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**ISSUE LINKAGE, CREDIBLE  
DELEGATION, AND POLICY  
COOPERATION**

Giancarlo Spagnolo

***INTERNATIONAL MACROECONOMICS,  
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## **ABSTRACT**

### **Issue Linkage, Credible Delegation, and Policy Cooperation \***

This Paper, a thorough revision of Spagnolo (1996), addresses the following questions: what is the optimal design for a set of self-enforcing international policy agreements? How many and which issues should each agreement regulate? Are GATT's constraints on issue linkage (cross-retaliation) welfare-enhancing? To facilitate international cooperation should governments keep policy issues under centralized control, or should they delegate them to independent agencies (e.g. central banks)? In the second case, which issues should be delegated? Finally, are institutions allowing governments to credibly delegate policy choices (e.g. to 'conservative' central bankers) good or bad for international policy cooperation?

JEL Classification: E61, F13, F42, H77

Keywords: cooperation, cross-border spillovers, delegation, international agreements, international institutions, linkages, policy coordination

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## NON-TECHNICAL SUMMARY

International trade cooperation is crucial to prevent nations from using beggar-thy-neighbour protectionist policies. Uncoordinated monetary and fiscal policies may lead to suboptimal outcomes. Global environmental and defence issues pose similar policy dilemmas, and international cooperation has been called for on competition, development, agriculture, drug control and other policies.

Many of these policy issues have, in their static structure, the features of an international Prisoners' Dilemma. Because countries face such policy dilemmas repeatedly in time, self-enforcing international agreements can be analysed as equilibria of infinitely repeated Prisoners' Dilemma games. I develop a stylized model with two countries and  $n$  policy issues with the strategic structure of infinitely repeated Prisoners' Dilemma to address the questions stated in the abstract.

In this model, rules constraining governments from linking more issues in one agreement (like those of GATT) turn out to be strictly welfare reducing, since they only constrain the optimal design of international agreements. When countries are symmetric and policy issues separable, issue linkage can facilitate policy cooperation by allowing the use of slack enforcing power (expected losses from punishment minus expected gains from deviation) that may be available on some issues to discipline cooperation on additional issues. Then a single 'grand international agreement' is optimal, as it aggregates available enforcement power allowing for its efficient reallocation to additional issues.

When countries are symmetric and policy issues interdependent (substitutes or complements), issue linkage may affect the amount of available enforcing power, besides its allocation. When two or more policy issues are substitutes, by forcing deviations and punishments to be simultaneous, a linkage makes punishments harder and deviations less valuable. The converse does not hold for complement issues: then a simultaneous deviation is relatively more profitable, but it must be deterred whether or not issues are linked. Then again a single 'grand international agreement' is optimal: it maximizes available enforcement power and optimizes its allocation.

Allowing countries to differ in the objective function does not change this result. Then issue linkage maintains the beneficial effects just mentioned, and in addition allows countries to overcome asymmetries by 'trading' cooperation on some issues against cooperation on others.

When issues are complements simultaneous deviations are more profitable. If governments could commit not to deviate simultaneously on complement issues, the amount of available enforcing power would increase. If issue

linkage prevents such commitment, then a single 'grand agreement' may no longer be optimal. I focus on commitment through delegation to different, independent national agencies with the same objectives as their government. When (a) issues are complements and similar with respect to available enforcing power (so that allocative gains from issue linkage are small), (b) issue linkage makes delegation impossible, and (c) delegation credibly prevents simultaneous deviations, then issue linkage may indeed harm cooperation.

Delegation of power to independent agencies always facilitates cooperation since it constrains defections. When delegation and issue linkage are compatible, cooperation is further enhanced: delegation reduces gains from defections (prevents simultaneous ones) while issue linkage makes punishments stronger (simultaneous on all linked issues).

Delegation may further facilitate cooperation when delegates' objective function can differ from that of governments. The opportunity to credibly delegate policy choices to 'more conservative' agents (e.g. central bankers) may facilitate policy cooperation by worsening governments' pay-offs when policy cooperation breaks down (strengthening available threats). Delegation also greatly facilitates international policy cooperation when used as a commitment to 'friendly' behaviour.

A simple law requiring changes of the delegation contracts (or of delegates) to be subject to parliamentary discussion and approval is shown to be sufficient in this model to give full commitment value to delegation, even when contract renegotiation is costless and information complete.

Finally, I relate these results briefly to the literature on multilateral trade agreements showing that Maggi's (1999) argument that trade diversion effects make punishments from multilateral trade agreements relatively stronger can be generalized to other policy issues.

# 1 Introduction

The process of “globalization” is making nations more interdependent than ever before. Higher interdependence means greater externalities of domestic policies imposed on neighbor countries. Greater cross-border spillovers imply an increased need for international policy cooperation.<sup>1</sup>

It is well known that the sovereignty of nations requires international agreements to be “self-enforcing,” that is, constructed so that each country finds it convenient to respect their requirements even in the absence of an international authority able to enforce them. This paper is a first attempt to address the following questions: What is the optimal design for a set of self-enforcing international policy agreements? Countries may benefit from cooperation on many different policy issues. How many and which issues should each self-enforcing international agreement regulate? Are institutions (e.g. GATT’s rules) limiting nations’ ability to link more issues in the same agreement welfare-enhancing? In order to facilitate international cooperation should governments keep policy issues under centralized control, or should they delegate some issues to independent national agencies (e.g., central banks), which would then enter into direct international agreements with their counterparts abroad? In the second case, which issues should be delegated? Finally, institutions allowing governments to credibly delegate policy choices to independent agencies with different objectives (e.g., to “conservative” central bankers) are good or bad for international policy cooperation?

The “real world” of international relations seems dominated by the belief that keeping policy issues as separate as possible is the best route to international cooperation.<sup>2</sup> Not only do we observe separate international agreements on trade, monetary, environmental, and defense policies; we even have separate agreements on, say, the control of CFCs emissions and the protection of whales. In the simple model developed here, focusing on single policy issues is generally not the best strategy to achieve international cooperation; and when it is, governments should delegate policy control to independent specialized agencies.

Many international policy issues have, in their static structure, strategic features similar to a Prisoner’s Dilemma game. Because countries face such policy dilemmas repeatedly

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<sup>1</sup>International cooperation is crucial to prevent beggar-thy-neighbor protectionist trade policies (Johnson 1953, Robinson 1947, and Scitovsky 1942 are the classical references; see also Bagwell and Staiger 1999); uncoordinated monetary and fiscal policies may lead to suboptimal outcomes (e.g. Bryant 1995); global environmental issues pose similar dilemmas and international cooperation has been called for on competition, development, agricultural, drug control, and other policies (for example by Cooper 1994, Scherer 1994, Peters and Stanton ed. 1991, Sachs 1987, and Cepeda 1994). Peace remains the most important public good in need of international cooperation.

<sup>2</sup>For example, GATT/WTO rules forbid countries to use trade sanctions to discipline cooperation on policy issues outside GATT, and even discourage cross-retaliation between different trade areas (Article 22.3).

in time, self-enforcing international agreements can be analyzed as equilibria of infinitely repeated Prisoner's Dilemma games.<sup>3</sup>

The model analyzed here is extremely stylized: two countries interacting simultaneously on  $n$  policy issues with the strategic structure of infinitely repeated Prisoner's Dilemmas under complete information. I adapt and extend Bernheim and Whinston's (1990) and Spagnolo's (1999) analyses of collusion in oligopolies with multimarket contact to determine the optimal design of international agreements. I then consider delegation, and show how it can affect international policy cooperation, both in single and multiple-issue interactions.

In this framework, any rule constraining governments from linking more issues in one agreement turns out to be strictly welfare-reducing, since it constrains the optimal design of international agreements.

When countries are symmetric and policy issues separable, issue linkage can facilitate policy cooperation by allowing to use the slack enforcing power (expected losses from punishment minus expected gains from deviation) available on some issues to discipline cooperation on additional issues.<sup>4</sup> Then a single "grand international agreement" is optimal, as it aggregates available enforcement power allowing for its more efficient *allocation* to additional issues.

