) $x^* = y$, $T = T^*$, and $p = 1$, such that

$$u = \frac{(b(1-y) + y)}{T+1}.$$

Equation (5) also reveals the two channels through which Home's economy suffers inefficiencies: tariffs and production distortions. Optimal are zero import tariffs ($T = 1$) and complete specialization ($y = 0$, $x = b$), which makes (5) equal to (2) - but as will become clear shortly neither will hold in Nash Equilibrium. When Home's government engages in industrial policy and tariff setting, it takes into account firms behavior (3) in both countries and the domestic consumers' choices (5). Further, it is constrained by the labor market clearing.

So the uncooperative, static maximization problem is

$$\max_{T,\bar{x},\bar{y}} u \qquad s.t.\ (3),\ (4),\ \text{and}\ (5) \tag{6}$$

while taking Foreign's policy functions T^*, $\bar{x}^*$, and $\bar{y}^*$ as given.
The optimality conditions[6] for the tariffs turn out to be

$$-\frac{y^*/T^2}{y(T^*+1)+y^*(1+1/T)}+\frac{x^*T^*}{x^*T^*(T+1)+x(T^*+1)}=0$$

which gives rise to the best response functions

$$T(T^*)=\sqrt{\frac{y^*}{x^*}\cdot\frac{x^*+x(1+1/T^*)}{y^*+(T^*+1)}} \tag{7}$$

This Best Response function with its equivalent for Foreign leads to the symmetric equilibrium tariffs

$$T^N=T^{*N}=\sqrt{x/y} \tag{8}$$

The implicit Best Response functions for industrial policies and (8) can be shown to lead to

$$\begin{array}{lll} \bar{y}^N=1/(b+1) & \bar{x}^N=0 & T^N=b \\ \bar{x}^{*N}=1/(b+1) & \bar{y}^{*N}=0 & T^{*N}=b \end{array} \tag{9}$$

and the symmetric equivalent for Foreign tariffs and subsidies.
Together, the Nash strategies (9) and utility (5) give

$$u^N=\frac{b^2+1}{b+1}\sqrt{b} \tag{10}$$

This is the utility of a citizen living in a world where governments uncooperatively choose import tariffs exploiting their market power in supplying their export-goods. This market power is smaller, the more the foreign country possesses of that good (compare (7)). So, in order to be less exposed to foreign tariffs, countries engage in industrial policy and produce their imported goods domestically. - While tariff setting is the aggressive part of the trade war by which countries try to change the terms of trade and extract gains, industrial policy is a defensive move that shields countries from foreign actions.
The two policies distort demand and production, respectively, such that trade war utility is less than free trade utility.
To sum up this section's main result, countries engage in commercial and industrial policies to improve their terms of trade, but these attempts mutually neutralize and the sole effect is the loss on all sides. Thus, the setting is a version of the prisoners' dilemma and as such the inefficiency can be cured through reputation building in a repeated game. Infinite repetition of the stage game described above is the topic of the next section.

[6] See appendix.

3 Repeated Trade and Cooperation

Despite the fact that countries are tempted to reap gains by charging tariffs unilaterally, such policies might not be optimal as this triggers future punishment. A defection country can well enjoy transitional gains, but after an initial period of surprise the other country will adapt its policies and a trade war breaks out, which incurs losses also for the cheater.
If the threat from future trade war is severe enough, free trade is self-enforcing. However, if countries heavily discount the flow of utilities, this is not necessarily the case. In such a situation, it is possible to sustain *some*, though not complete liberalization of trade. It is then necessary to analyze which of the trade barriers are preferably to be removed and which are efficient in keeping the agreement self-enforcing. This section explores what policy instruments - tariffs or industrial policy - are appropriate to make trade agreements sustainable in a setting of repeated trade games.
The next subsection prepares the ground and illustrates the conditions under which free trade is self-enforcing, while the following then deals with the situations under which this is not the case and delivers results on whether to use commercial or industrial policy to sustain trade agreements.

3.1 Sustaining Free Trade

Assume that the stage game of the previous section is repeated infinitely often. Let β be the factor the two countries discount the flow of utilities (1) with. Now consider the following "trigger strategies" in order to sustain free trade: both countries do not charge tariffs and do not engage in industrial policy ($T = T^* = 1$ and $y = x^* = 0$) as long as both did so in every period in the past. If one defects and deviates from this pattern the other cannot react in the same period but both countries play Nash strategies ever after and end up with the utility (10).

In general, cooperation is self-enforcing if the future discounted flow of utilities under cooperation is bigger than that of defection:

$$V^{Cooperate} = \sum_{t \geq 0} \beta^t u_t^C \geq u_0^D + \sum_{t \geq 1} \beta^t u_t^N = V^{Defect} \tag{11}$$

or

$$\beta \geq \frac{u^D - u^C}{u^D - u^N} \tag{12}$$

in a time-invariant setting.
In (11) and (12), u^C stands for the cooperation utility, u^N for the Nash utility (10), and u^D for defection utility. Defection itself means that one country, say Foreign, sets tariffs and industrial policy unilaterally while free trade was agreed upon originally. This hits by surprise Home's government and workers, which can adapt neither tariffs nor output in the same period.

Equation (11) is the self-enforcement constraint (SEC) and plays a central role in the following analysis. The main tasks will be to explore when it binds and how to use commercial and industrial policies optimally to make it hold.

