Do credible domestic institutions promote credible international agreements?[☆]

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ABSTRACT

We examine the relationship between international policy coordination and domestic policy reputation when both are self-sustaining. We show that domestic policy commitment does not necessarily facilitate international cooperation; rather, efficient policies may be most easily sustained when governments are unable to pre-commit to policy domestically. Moreover, the lack of domestic commitment is more likely to facilitate international cooperation the larger the international spillovers of domestic policies are.

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1. Introduction

Do countries with more credible domestic institutions make for better international partners? The literature on rules versus discretion[1] has mainly focused on the reverse question, i.e., how the participation in international agreements affects domestic policy credibility. Staiger and Tabellini (1987) and Maggi and Rodriguez-Clare (1998), among others, have argued that *binding* international agreements, by making domestic policy changes more difficult to reverse, could enhance the credibility of policymakers when policy commitment cannot be achieved domestically.[2] The same argument is often heard in the policy debate. For example, it has been said that a desire to bolster the credibility of domestic reforms was central to Mexico's negotiations of the North American Free Trade Agreement (NAFTA).[3] Similarly, China's WTO accession has been viewed as a way to "... lock-in the agenda for fundamental domestic reforms, which has been difficult to implement by domestic measures alone" (Bajona and Chu, 2004). This view would suggest that countries with more unreliable domestic institutions could actually be more willing partners in international agreements.

The above arguments, however, neglect enforcement considerations: absent a supranational authority with autonomous powers of enforcement, international agreements need to be sustained by the credible threat of punishment between the parties involved.[4] If international agreements are not automatically binding, one could conjecture the existence of a reverse linkage: the inability to commit domestically might make it more difficult to undertake commitments *vis-à-vis* international partners. The nature and direction of the

[1] The idea that policy discretion can provide governments with an incentive to renege on earlier promises, undermining the sustainability of efficient policies, was introduced in a seminal paper by Kydland and Prescott (1977), and has since found applications in most areas of economic analysis, including the study of monetary and fiscal policy formation (see Persson and Tabellini, 1994, for a review), trade policy (e.g., Staiger and Tabellini, 1987; Matsuyama, 1990; Tornell, 1991), and environmental policy (e.g., Laffont and Tirole, 1996).

[2] In a more recent paper, Staiger and Tabellini (1999) find that GATT rules did indeed help the US government to make domestic trade policy commitments to its private sector.
[3] Whalley (1998, pp. 71–72) argues that "Mexican negotiators were less concerned to secure an exchange of concessions. [...] The idea was clearly to help lock in domestic reforms through this process."
[4] The problem of enforcement has been repeatedly stressed in recent literature on international cooperation (see, for example, Bagwell and Staiger, 1997; Maggi, 1999; Ederington, 2001a).

linkage between domestic policy credibility and international policy cooperation is what we set out to investigate in this paper.

Despite being frequently alluded to in the policy debate, the relationship between domestic and international policy credibility has never before been examined formally. Some papers (e.g., Rogoff, 1985a; Kehoe, 1989) have examined how policy coordination between governments affects time-consistent policy choices in a single round of strategic interaction, thus abstracting from the problem of enforcement—an aspect that has become a central concern in the more recent debate on international agreements. However, as our analysis will show, the manner in which time-consistent policymaking interacts with international policy cooperation under repeated interaction does not at all mirror what takes place within a single round.

If full commitment is unattainable, either domestically or internationally, vertical coordination—between each policymaker and its private sector—and horizontal coordination—between policymakers of different countries—must both be sustained by balancing each party's temptation to deviate from a given policy against the threat of punishment triggered by unilateral defections. We show that, in this case, if the international spillover of domestic policies is sufficiently large, the inability to commit domestically can make a policymaker less tempted to deviate unilaterally, making it easier to sustain globally efficient policies. The intuition behind this result is that, in the absence of vertical coordination, a unilateral deviation from the efficient policy level is not anticipated by the private sector, and so investment choices cannot optimally adjust to it. In contrast, under vertical coordination, investors can observe unilateral deviations and adjust their choices accordingly. The size of the miscoordination costs associated with unanticipated defections is larger the larger is the gap between the globally efficient policy and the unilateral optimal policy, which in turn is larger the larger is the international spillover from the policy. Therefore, for large enough international spillovers, governments' inability to coordinate with their investors can reduce the temptation to defect from international agreements. In addition, the lack of commitment can help to sustain efficient policies by increasing the severity of the punishment triggered by unilateral defections. Thus, the need to sustain policy reputation *vis-à-vis* the private sector can help sustain international cooperation.

The remainder of the paper is organized as follows. In Section 2 we model policy formation within a single round of interaction between policymakers and investors. We then consider repeated interaction over an infinite horizon in Section 3. Section 4 discusses an application to environmental policy. Section 5 concludes.

2. Vertical and horizontal miscoordination in policy formation

Our arguments are developed in a model of policy formation that combines a domestic and an international dimension of strategic policy interaction: within each country, the government faces a large number of individually small domestic players, its private sector, and is unable to pre-commit to certain policies; governments of different countries are also engaged in a prisoners' dilemma-type policy game, stemming from the presence of an international policy spillover. Policy formation thus suffers from both a *vertical* coordination problem between each government and its private sector and a *horizontal* coordination problem between governments. This section describes policy formation in a single round of interaction, while the next section will focus on repeated strategic interaction.

Following in the steps of a vast literature on the subject (e.g., Kydland and Prescott, 1977; Fischer, 1980), the policy credibility problem faced by government *vis-à-vis* its private sector is represented here, in quite general terms, by the following reduced-form specification.

Let I be an action (investment) undertaken by the private sector, and let $P(I)$ be the private sector's associated payoff, with P being twice continuously differentiable, strictly concave, and admitting a unique interior global optimum, I^N. Private investment also generates

a socially relevant domestic spillover, represented by a twice continuously differentiable and monotonic function $S(I)$. Without loss of generality, we shall assume $S'(I)>0$, which implies that the level of private investment which maximizes $P(I)+S(I)$ lies above the private optimum, I^N. In order to induce a level of private investment above the private optimum, the government employs a policy, t, as part of an incentive scheme $H(I,t)$ that enters the private sector's payoff (e.g., a conditional transfer scheme), making the private sector's choice a function, $I(t)$, of the policy. Suppose that the incentive scheme is such that $I'(t) \equiv -H_{It}/(P''+H_{II})>0$, and let t^N be the (null) policy level that induces the level of investment I^N. Then, in order for the policy to have the desired effect, it will have to be set at a level above t^N.

Also, suppose that deviating from t^N produces another socially relevant, direct cost, $D(t) \leq 0$, where D is twice continuously differentiable, strictly concave, and admits a unique interior global optimum at t^N, with $D(t^N)=0$.[5] We shall also assume the total payoff $D(t)+P(I(t))+S(I(t))$ to be concave in t, as would be implied by any well-behaved microfoundations of the abstract formulation of the model, such as the example we present in Section 4.[6]

If the policy is selected by the government prior to investment decisions being made, the government, anticipating the effect of the policy on private choices, will select an efficient policy level, t^E, such that

$$D' + (P' + S')I' = 0. \tag{1}$$

This social optimum—the *ex-ante* optimal policy—will lie above t^N, and will induce a level of private investment $I^E \equiv I(t^E)>I^N$, reflecting an optimal tradeoff between the direct cost of the policy ($D(t)<0$) and its indirect effect through private investment choices ($P(I)+S(I)$).[7]

If, on the other hand, the private sector's choice precedes the policy choice, the *ex-post* optimal policy level, for any given level of private investment, will be t^N; this is the level that maximizes $D(t)$ while fully disregarding the indirect effects of the policy, i.e., the policy level for which

$$D' = 0. \tag{2}$$

Anticipating this choice, the private sector will select the level of investment I^N. Thus, if the government is unable to pre-commit to a given policy, it will be unable to adopt the efficient policy, and "promises" to do so will not be credible. This policy credibility problem results from a lack of coordination between the government and investors, and can be described as a domestic, *vertical* coordination problem.[8]

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[5] In this specification, the direct and indirect effects of the policy are additively separable, a formulation that best serves to illustrate our arguments.