When countries are symmetric and policy issues interdependent, issue linkage may affect the *amount* of available enforcing power, besides its allocation. When two or more policy issues are substitutes for governments, by forcing deviations and punishments to be simultaneous a linkage makes punishments harder and deviations less valuable, increasing available enforcing power. The converse does not hold for complement issues: then a simultaneous deviation is relatively more profitable, but it must be deterred whether or not issues are linked. Again, a single "grand international agreement" is optimal: it maximizes available enforcement power and optimizes its allocation.

Allowing countries to differ in the objective function does not change this result. Then issue linkage maintains the beneficial effects just mentioned, and in addition it allows countries to overcome asymmetries by "trading" cooperation on some issues against cooperation on others.

When issues are complements simultaneous deviations are more profitable. If governments could commit not to deviate simultaneously on complement issues available enforcing power would increase. And if issue linkage prevents such commitments, a single "grand agreement" may no longer be optimal. I show that this may be the case by focusing on

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<sup>3</sup>Aumann (1974) suggested that equilibrium points of noncooperative games can be view as self-enforcing agreements.

<sup>4</sup>For "facilitates cooperation" I will mean throughout the paper "makes countries' incentive constraints for respecting any agreement less stringent," so that a larger set of agreements becomes sustainable at any given intertemporal discount factor, and any given set of agreements becomes supportable at lower discount factors.



commitment through observable delegation of power to different, independent national agencies with the *same* objectives as their government.

When delegation credibly prevents simultaneous deviations, delegation to agencies with the same objectives as their government always facilitates cooperation, as it constrains the optimal choice of defections. When delegation and issue linkage are compatible, cooperation is further enhanced: delegation reduces gains from defections while issue linkage makes punishments stronger (simultaneous on all linked issues).

Delegation may further facilitate cooperation when delegates' objective function can differ from that of governments. The opportunity to delegate policy choices to more "conservative" agents (e.g. central bankers) worsens governments' payoffs when policy cooperation breaks down, thereby strengthening available threats. Delegation to agents with low gains from defection acts as a commitment to "friendly" behavior.

As for the credibility of the commitment, a law requiring changes of delegation contracts (or of delegates) to be subject to a parliamentary discussion and approval is shown sufficient here to give full commitment value to delegation, even when contract renegotiation is costless and information complete.

Finally, I briefly relate these results to the literature on multilateral agreements showing that Maggi's (1999) argument that trade diversion effects make punishments from multilateral trade agreements relatively stronger can be generalized to other policy issues, thus reinforcing the case for multilateralism.

Supergames have been used by many authors to analyze policy cooperation: for example by Bagwell and Staiger (1990), Hungerford (1991), Riezman (1991), Maggi (1999), for free trade agreements (see also Staiger 1995); by Canzoneri and Henderson (1991) and Currie and Levine (1993) for monetary policy cooperation; by Barret (1994) for international environmental agreements; and, more recently, by Ederington (2000) to analyze linkages between two instruments, an efficient and an inefficient one, that affect the same policy issue (trade). All these papers focus on a single policy issue and do not tackle the questions addressed here.

Early contributions on "issue linkage" in international environmental agreements, for example, by Folmer, van Mouche and Ragland (1993), Carraro and Siniscalco (1995, 1997), and Cesar and de Zeeuw (1996), and the more recent work of Abrego et al. (1997) and Conconi and Perroni (2000) do focus on multiple issues. However, these analyses address either static strategic situations or negotiations, not the *enforcement* of international agreements.

The model is presented in Section 2; Section 3 analyzes issue linkage; Section 4 discusses delegation; and Section 5 concludes. Proofs are in the Appendix unless stated otherwise.

## 2 Set up

### 2.1 A simple model

I will work with a stylized two-country, complete information, infinite horizon model with  $n$  policy issues.<sup>5</sup> Countries are assumed individual, rational players, and I will use the terms “country” and “government” as synonyms. In all what follows I abstract from any “transaction,” “bureaucratic,” or “complexity” costs of issue linkage and delegation.

Because of international spillovers, each policy issue presents the features of an infinitely repeated Prisoner’s Dilemma game. Time is discrete (to simplify notation we will avoid the time superscript wherever possible), the two countries are named A and B, and the  $n$  policy issues are indexed by the subscript  $i \in \{1, 2, \dots, n\}$ . The one-period strategic interaction on each issue can be represented as a separate Prisoner’s Dilemma game in which each country can choose to cooperate ( $C_i$ ) or defect ( $D_i$ ). In each period all policy (stage-)games are played simultaneously. The  $i$ -th static (one-shot) policy dilemma is characterized by governments’ symmetric action space  $\Theta_i^h = \{C_i, D_i\}$ , with  $h \in \{A, B\}$ , and “material” payoff functions  $\Pi_i^h : \Theta_i \rightarrow R^2$ , where  $\Theta_i = \Theta_i^A \times \Theta_i^B$ , which generate the symmetric “material payoff matrices”:

		Country B	
		$C_i$	$D_i$
Country A	$C_i$	$X_i$	$Z_i$
	$D_i$	$Y_i$	$N_i$

with  $Y_i > X_i > N_i > Z_i$ . Material payoffs from all policy issues enter the governments’ continuous and twice differentiable static objective functions  $U^h = U^h(\Pi_1, \Pi_2, \dots, \Pi_n)$ , with  $\frac{\partial U^h(\cdot)}{\partial \Pi_i} > 0$  for every  $h \in \{A, B\}$  and  $i \in \{1, \dots, n\}$ . I let  $\delta < 1$  denote governments’ common intertemporal discount factor, so that in each period  $t$  government  $h$  maximizes the intertemporal welfare function  $W^h = \sum_{\tau=t}^{\infty} \delta^{\tau-t} U^{h\tau}$ .

The focus is restricted to stationary agreements sustained by stationary punishment strategies. I consider threats from unrelenting “grim trigger” strategies (“revert to the

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<sup>5</sup>The model can be extended to the case of  $n$  countries and continuous policy instruments with no major change in the analysis (nor, I believe, in the results). Also, games repeated a finite but uncertain number of periods lead to identical results since a constant probability of the supergame ending each period can be incorporated in the discount factor.

static Nash equilibrium forever if a deviation is observed”) as they are the simplest optimal punishment keeping countries at their security levels (see Friedman 1971, and Abreu 1986, 1988). It is easy to verify that little would change if the punishment phase would last a finite number of periods, or if the asymmetric renegotiation-proof punishment strategies proposed by van Damme (1989) were adopted.

## 2.2 Definitions

### 2.2.1 Linking issues

Two agents interacting strategically on several issues are naturally represented by a single game in which players’ strategy sets include choices on all the issues at stake. These issues could be said “linked” in one game. In this sense, all policy issues would be naturally linked if the institutional framework (the rules of GATT mentioned in the introduction, old customs in international relations, internal delegation of power, etc.) would not segment the policy interaction between governments in several disjoint compartments. The separation between policy issues induced by the institutional framework, when credible, is an artificial restriction on players’ strategy sets. So a first question to ask is whether the institutional restrictions that segment the strategic interaction between governments are welfare enhancing. To do this, we introduce the following definition.

**Definition 1 *Weak linkage.*** *Two or more policy issues are “weakly linked” when there is no institutional restriction preventing governments from conditioning strategies on any (subset) of these policy issues on the history of any other (subset) of these issues.*

The reader familiar with the industrial organization literature will recognize that this definition for policy games corresponds to that of “multimarket contact” for oligopolies (Bernheim and Whinston 1990, Spagnolo 1999).

Other questions to address are how many and which issues should each international agreement regulate, or how many international agreements should there be. To try answering these questions we introduce another definition.

**Definition 2 *Issue linkage.*** *Two or more policy issues are “linked in one international agreement,” or simply “linked,” when governments agree to cooperate on all these issues and to punish any unilateral deviation (on any subset of the issues) by reverting to the static Nash equilibrium forever on all linked issues.*

*An agreement is “sustainable” (self-enforcing) when such punishment is sufficient to deter any deviation.*

Exploiting further the parallel with the industrial organization literature, this definition for policy games corresponds to that of a “multimarket collusive agreement” for oligopolies,

and to that of a “multimarket collusive equilibrium” when the policy agreement is sustainable.