To check whether free trade is self-enforceable in a time-invariant game, one has to collect the respective utilities in (12). The best response tariffs (7) show that defection tariffs on free trade are infinity and for $b \geq 2$ it can be shown[7] that best response production implies $y = 0$ such that the momentary utility from defecting on a free trade agreement is $u^D = b/\sqrt{2}$. Free trade utility is $u^F = b/2$. Then, (13) becomes

$$\beta \geq \frac{\sqrt{2}-1}{\sqrt{2}-2u^N/b} = \beta^{FT} \tag{13}$$

Note that by (10) β^{FT} is decreasing in b and the constraint relaxes. Thus, as the differences in productivity grow larger, the more likely free trade is sustainable. The reason is simply that an increase in b makes the value of cooperation grow faster than the value of defection. To see why, notice that an increase in b improves the production possibilities but also increases the mutual dependence, which makes the trade war tougher and tends to reduce trade war utility. The overall impact of an increase in b on trade war utility is therefore less than its impact on cooperation utility. Now, as the value of defection is a composite of the instantaneous gains and the trade war consequences, the increase in b increases cooperation value more than the defection value and thereby relaxes the self-enforcement constraint. Note that this comparison is ceteris paribus and I will return to it in a dynamic context in Section 4.

Now, when countries heavily discount future utility at low β, (13) is violated - the threat of a trade war is not enough to sustain free trade. For the rest of the paper I will assume that such heavy discounting, a key condition for the results is satisfied[8].

It is well understood that in a situation where free trade is not self-enforcing, the implementation of positive but moderate trade barriers is self-enforcing, since they tend to decrease the value of defection more than the value of cooperation (see Bagwell and Staiger (2000)). In the framework of this paper there are now two policy instruments at hand - commercial and industrial policy - both of which can be employed to relax the self-enforcement constraint. The natural question arising is, which of them should be used to relax the self-enforcement constraint. This is the focus of the following subsection and its implications constitute the main contributions of the paper.

[7]See Appendix. Assumption $b \geq 2$ is convenient for the equations but not necessary for the result. For $b < 2$, $u^D = \sqrt{b}(2+b)/4$ and the SEC changes accordingly.

[8]Seeking remedy from this inefficiency, some scholars follow Dixit (1987) and assume autarky as a harsher threat which also constitutes a Nash equilibrium. While this makes cooperation on free trade more likely it obviously does not guarantee it. The results in the following do not depend on the choice of (10) as the threat.

3.2 Sustaining Agreements through Intervention

Assume that countries are impatient and free trade is not self-enforcing. Then, starting from the trade war level, a *partial* liberalization of trade and industrial policies is still self-enforcing. The idea is to keep small amounts of trade barriers to reduce incentives to defect and thus make cooperation possible[9]. The inefficiencies these policies create are the price to pay for avoiding much larger losses of a trade war. The key question now concerns the right combination of tariffs and industrial policy to make the self-enforcement constraint hold.
To find this right combination of policies, call the tariff and industrial policy agreed upon in the agreement $\bar{y}^A$, $\bar{x}^A$, and T^A. the optimal symmetric self-enforcing trade agreement as the solution of

$$\max_{T,\bar{x}^A,\bar{y}^A} u(\bar{y}^A, \bar{x}^A, T^A) \qquad s.t.\ \beta \geq \frac{u^D(\bar{y}^A, \bar{x}^A, T^A) - u^C(\bar{y}^A, \bar{x}^A, T^A)}{u^D(\bar{y}^A, \bar{x}^A, T^A) - u^N} \tag{14}$$

Note that by symmetry, the solution of (14) maximizes both countries' utility. Also, both countries face the same self-enforcement constraint such that (14) entirely defines the symmetric problem.
The solutions of (14), the policy functions $(\bar{y}^A, \bar{x}^A, T^A)$ are the policies eventually fixed in the agreement. Cooperation utility is $u^C = (\bar{x}^A + \bar{y}^A)\sqrt{T^A}/(T^A+1)$ according to (5), u^N is from (10) and u^D is the defection utility. The arguments of u^D are the cooperation policies that are defected on. The actual defection strategies are defined by equation (7) and implicitly by the optimality conditions (A4) and (A5) (see appendix).

As discussed above already, the solution to this problem is no intervention at all provided that the discount factor β is large enough - i.e. the self-enforcement constraint does not bind. If $\beta = 0$, on the other hand, the future is not valued at all and the outcome is a trade war as in the previous section. For any intermediate range of β, the self-enforcement constraint does bind and one can show that , $\bar{y}^A > 0$, $\bar{x}^A = 0$ and $T^A > 1$ in that case[10].
The domestic output of the imported good is of special interest here. Its optimal level is positive because it is an efficient means to reduce defection incentives of the foreign country. To see this, assume that, say, Home does not produce y at all. As Foreign is a monopolist in a good essential for Home, Home's dependence on Foreign supplies is extremely high and so are Foreign's gains from defecting. But small amounts of y-production in Home already break the Foreign's monopoly position and dramatically reduce its ability to extract output from Home.
Thus, positive domestic production of the imported good is part of any trade agreement that does not implement free trade.
But this does not necessarily mean that markets fail to provide the optimal quantity y^A and governments have to engage in industrial policies. Yet, it is

[9] For the explanation of this general feature, see e.g. Bagwell and Staiger (2000).
[10] Strictly speaking, governments are indifferent in giving subsidies to the exporting sector up to the level $\bar{x}^A = b(1 - \bar{y}^A)$, however, an $\varepsilon > 0$ cost of subsidizing would prevent this.

readily shown that relative import prices under optimal trade agreements are always below the marginal rate of transformation

$$pT^A = T^A < b$$

Thus, a decentralized market completely specializes on the export good and the government has to step in and set the minimum level . At the same time, there is no need to subsidize export production and its centrally induced minimum level is zero.
These findings are summarized in the following

Proposition 1 *In the economy described in Section 2, any symmetric self-enforcing optimal trade agreement that does not implement free trade includes industrial policy favoring import competitors.*

Proof. See Appendix. ■

Figure 1 illustrates the finding of the proposition. On the horizontal axis of the top panel, the discount factor β runs from zero to one. For large , inequality (13) is satisfied and free trade is sustainable. Consequently, no tariffs are charged and there is no import competing production under the optimal trade agreement. As soon as β drops below the threshold in (13) the optimal trade agreement includes positive y-production. As the discount factor approaches zero countries ignore future benefits, which constitute the only reason for respecting the agreements; consequently the optimal trade policies $(\bar{y}^A, T^A)$ approach the Nash levels (9).