[6] A sufficient but not necessary condition for concavity of the payoff in t is that the mapping $D(I^{-1}(I))$ be concave in I, where $I^{-1}(I)$ is the inverse of $I(t)$; this amounts to saying that the direct marginal cost of bringing about a given increase in I through the policy is increasing.

[7] Since in this scenario I is selected after t, it may be more natural to think of I as a current output choice rather than an investment choice. Nevertheless, in our discussion we will keep referring to I as "investment", irrespectively of the timing structure considered.

[8] The existence of a policy commitment problem can be linked to the quality of domestic institutions. There are a number of institutional commitment devices that governments can rely upon to achieve some degree of vertical coordination—such as policy delegation or budgeting rules—many of which have been extensively studied in the literature (e.g., Lucas and Stokey, 1983, Rogoff 1985b). Institutions able to achieve policy commitment could be formally incorporated in our model by introducing a distinction between *ex-ante* policy announcements and *ex-post* policy choices, and specifying a cost for deviations of policies from announcements. If this cost is large enough, then the resulting game would be equivalent to that which obtains under a timing structure where policies are selected before private investment choices are made (see, however, Footnote 15 for a discussion of scenarios where this equivalence might break down). In rest of our analysis, we will rely on this equivalence, and use the term "binding announcements" to refer to scenarios in which policies are chosen *and* enacted prior to investment choices being made.

To model the international policy coordination problem, the preceding setup can be augmented as follows. As before, in addition to its effect on the private sector's payoff, private investment in the home country generates a spillover. However, suppose that only a fraction $(1-\alpha)S(I)$ ($\alpha \in [0,1]$) is experienced domestically, while the remaining fraction $\alpha S(I)$ is a spillover on other countries (the rest of the world). To simplify our exposition, we shall focus first on the case of two symmetric countries, denoted by home and foreign; as discussed in the next section, our analysis can be readily generalized to a scenario with multiple, asymmetric countries.

The payoff of country i can then be written as a function of the domestic policy and of the foreign spillover:

$$D(t) + P(I(t)) + (1-\alpha)S(I(t)) + \alpha S\left(I\left(t^*\right)\right) \equiv \Pi\left(t, I(t), I\left(t^*\right)\right), \quad (3)$$

where $S(I(t^*))$ is the spillover generated in the foreign country as a result of the foreign policy level t^*. This specification gives rise to a prisoners' dilemma-type game—and to an international, *horizontal* policy coordination problem.

Consider a timing structure where first governments simultaneously and independently select policies and then, after observing these policies, private investors make their choices. This can be described as a *vertical coordination* regime (isolating the international policy coordination problem). The globally optimal level of policy is t^E as before (identified by Eq. (1)), but the unilaterally optimal policy level chosen by each government, if it can vertically coordinate actions with its private sector—i.e., if policies are simultaneously and noncooperatively chosen by the two governments prior to investment choices being made—is the level $t^V < t^E$ that satisfies

$$D' + (P' + (1-\alpha)S')I' = 0, \quad (4)$$

resulting in a level of investment $I^V \equiv I(t^V) < I^E$. Thus, even when a vertical coordination problem is absent, the lack of (international) horizontal coordination between the two governments results in suboptimal levels policies and suboptimal levels of private investment.

Consider next a timing structure where private investment choices are made first and then governments select policies in a coordinated manner—formally identical to a scenario with $\alpha = 0$ and where policy choices follow investment choices. This can be described as a *horizontal coordination* regime (isolating the domestic policy commitment problem), and produces the same outcome as the one just derived for a single-country scenario, i.e., a policy level $t^H = t^N$.

A fully uncoordinated regime in which policies are simultaneously and noncooperatively chosen by the two governments *after* investment choices are made then combines two separate coordination problems—an international, horizontal coordination problem and a domestic, vertical coordination problem—each involving the same strategic choice but different players—respectively each government and its private sector vertically and the two governments horizontally. The vertical relationship between governments and investors is modeled here as being exclusively domestic in nature: domestic policies have no effect on foreign investors, and, *vice-versa*, foreign policies have no effect on domestic investors;[9] this feature of our model enables us to derive clear-cut results concerning the relationship between domestic policy credibility and international cooperation.

In this specification the two forms of miscoordination operate in the same direction; both bias policies downwards, and cannot directly offset each other as they do, for example, in the problems studied by Rogoff (1985a) and Kehoe (1989). This implies that removing either one of the coordination problems can never be undesirable in the stage game:

Proposition 1. *Within a single round of interaction, vertical coordination (between governments and investors) and horizontal coordination (between governments) can never be undesirable.*

Proof. Comparing Eq. (2) with Eq. (4), it is straightforward to verify that within a single round of interaction vertical coordination leads to the adoption of higher policies: $D'(t^N) = 0$, $P'(I(t^N)) = 0$, and $S'(t) > 0$ together imply $t^V > t^N$. In turn, higher policies lead to higher welfare, since Π is monotonically increasing in t for $t < t^E$. In the absence of vertical coordination, horizontal coordination leads to the same policy level as the case of no coordination ($t^H = t^N$), and thus has no effect on welfare. □

In the next section, we will show that this conclusion can be overturned when the interaction between governments and investors is repeated indefinitely.

3. Policy formation under repeated interaction

Countries are typically unable to enter into binding coordination agreements between them—unless they form a political union—given that no enforcement power exists outside them. In contrast, institutional arrangements that can make domestic policy announcements binding *are* available in some cases (e.g., currency boards, guarantees of central bank independence, balanced budget rules). However, even in the absence of any binding coordination arrangements, horizontal and vertical coordination can be achieved under repeated strategic interaction.

To rationalize the existence of international agreements—as self-enforcing (as opposed to binding) arrangements—the international economics literature has appealed to the notion that, when countries repeatedly interact, the threat of future punishments can be used in support of international cooperation. Intuitively, an agreement to maintain policy at the efficient level can be enforced if the one-time gain from cheating on the agreement is sufficiently small relative to the discounted future cost of the "policy war" that would be triggered as a consequence (Dixit, 1987). The literature on policy credibility has independently appealed to the well-known idea that repeated interaction creates incentives to maintain reputation, and can therefore help overcome domestic credibility problems, or at least mitigate them—an argument that was first formulated by Selten (1975).[10] As described in Stokey (1989), when the interaction between each government and its domestic sector is repeated indefinitely, domestic policy commitment problems can be overcome by the credible threat of the private sector permanently reverting to the expectation of future inefficient policies.[11]

Both arguments are applications of folk theorems for repeated games. In such constructions, equilibrium strategies punish defections by switching to alternative continuation equilibria in which the defector experiences a lower average payoff than along the equilibrium path of play. Accordingly, equilibrium strategies must satisfy incentive constraints that involve a comparison between defection gains and punishment losses.