An additional definition will facilitate exposition.

**Definition 3 *Isolation.*** *A set of issues is “isolated” when strategies on any issue in the isolated set are not conditional on the history of any issue outside the isolated set, and vice versa.*

To be able to talk about different agreements without ambiguities, I assume that each policy issue can only be part of one agreement, so that if more self-enforcing agreements exist, they (the set of issues they link) are isolated.

### 2.2.2 Costs and benefits of defecting

I will let  $BD_i^h$  denote government  $h$ 's short-run benefit from defecting unilaterally from cooperation on an isolated issue  $i$  only, and  $CD_i^h$  its cost of such a unilateral defection in terms of loss of future gains from cooperation, with

$$BD_i^h = U^h(\Pi_1, \dots, Y_i, \dots, \Pi_N) - U^h(\Pi_1, \dots, X_i, \dots, \Pi_N),$$

and

$$CD_i^h = \frac{\delta}{1 - \delta} \left[ U^h(\Pi_1, \dots, X_i, \dots, \Pi_N) - U^h(\Pi_1^{D(i)}, \dots, N_i, \dots, \Pi_N^{D(i)}) \right],$$

where  $\Pi_j^{D(i)}$  denotes per-period payoffs a country obtains on issue  $j$  after it deviates unilaterally from cooperation on issue  $i$  (which may be unchanged, in which case  $\Pi_j^{D(i)} = \Pi_j$ ). An agreement to cooperate on the isolated issue  $i$  is then sustainable as long as  $BD_i^h \leq CD_i^h$  for all  $h \in \{A, B\}$ .

When two (or more) formerly isolated policy issues – say issue 1 and issue 2 – become *weakly linked*, countries start playing the correspondent policy supergames as a single supergame whose stage-game strategy set  $\Theta_{1,2}$  is the Cartesian product of the strategy sets of the two previously isolated stage-games,

$$\Theta_{1,2} = \Theta_1 \times \Theta_2 = \{(C_1, C_2), (C_1, D_2), (D_1, C_2), (D_1, D_2)\}.$$

Then the costs and benefits of unilateral defections will depend on the set of issues governments choose to link in the same agreement.

When two or more policy issues are *linked* in a single international agreement, unilateral deviations on any subset of the linked issues are punished with the interruption of cooperation on all linked issues. Then if a government chooses to deviate unilaterally from an international agreement on several linked issues, it always finds it optimal to defect on all the linked issues simultaneously (Bernheim and Whinston 1990). In other words, when two

isolated policy issues 1 and 2 become linked in one international agreement each government's set of undominated strategies in the stage game relative to the linked issues becomes  $\Theta_{1,2}^A = \{(C_1, C_2), (D_1, D_2)\}$ . One can therefore define government  $h$ 's cost and benefit of deviating unilaterally from a policy agreement that links, say, three formerly isolated issues  $i$ ,  $j$ , and  $k$ , as

$$BD_{ijk}^h = U^h(\Pi_1, \dots, Y_i, \dots, Y_j, Y_k, \dots, \Pi_N) - U^h(\Pi_1, \dots, X_i, \dots, X_j, X_k, \dots, \Pi_N),$$

and

$$CD_{ijk}^h = \frac{\delta}{1-\delta} \left[ U^h(\Pi_1, \dots, X_i, \dots, X_j, X_k, \dots, \Pi_N) - U^h(\Pi_1^{D(ijk)}, \dots, N_i, \dots, N_j, N_k, \dots, \Pi_N^{D(ijk)}) \right].$$

The agreement to cooperate on the linked issues  $i$ ,  $j$ , and  $k$  will be sustainable as long as  $BD_{ijk}^h \leq CD_{ijk}^h$  for all  $h \in \{A, B\}$  (the alternative notation  $BD_S^h \leq CD_S^h$  with  $S = \{i, j, k\}$  will also be used).

### 3 Issue Linkage and Policy Cooperation

#### 3.1 Symmetric countries, separable issues

Linking policy agreements on different issues may foster international cooperation by improving the allocation of available “enforcing power.” This argument can be fully developed within the simplest case of separable policy issues and symmetric countries, so in this subsection we assume

$$U^A(\cdot) = U^B(\cdot) = U_1(\Pi_1) + U_2(\Pi_2) + \dots + U_n(\Pi_n).$$

Then each government maximizes the additive intertemporal welfare function  $W = \sum_{\tau=t}^{\infty} \sum_i \delta^{\tau-t} U_i^\tau(\Pi_i)$ , and deviations on one or more issues do not affect other issues through payoff externalities (income effects), so that  $\Pi_j^{D(S)} = \Pi_j$  for any  $S$  and  $j \notin S$ . Under these assumptions it is  $BD_i = U(Y_i) - U(X_i)$ ,  $CD_i = \frac{\delta}{1-\delta} [U(X_i) - U(N_i)]$ ,  $BD_{jk} = BD_j + BD_k$ ,  $CD_{jk} = CD_j + CD_k$ , and so on.

In a symmetric setting it is possible to unambiguously define the concept of “enforcing power.” I will call available (or slack) enforcing power from a set of issues  $\Gamma$  the excess of expected gains from cooperation over expected gains from defecting from an agreement that links the issues in this set, equal to the difference (if positive) between costs and benefits of defecting  $CD_\Gamma - BD_\Gamma$ .

I can now state the first result.

**Proposition 1** *Suppose countries are symmetric and policy issues separable. Then:*

(a) *By improving the allocation of available enforcing power issue linkage may strictly enlarge the set of issues on which cooperation can be sustained;*

(b) *The “grand international agreement” that links all policy issues in the set  $S^*$ , where*

$$S^* = \arg \max_S \left\{ \sum_{i \in S} U_i(X_i) + \sum_{j \notin S} U_j(N_j) \right\}$$

*s.t.*  $BD_S \leq CD_S,$

*is a welfare maximizing agreement, and may be the unique one.*

Statement (a) simply says that issue linkages may strictly improve welfare by allowing cooperation to be sustained on additional policy issues. As in Bernheim and Whinston’s (1990) model of collusion with multimarket contact, this happens when net expected gains from cooperation ( $CD_i - BD_i$ ) are strictly positive for some weakly linked (sets of) issues and strictly negative for others. Then governments can link these issues in one agreement, so that the enforcing power available from the first issues can discipline cooperation also on the second issues. The “may” in the statement depends on the simple structure of the discounted repeated Prisoner’s Dilemma. The non-divisibilities induced by the binary stage-game strategy space imply that at a given discount factor players either can sustain cooperation or cannot. Then an improvement in the allocation of enforcing power may not be large enough to enforce cooperation on any additional policy issue, and a badly designed linkage may even reduce the scope of policy cooperation. However, one can simply rephrase statement (a) in terms of the minimum discount factor at which cooperation can be simultaneously sustained on two or more issues, and state that issue linkage always facilitates cooperation, in the standard sense of (weakly) reducing such minimum discount factor (as in Bernheim and Whinston’s 1990, and Spagnolo 1999).<sup>6</sup>

Statement (b) says that a single, optimally designed international agreement that links all issues on which governments cooperate cannot be improved upon and may not be replicated by any set of smaller agreements. With separable issues any cooperative outcome implemented by a set of agreements can be replicated by a larger agreement that links all issues included in the smaller agreements. This is because when cooperation is being sustained on two or more isolated (or non-linked) sets of issues, each government remains free to deviate simultaneously on all those issues if it wishes. Therefore, a set of agreements is sustainable only if defecting simultaneously on all issues in all these agreements is not profitable. But this implies that the single “grand agreement” linking all the issues

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<sup>6</sup>Analogously, if one applies the result to a discounted policy supergames with the strategic structure of a Prisoner’s Dilemma but with a continuous-strategy stage game, obtains that the reallocation of available enforcing power between linked issues always (weakly) improves welfare by allowing to change the “degree of cooperation” sustained on each issue to equate marginal gains from cooperation on all linked issues.

in the smaller agreements is also sustainable. The linkage reduces the number of incentive constraints that have to be satisfied by eliminating those for single issue deviations (dominated by simultaneous ones). So nothing can be lost by reducing the number of agreements. The converse, however, does not hold. Linking agreements aggregates available enforcing power facilitating its optimal reallocation to enforce cooperation on *new* issues. Increasing the number of agreements disaggregates available enforcement power, so that it may not be possible to replicate the outcome of a single optimally designed agreement: the parcellization of available enforcing power may constrain its optimal reallocation.