For a deeper understanding recall that the situation in a tariff game with competitive firms is roughly the following: the countries' governments - not caring about foreign consumers' losses but well about domestic producers' gains - try to replicate monopoly markups on the countries exports and set tariffs to this end. Monopoly markups, however, depend on the elasticity of demand ε by the factor $1/(\varepsilon - 1)$. Now, by engaging in production of the import good, a country *increases* its import elasticity. Thus, it reduces foreign market power and thereby the surplus foreigners can extract when defecting. Consequently, foreign incentives to defect fall.
The Cobb-Douglas utility has an elasticity of substitution of one. When there is no production of the imported good, the elasticity of import demand σ is equally one, so the markup $1/(\sigma - 1)$ is unbounded. Producing small amounts of the import-good domestically increases import elasticity somewhat but reduces the markup dramatically. This is the reason why import competing production is extremely efficient in reducing the defection utility and therefore in relaxing the self-enforcement constraint.

Proposition 1 states that industrial policy can be extremely efficient in reducing vulnerability to unreliable suppliers. The energy crisis of 1973 can be read as an illustrative application of such strategies. When the OPEC imposed an embargo on western industrialized countries, these latter spent huge subsidies to set up national energy programs. The clear aim was to reach some degree of self-sufficiency and reduce the vulnerability to the countries that just had demonstrated their ability to collude to a cartel of suppliers. With quite low estimates for the elasticities of substitution between energy and key aggregates ranging around one and below (see Özatalay, Grubaugh and Long (1979)), this behavior fits well in the explanation pattern of Proposition 1. A common and natural objection to such politics is that energy reserves should not be depleted in times of relative abundance but rather be kept for periods when world markets are tighter. The scenario developed above shows instead that subsidized energy production might precisely prevent such a tightening by reducing the incentives of oil-producers to collude.

Note finally, that optimal subsidies are favoring import-competing sectors. Rodrik (1995) identifies an "anti-trade bias" in trade policy. Attempts to explain it usually take a political economy-approach and rely on rather specific assumptions (see Limao and Panagariya (2002)). In contrast, Proposition 1 suggests that this anti-trade bias may be exactly what is needed to make trade agreements sustainable.

3.3 Self-Enforcing Agreements without Industrial Policy

Before closing this section, it is instructive to look at the consequences of impeding any kind of industrial policy. Proposition 1 implies that this makes self-enforcing trade agreements suboptimal. As will become clear in a moment, such a ban may actually lead to a collapse of *any* efficiency-enhancing agreement.

Assume that government has no policy instrument apart from import tariffs. This implies that import competing production is zero as soon as symmetric tariffs are below the Nash level $T^A = b$. Going back to the Best Response functions (7), one gets that the defection tariff grows unbounded $T \to \infty$; (4) shows then that Home prices of good y are $pT \to T^A + 1$. Moreover, imports of y are $b/(T^A + 1)$, such that Home optimally stays out of y-production ($y = 0$): This leads to

$$u^D(T^A) = b/\sqrt{T^A + 1}$$

where T^A is the tariff actually defected on. The cooperation utility is $u^C(T^A) = b\sqrt{T^A}/(T^A{+}1)$, and trade war utility is u^N from (10). Then, the self-enforcement constraint (12) tells that in order to sustain *any* trade agreement (other that the trade war) the discount factor β must exceed the minimum level of[11]

$$\beta^M(b) \min_{T^A \in [1,b]} \left\{ 1 - \frac{u^C(T^A) - u^N}{u^D(T^A) - u^N} \right\} > 0 \tag{15}$$

[11] It is quick to check that the strict inequality holds.

This leads to the following

Remark to Proposition 1 *If countries cannot engage in industrial policy, any discount factor that falls short of (15) leads to a trade war.*

This remark highlights the importance of industrial policy for trade agreements. A country living in such a world where future gains are heavily discounted would turn down the possibility to join a trade agreement that bans all kinds of industrial policies. It would rationally assume that its vulnerability to foreign suppliers would create too high incentives for them to defect on the agreement. Tariffs alone could not cut these incentives enough and cooperation is not possible.

While the present section made the case for the use of industrial policy to sustain self-enforcing trade agreements the following section sets this finding in a dynamic framework in which productivities are changing over time.

4 Changes in Comparative Advantage

As discussed in the previous section, a deepening of the comparative advantage (i.e. an increase in the parameter b) raises the gains from cooperation more than the gains from defection and makes free trade more likely. The present section takes a dynamic approach to this point and shows how a carving in of the comparative advantage can lead to gradual trade liberalization and explain the protection of declining industries.

In a simple but suggestive way the present section will remove the assumption that the pattern of comparative advantage is constant over time. In a first step, the comparative advantage is assumed to deepen exogenously, i.e. independent of the trade policies the countries engage in. It is shown that a single jump in export productivities can lead to a gradual reduction of trade barriers, which sets in before the date of the technology change. Under the optimal dynamic agreement, the import-competing industries decline in the period of stepwise trade liberalization. Consequently, the protection of declining industries can be part of an optimally designed trade agreement.
A second step connects the increase in the comparative advantage to a simple learning by doing process. In the case that the deepening of comparative advantage takes place conditional on trade cooperation, agreements that eventually allow free trade may indeed *require* the transitional use of industrial policy in favor of import-competing industries. So banning it makes any outcome other than trade war impossible.

4.1 Declining Industries

In a repeated game where future gains form cooperation make the players respect the rules, all upcoming events enter the participation constraint today. Thus, a future trade liberalization that is expected to increase gains from cooperation increases also today's value of respecting the agreement. This, in turn, relaxes today's self-enforcement constraint and allows trade liberalization today already. Consequently, the liberalization process is gradual.