Previous literature has examined each of these two coordination problems separately. Sustaining cooperation vertically in the domestic policy reputation game—in isolation from the international cooperation game—implies a comparison of the gains from vertical defections with the losses from vertical punishment; sustaining cooperation horizontally in the international policy game—in isolation from the domestic

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[9] An example of a policy characterized by this structure is provided in Section 4, in which we describe an application of the general model to environmental policy.

[10] Here the term "reputation" is used—consistently with its use in some of the literature—to refer to policy credibility in the context of a game of complete information. For a discussion of reputation in games of incomplete information, see Fudenberg and Tirole (1996).

[11] Since investment projects are assumed to last only one period in the model, private agents are effectively finitely-lived players; nevertheless, their investment choices can be made to depend on past history.

policy reputation game—implies a comparison of the gains from horizontal defections with the losses from horizontal punishment. In the problem we are analyzing, however, both the horizontal and the vertical reputation mechanisms are at work. This effectively involves a pooling of sustainability constraints, comparing the gains from deviations along both the horizontal and the vertical dimensions against the punishment that can be administered along both dimensions.

The theoretical implications of the pooling of separate incentive constraints under repeated interaction were first examined by Bernheim and Whinston (1990) for the case of oligopolistic firms sustaining collusion across multiple markets. Their analysis shows that the effect of pooling is ambiguous, and that under some conditions pooling has no effect on cooperation. The form of pooling they analyze, however, is between different horizontal cooperation games, each involving a different strategic variable.[12] In our problem, pooling takes place instead between a horizontal and a vertical cooperation game that both involve the same strategic variable; to the best of our knowledge, this problem has not been studied before.

If fully eliminating both forms of miscoordination (vertical and horizontal) were possible, then it would clearly always be desirable to do so—even under repeated interaction. But we are concerned here with situations in which it is *not* possible to achieve full coordination within the stage game. Examining the relationship between the domestic policy credibility problem and the international cooperation problem under repeated interaction thus involves comparing a scenario where both coordination problems are simultaneously present in the stage game (the pooled case) with scenarios where only one type of miscoordination—horizontal or vertical—is at work (the unpooled cases). Given the specific structure of the incentive constraints that characterize equilibria under repeated interaction, we should not expect pooling to have the same effect here as it has on best responses in the stage game.

The general structure of the incentive constraint for the sustainability of an efficient policy, t^E, under repeated interaction can be expressed as

$$\Phi \leq \Gamma, \tag{5}$$

where Φ is the one-shot gain experienced by a country by optimally deviating from t^E in any given period; Γ captures the punishment for defecting, which is equal to the (negative of the) change in the continuation payoffs and depends on the particular punishment strategies adopted by the players.

Let Φ^V and Γ^V respectively denote the one-shot gain and the punishment in the vertically coordinated regime (policy choices in each round are made cooperatively between governments following investment choices), i.e., when there is only an international policy coordination problem and no domestic policy commitment problem. In this case the incentive constraint for the sustainability of t^E under repeated strategic interaction is

$$\Phi^V \leq \Gamma^V. \tag{6}$$

This incentive constraint isolates deviation incentives and punishment costs that pertain to the international policy coordination problem.

Let Φ^H and Γ^H respectively denote the one-shot gain and the punishment in the horizontally coordinated regime (policy choices in each round precede investment choices), i.e., when there is only a domestic policy commitment problem and no international policy coordination problem. In this case the incentive constraint for the sustainability of t^E under repeated strategic interaction is

$$\Phi^H \leq \Gamma^H. \tag{7}$$

This incentive constraint isolates deviation incentives and punishment costs that pertain to the domestic policy reputation problem.

Finally, let Φ^N and Γ^N respectively denote the one-shot gain and the punishment for a scenario in which both the domestic vertical coordination problem and the international horizontal coordination problem are present (the pooled case). The incentive constraint for the sustainability of t^E under repeated strategic interaction when both an international policy coordination and a domestic policy commitment problem are present is then

$$\Phi^N \leq \Gamma^N. \tag{8}$$

The pooled incentive constraint (8) involves incentives along both the international, horizontal dimension and the domestic, vertical dimension. In order to examine the effects of pooling on the sustainability of efficient policies, we must compare the pooled incentive constraint (8)—which refers to scenarios where policy choices are made simultaneously and noncooperatively in each round following investment choices—with each of the unpooled incentive constraints, (6) and (7), that arise when only one of the two coordination problems is present in the stage game.

The structure of the incentive constraint implies that we can examine the effects of pooling by separately examining its effects on each side of the constraint, i.e., by first comparing Φ^V, Φ^H and Φ^N, and then comparing Γ^V, Γ^H and Γ^N.

Consider first Φ^V, the deviation incentives that arise the presence of vertical coordination in the stage game—i.e., in a scenario in which governments select policies in each round before private investment choices are made. In this scenario, if a government were to deviate from equilibrium play in a certain period, such a deviation would be accounted for by its investors. The unilaterally optimal deviation policy would then be t^V as derived from Eq. (4), private investment in the deviation phase will be $I(t^V)$, and the one-shot deviation gain experienced from such a deviation would be equal to

$$\Phi^V = \Pi\left(t^V, I^V, I^E\right) - \Pi\left(t^E, I^E, I^E\right)$$
$$= D\left(t^V\right) - D\left(t^E\right) + P\left(I^V\right) + (1-\alpha)S\left(I^V\right) - P\left(I^E\right) - (1-\alpha)S\left(I^E\right). \tag{9}$$

Consider next Φ^H, the deviation incentives in the presence of horizontal coordination in the stage game—i.e., in a scenario where governments can coordinate their choices in each period (as though they were a single country) but cannot pre-commit to policy choices. In this scenario, if governments were to deviate from equilibrium play in a certain period, such a deviation would not be accounted for by investors. In this case, their best coordinated deviation is to t^N as derived from Eq. (2), private investment in the deviation phase will still be equal to $I(t^E)$, and the one-shot deviation gains would be

$$\Phi^H = \Pi\left(t^N, I^E, I^E\right) - \Pi\left(t^E, I^E, I^E\right) = D\left(t^N\right) - D\left(t^E\right). \tag{10}$$

To characterize Φ^N, we must consider deviations from t^E in the absence of horizontal coordination (between governments) and vertical coordination (between each government and its domestic investors). If both governments keep to this choice, the policy level in both countries will be t^E in all periods. In the absence of domestic policy commitment, defections are not anticipated by investors. In this case, the unilaterally optimal deviation is to t^N, and the one-shot deviation gain is

$$\Phi^N = \Pi\left(t^N, I^E, I^E\right) - \Pi\left(t^E, I^E, I^E\right) = \Phi^H. \tag{11}$$

Does domestic policy commitment increase or reduce the incentives to deviate from the optimal policy t^E? To answer this question we can look at the effect of vertical coordination on deviation

incentives, as captured by the difference between Φ^N and Φ^V—the deviation gains for the pooled and unpooled (vertically coordinated) games respectively. We will show that this difference can be negative, implying that, other things being equal (more specifically, abstracting the effects of punishment, which will be examined below), the lack of domestic policy commitment can make it easier to sustain efficient policies.