### 3.2 Institutional restrictions on issue linkage

One question to address is whether the institutional restrictions that segment (or try to segment) the strategic interaction between governments is welfare enhancing. An obvious result follows from Proposition 1, together with Section 2's definitions and the (implicit) assumption that governments are rational, in the sense that they act to maximize their objective function.

**Proposition 2** *In this model weakly linking isolated sets of issues is always (weakly) welfare enhancing.*

A formal proof is not needed. The definition of weakly linked issues leaves governments free to choose whether or not to link those issues in one agreement. Rational governments would not link issues in one agreement if this would reduce the number of issues on which cooperation is sustainable, so weak linkages cannot harm policy cooperation and reduce welfare. Proposition 1 shows that there are cases where weakly linking issues strictly improves welfare by allowing governments to link issues in the same agreement. So according to this simple model, institutional constraints on issue linkage are always (weakly) welfare reducing and should be removed.

### 3.3 Symmetric countries, interdependent issues

When issues are not separable the efficient allocation of available enforcing power is not the only concern. Then the design of international agreements may also affect the *amount* of available enforcing power.

With interdependent issues the strategic structure of the model departs from that of Bernheim and Whinston (1990), but we can exploit the analogy with Spagnolo (1999) where the multimarket contact model is extended to the case where players' objective functions are submodular in payoffs from different supergames. For the sake of clarity here I will focus

on the simplest and better known forms of interdependence, substitutability and complementarity, defined as follows.<sup>7</sup>

**Definition 4** *Two policy issues  $j$  and  $k$  are “substitutes” for country  $h$  when  $\frac{\partial^2 U^h(\Pi_1, \dots, \Pi_n)}{\partial \Pi_j \partial \Pi_k} < 0$ , and “complements” when  $\frac{\partial^2 U^h(\Pi_1, \dots, \Pi_n)}{\partial \Pi_j \partial \Pi_k} > 0$ .*

Issue interdependence adds a number of complications to the model, so as a first step I retain the symmetry assumption (to be relaxed in the next section).

One complication to take into account with interdependent issues is that payoff changes from isolated sets of issues may now affect other isolated issues through payoff externalities (income effects), so that  $\Pi_j^{D(S)} \neq \Pi_j$  for some  $S$  and  $j \notin S$ .

I first characterize the effects of substitutability and complementarity when income effects are “weak,” in the sense that income effects from linking some issues have no strategic effects on issues not involved in the linkage, so that  $\Pi_j^{D(S)} = \Pi_j$  for all  $S$  and  $j \notin S$ .

**Lemma 1** *Suppose  $\Pi_j^{D(S)} = \Pi_j$  for any  $S$  and  $j \notin S$ . Then:*

- (a) *If two policy issues  $j$  and  $k$  are substitutes,  $BD_{jk} < BD_j + BD_k$  and  $CD_{jk} > CD_j + CD_k$ ;*
- (b) *If they are complements,  $BD_{jk} > BD_j + BD_k$  and  $CD_{jk} < CD_j + CD_k$ .*

As with Spagnolo’s (1999) submodular objective functions, when two (or more) issues are substitutes for governments, simultaneous defections on those issues are less attractive because *i*) when a government is defecting on some issues it values relatively less short-run gains from simultaneous defections on additional issues, and *ii*) a simultaneous punishment on more policy issues is a relatively stronger threat, as when a country is not cooperating on an issue it values relatively more cooperation on substitute issues. The opposite happens when issues are complements. Then a simultaneous defection on more issues increases the value of short-run gains from defection, since the high payoffs from each issue increase the marginal value of additional payoffs from other issues, while the value of losses from a simultaneous punishment phase is reduced by the opposite effect.

Lemma 1(a) clearly implies that, absent income effects on other issues, linking two (or more) substitute issues will facilitate cooperation in two ways: a linkage maintains the positive allocative effects on available enforcing power discussed in Sections 3.1, and in addition it increases the amount of available enforcing power.

What if issues are complements? The converse argument does not apply: a linkage between two (sets of) issues on which cooperation is sustainable cannot reduce available enforcing power. Lemma 1(b) says that, with complement issues, the condition for a simultaneous deviation on two issues not being profitable is more stringent than the correspondent

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<sup>7</sup>Results analogous to those for substitutes (complements) obtain when  $U$  is strictly submodular (supermodular) in material payoffs; see Spagnolo (1999).



conditions *when deviations and punishments are not simultaneous*. But again, when some issues are not linked nothing prevents a government from deviating simultaneously on (some or all of) them, so cooperation on both issues is sustainable only if also the more stringent condition for simultaneous deviations is satisfied. This means that cooperation on two (or more) isolated complement issues can only be sustained when it can also be sustained when the issues are linked, and consequently that linking complement issues on which cooperation was sustainable cannot reduce available enforcing power (although it can still improve on its allocation).

Let's now allow for more general payoff externalities, so that for some  $S$  and  $j \notin S$  it can be  $\Pi_j^{D(S)} \neq \Pi_j$ . In this case nothing as general as Lemma 1 can be stated on the effects of a linkage of interdependent issues on available enforcing power. Even though substitutability will still make simultaneous deviations less valuable, a *per se* stronger simultaneous punishment on substitute issues may have payoff externalities that allow cooperation to be sustained on issues on which cooperation would not be sustainable otherwise, eventually increasing payoffs. Still, I can state the following.

**Proposition 3** *With symmetric countries and interdependent issues:*

(a) *Issue linkage may increase available enforcing power (when some issues are substitutes) and improve its allocation strictly enlarging the set of policy issues on which cooperation can be sustained, and may allow cooperation to be sustained on non-empty sets of issues even when it is not sustainable on any isolated issue;*

(b) *The “grand international agreement” that links all policy issues in the set  $S^*$ , where*

$$\begin{aligned} S^* &= \arg \max_S U(S) \\ \text{s.t. } BD_S &\leq CD_S, \end{aligned}$$

*is a welfare maximizing agreement and can be the unique one.*

A single “grand agreement” remains optimal because – even with unconstrained payoff externalities – a larger agreement obtained by linking (all issues formerly in) two sustainable agreements is also always sustainable. For cooperation being sustainable on a set of isolated (subsets of) issues the incentive constraints for individual deviations, for deviations on all (subsets of) issues in the set, and for a simultaneous deviation on all issues in the set have to be satisfied. The last among these conditions also ensures that when these (subsets of) issues are linked in one or more agreements cooperation will remain sustainable. Consider the welfare maximizing outcome sustainable without linkages: it consists of a (possibly empty) set of isolated issues on which cooperation is sustained, and of the complement set of issues on which cooperation is not sustained. Since governments can defect simultaneously on any set of non linked issues on which they are cooperating, the incentive constrain for a simultaneous deviation on all issues on which cooperation is sustained must be satisfied, so

that the “grand agreement” linking all those issues is also sustainable independent of size and direction of income effects. In addition, the linkage may now allow cooperation to be sustained on new issues because of the increase in (when some issues are substitutes) and the improved allocation of (aggregated) enforcing power. Cooperating on additional issues will generate new payoff externalities that may have positive or negative effects on the amount of policy cooperation sustainable. But governments are free not to link new issues if their income effects reduce welfare, and will choose to link the new issues that increase welfare the most given the payoffs and the income effects they generate.