To explore this argument in more detail, assume that the productivity in the exporting sector, b, increases with a single exogenous jump at some future date t_0. This assumption not only simplifies the formalities, it also shows that the gradualism does not hinge on a stepwise increase in b. The process $\{b_t\}$ is summarized in the following

$$b_t = \begin{cases} \underline{b} & if\ t < t_0 \\ \bar{b} & if\ t \geq t_0 \end{cases}$$

with $\bar{b} > \underline{b}$. Rational agents anticipate this jump.
Now, for a given parameter b and symmetric trade agreement defined by (T^A, y^A), define the gain from defection relative to Nash outcome as

$$\delta(T^A, y^A; b) = u^D(T^A, y^A, b) - u^N(b)$$

and the gain from cooperation relative to Nash outcome as

$$\xi(T^A, y^A; b) = u^C(T^A, y^A, b) - u^N(b)$$

Then, dropping the superscripts $(^A)$ and writing simply (T, y) for the trade agreements, the participation constraint at time t can be written as

$$\delta(T_t, y_t; b_t) \leq \sum_{\tau \geq t} \beta^\tau \xi(T_{t+\tau}, y_{t+\tau}; b_{t+\tau})$$

As an increase in b was shows to relax the static free trade self-enforcement constraint (12), it is possible to assume that free trade is sustainable under $\bar{b}$ but not under $\underline{b}$:

$$\delta(1, 0; \bar{b}) \leq \frac{1}{1-\beta}\xi(1, 0; \bar{b}) \qquad\qquad \delta(1, 0; \underline{b}) > \frac{1}{1-\beta}\xi(1, 0; \underline{b})$$

Then, assuming that t_0 is far enough in the future, free trade is not sustainable at $t = 0$. So there must be a time $t_1 \leq t_0$ such that free trade is sustainable ever after

$$\delta(1, 0; b_{t_1}) \leq \frac{1-\beta^{t_0 - t'}}{1-\beta}\xi(1, 0; \underline{b}) + \frac{\beta^{t_0 - t'}}{1-\beta}\xi(1, 0; \bar{b}) \qquad\qquad t' \geq t_1$$

but at $t_1 - 1$ it is not

$$\delta(1,0;b_{t_{1-1}}) > \frac{1-\beta^{t_0-t'+1}}{1-\beta}\xi(1,0;\underline{b}) + \frac{\beta^{t_0-t'+1}}{1-\beta}\xi(1,0;\bar{b})$$

Suppose again that countries always implement the efficient symmetric subgame perfect trade agreement. From time onwards this ,means the laisser-faire policies $(T, y) = (1, 0)$. At time $t_1 - 1$, the most efficient trade agreement maximizes cooperation utility $u^C(T_{t_1-1}, y_{t_1-1})$ subject to

$$\delta(T_{t_1-1}, y_{t_1-1}; \underline{b}) - \xi(T_{t_1-1}, y_{t_1-1}; \underline{b}) \leq \beta \sum_{\tau \geq 0} \beta^{\tau} \xi(1, 0; b_{t_1+\tau}) \tag{16}$$

Note that by construction of t_1 the constraint must be binding such that the value function of this maximization problem is less than under laisser-faire, $u^C(1, 0)$, and consequently the gains from cooperation will be less

$$\xi(T_{t_1-1}, y_{t_1-1}; \underline{b}) > \xi(T_{t_1}, y_{t_1}; \underline{b}) = \xi(1, 0; \underline{b}) \tag{17}$$

The outcome of the maximization problem deliver the policy functions (T_{t_1-1}, y_{t_1-1}) for time $t_1 - 1$.
At time $t_1 - 2$, policymakers take (T_{t_1-1}, y_{t_1-1}) as given to calculate the most efficient sustainable trade agreement, maximizing $u^C(T_{t_1-2}, y_{t_1-2})$ s.t.

$$\begin{aligned}\delta(T_{t_1-2}, y_{t_1-2}; \underline{b}) - \xi(T_{t_1-2}, y_{t_1-2}; \underline{b}) \leq \beta\xi(T_{t_1-1}, y_{t_1-1}; \underline{b}) \\ +\beta \textstyle\sum_{\tau \geq 0} \beta^{\tau} \xi(1, 0; b_{t_1+\tau})\end{aligned} \tag{18}$$

Note that by (17) the RHS of (18) is larger than the RHS of (16) so the self-enforcement constraint at time $t_1 - 2$ (18) is tighter than at time $t_1 - 1$ (16). Consequently, the trade agreement at time $t_1 - 2$ (T_{t_1-2}, y_{t_1-2}) is less liberal than the one at $t_1 - 1$ (T_{t_1-1}, y_{t_1-1}). An induction argument completes the proof that, going backwards in time from t_1 onwards the trade agreement gets gradually less liberal.
It is quick to check that at each time, the optimality conditions for the trade agreements are identical with those of the problem (15). As the policy functions of the maximization problem (14), i.e. (T^A, y^A) were shown to be decreasing in the value function u^C, tariff and industrial policy gradually grow smaller and eventually vanish. This finding is summarized in the following

Proposition 2 *An anticipated exogenous deepening of comparative advantage at time , increases the anticipated gains from the trade agreement. Thereby, it relaxes the self-enforcement constraint even before date , and consequently trade is liberalized gradually. During the liberalization period declining industries are protected.*

The proposition has two parts, which address gradualism of trade liberalization and the protection of declining sectors. While the finding of gradualism

basically repeats the result of Devereux (1997), the novel and interesting part of Proposition 2 is the fact that optimal trade agreements protect declining industries.
The reason for a stepwise reduction of protection does not come from the desire to cushion or reduce political resistance but it is an optimal policy because the self-enforcement constraint impedes to let them go at once. Some sectors, so the argument runs, have to be protected in order to guarantee self-enforceability of the agreement; and as the self-enforcement constraint relaxes stepwise, they are gradually faded out.
Protection of declining industries is usually explained by political economy arguments. The contraction of an industry, a standard argument runs, is followed by a decrease in lobbying activity, which in turn leads to less protection and further decline (see Hillman (1982)). The present paper's argument, in contrast, relies on purely welfare-maximizing governments.