The above difference can be written as

$$\Phi^N - \Phi^V = D\left(t^N\right) - D\left(t^V\right) \tag{12}$$
$$-\left(P\left(I^V\right) + (1 - \alpha)S\left(I^V\right) - P\left(I^E\right) - (1 - \alpha)S\left(I^E\right)\right).$$

The first line of Eq. (12) is always positive and identifies a "direct surprise effect" of noncommitment, consisting of the additional reduction in the direct costs of the policy that results from lowering the policy to t^N rather than to $t^V > t^N$. The second line of Eq. (12) is an "indirect surprise effect," stemming from the fact that without policy commitment defections surprise investors, resulting in a level of private investment equal to I^E in the deviation phase, rather than the level, $I(t^V)$, that would have occurred if a deviation had been anticipated. When negative, this latter effect can be thought of as the fraction of the indirect cost of cooperation that remains sunk in the deviation phase when a government cannot coordinate its deviation with its own private sector.

If this indirect surprise cost outweighs the direct surprise gain, the ability to commit domestically makes a policymaker more tempted to defect. For this to be possible, the indirect surprise effect must be negative, i.e., cooperation must take each country to a point where it would gain from unilaterally lowering its level of private investment, even when neglecting the direct effect of the policy. In turn, this means that the size of the international spillover must be sufficiently large:

Lemma 1. *When efficient policies must be sustained by repeated strategic interaction, for large enough international spillovers, the ability to commit to domestic policy announcements implies a* greater *temptation to deviate from optimal policies; for small enough international spillovers, the ability to commit implies a* lesser *temptation.*

Proof. Denote with $\Pi^V = D(t^V) + P(I^V) + (1 - \alpha)S(I^V) + \alpha S(I^E)$ the unilateral deviation payoff with vertical coordination in the stage game. We have $d(\Phi^N - \Phi^V)/d\alpha = -\partial\Pi^V/\partial\alpha = S(I^V) - S(I^E) < 0$ (by the Envelope Theorem), which implies that $\Phi^N - \Phi^V$ is monotonically decreasing in α for $\alpha \in [0, 1]$. Moreover, this difference is positive for $\alpha = 0$ (where $t^V = t^E$) and negative for $\alpha = 1$ (where $t^V = t^N$). Therefore, there exists an interval $(\underline{\alpha}, 1]$, $\underline{\alpha} > 0$, over which $\Phi^N - \Phi^V$ is negative.   □

Under repeated interaction, vertical coordination alone can thus be undesirable, because it can make a country more effective at defecting from an international agreement. The reason why vertical miscoordination has a different effect on the deviation phase than on the equilibrium of the stage game (Proposition 1) is simply that, in the former, the deviation from the efficient policy level is not anticipated by investors. From the point of view of the deviating government, this implies both a benefit—associated with the additional reduction in the direct costs of the policy—and a cost—stemming from the fact that investors are unable to reduce investment to its domestically optimal level. If the second effect dominates the first, vertical miscoordination can help sustain efficient policies.[13] The lack of commitment is more likely to be desirable the larger the international policy spillover is,

because a larger international spillover entails a comparatively larger cost of miscoordination between a government and its private sector during unanticipated deviations.[14]

Lemma 1 thus shows that the temptation to deviate under vertical coordination becomes comparatively larger, relative to that under no coordination, the larger the size of the international spillover is. Whether or not a lack of domestic policy commitment results in smaller deviation gains will also depend on the size of the direct domestic effect of the policy: the smaller this direct effect is, the less likely it is that the direct surprise effect of noncommitment, $D(t^N) - D(t^V)$, will dominate the indirect effect.

To examine how horizontal coordination affects deviation incentives in the absence of policy commitment we must compare Φ^N with Φ^H — the deviation gains for the pooled and unpooled (horizontally coordinated) games respectively. As shown in Eq. (11), Φ^N with Φ^H are the same. Thus, in this model, horizontal coordination generates no effect on the deviation gains, and can only affect the sustainability of t^E through its effect on the punishment.

When focusing on repeated strategic interaction, many different continuation equilibria can be invoked in support of equilibrium play. The effect that the pooling of incentives has on the punishment thus depends on the particular continuation equilibrium considered. This is not so for deviation gains: the effect of pooling on deviation incentives is the same irrespective of which particular equilibrium strategies we consider. This means that conclusions concerning the deviation phase have general validity—and should therefore be viewed as being the central results of our analysis—whereas any results we may derive concerning the punishment are necessarily much less general.

In what follows, we will consider two alternative punishment strategies: Nash-reversion strategies, and renegotiation-proof strategies.

Under Nash-reversion punishment, a deviation from t^E by a country triggers indefinite reversion to noncooperation in the following period. With vertical coordination in the deviating country and no horizontal coordination between countries, deviation triggers an indefinite reversion to $t = t^V$ in the deviating country. The severity of the punishment suffered by the defecting country will depend on the other country's institutions. If the other country faces a domestic commitment problem, it will revert to $t^* = t^N$; let the payoff reduction experienced in this case by the deviating country be denoted by Ω^{VN}. If, instead, the other country does not face a commitment problem, it will revert to $t^* = t^V > t^N$; in this case, the deviating country will experience a smaller payoff reduction, $\Omega^{VV} < \Omega^{VN}$.[15]

In the absence of vertical coordination in the deviating country, the lack of domestic policy commitment implies not only that the other government would cease to select polices cooperatively following a defection, but also that investors in the country would mistrust the deviating government forever, i.e., indefinite reversion to $t = t^N$ in the deviating country. The other country will revert to either $t^* = t^N$ or $t^* = t^V$, depending on whether or not it also faces a domestic vertical coordination problem; as above, the severity of punishment faced in

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[13] A different but somewhat related mechanism has been described by McLaren (1997). In his analysis, the private sector's ability to anticipate trade liberalization—starting from higher trade barriers—can undermine a country's bargaining power in trade negotiations.

[14] In the real world, we may expect investment to be slow to adjust to policy changes (i.e., adjustment may take more than one period). If this is the case, we would expect vertical coordination to have a quantitatively smaller impact on the temptation to defect from t^E, although this impact would be qualitatively the same as when investment can adjust in a single period. Moreover, independently of the speed at which investment adjusts, a defecting country would always experience a gain in the deviation phase—Φ^V is always positive no matter how close I^V is to I^E.

[15] In all scenarios we examine, policy choices occur simultaneously in each round, and punishment is therefore always delayed by at least one period. Suppose, however, that announcements and policy choices were modeled as separate choices—as outlined in Footnote 8—and that binding announcements in countries with domestic commitment were assumed to precede policy choices in countries without commitment. In such a game, a country suffering from a domestic policy commitment problem would be able to start punishing a defecting country that has no commitment problem during the deviation phase. This is not implausible: the institutional constraints and protocols that can make policy commitment possible could also make a country comparatively slower at enacting policy changes.

each subsequent period by a defector will be different in the two cases: Ω^{NN} in the first case, and $\Omega^{NV} < \Omega^{NN}$ in the second case.