### 3.4 Asymmetric countries

Allowing for asymmetries in governments’ objective functions has two direct consequences in our model.<sup>8</sup> The first one is that it is now harder to find a clear-cut definition of available enforcing power for a set of issues. When  $CD_i^A - BD_i^A = E_i^A > 0$  and  $CD_i^B - BD_i^B = E_i^B > 0$  one can clearly say that on issue  $i$  there is slack enforcing power, although since  $E_i^A \neq E_i^B$  it is not clear how to quantify it (we could perhaps, somewhat arbitrarily, define  $\min\{E_i^A, E_i^B\}$  as the enforcing power available on issue  $i$ ). However, when for example  $CD_i^A - BD_i^A = E_i^A > 0$  and  $CD_i^B - BD_i^B = E_i^B \leq 0$ , one cannot say that on issue  $i$  there is slack enforcing power in general, although one might say that there is slack enforcing power *for country A on issue i*. The second consequence of asymmetries in objective functions is that there may not exist a joint-welfare-maximizing agreement. Since countries’ preferences are different, there may be a number of Pareto-efficient outcomes ranked differently by the two countries.

I can now state my most general result on issue linkage.

**Proposition 4** *Let countries differ in their objective functions. Then, independent of whether issues are interdependent:*

(a) *Issue linkage may strictly enlarge the set of issues on which policy cooperation can be sustained, and may allow cooperation to be sustained on (non-empty) sets of issues even when it could not be sustained on any isolated issue;*

(b) *Any sustainable Pareto-efficient outcome can be implemented by a single “grand international agreement” and may not be implementable otherwise.*

Clearly, with asymmetric countries issue linkage maintains the positive across-issue allocative effects. And again, isolated (sets of) issues on which cooperation is sustainable

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<sup>8</sup>Results similar to those obtained here could be derived for other forms of asymmetry than different objective functions; but this form of asymmetry seems a natural one in this environment, since different lobbies have typically a different relative influence on governments in different countries. Moreover, this kind of asymmetry is more novel than others, as Bernheim and Whinston did not consider it for firms with multimarket contact.

can be linked, generating additional gains from cooperation when some of them are substitutes for a country. What differs with asymmetries is that issue linkage may also facilitate cooperation by pooling incentive constraints between countries, besides between issues, independent of issue interdependence. When country  $A$  is highly interested (able) to sustain cooperation on one issue, say issue 1, and country  $B$  has very large gains from cooperation on issue 2, issue linkage may make cooperation sustainable on both issues even when, if the issues were not linked, country  $B$  would defect from an agreement on issue 1 and country  $A$  would do it from an agreement on issue 2. The logic here is one of removing “market segmentation,” or of opening the market for the good “cooperation on issue  $x$ .” This market allows countries to realize, through linkages (exchanges), available gains for trading cooperation on issues relatively more valuable to one country against cooperation on issues relatively more valuable to the other.<sup>9</sup>

Statement (b) says that whatever cooperative outcome countries agree on among the sustainable Pareto efficient ones, the outcome can always be implemented through a single “grand agreement.” This is for the same reason as with symmetric countries: if cooperation on isolated sets of issues is sustainable, cooperation on the union of the two sets is also automatically sustainable. The best no-linkage outcome can then be replicated by a single agreement and improved upon through linkages of additional issues, enforced by aggregated (country-specific) enforcing power, by the additional (country-specific) enforcing power generated by linkages of substitute issues, and by “gains from trade” in asymmetries on additional issues. Provided, of course, that the additional issues are chosen so that their income effects do not offset additional gains from cooperation.

## 4 Delegation

### 4.1 Delegation as separation of powers

Section 3 results all point at the benefits of issue linkage, and should be seen as benchmarks. There are several ways to make the simple model studied here more realistic, and some of them would obviously deliver costs of issue linkage (see the concluding remarks). Here I will focus on a slightly less obvious way in which issue linkage might hinder policy cooperation.

The second part of Lemma 1 tells us that the enforcing power available on two or more complement issues is reduced by a government’s ability to deviate simultaneously on these issues. This suggests that if governments could credibly commit not to deviate simultaneously on complement issues, such commitment could in some cases facilitate cooperation. To analyze the effects of such a commitment in our model we introduce the following definition.

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<sup>9</sup>If feasible, monetary transfers (flows of payments) would be an alternative, more efficient way of overcoming this kind of asymmetry.

**Definition 5 Decentralization.** *Two or more policy issues are “decentralized” when it is not possible to coordinate deviations (to deviate simultaneously) on these issues.*

One way to implement decentralization could be internal delegation of power. Governments could delegate policy choices to different, independent national agencies. To develop this argument in the simplest way, I focus on symmetric countries, public delegation contracts,<sup>10</sup> and two complement policy issues  $j$  and  $k$  on which there is the same amount of available enforcing power  $CD_j - BD_j = CD_k - BD_k = A \geq 0$ , with  $\Pi_i^{D(S)} = \Pi_i$  for all  $S$  and  $i \notin S$ .

Assume (temporarily) that the contract between a government and its delegates is publicly observable and cannot be secretly renegotiated, and that delegation of two policy issues to different, independent agencies implements decentralization. Without delegation, and whether or not the issues are linked, cooperation on both issues is sustainable only if  $CD_{jk} - BD_{jk} \geq 0$  is also satisfied, so that simultaneous deviations are deterred. Since by Lemma 1(b)  $CD_{jk} - BD_{jk} < CD_j - BD_j + CD_k - BD_k$ , when  $A$  is small  $CD_{jk} - BD_{jk} < 0$  and cooperation is sustainable on one issue only. Then if governments delegate issues so that they become decentralized, cooperation on both issues becomes sustainable even though  $CD_{jk} - BD_{jk} < 0$ , since the only relevant conditions  $CD_j - BD_j = CD_k - BD_k = A \geq 0$  are satisfied.<sup>11</sup> Of course, the same argument applies when the complement issues are not identical, as long as  $CD_j - BD_j = A_j \geq 0$ ,  $CD_k - BD_k = A_k \geq 0$ , but  $CD_{jk} - BD_{jk} < 0$ . This reasoning is summarized by the following lemma.

**Lemma 2** *Suppose delegation implements decentralization. Then when two (or more) isolated issues are complements and sufficiently similar in terms of available enforcing power, delegating them to different independent agencies with the same objective function as governments facilitates policy cooperation (increases the enforcing power available on the two issues).*

Consider now to the interaction between delegation and issue linkage. One could argue that when two issues are decentralized they can hardly be linked, as the simultaneous punishment required by the linkage after any deviation could not be implemented (so that a single agreement requires a single agency). Governments could limit delegation/decentralization to cooperative phases only, to also allow for issue linkage. But it can still be argued that if two issues are linked in the same agreement interdependence increases at the point that

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<sup>10</sup>Early studies of delegation with observable contracts are Crawford and Varian (1979) and Sobel (1981) in bargaining, and Vickers (1985), Fershtmann and Judd (1987) and Sklivas (1987) in oligopoly.

<sup>11</sup>Note that in this situation delegating is governments' dominant strategy. Nothing can be lost by delegating first and unilaterally: agencies have the same objectives as governments, so they act exactly as their government as long as the other government does not delegate, while they allow for cooperation as soon as the other government also delegates.

it may become hard or impossible to implement such state-contingent delegation. When this is the case, then a single “grand agreement” may no longer be optimal. It is easy to verify that this is what happens in the example above if one assumes that issue linkage makes delegation impossible. When  $CD_{jk} - BD_{jk} < 0$  and  $A \geq 0$  (or  $A_j, A_k \geq 0$ ) a linkage brings no benefits, while preventing decentralization it makes cooperation on both issues unfeasible.

If, on the other hand, delegation limited to cooperative phases is feasible and able to implement decentralization even for issues linked in the same agreement, then the benefits of decentralization add to those of issue linkage. By excluding simultaneous deviations on more issues delegation/decentralization reduces the benefits of unilaterally deviating from an agreement that links two issues  $j$  and  $k$  to at best  $\max\{BD_j, BD_k\}$ . At the same time, issue linkage keeps the costs of any defection up at  $CD_{jk}$ . Then the only condition required for cooperation being sustainable on both the delegated-and-linked issues is  $\max\{BD_j, BD_k\} \leq CD_{jk}$ , which since  $\max\{BD_j, BD_k\} < BD_{jk}$  is strictly less stringent than the conditions without linkage and/or delegation.

This conclusions can be restated as follows.