The next subsection will explore the situation where the deepening of comparative advantage is conditional on trade cooperation.

4.2 Declining Through Protection

With a simple example, this section highlights the prominent role industrial policy plays in trade agreements. It shows that the transitional engagement in industrial policy may be necessary in order to reach a free trade agreement.
The mechanism draws on the Remark to Proposition 1 in Section 3, which states that protection of import-competing sectors is necessary to reach any kind of efficiency-enhancing trade agreement provided that the discount factors are small. Then, if learning by doing is such that the pattern of comparative advantage deepens only if there is international specialization, countries can choose to stick to trade war forever, or to engage in industrial policy temporarily experience a period of moderate protection during which the comparative advantages carve in and give finally way to a fully liberalized self-enforcing trade agreement.

Assume that there is sector-specific disembodied knowledge κ^z $(z = x, y)$, which accumulates through learning by doing. However, there has to be a minimum level of activity in each sector for the stock of knowledge to increase[12]. In particular, assume that evolves according to

$$\kappa^z_{t+1} = \kappa^z_t + \varepsilon_t \qquad \varepsilon_t = \begin{cases} \overline{\varepsilon} & if \quad z_t > \underline{b}/(\underline{b}+1) \\ 0 & else \end{cases} \tag{19}$$

[12]To justify this assumption, one can think of various micro-foundations. As one possible example, suppose that at the end of each period workers meet and talk. If there are more than a share of $\underline{b}/(\underline{b}+1)$ workers from the same sector, they talk about work and increase the stock of knowledge. However, if there are less than a share of $\underline{b}/(\underline{b}+1)$ workers present, the minority complains about specialist talk and all discuss soccer, which does not improve the sector-specific stock of knowledge. This leads to (**??**).

in Home and equivalently in Foreign.
Finally, suppose that the stock of knowledge affects the aggregate productivity in the following way[13]:

$$b(\kappa^x) = \begin{cases} \overline{b} & if\ \kappa^x \geq \overline{\kappa} \\ \underline{b} & else \end{cases} \qquad \text{and} \qquad a(\kappa^y) = \begin{cases} \overline{a} & if\ \kappa^y \geq \overline{\kappa} \\ 1 & else \end{cases} \tag{20}$$

Under these conditions, there is will be no improvement in technologies under trade war since . However, under some international specialization the stock of knowledge in the exporting sector grows and pattern of comparative advantage carves in at some date t_0. The situation is now the same as in the previous subsection with the jump in export productivities according to (**??**) with the only difference that the jump in b is conditional on trade integration.

When initially $\underline{b}$ and β are such that $\beta < \beta^M(\underline{b})$ (compare (15)) and is far in the future, the effect of the additional gains on the self-enforcement constraint is negligible. Thus, the self-enforcement constraint is essentially the static one (12) and no efficiency-enhancing trade agreement is feasible without the use of industrial policy. If now in such a world industrial policy is prohibited, no trade agreement will be put in place and consequently the technologies are not improving. All parameters remain constant over time and countries have no choice but living under a non-cooperative trade regime.
However, when countries have the possibility to engage in industrial policies, a moderate liberalization will take place initially. This leads to some degree of specialization and by (19) the knowledge in the respective export-technologies starts to grow in every consecutive period, which eventually leads to the jump in technologies. If the impact of the technology is large enough, it will lead to free trade ($\beta^{FT}(\overline{b}) < \beta$ - compare (13)). Repeating the logical steps that led to Proposition 2, one derives the following

Proposition 3 *Under learning by doing as in (19) and (20) and assuming that $\beta^{FT}(\overline{b}) < \beta < \beta^M(\underline{b})$, any self-enforcing trade agreement that eventually leads to free trade necessarily implements industrial policy temporarily.*

Figure 3 shows the relation between discount factor and increase in productivity b that can lead to this scenario.

This example illustrates that, somewhat paradoxically, certain sectors may decline and give way to liberalization only if they are temporarily protected. Countries that fear dependence on foreign imports of essential goods may refuse to enter trade agreements when they are not allowed to promote the domestic production of these goods by industry policies. However, if the agreement leaves

[13] Assume e.g. that a certain amount of sector-specific knowledge is needed to adopt a new technology that makes b jump from $\underline{b}$ to $\overline{b}$.

this door open to them, they may partially open to trade, which sets them on the track to eventually complete liberalization.

The past sections made a strong case for subsidies and industrial policy in general, pointing out some beneficial effects it can have in a competitive world without externalities and with a welfare-maximizing government. It is important, however, to highlight the qualifications of this reasoning. This is the role of the next section.

4.3 Limitations: A More Rigid Industrial Policy

It was pointed out already in sufficient detail that key assumptions for the previous results require that countries be impatient, the imported goods be essential, and their suppliers be monopolists on the world market. But there is another less explicit assumption, which is crucial for the findings to go through. This assumption concerns the flexibility of industrial policies.

In the previous sections, industrial policy was modeled as flexible enough to be changed from period to period. In particular, the time to change commercial and industrial policies was assumed to identical. However, when industrial policy includes ports, highways, pipelines or the like - in short, public infrastructure that needs time to build - it is rather long-lived and subject to slow changes at best.
The present section therefore deals with the case where the time to change commercial policy is significantly shorter than the horizon for changing industrial policies. It will turn out that this change in assumptions considerably alters the previous results.