Nevertheless, given the assumed separability structure of the payoffs with respect to the foreign spillover, it can be readily verified that the impact of the lack of domestic policy credibility on the severity of Nash-reversion punishment experienced by the deviating country is independent of whether or not the other country suffers from a domestic credibility problem (the *difference* between the right-hand sides of the pooled and unpooled no-deviation constraints for any given country does not depend on the Nash-reversion policy in the other country).[16] We can thus state the following result:

Lemma 2. *Lack of domestic commitment increases the severity of Nash-reversion punishment following a deviation.*

Proof. The impact of the lack of domestic policy credibility on the severity of Nash-reversion punishment experienced by the deviating country is captured by

$$\Omega^{NN} - \Omega^{VN} = \Omega^{NV} - \Omega^{VV} = \Delta\Omega, \tag{13}$$

where

$$\Delta\Omega \equiv D\left(t^V\right) - D\left(t^N\right) + P\left(I\left(t^V\right)\right) - P\left(I\left(t^N\right)\right) + \alpha\left(S\left(I\left(t^V\right)\right) - S\left(I\left(t^N\right)\right)\right) > 0. \tag{14}$$

Therefore, independently of the ability (or lack thereof) by the other government to commit *vis-à-vis* its private sector, the presence of a domestic policy commitment problem always increases the severity of the punishment suffered by the defecting country in each period following the defection. Denoting by $\delta < 1$ the factor by which the deviating government discounts the future, the change in the right-hand side of the incentive constraint (5) can be expressed as

$$\begin{aligned}
\Gamma^{NN} - \Gamma^{VN} &= \frac{\delta}{1-\delta}\left(\Omega^{NN} - \Omega^{VN}\right) \\
&= \Gamma^{NV} - \Gamma^{VV} = \frac{\delta}{1-\delta}\left(\Omega^{NV} - \Omega^{VV}\right) \\
&= \frac{\delta}{1-\delta}\Delta\Omega \equiv \Delta\Gamma > 0,
\end{aligned} \tag{15}$$

which is also independent of whether or not a vertical coordination problem exists in the other country.   □

Combining Lemmas 1 and 2, we obtain the following result:[17]

Proposition 2. *For large enough international spillovers, the ability to commit to domestic policy announcements raises the minimum discount factor for which efficient policies can be sustained under repeated strategic interaction by Nash-reversion punishment strategies.*

Proof. The general expression identifying the minimum discount factor that makes it possible for a country to sustain t^E is

$$\underline{\delta} = \frac{\Phi}{\Omega + \Phi}, \tag{16}$$

where Φ and Ω vary according to the scenario considered, and are both independent of whether vertical coordination is present in the

other country. In Lemma 1 we have shown that, for $\alpha > \underline{\alpha}$, vertical coordination increases Φ; in turn, this raises the numerator of Eq. (16) by more than it does the denominator, thus leading to an increase in $\underline{\delta}$. Under Nash-reversion punishment, this effect is compounded by the fact that domestic commitment leads to a lower Ω (Lemma 2), implying a fall in the denominator of Eq. (16) and an increase in the minimum degree of patience required to sustain efficient policies.   □

If we consider the effects of horizontal coordination under Nash-reversion punishment, then neither the deviation gains nor the punishment is affected. This is because, in the absence of vertical coordination, the Nash-reversion policy is independent on whether or not governments act cooperatively ($t^H = t^N$); and, as shown earlier, deviation gains are also unaffected.[18]

We next shift our attention to renegotiation-proof punishment strategies. Although in principle many types of punishment strategies can be sustained as part of a subgame-perfect equilibrium, there are compelling theoretical reasons to regard some of them as being more plausible. In particular, punishment strategies relying on continuation equilibria that are Pareto dominated by alternative continuation equilibria seem implausible, as they would be vulnerable to renegotiation: although Nash reversion is a credible threat—since playing t^N indefinitely is always an equilibrium strategy in the continuation game—once a defection has occurred, players will have an incentive to forgo punishment and re-coordinate to an equilibrium that gives them all a higher continuation payoff. In the remaining of this section we shall show that, if we restrict our attention to renegotiation-proof equilibrium strategies—i.e., strategies such that leave no joint incentive to renegotiate to an alternative continuation equilibrium upon entering the punishment phase (Farrell and Maskin, 1989)—we can obtain even more clear-cut predictions about the effects of removing vertical or horizontal miscoordination on the sustainability of efficient policies.[19]

Consider the following strategy profile: each country plays the efficient policy t^E as long as the other country does the same; if country i defects in a given period (and country j does not), then country j (the punisher) will play t^V until the defector country i (the defector) reverts to t^E; as soon as country i has "repented" by playing t^E, country j "forgives" the initial defection and returns to playing t^E. Since the punishing country experiences a net gain relative to cooperation upon entering the punishment phase, this strategy profile is renegotiation-proof.[20]

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[16] Note that this is not to say that the presence of vertical coordination in the other country has no effect on the ability to sustain cooperation, since lack of coordination in the other country raises the punishment for the defecting country; only that the way vertical coordination within a country affects the punishment experienced by the defecting country is the same irrespectively of the extent vertical coordination elsewhere.

[17] We assume no interaction between the strength of a country's institutions and the degree of patience of its policymakers. This result would clearly be weakened if better domestic institutions also meant that governments are more attentive to the long-run consequences of their actions.

[18] We can view this result as being somewhat analogous to the "irrelevance result" described by Bernheim and Whinston (1990) for the horizontal (multimarket) pooling of incentive constraints with constant-returns-to-scale technologies.

[19] This type of equilibrium is also attractive because the comparison between deviation incentives and punishment does not depend in this case on how the length of each individual period is defined—unlike with Nash reversion, where considering shorter periods of interaction lowers the temptation to deviate but leaves the punishment unchanged.

[20] These punishment strategies have a structure analogous to that described by Van Damme (1989) for a discrete prisoners' dilemma game. For these strategies to be subgame-perfect, renegotiation-proof equilibrium strategies, three conditions must be met: (i) *Nash equilibrium*: adhering to these strategies must give each player a higher discounted payoff than the alternative of unilaterally deviating from them; (ii) *subgame perfection*: adhering to these strategies following a defection must constitute a continuation equilibrium—in which the defector plays t^E indefinitely and the punisher plays t^V for one period reverting to t^E thereafter; in turn, this means that the promise of reversion to t^E by the punisher must offset the defector's temptation to deviate from repentance and thus postpone reversion to cooperation; (iii) *renegotiation proofness*: the continuation equilibrium supporting equilibrium play must not be Pareto dominated by other possible Pareto undominated continuation equilibria. Note that, as is generally the case when considering repeated interaction, many continuation equilibria are possible. However, only Pareto undominated continuation equilibria need be considered. In turn, if we restrict our attention to equilibria with $t \leq t^E$ for both players, the continuation equilibrium we describe is Pareto undominated by any other Pareto undominated continuation equilibrium (since any alternative continuation equilibrium in which, in the punishment phase, the punisher plays $t \neq t^V$ and/or the defector plays $t < t^E$ would result in the punisher being worse off), while achieving maximum punishment for the defector.