**Proposition 5** *Suppose delegation implements decentralization. Then:*

(a) *When linked issues cannot be delegated and some issues are complements, a single “grand agreement” may be suboptimal: it may not allow to implement Pareto-efficient outcomes sustainable through delegation and a plurality of smaller agreements;*

(b) *When linked issues can be delegated, any sustainable Pareto-efficient outcome can be implemented through full delegation (each government delegates each issue to a different agency) and a single “grand international agreement,” and may not be implementable otherwise.*

## 4.2 Delegation and policy cooperation

Whether delegation to independent agencies with the same objectives than governments can achieve full decentralization in reality is debatable. However, if one allows for credible delegation to agencies with a *different* objective function than their governments’, then full decentralization is easily achieved, for example through a delegation contract that penalizes delegates in the event of a simultaneous deviation.

Allowing for credible delegation to agencies with a different objective function than their governments’ opens a number of other ways by which delegation can facilitate policy cooperation.

### 4.2.1 Delegation as a threat

Dolado et al. (1994) and Currie et al. (1996) showed within two-stage models with (monetary) policy spillovers that governments' opportunity to delegate policy choices may worsen the international situation by generating an additional international Prisoner's Dilemma. Each government may find it unilaterally optimal to choose a "more conservative" agent (e.g. central banker) in order to enjoy larger spillovers from other countries. When all governments have the opportunity to delegate, all chosen policy makers are too conservative and the original policy dilemma is worsened.

Fortunately, most policy spillovers are not "once-in-a-life-time" events, countries normally interact repeatedly in time. In an infinitely repeated policy game (as in one repeated a finite but uncertain number of times), the effect of the opportunity to delegate turns out to be quite different. Let  $\underline{Y}_i$  denote country  $i$ 's welfare (national product, in the example of monetary policy) in a period in which both countries delegate a policy issue with international spillovers to "more conservative" agents,  $\bar{Y}_i$  denote country  $i$ 's welfare when it delegates but the opponent country does not,  $Y_i^n$  welfare when credible delegation is not feasible but countries do not cooperate,  $Y_i^c$  welfare when countries cooperate choosing the globally optimal policies that internalize spillovers, and  $Y_i^d$  welfare when country  $i$  unilaterally deviates from an international agreement to choose globally optimal policies, with  $Y_i^d > Y_i^c, \bar{Y}_i > Y_i^n > \underline{Y}_i$ .

Then one can state the following result.

**Proposition 6** *In this model the opportunity to credibly delegate policy choices to "over-conservative" agents facilitates international policy cooperation.*

The additional Prisoner's Dilemma induced by the possibility to commit through delegation worsens countries' situation in the absence of an international agreement (lowers their security levels), thereby strengthening the threat to revert to non-cooperative policies. On the other hand, delegation cannot increase short-run gains from violating an agreement ( $Y_i^d$ ) since to increase its government's payoffs (by affecting opponents' behavior) the delegate's choice of action must be anticipated, but if a deviation from cooperation is anticipated gains from deviation vanish.<sup>12</sup> Since delegation increases losses from punishment phases but not

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<sup>12</sup>This point is quite general. Delegation, as any other pre-commitment, distorts the committing player's behavior, so it reduces his payoffs unless it advantageously affects the opponent players' choices. To affect opponents' choices, however, commitments must be observed. On the contrary, to deliver positive gains unilateral defections from cooperation in supergames must be secret, unexpected. If a defection from cooperation is anticipated opponents react according to their static (non-cooperative) best response, rather than sticking to agreed strategies. Therefore, unless gains from unilaterally precommitting under non-cooperative play are larger than gains from unilaterally defecting from cooperation (an extreme case where cooperation could never be sustained) pre-commitments cannot increase short-run gains from deviations (Spagnolo, 1998).

gains from defections, it makes policy cooperation easier to sustain.

#### 4.2.2 “Friendly” delegation

In an earlier version of the paper (1996b) I showed that a second way by which governments can use delegation to foster international cooperation is designing the delegates’ incentives so that their *gains from defecting are reduced*. For example, a delegation contract making the delegate’s utility (or compensation) a strictly concave transformation  $f(U_i(\Pi_i))$  – with  $f' > 0$  and  $f'' < 0$  – of the government’s utility would strictly facilitate policy cooperation. Analogously, a contract such that the delegate receives a fixed per-period rent (a high constant wage, perquisites, etc.) as long as policy results are “satisfactory,” and is fired if the results become “bad” removes all the delegate’s short-run incentives to defect from an international agreement that delivers satisfactory policy results. If all countries would adopt such an observable delegation contract, international cooperation would always be sustainable.<sup>13</sup>

#### 4.3 Is delegation a credible commitment device?

Dewatripont (1988), Katz (1991), and others have questioned the commitment value of contractual devices, such as delegation, when renegotiation is costless and information complete. Contracts are pieces of paper that can be secretly renegotiated away when this is in the interest of the contracting parties. This issue has been recently brought up by McCallum (1995) and Jensen (1997) in the context of monetary policy delegation.

Although the intrinsic costs of bargaining on gains from renegotiation may always confer commitment value to contracts (e.g. Anderlini and Felli 1998), in two-parties relations under complete information secret renegotiation may greatly reduce such value. However, this is much less so for democracies where governments are constrained to respect the law (as long as they are in force; of course, ruling majorities can always change the law). First, in democracies governments are often supported by coalition of parties. A multiplicity of parties increases the complexity of bargaining on gains from renegotiation and consequently the intrinsic cost of secret renegotiation. Second, and far more importantly, independent of renegotiation costs a stable democracy can confer commitment value to delegation and other contractual devices by making *secret* renegotiation impossible. It can introduce a law requiring any change of a delegation contract (or of delegate) to be subject to parliamentary discussion and approval.<sup>14</sup> Since these are public events, such a law bans secret renegotiation and confers commitment value to delegation even when renegotiation is costless and

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<sup>13</sup>This is consistent with the casual observation that cooperation between flat-compensated central bankers appears more easily achieved than cooperation between governments. See Spagnolo (1996b) for a detailed discussion of how delegation contracts can implement cooperation in (oligopolistic) supergames.

<sup>14</sup>This is the case, for example, of New Zealand’s central banker’s incentive scheme.

information complete.

To be more concrete, consider the simple model of this paper and let governments free to secretly renegotiate contracts with the independent agencies at any point in time under complete information. Let us adopt the extreme assumption that there are neither exogenous nor intrinsic (bargaining) costs of renegotiation.<sup>15</sup> Still, one can state what follows.

**Proposition 7** *Suppose that secret renegotiation is feasible and costless, and that governments must respect the law.<sup>16</sup> Then a law requiring changes of delegation contracts (or of delegates) to be subject to parliamentary approval gives delegation full commitment value thereby allowing to sustain policy cooperation in all cases.*

Suppose governments introduce such a law and delegates policy choice to cooperation-friendly agents – as described in section 4.2.2 – who start cooperating. Then, the only reason for a government to modify the delegation contract or the law that makes it credible is to induce an unilateral defection from cooperation. As soon as any such change is observed other governments or their delegates anticipate a deviation and react optimally by also immediately deviating.<sup>17</sup> Therefore, no short-run gain can be obtained by modifying/renegotiating the delegation contract. A simple law banning secret renegotiation is here sufficient to remove all gains from renegotiation and give *full* commitment value to delegation contracts, even in the extreme case of costless renegotiation and complete information. Of course, a similar argument may apply to other forms of contractual commitments, available to democracies because they can credibly force renegotiation to be public, where other forms of government cannot.

## 5 Extensions and conclusions

### 5.1 Multilateral versus bilateral cooperation

Maggi (1999) analyzes multilateral trade cooperation in the presence of asymmetric trade relations. In a three-country model with separable trade relations he demonstrates, among other things, that a multilateral approach facilitates international trade cooperation by allowing for “third-party sanctions.” Concluding the paper Maggi informally argues that a multilateral approach facilitates cooperation even more when trade diversion effects are

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<sup>15</sup>The assumption is particularly extreme for democracies, as these can also easily increase the costs of contract renegotiation (Giordani and Spagnolo 2001).

<sup>16</sup>Allowing governments to violate the law at the cost of being sanctioned with some probability would lead to the same qualitative results; then the commitment value of delegation increases with the expected sanction (e.g. Giordani and Spagnolo, 2001).