For the interpretation of a more long-lived industrial policy, assume that governments have control over a perfectly divisible natural resource whose amount is normalized to unity. Allocation of the resource to one of the sectors makes it become a sector-specific input good. This government input is essential in each industry but exhibits decreasing returns. Further, there is congestion in the use of this publicly provided input good, which leads to decreasing returns to labor as well. Government distributes a fraction γ of it to the exporting and $1-\gamma$ to the importing sector. The following production functions reflect the assumptions

$$\begin{aligned} x &= b(\gamma/L_x)^\alpha L_x \\ y &= ((1-\gamma)/L_y)^\alpha L_y \end{aligned}$$

for Home and the symmetric counterpart for Foreign. By assumption, let $\alpha \in [0,1]$ and b be still bigger than unity, which gives Home a natural comparative advantage in good x under symmetry. Atomistic workers produce competitively taking overall productivities $b(\gamma/L_x)^\alpha$ and $((1-\gamma)/L_y)^\alpha$ as given. Wages equalization leads to

$$L_x = \frac{\gamma}{\gamma + (1-\gamma)(pT/b)^{1/\alpha}} \qquad L_y = \frac{(1-\gamma)(pT/b)^{1/\alpha}}{\gamma + (1-\gamma)(pT/b)^{1/\alpha}}$$

and the output

$$x = b\frac{\gamma}{(\gamma + (1-\gamma)(pT/b)^{1/\alpha})^{1-\alpha}} \qquad L_y = \frac{(1-\gamma)(pT/b)^{(1-\alpha)/\alpha}}{(\gamma + (1-\gamma)(pT/b)^{1/\alpha})^{1-\alpha}}$$

In the limit $\alpha \to 1$, output is equal to $x = b\gamma$ and $y = 1-\gamma$, which will be taken as a benchmark here[14].

The assumption of the last section - namely that output structure can be changed every period - is now replaced by the opposite and equally extreme assumption that industrial policy is completely inflexible. Initially, governments choose the output patterns through their industrial policy (i.e. γ), which determines output ever after. This initial choice of γ is assumed to be free from commitment problems[15]. After the initial period, countries are only able to defect on tariffs.

The effect of adding the rigidity can be read one more time from the self-enforcement constraint (11): Unlike the previous section, the initial choice of industrial policy now does affect the utilities in all consecutive periods, in particular, it predetermines losses from a trade war. When capacities to produce the imported good are set to zero, a trade war appears especially grim. But this means that countries have an excellent possibility to commit to free trade by setting the industrial structure γ to zero. In fact, the deliberate creation of mutual dependence constitutes a commitment-device for cooperation.
For a formal exposition of this idea, assume that the industrial structure γ is set at the initial period and stays fix forever. Then, in the case of cooperation breakdown, both countries suffer the severe punishment of a trade war. This punishment utility is[16]:

$$u^P = \frac{b(1-\gamma+\gamma)}{\sqrt[4]{b(1-\gamma)/\gamma} + \sqrt[4]{\gamma/b(1-\gamma)}} \tag{21}$$

which now enters the self-enforcement constraint (11) instead of u^N.

$$\beta \geq \frac{u^D - u^C}{u^D - u^P} \tag{22}$$

[14]For general , the model is not analytically solvable but simulations show that there is no qualitative difference in the results.
[15]XXXXXX

Argue with the cost of monitoring.
[16]Use the best response function (7) and utility (5).

Note that the punishment utility is zero at γ and that it is increasing in γ. Clearly, when production of the imported good is zero for all periods to come, a trade war leads to zero utility - which is in fact worse than the Nash utility (10) ($u^N > u^P = 0$). The direct consequence is the

Proposition 4 *Other things equal, free trade is more likely to be self-enforceable in a world with rigid output than with flexible one.*

Proof. See Appendix. ■

This result applies when output capacities are sufficiently slow to build. Under this condition, the creation of mutual dependence can serve as a commitment device and helps to sustain free trade when it would not be under more flexible output patterns. In fact, the deliberate destruction of capacities in import competing sectors may be an adequate policy by generating this dependency.
Such a creation of mutual dependence was an argument put forward by the founders of the European Coal and Steel Community (ECSC), which laid the basis of the later European Union. The pooling of the essential goods steel and coal was meant to create a mutual dependence between the six western European member nations that made future cooperation indispensable (see Gillingham (1991)). The strategic motive for this act is the same that makes an army burn the bridges behind to commit to going ahead.

The next task is to analyze the impact of industrial policy on the self-enforcement constraint and to check to what extent Proposition 1 generalizes under persistent industrial structure. As can be read from (21), small amounts of domestic production of the essential imported good make a trade war less threatening. Obviously, with the adequate production capacities at hand a trade war does not seem so bad, which increases the value of defection and thereby tends to *tighten* the self-enforcement constraint. This remarkably opposes the finding from Proposition 1.

Of course, the effect just described is not the only one and the force described in the previous section that *relaxes* the constraint when the import-competing production increases must still be present. However, it is shown in the Appendix that the negative effect prevails at the margin and small amounts of import competing production unambiguously tighten the self-enforcement constraint. The consequence is the following

Proposition 5 *Under rigid output patterns, small amounts of industrial policy unambiguously tighten the self-enforcement constraint and the optimal trade agreement either employs industrial policy in large amounts or not at all.*

Proof. See Appendix. ■

Figure 4 illustrates the finding of the proposition. In the top panel, there are now three different ranges for the discount factor. At high levels, the economy is undistorted under the optimal agreement. For medium values, free trade is not sustainable but only a moderate relaxation of the self-enforcement constraint (11) is required. For those small relaxations a promotion of the import-competing sectors is inadequate since it optimally is either null or big time. For even lower β positive tariffs are not enough to make a trade agreement self-enforceable and both, tariffs and industrial policy, are employed in positive quantities.
Notice that the driving forces of Propositions 1 and 5 are quite distinct. When commercial and industrial policies are equally quick to change, stimulating small quantities of domestic production of the imported good reduce the *foreign* country's incentives to defect on the agreement. In the case of more rigid output patterns, the commitment device aims to tie ones hands and is directed against the own defection incentives.
The two effects highlight the fact that to sustain trade agreements, at least one of the two is needed: one-time defection has to appear little attractive or future consequences of defection must be severe.