Crucially, renegotiation-proofness requires that, even in a scenario where there is no vertical coordination, the punishing country must adopt t^V (rather than t^N) in the punishment phase. This is because a choice of t^N by the punisher would be Pareto dominated by a choice of t^V (since all players are better off when t^V is chosen and a choice of t^V can be sustained) and would therefore not be renegotiation-proof. Thus, the continuation equilibrium is the same for the vertical coordinated and the vertical uncoordinated cases, which implies that vertical coordination has no effect on the severity of the punishment that follows a defection from t^E, and only affects the extent of the deviation gains. Lemma 1 then translates directly into predictions about the effect of vertical coordination on the sustainability of efficient policies:

Proposition 3. *For large enough international spillovers, the ability to commit to domestic policy announcements raises the minimum discount factor for which efficient policies can be sustained under repeated strategic interaction by renegotiation-proof punishment strategies.*

Proof. Under the strategy profile described above, a defector will face a reduction in the continuation payoff equal to $\delta\alpha(S(t^E) - S(t^V))$, irrespective of whether or not vertical coordination is present (in either country or in both countries). The no-deviation constraint can then be written as

$$\Phi \leq \delta\alpha\left(S\left(t^E\right) - S\left(t^V\right)\right), \tag{17}$$

where Φ is either Φ^V or Φ^N, depending on whether or not vertical coordination is present. The minimum discount factor that prevents defections is identified by

$$\underline{\delta} = \frac{\Phi}{\alpha(S(t^E) - S(t^V))}. \tag{18}$$

For the continuation equilibrium to be subgame perfect, the players must also have no incentive to deviate from the stated punishment—i.e., the continuation play triggered by defections must represent an equilibrium of the continuation game. If the defector optimally deviates from t^E during the punishment phase, it experiences a one-shot gain equal to either Φ^V or Φ^N, but suffers a loss equal to $\delta\alpha(S(t^E) - S(t^V))$ (in discounted terms) from the postponement of reversion to cooperation. This means that the condition for the stated punishment strategies to be subgame-perfect equilibrium strategies is formally identical to Eq. (17). Whether $\underline{\delta}$ (as identified by Eq. (18)) is smaller or larger in the presence of policy commitment depends directly on the comparison between the deviations gains Φ^V and Φ^N. We can thus conclude that the condition identified in Lemma 1 ($\alpha > \underline{\alpha}$) is both necessary and sufficient for the lack of domestic policy commitment to make it easier to sustain efficient policies. □

Finally, we can examine how horizontal coordination in the stage game affects the severity of the punishment under renegotiation-proof punishment strategies. Under this requirement, horizontal coordination implies that no degree of patience is high enough to solve the domestic policy credibility problem. This is because there exist no credible punishment strategies giving investors a higher continuation payoff, once punishment is triggered, than the payoff they would obtain by renegotiating a reversion to cooperation jointly with government. Therefore, in the absence of any strategic interaction with a foreign country, any policy level above t^N would be unsustainable.

3.1. Extension to an asymmetric, multi-country setting

The analysis carried out in the previous sections in the context of a symmetric, two-country setting can be readily extended to a multilateral setting in which countries can be asymmetric.

Assume that there are M countries. We retain the assumption that payoffs have the separable structure described in Eq. (3), but now allow countries to differ with respect to the policy spillover they inflict on each other. The payoff of country i can then be written as

$$D_i(t_i) + P_i(I_i(t_i)) + \left(1 - \sum_{j \neq i}\alpha_i^j\right)S_i(I_i(t_i)) + \sum_{j \neq i}\alpha_j^i S_j\left(I_j\left(t_j\right)\right), \tag{19}$$

where α_i^j denotes the extent of the spillover from country i that is experienced by country j (with $\sum_j\alpha_i^j = 1$).

Suppose that countries must sustain efficient policy levels $(t_1^E,\dots, t_M^E)$ through repeated interaction, where t_i^E is identified by $D_i' + (P_i' + S_i')I_i' = 0$, a country-specific condition equivalent to Eq. (1).

As in the symmetric two-country case, the relevant incentive constraint for sustainability of agreed-upon policies will require that country-specific deviation gains, Φ_i, do not exceed the punishment, Γ_i, faced by each defecting country. And as before, the effect of vertical coordination on the relevant incentive constraint for any given country can be uncovered by separately looking at its effects on the left-hand side and on the right-hand side of the constraint. The analysis we conducted for the symmetric two-country case then carries over to this scenario with no changes, and the same results apply—now stated in terms of bounds on $\alpha_{-i} \equiv \sum_{j \neq i}\alpha_i^j$, the overall external fraction of the spillover generated by i.[21]

4. An application to environmental policy

In this section we show how the results of the analysis carried out above can be applied to the case of pollution taxes, when emissions are transboundary, emissions abatement requires private investment, and environmental taxes have adverse distributional effects that give rise to a time-consistency problem. A crucial feature of this application is that, as in the theoretical model described in Section 2, domestic policies have no effect on foreign investors, and, *vice-versa*, foreign policies have no effect on domestic investors.[22]

There is evidence that international environmental agreements (IEAs) suffer from an enforcement problem.[23] There is also evidence that environmental policy suffers from a domestic credibility problem. Politicians often pledge to introduce tough environmental policies but then adopt much softer policies (e.g., Helm et al., 2005). It has been suggested that this credibility problem stems from a tension between the goal of encouraging innovation and investment in environment-friendly technologies on the one hand, and distributional concerns on the other: the prospect of future environmental taxes is instrumental to inducing firms to undertake abatement-related investment; environmental taxes, however, produce unwanted distributional effects,[24] which are difficult to offset through compensation schemes,

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[21] Our arguments and results can be readily extended to the more general case where countries must sustain a constrained Pareto-efficient combination $(t_1^{CE},\dots, t_M^{CE})$, as long as $t_i^{CE} > t_i^V$, $i = 1,\dots, M$.

[22] In other settings, government policies in one country have an impact on private sector's choices abroad, and it is thus harder to isolate the horizontal and vertical coordination problems and examine the interaction between them. Consider, for example, import tariffs selected after investment in import-competing sectors (e.g., Matsuyama, 1990; Tornell, 1991), or capital tax rates selected after investment when capital is internationally mobile (e.g., Gordon, 1986); in both cases, domestic policies also affect the choices of the foreign private sector. Nevertheless, as long as the domestic vertical policy linkages are stronger than the indirect vertical linkages—as is the case for import tariffs and capital taxes if there are mobility costs—the mechanisms we identify in our analysis will tend to dominate those indirect effects.

[23] Keohane (1995, p. 217) has argued that "every study that has looked hard to compliance [of all major IEAs] has concluded [...] that compliance is very spotty." Brown Weiss and Jacobson (1997) also endorse this view.

[24] Most energy and environmental taxes are well known to be regressive, since poorer people pay a disproportionate share of their income on these taxes relative to richer people (see, for example, Poterba, 1991; OECD, 1995).

since these typically run against incentive-compatibility problems.[25] What this implies is that, once innovation has taken place, policymakers are driven to reduce environmental taxes in order to minimize their distributional effects. As firms anticipate the *ex-post* incentives of policymakers, the promise of high future emissions taxes is not credible.[26]

The simultaneous presence of a horizontal and a vertical coordination problem affecting policies required to address global environmental emissions gives rise to a structure such as the one described in our previous discussion. The specific application to environmental emissions can be modeled as follows (as in the general formulation, we shall focus first on a symmetric, two-country scenario, and later discuss implications for multilateral cooperation).

In each country, consumers must consume a fixed amount X of a good that can be produced by two alternative methods: a "dirty" technology, which produces one unit of the good at a constant marginal cost of unity while generating one unit of environmental emissions; and a "clean" technology, which generates no emissions but requires *ex-ante* investment.[27] If a total amount, I, of the good is produced using the clean technology, total domestic emissions are

$$Z = X - I. \tag{20}$$

The government levies a tax t per unit of emissions, which makes the gross-of-tax price of the polluting good equal to $p = 1 + t$. Revenues from environmental taxation, tZ, are assumed to be returned to the consumers in equal shares and in lump-sum fashion.