<sup>17</sup>Alternatively, the agreement between delegates could state explicitly that any renegotiation of a delegation contract is considered a violation of the agreement punished with the reversion to the static Nash equilibrium.



taken into account: these effects weaken threats in bilateral relations since each country can partially substitute trade with one partner with trade with another.

The argument is close to that in Section 3.3 of this paper for the case of substitute issues, although here the multiplicity of relations affects incentives to deviate besides the strength of the punishments. Indeed, Lemma 1(a) can be reinterpreted to prove that *whenever policy cooperation with a country is a substitute for policy cooperation with others, multilateral agreements facilitate international cooperation.*

Consider, for example, three symmetric countries  $i$ ,  $j$ , and  $k$ , and a single policy issue, and suppose the policy interaction between each two countries has the stage game payoffs matrix described in Section 2.1. Then, a country  $k$  will respect a multilateral agreement (where a defection is punished by all participating countries) if and only if  $BD_{ij} \leq CD_{ij}$  – where the subscripts refer now to the two other countries – while the necessary conditions for cooperation being sustainable in bilateral agreements are  $BD_i \leq CD_i$  and  $BD_j \leq CD_j$ . By Lemma 1(a), when payoffs from policy cooperation with the two countries are substitutes  $BD_{ij} < BD_i + BD_j$  and  $CD_{ij} > CD_i + CD_j$ , so that a multilateral framework always facilitates cooperation independent of asymmetries in bilateral policy games.

## 5.2 Concluding remarks

To clarify how the results on issue linkage could apply to real world situations, consider an hypothetical linkage between trade and environmental policies. There is an strong asymmetry in available enforcing power between these two (sets of) issues.<sup>18</sup> Then the allocative argument behind Proposition 1(a) suggests that linking environmental agreements to trade could be a good idea. Different issues in defense policy seem partial substitutes (for example, air and sea defense), in which case Lemma 1(a) and Proposition 3(a) suggest that a comprehensive defense agreement could stabilize international cooperation. Monetary and fiscal policies are sometimes regarded as complements (e.g. McKibbin and Sachs 1991). If this is the case, Proposition 5 suggests that – if asymmetries in enforcing power are not too large – keeping the two issues separate by increasing central banks’ independence might be a good strategy.

The results in this paper are a first step towards a theory of optimal international agreements, and should be regarded as benchmarks. While the results on delegation appear very robust, the results on issue linkage and in particular on the optimality of a single “grand international agreement” may not survive in a richer model. For example, the policy of punishing all deviations with the strongest available sanctions, optimal in this paper’s complete information framework (and in standard models of multimarket oligopolies), may

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<sup>18</sup>Global environmental goods like the atmosphere and biodiversity are non-excludable, while free trade is an excludable good; excludability allows trade sanctions to be selective, hitting only the defecting country, and therefore much stronger than environmental sanctions.

not be optimal in an imperfect information world where stronger punishments are more costly as they are implemented along the equilibrium path (e.g. Green and Porter, 1984). Analogously, a referee noted that if countries make mistakes, too strong punishments may be suboptimal from an *ex ante* point of view; linking all issues in one agreement might be too risky. Paralleling the literature on optimal law enforcement after Becker's (1968) result on maximal sanctions (see Polinsky and Shavell, 2000), future work should ask when and why "fit-the-crime" punishments may do better than maximal sanctions in the enforcement of international agreements (and of multimarket contact collusive agreements), and how this affects the optimal design of international agreements.

## 6 Appendix

**Proof of Proposition 1.** Claim (a). When two separable issues  $j$  and  $k$  are linked in a single international agreement the highest benefit a country can get by defecting unilaterally is  $BD_{jk} = BD_j + BD_k$ , the cost of such defection is  $CD_{jk} = CD_j + CD_k$ , and cooperation is sustainable if  $BD_{jk} = BD_j + BD_k \leq CD_j + CD_k = CD_{jk}$ . With separable issues it can be that  $BD_j < CD_j$  and  $BD_k > CD_k$  (or the opposite), and  $BD_j + BD_k \leq CD_j + CD_k$ . Then cooperation on both issues is sustainable only if  $j$  and  $k$  are linked, and issue linkage strictly improves welfare.

Claim (b). Consider two international agreements to cooperate on the disjoint sets of linked policy issues  $S^1$  and  $S^2$ , and suppose  $BD_{S^1} \leq CD_{S^1}$  and  $BD_{S^2} \leq CD_{S^2}$ , so that both agreements are sustainable. If the sets  $S^1$  and  $S^2$  are linked in a larger international agreement on all issues in  $S^1 \cup S^2$ , this agreement is also sustainable, as  $BD_{S^1} \leq CD_{S^1}$  and  $BD_{S^2} \leq CD_{S^2}$  imply  $BD_{S^1 \cup S^2} = BD_{S^1} + BD_{S^2} \leq CD_{S^1} + CD_{S^2} = CD_{S^1 \cup S^2}$ . Since this logic applies to any couple of agreements, policy cooperation remains sustainable after linking in one agreement all issues previously linked in different, sustainable agreements, and any welfare maximizing outcome reached with more than one agreement can be replicated by a single “grand international agreement”. Now suppose that  $S^*$  includes four issues, 1, 2, 3, and 4. Under the current assumptions it can be the case that although  $CD_{S^*} - BD_{S^*} \geq 0$ ,  $BC_1 - CD_1 = l > 0$ , and  $CD_h - BD_h = \alpha l$  for every  $h \in \{2, 3, 4\}$ , where  $1/3 \leq \alpha < 1/2$ . It is immediate to verify that the “grand international agreement” to cooperate on the set of linked issues  $S^*$  is the unique welfare maximizing sustainable agreement.  $\square$

**Proof of Lemma 1.** I proceed by contradiction. Suppose that  $j$  and  $k$  are substitutes, and that  $BD_{jk} \geq BD_j + BD_k$ . Substituting from the definitions and compacting notation one obtains

$$U(Y_j, Y_k, \Pi_{-j-k}) - U(X_j, X_k, \Pi_{-j-k}) \geq U(Y_j, X_k, \Pi_{-j-k}) - U(X_j, X_k, \Pi_{-j-k}) + U(Y_k, X_j, \Pi_{-j-k}) - U(X_k, X_j, \Pi_{-j-k}),$$

where  $\Pi_{-j-k} = \{\Pi_i\}_{i \neq j, k}$  are all constants. Simplifying and rearranging one obtains

$$U(Y_j, Y_k, \Pi_{-j-k}) + U(X_j, X_k, \Pi_{-j-k}) \geq U(Y_j, X_k, \Pi_{-j-k}) + U(X_j, Y_k, \Pi_{-j-k}),$$

which is the definition of supermodularity for the function  $U$  with respect to arguments  $j$  and  $k$ . But this cannot be satisfied, since a differentiable function is supermodular if and only if the cross derivative is weakly positive for all its arguments (a simple proof of this is in Fudenberg and Tirole 1991, p. 490, footn. 14), which contradicts the assumption that issues  $j$  and  $k$  are substitutes.

Analogously, suppose that  $j$  and  $k$  are substitutes and that  $CD_{jk} \leq CD_j + CD_k$ . Substituting from the definitions, simplifying common factors, and compacting notation I obtain

$$U(X_j, X_k, \Pi_{-j-k}) - U(N_j, N_k, \Pi_{-j-k}) \leq U(X_j, X_k, \Pi_{-j-k}) - U(N_j, X_k, \Pi_{-j-k}) + \\ + U(X_k, X_j, \Pi_{-j-k}) - U(X_k, N_j, \Pi_{-j-k}).$$

Further simplifying and rearranging I obtain

$$U(N_j, X_k, \Pi_{-j-k}) + U(X_k, N_j, \Pi_{-j-k}) \leq U(X_j, X_k, \Pi_{-j-k}) + U(N_j, N_k, \Pi_{-j-k}),$$

which is again the definition of supermodularity for the function  $U$  with respect to arguments  $j$  and  $k$ , contradicting the assumption that  $j$  and  $k$  are substitutes.