Before closing the analysis of the rigid output assumption, I quickly consider the intermediate case between flexible and rigid production. Assume that after defection on tariffs, H periods are required to adapt industrial policy to the new uncooperative environment . In this case, the self-enforcement constraint becomes

$$V^{Cooperate} = \sum_{t\geq 0} \beta^t u^C \geq u^D + \sum_{t=1}^{H} \beta^t u^P + \sum_{t>H} \beta^t u^N = V^{Defect}$$

or

$$u^C - (1-\beta)u^D \geq \beta\left((1-\beta^H)u^P + \beta^H u^N\right) \tag{23}$$

The LHS of (23) tightens with increasing H, varying between (15) and (22) when $H \in \{0, 1, 2, ...\}$. Going back to the calculation that led to(15), it becomes apparent that Proposition 4 still goes through in this somewhat less rigid world: cooperation on free trade is more likely under rigid output patterns.
With the help of (A9) and (A10) it is also quick to establish that Proposition 5 survives the change to this somewhat less rigid world: Starting from zero, small increases in $\overline{y}$ unambiguously tighten the self-enforcement constraint and hinder cooperation.

5 Conclusion

This paper has argued that in a world without externalities, with governments maximizing social welfare, and in absence of interest groups the use of industrial policy can be part of a optimal strategy when international trade agreements are required to be self-enforcing. Optimal interventions must favor sectors of comparative disadvantage, which face competition from imports. The distortions these policies create are the price that must be paid to prevent the even more severe damage of a trade war. Preconditions for these results are low elasticities of demand of the import-goods, heavy discounting of future benefits and strong specialization patterns of international production.

A dynamic extension of the model introduced learning by doing in a simplified way and provided a rationale for the protection of declining industries.

A final extension of the model draws the attention to the role of the flexibility of the industrial structure. When output patterns are slow to change, mutual dependence can serve as a commitment device, encouraging adherence to an agreement. In this case the stimulation of import competing sectors may even undermine trade agreements, and the deliberate creation of mutual dependence through a policy that works against import-competing sectors may be desirable.

Appendix

I. The Nash Equilibrium. The program is to maximize (5) over T, $\overline{x}$ and $\overline{y}$ s.t. (3) and (4). The proof proceeds in two steps. The first step disregards (3) and assumes that Home's choice variables are T, x and y (fixing the actual output instead of the minimum levels $\overline{x}$ and $\overline{y}$). The second step shows that the original problem has the same solution.

First step. The program is to maximize (5) over T and y subject to (4) and the resource constraint, or

$$\max_{T,y} \ln\left(\frac{x+yp}{\sqrt{p}}\frac{\sqrt{T}}{T+1}\right) \qquad s.t.\ (4) \text{ and } \quad x = b(1-y) \tag{A1}$$

Dealing with the two-dimensional maximization problem requires in general the calculation and evaluation of the Hessian. This is a route that one should try to avoid. Fortunately, a unique and closed form solution the best response function of the tariff has been derived by Kennan and Riezman [1988] already and can be replicated by establishing the FOC w.r.t the tariff T

$$\left(\frac{py}{x+py} - \frac{1}{2}\right)\frac{d}{dT}\ln(p) + \frac{1}{2T} - \frac{1}{T+1} = 0$$

Using (4) gives

$$\frac{d}{dT}\ln(p) = \frac{x^*T^*}{x^*T^*(T+1)+x(T^*+1)} - \frac{y(T^*+1)+y^*}{yT(T^*+1)+y^*(T+1)} \tag{A2}$$

and leads to the old result

$$T(T^*, x^*) = \sqrt{\frac{y^*}{x^*}\cdot\frac{x^*+x(1+1/T^*)}{y^*+y(T^*+1)}} \tag{A3}$$

Whatever the best strategy on the output may be, (A3) establishes the unique best response tariff. To derive the optimal output (y, x), use $x = b(1-y)$ and set $du/dy = 0$:

$$\frac{p}{x+py} + \frac{1}{2}\left(\frac{py-x}{x+py}\right)\frac{d}{dy}\ln(p) = 0 \tag{A4}$$

The derivative of the price (4)

$$\frac{d}{dy}\ln(p) = \frac{-b(T^*+1)}{x^*T^*(T+1)+x(T^*+1)} - \frac{T(T^*+1)}{yT(T^*+1)+y^*(T+1)} \tag{A5}$$

gives

$$\begin{aligned} 0 \quad = \quad & 2\frac{x(T^*+1)+x^*-b(y(T^*+1)+y^*)}{xy(T^*+1)+xy^*+yx^*} \\ & -\frac{T^*+1}{y(T^*+1)+y^*(1+1/T)} + b\frac{T^*+1}{x(T^*+1)+x^*T^*(T+1)} \end{aligned}$$

This is a necessary condition a Nash equilibrium has to satisfy. *If* an equilibrium now happened to be symmetric ($T = T^*$, $y = x^*$), the necessary condition implied that the optimal y is

$$y = \frac{\max\{T + 2 - b; 0\}}{3b(T+1) - b^2 - T} \tag{A6}$$

(Note that for the relevant range ($b > 1$ and $T \geq 1$) the denominator is positive as long as the numerator is so.) Finally, (A3) and (A6) together give

$$T^N = b \qquad y^N = \frac{1}{b+1} \qquad x^N = \frac{b^2}{b+1} \tag{A7}$$

To complete the proof that (A7) in fact describes a Nash Equilibrium, set Foreign variables according to (A7), i.e. $T^* = b$ and $x^* = \frac{1}{b+1}$. Writing further the short-hand $p = r_1/r_2$ with $r_1 = b(T+1) + x(b+1)^2$ and $r_2 = b^2(T+1) + yT(b+1)^2$, the optimality conditions (A4) and (A5) give

$$2\,(br_2 - r_1) = (b+1)^2(br_2 + Tr_1)\left(\frac{x}{r_2} - \frac{y}{r_1}\right)$$

The LHS of that equation is increasing in y while the RHS is decreasing in y ($(br_2 + Tr_1)$ and $x/r_2 - y/r_1$ are positive and decreasing in y). As the choice variables are restricted to a compact set $(y, T) \in [0,1] \times [1, 2b]$ (see (A3)). This proves that the unique optimal response on $T^* = b$ and $x^* = \frac{1}{b+1}$ for Home is given by (A7).