There is a large number, n, of domestic firms having access to the clean technology. We will assume that, for the clean technology, *all costs are investment costs*.[28] For each firm, the investment costs required to produce an amount k of the clean alternative are assumed to be quadratic in k and equal to

$$c(k) \equiv k + \varphi k^2 / 2, \tag{21}$$

with $\varphi > 0$. In this formulation, the marginal cost of producing clean alternatives is always greater than that of producing the dirty alternative (unity) and is increasing in k. We shall restrict our attention to scenarios where both the clean and the dirty alternatives are produced in equilibrium (the implied parameter restrictions will be discussed later), which means that each unit of the clean good will sell for a net-of-tax price equal to $p = 1 + t$. Thus, if the private sector foresees a certain tax, t, the expected profits to a firm from producing an amount k of the clean good are

$$tk - \varphi k^2 / 2, \tag{22}$$

and the first-order condition for a profit-maximizing abatement choice is

$$t - \varphi k = 0, \tag{23}$$

which means that pollution abatement by a firm will take place up to the point where marginal abatement costs equal marginal abatement

benefits. This identifies a function, $k(t) = t/\varphi$, linking the privately optimal level of investment in pollution abatement by each firm to the tax.

In each country, the population comprises h consumers of two types, A and B, each present in equal numbers ($h/2$), and individually endowed with exogenous income levels equal to m^A and m^B, respectively. Consumers all have equal stakes in production activities, implying that the total profits from abatement, R, are distributed uniformly in the population. Disposable income for each individual of type j is then $y^j = m^j + (R + tZ)/h$, $j = A, B$. Consumption takes place in the second period, and individuals spend a fraction of their income to consume a fixed amount of the pollution generating commodity— $x^j = \gamma^j X/h$, $j = A, B$, with $\gamma^A + \gamma^B = 2$—and spend the rest of their income on other non-polluting goods, in amounts equal to $c^j = y^j - (1 + t)x^j$.[29] In the rest of our discussion, we shall assume $\gamma^A > \gamma^B$.[30]

Emissions are transboundary. The valuation of environmental damage by a representative domestic consumer is assumed to be additively separable in preferences, and linear in the global level of emissions:

$$\frac{\mu}{h}\left((1 - \alpha)Z + \alpha Z^*\right), \tag{24}$$

where Z^* denotes emissions by firms located abroad, α $(0 \le \alpha \le 1)$ represents the extent to which environmental emissions are transboundary, and $\mu > 0$ is the per-unit domestic valuation of environmental damage. The (indirect) utility of consumers of type j can then be written as

$$u^j = m^j + \frac{-(1 + t)\gamma^j X + R + tZ - \mu\left((1 - \alpha)Z + \alpha Z^*\right)}{h}, \quad j = A, B. \tag{25}$$

We wish to focus on a scenario where environmental taxes have undesirable distributional effects—i.e., where the distribution of welfare under $t = 0$ is viewed by society as being desirable, so that emissions taxes would not independently be used to pursue distributional objectives in the absence of environmental costs. This can be modeled by specifying endowments as $m^A = m^B + (\gamma^B - \gamma^A) X/h$, so that $t = 0$ implies $u^A = u^B$, and $t > 0$ implies $u^A < u^B$, and so any increase in t from zero will skew the distribution of welfare against group A.[31] If we then assume the government's objective to be a weighted linear combination of individual utilities, $W(u^A, u^B) = h(w^A u^A + w^B u^B)$, we can represent inequality aversion by attaching a premium ρ to the utility of the less favored group (type A if we assume $\gamma^A > \gamma^B$) and specifying normalized weights as $w^A = (1 + \rho)/(2 + \rho)$, $w^B = 1/(2 + \rho)$.[32] The government's payoff, as a function of the domestic tax and of the foreign level of abatement, is then

$$\Pi\left(t, I(t), I^*\right) \equiv -\beta t + \Lambda - \phi I(t)^2 / 2 + \mu\left((1 - \alpha)I(t) + \alpha I^*\right), \tag{26}$$

where $\Lambda = h(w^A m^A + w^B m^B) - (\gamma^A w^A + \gamma^B w^B)X + \mu((1 - \alpha)X + \alpha X^*)$, $\phi \equiv \varphi/n$, and $\beta = -\rho X(1 - \gamma^A)/(2 + \rho) > 0$ are constants, $I(t) = nk(t) = t/\phi$ is total domestic abatement when all domestic firms correctly forecast the tax, and I^* is foreign abatement. The term βt in Eq. (26) represents the

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[25] For example, grandfathering rules in the allocation of emission permits among firms can in principle neutralize distributional effects, but require verification of past emissions, which can generate *ex-ante* incentives for firms to increase emissions.

[26] Much of the existing literature has focused on credibility problems arising from efficiency considerations only. An exception is Pearce and Stacchetti (1997), who analyze time-consistent taxation when a government cares about both efficiency and distribution.

[27] Investment in R&D and new equipment is the principal means by which pollution abatement takes place. Estimates presented by the European Commission from studies carried out by several research institutions show that a European Carbon tax can only be effective in reducing CO_2 emissions if it can induce substantial investment and innovation (DRI, 1992).

[28] This is a limit scenario. In general, one would expect a combination of *ex-ante* investment and ex-post variable costs (this more general specification is explored in Conconi and Perroni, 2003). See also Footnote 7.

[29] Formally, such demand patterns are consistent with preferences represented by a utility function having the form $u(x^j, c^j) = \lambda \min\{x^j - \gamma^j X/h, 0\} + c^j$, $j = A, B$, for λ sufficiently large.

[30] For example, group A could be identified with the rural population, who consume comparatively more automotive fuel.

[31] Much of the debate on the distributional costs of environmental taxation revolves around the differential impacts these taxes can have across productive sectors, rather than consumers. A structure analogous to the one described here arises if ownership of the factors associated with the production of either the dirty or clean variety is concentrated in the hands of a minority. Then an increase in the tax would alter factor returns and would be distributionally nonneutral.

[32] This formulation can be derived from a hybrid Utilitarian/Rawlsian symmetric social welfare (or political support) function of the form $W(u^1, ..., u^h) = \min_i\{(1 + \rho)u^i + \sum_{l \ne i} u^l\}$.

distributional cost of emissions taxes, an effect that we shall assume cannot be neutralized by any feasible compensation mechanism.[33]

With reference to the general formulation of the stage game described in Section 2, the government payoff in Eq. (26) can be expressed as $D(t) + P(I(t)) + (1 - \alpha)S(I(t)) + \alpha S(I^*)$, where

$$D(t) \equiv -\beta t, \quad P(I) \equiv \Lambda - \phi I^2 / 2, \quad S(I) \equiv \mu I, \quad I(t) \equiv t / \phi. \tag{27}$$

The efficient tax, as identified by a condition analogous to Eq. (1) is[34]

$$t^E = \max\{\mu - \beta\phi, 0\}. \tag{28}$$

We shall assume that $\mu > \beta\phi$, implying that the efficient tax is positive. We shall additionally assume $X > \mu/\phi - \beta$, which implies that the constrained efficient policy does not entail full abatement (as assumed earlier).[35]

Consider first a single round of interaction in a scenario in which environmental policy suffers both from a horizontal coordination problem—stemming from the fact that the two governments act unilaterally—and a vertical coordination problem—resulting from a lack of coordination between each government and its private sector. In this scenario, the tension between efficiency and distributional goals combines with the dynamic dimension of pollution abatement to give rise to a time-inconsistency problem in the choice of emissions taxes: once firms have installed a certain amount of investment, private abatement choices become unresponsive to changes in the tax; then, because of the adverse distributional costs of environmental taxation, the government will be induced *ex post* to select a tax which is less than the one it would have committed to *ex ante*. Consistently with Eq. (2), if the private sector's choice precedes the policy choice, the *ex-post* optimal policy level will be that which maximizes $D(t)$; under the restriction $t \geq 0$, this implies

$$t^N = 0. \tag{29}$$

Notice that, as in our earlier general formulation of the stage game, in this application horizontal coordination by itself would have no effect on policies and welfare. This is because, in the absence of commitment, investors anticipate that governments will have an incentive to set taxes equal to $t^H = t^N = 0$, independently of whether or not they coordinate their policy choices with one another.