The proof of the second statement is fully analogous and is omitted.  $\square$

**Proof of Proposition 3.** Claim (a). Consider two interdependent issues  $j$  and  $k$ . Whatever payoff externalities are present, it can be that if cooperation is sustained on one or none of those two issues, it cannot be sustained on any other issue. Suppose this is the case. Independent of whether  $j$  and  $k$  are complements or substitutes, if they are not linked cooperation is sustainable on both issues when  $CD_j - BD_j \geq 0$ ,  $CD_k - BD_k \geq 0$ , and  $CD_{jk} - BD_{jk} \geq 0$ ; and if they are linked when only  $CD_{jk} - BD_{jk} \geq 0$  is satisfied. When  $j$  and  $k$  are complements it can be that  $CD_{jk} - BD_{jk} \geq 0$  although  $CD_j - BD_j < 0$  (or  $CD_k - BD_k < 0$ ). When they are substitutes, it can be that  $CD_{jk} - BD_{jk} \geq 0$  although  $CD_j - BD_j < 0$ ,  $CD_k - BD_k < 0$ , or both (by Lemma 1(a)). In both cases issue linkage strictly improves welfare by allowing cooperation to be sustained on both issues, in the case of substitutes even when no cooperation is sustainable without a linkage.

Claim (b). Consider a couple of international agreements to cooperate on the isolated sets of linked policy issues  $S^1$  and  $S^2$ . Since governments are free to defect simultaneously on issues that are not linked, independent of whether issues are complement, substitute or separable, and independent of the strength and direction of income effects on issues outside the agreements, the two agreements are sustainable only if, besides being  $CD_{S^1} - BD_{S^1} \geq 0$  and  $CD_{S^2} - BD_{S^2} \geq 0$ , it is also  $CD_{S^1 \cup S^2} \geq BD_{S^1 \cup S^2}$ . This implies that if the two isolated agreements are sustainable, the larger international agreement to cooperate on all the issues included in  $S^1 \cup S^2$  is also sustainable. Since this logic applies to any couple (set) of agreements, policy cooperation remains sustainable after linking in one agreement all issues previously linked in different, sustainable agreements, and any welfare maximizing outcome with more agreements is replicated by one “grand international agreement” to cooperate on all issues in those agreements. Suppose now that  $S^*$  includes three issues, 1, 2, and 3. Under the current assumptions it can be the case that  $CD_{S^*} - BD_{S^*} \geq 0$ , but  $CD_1 - BC_1 < 0$  and  $CD_{1i} - BC_{1i} < 0$  for  $i = 2, 3$ . Then cooperation on all three issues is sustainable only within the “grand international agreement” on  $S^*$ , which is therefore the unique welfare maximizing agreement.  $\square$

**Proof of Proposition 4.** Claim (a). Consider two interdependent issues  $j$  and  $k$ . Whatever payoff externalities are present it can be that if cooperation is not sustained on those two issues, it cannot be sustained on any other issue. Suppose this is the case. Independent of whether  $j$  and  $k$  are complements or substitutes, if they are not linked cooperation is sustainable on both issues when  $CD_j^h - BD_j^h \geq 0$ ,  $CD_k^h - BD_k^h \geq 0$ , and  $CD_{jk}^h - BD_{jk}^h \geq 0$  for each  $h \in \{A, B\}$ ; and if they are linked when only  $CD_{jk}^h - BD_{jk}^h \geq 0$  is satisfied for each  $h \in \{A, B\}$ . Now independent of whether  $j$  and  $k$  are complements, substitutes or separable, it can be that  $BD_j^A < CD_j^A$ ,  $BD_k^A > CD_k^A$ , and  $BD_{jk}^A \leq CD_{jk}^A$ ; and that  $BD_j^B > CD_j^B$ ,  $BD_k^B < CD_k^B$ , and  $BD_{jk}^B \leq CD_{jk}^B$ . If issues are isolated cooperation is not sustainable on  $j$  because  $BD_j^B > CD_j^B$ , nor on  $k$  because  $BD_k^A > CD_k^A$ . Then issue linkage strictly improves welfare by allowing cooperation to be sustained on both issues even though no cooperation is sustainable without a linkage.

Claim (b). Consider again two isolated international agreements to cooperate on the isolated sets of linked policy issues  $S^1$  and  $S^2$ , and suppose that both agreements are sustainable. If the sets  $S^1$  and  $S^2$  are linked in a larger international agreement to cooperate on all issues in  $S^1 \cup S^2$ , this agreement is also sustainable, since governments are free to deviate simultaneously on two agreements so that condition  $BD_{S^1 \cup S^2} \leq CD_{S^1 \cup S^2}$  had to be satisfied for cooperation being sustainable in the two separate agreements. Since this logic applies to any two sets of agreements, any outcome implementable with more than one agreement is also implementable by a single agreement. Now suppose that a single sustainable Pareto-efficient “grand agreement” enforces cooperation on the set  $S^P$  containing three issues, 1, 2, 3, such that  $CD_{S^P}^h - BD_{S^P}^h \geq 0$  for every  $h \in \{A, B\}$ . Suppose further that when cooperation is being sustained on the three issues, it is  $CD_1^A - BD_1^A < 0$  and  $CD_{1i}^A - BD_{1i}^A < 0$  for  $i \in \{2, 3\}$ . Then the outcome of the “grand agreement” on  $S^P$  cannot be replicated by any set of smaller agreements.  $\square$

**Proof of Proposition 5.** Statement (a) follows immediately from Lemma 2. Statement (b) follows from Proposition 4 together with delegation restricting the set of possible deviations (preventing simultaneous ones), thereby reducing the value of the best deviation from any (set of) agreement(s).  $\square$

**Proof of Proposition 6.** When delegation is not feasible  $CD_i = \frac{\delta}{1-\delta} [Y_i^c - Y_i^n]$ ,  $BD_i = Y_i^d - Y_i^c$ , and each country  $i$  is willing to respect an international policy agreement if  $BD_i \leq CD_i$ . When credible delegation is feasible gains from (an optimal) deviation are still  $BD_i^{DEL} = Y_i^d - Y_i^c = BD_i$ , as unobserved delegation can only distort the deviant behavior reducing short-run gains from deviation, while observed delegation reveals the defection again reducing gains from deviation (to  $\bar{Y}_i < Y_i^d$ ). In the non-cooperative punishment phase, instead, countries are caught into the delegation Prisoner’s Dilemma obtaining  $\underline{Y}_i < Y_i^n$  each period, so that the cost of defecting become  $CD_i^{DEL} = \frac{\delta}{1-\delta} [Y_i^c - \underline{Y}_i] > CD_i$  making

$BD_i^{DEL} \leq CD_i^{DEL}$  strictly less stringent than  $BD_i \leq CD_i$ .  $\square$

**Proof of Proposition 7.** Consider two symmetric democracies and a separable isolated (set of) policy issue(s)  $i$  such that  $BD_i > CD_i$ . Suppose both countries introduce a law by which the contract of a government's delegate can be only renegotiated if the parliament decides to do so, i.e. with a public vote following a public discussion. Consider any objective function  $f(U_i(\Pi_i))$ , with  $f$  increasing and such that (e.g. sufficiently concave to make)  $BD_i^f \leq CD_i^f$ , where  $BD_i^f = f(U_i(Y_i)) - f(U_i(X_i))$ , and  $CD_i^f = \frac{\delta}{1-\delta} [f(U_i(X_i)) - f(U_i(N_i))]$ . If one government only delegates, everything remains unchanged as the government that did not delegate would deviate from any agreement and this is known to the other government's delegate. If both governments delegate, cooperation becomes sustainable since  $f$  satisfies  $BD_i^f \leq CD_i^f$ . Once delegates start cooperating each government would gain if it could secretly renegotiate the delegation contract, take back control on the policy issue (or establish a prize for the agent if it deviates), and defect unilaterally. But since a parliamentary discussion is necessary for any renegotiation to take place, the opponent country's delegate would observe that renegotiation is taking place *before* the deviation takes place, anticipate the renegotiating government's deviation, and react optimally by also deviating (as a strictly dominant strategy). Hence renegotiation cannot deliver short-run gains from a defection, while it induces a loss of future gains from cooperation. Since renegotiation is unprofitable, delegation is credible and the statement follows.  $\square$

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