Second step. Choice variables are tariffs and minimum levels of output in the sectors and players internalize (3).
Show that internalizing (3) does not change (A7). Set Foreign's choice variables to the Nash levels: $T^* = b$ and $\overline{x}^* = \frac{1}{b+1}$. (3) implies then

$$\begin{array}{lll} pT = b & \text{or} \;\; pT \leq b \;\; \text{and} \;\; y = \overline{y} \\ p = 1 & \text{or} \;\; p \geq 1 \;\; \text{and} \;\; x^* = 1/(b+1) \end{array}$$

while $T^* = b$ always. First note that $p > 1$ cannot be optimal since it implied $x^* = 1/(b+1)$, which induced the Nash responses (A7) in Home and contradicts $p > 1$. Therefore, $p = 1$ throughout. This is equivalent to

$$x^* \cdot 2b(T+1) = y(T+b)(b+1) - b(b-T) \tag{A8}$$

Next consider the case $pT = T = b$. (A8) induces $x^* = y$ and (5) $u = (x + y)\sqrt{T}/(T+1)$. The optimal y is therefore $y = \min(x^*) = 1/(b+1)$.
Remains the case $pT < b$ and $y = \overline{y}$. Taking implicit derivatives with (A8), one has

$$\frac{dT}{dx^*} = \frac{2b(T+1)}{b + y(b+1) - 2bx^*} > 0 \qquad \text{and} \qquad \frac{dy}{dx^*} = \frac{2b(T+1)}{(b+T)(b+1)} > 0$$

such that the locus where (A8) holds shifts out on the (y, T)-plane when x^* increases (T increases in x^* for constant y and vice versa). As $u = (x+y)\sqrt{T}/(T+1)$ decreases in y and T, the optimal x^* is the minimal, i.e. $x^* = 1/(b+1)$, which again leads to the Nash responses (A7) in Home.
■

II. Defection Utility on Free Trade. Note first that $T^{BR} \to \infty$ as $(x^* \to 0)$. Use (4) and (A3) to see that $x^* \to 0$ implies $pT \to x/(y + b/(T^* + 1))$. Wage equalization in the active sectors[17] lead to

$$y = \max\{\tfrac{1}{2}(1 - \tfrac{b}{T^*+1}), 0\}$$

At $T^* = 1$ and for $b \geq 2$ this implies $y^D = 0$ and

$$u^D = b/\sqrt{2}$$

III. Proof of Proposition 1. Setting $x^* = y^A$ and using equations (4), (5), and (A3), one gets

$$2\frac{d}{dy^A}\ln(u^D) = -\frac{c_o}{\sqrt{y^A}} + o\left((y^A)^{-1/2}\right) \tag{A9}$$

where c_o is positive and a constant in y^A. Taking derivatives of the RHS of (12) delivers

$$\frac{d}{dy^A}RHS = \frac{d}{dy^A}\left(1 - \frac{u^C - u^N}{u^D - u^N}\right) = -\frac{du^D/dy^A}{u^D - u^N} + \frac{u^C - u^N}{(u^D - u^N)^2}\frac{du^D}{dy^A}$$

Since du^C/dy^A is finite, this derivative must be minus infinity $-\infty$ at $y^A = 0$. In other words, small amounts of import-competing production relax the SEC at a cost-benefit ratio of zero. Consequently, the problem (14) has an interior solution, i.e. $y^A > 0$. ■

IV Proof of Proposition 4 and 5. It is quick to verify that

$$\frac{d}{dy^A}u^P(T^A, y^A) = \frac{c_1}{(y^A)^{3/4}} + o\left((y^A)^{-3/4}\right) \tag{A10}$$

with $c_1 > 0$. Since du^P/dy^A increase at a higher order than du^D/dy^A decreases, one gets

$$\frac{d}{dy^A}\left(\frac{u^D - u^C}{u^D - u^P}\right)\Bigg|_{y^A=0} = +\infty$$

[17] Note that when defecting, the strategic subsidies are obsolete and countries can rely on efficiency of the market solution again.

In other words, small amounts of import-competing production tighten the SEC and moreover induce efficiency losses. This proves proposition 5.

V. y^A and T^A are non-decreasing in β. First define the differences between cooperation and trade war utility, and between defection and trade war utility as

$$\begin{aligned}\Delta^C(y^A,T^A) &= u^C(y^A,T^A)-u^N\\ \Delta^D(y^A,T^A) &= u^D(y^A,T^A)-u^N\end{aligned}$$

Note that in the case when the constraint does not bind,y^A and T^A are trivially non-decreasing in β. Therefore, consider the case when the constraint binds. This means that $(1-\beta)\Delta^D-\Delta^C=0$. The solution ($y^A$,$T^A$) of this equation is interior by Proposition 1; so one can take derivatives implicitly to get

$$\frac{dy^A}{d\beta}=\frac{\Delta^D/\Delta^C}{\Delta^C_y/\Delta^C-\Delta^D_y/\Delta^D} \tag{A11}$$

Now, any increment in y^A creates distortions at the margin and reduces the cooperation utility u^C (compare (5)) (i.e. $d\Delta^C/y^A<0$). Thus, any optimal policy y^A necessarily relaxes the self-enforcement constraint at the margin. This amounts to $d(\Delta^C/\Delta^D)/dy^A>0$. Together with $\Delta^C,\Delta^D>0$ this proves that (A11) is negative. The equivalent reasoning for optimal tariffs T^A leads to $dT^A/d\beta<0$.
■

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