Next, consider a situation in which policymakers can credibly pre-commit to environmental taxation before investment decisions are made, but choose their policies unilaterally. Horizontal miscoordination between governments results in taxes that fail to internalize the transboundary emission spillovers, although each government anticipates the effect of the policy on private choices. The analogous of condition (4) then yields

$$t^V = \max\{(1 - \alpha)\mu - \beta\phi, 0\}. \tag{30}$$

We now turn our attention to the indefinite repetition of the above stage game, and examine the effects of vertical coordination on the sustainability of efficient emissions taxes. Following our analysis in

Section 3, we will consider first the effects of vertical coordination on the deviation incentives and then examine its effects on punishment. The analysis of the effects of horizontal coordination is exactly the same as for the general case.

In the absence of domestic policy commitment, the *ex-post* optimal policy by a deviating government is $t^N = 0$, and the associated deviation gain, as identified by Eq. (11), is equal to

$$\Phi^N = \beta(\mu - \beta\phi). \tag{31}$$

If a government can commit to policy announcements in each round before private investment choices are made (vertical coordination), its optimal deviation level of emissions taxation is t^V.

Unlike in the general model described in Section 2, where S was assumed to be strictly convex, the linear specification of damage in this environmental application means that we have to consider the possibility of corner solutions. These occur for $\alpha \geq 1 - \beta\phi/\mu \equiv \tilde{\alpha}$, implying $t^V = t^N$. Taking such corner solutions into account, we find that, depending on parameter values, the following two regimes can apply (see Appendix A for their derivation):

– For $\beta \leq \mu/(3\phi)$ the minimum spillover level above which noncommitment lowers the temptation to defect ($\Phi^N < \Phi^V$) is $(2\beta\phi(\mu - \beta\phi))^{1/2}/\mu \equiv \alpha' > 0$;
– For $\beta > \mu/(3\phi)$ the minimum spillover level above which noncommitment lowers the temptation to defect ($\Phi^N < \Phi^V$) is $(\mu + \beta\phi)/(2\mu) \equiv \alpha'' > 0$.

We can therefore obtain a result analogous to Lemma 1 (with $\underline{\alpha}$ now identified by either α' or α'' above). Moreover, consistently with Lemma 2, we can establish that the minimum level of international spillover above in which the lack of domestic policy commitment lowers the temptation to deviate from efficient policies is larger the larger are the distributional cost of emissions taxes: for $\beta \leq \mu/(3\phi)$, the critical level α' is increasing in β; for $\beta > \mu/(3\phi)$, the critical level α'' is increasing in β.

Turning next to the effects of vertical coordination on Nash-reversion punishment, we have:

$$\Delta\Omega = \Omega^{NN} - \Omega^{VN} = \Omega^{NV} - \Omega^{VV} = \left(\beta + t^V/(2\phi) + (1 - \alpha)\mu/\phi\right)t^V \geq 0, \tag{32}$$

where the inequality is strict in scenarios where t^V is strictly greater than t^N. Here, we need to distinguish between two possible cases:

– For $\alpha < \tilde{\alpha}$ (and thus $t^V > t^N$), vertical coordination increases the severity of the punishment suffered by the defecting country; in this case, $\alpha > \underline{\alpha}$ is a sufficient (but not necessary) condition for a lack of commitment to help sustaining efficient policies;
– For $\alpha \geq \tilde{\alpha}$ (and thus $t^V = t^N = 0$), vertical coordination has no effect on the severity of the punishment; in this case, $\alpha > \underline{\alpha}$ is necessary and sufficient condition for a lack of commitment to help in sustaining efficient policies.

A result equivalent to Proposition 2 thus applies. For the case of renegotiation-proof punishment strategies, a result equivalent to Proposition 3 can also be derived.

Further implications can be drawn from extending the above analysis to a multilateral, asymmetric scenario as described in Section 3.1. Let μ_i be country i's per-unit valuation of environmental damage and h_i be country i's population. Consider a scenario where the externality is fully "diffuse" and the per capita valuation is the same everywhere (the ratio $\mu_i/h_i \equiv \eta$ is the same for all countries). Then, the global damage from a unit of emissions would be $\eta\sum_i h_i$; the fraction of that damage accruing to country i would be $h_i/\sum_j h_j = \alpha^i_j$, for all j; and the fraction of the damage from emissions generated in i that is borne by countries other than i would

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[33] A consumption subsidy lowering the price of both the dirty good and its clean substitute could in principle neutralize the effects of the emissions tax. Such a scheme, however, would not be feasible if the level of consumption of the clean substitute (reflecting how consumers substitute away from the polluting good) is either unobservable or non verifiable; or it may not be viable if the social opportunity cost of the public funds required for such a subsidy is prohibitively high.

[34] This represents a constrained (second-best) optimum; the unconstrained (first-best) optimum—a Pigouvian tax equal to μ—could only emerge in the absence of distributional effects (i.e., for $\beta = 0$).

[35] The condition for the clean and the dirty good to be both produced in equilibrium is $X > I(t)$; in order for this condition to be satisfied for all $t \leq t^E$, we must have $X > I(t^E) = \mu/\phi - \beta$ (for $\mu > \beta\phi$).

be $\alpha_{-i} = \sum_{j \neq i} \alpha_i^j = 1 - h_i / \sum_j h_j$, which is decreasing in h_i; i.e., the transboundary fraction of the spillover generated by a country will be larger the smaller the country is. Our results then suggest that, everything else being equal, the lack of domestic policy commitment should be more likely to facilitate environmental policy cooperation if a country is small, whereas cooperation by large countries would be easier to sustain in the presence of domestic policy commitment.

5. Conclusion

It is well understood that in noncooperative games partial coordination among a subset of players can give rise to a less efficient outcome than no coordination.[36] Our analysis can be thought of as providing a counterpart of that general principle in a setting of repeated interaction, where cooperative choices must be supported by noncooperative equilibrium strategies. Under repeated interaction, partial binding coordination can be an obstacle in supporting efficient policies, independently of whether or not it is beneficial when interaction is not repeated.

In the policy formation game we have analyzed, two different forms of miscoordination are simultaneously present—vertical and horizontal—both operating in the same direction within the stage game; consequently, partial coordination always results in more efficient policies in a single round of interaction. Nevertheless, when the game is repeated indefinitely, partial coordination in the stage game can be counterproductive. Thus, the effects of partial binding coordination under repeated interaction do not parallel its effects within a single round of interaction.

Under repeated interaction, lack of domestic policy commitment can facilitate international cooperation, both because it can impair vertically coordinated defections and because it can increase the severity of the punishment following a defection. Thus, absent institutions that can eliminate *all* forms of miscoordination, international policy cooperation may be better served by weak domestic institutions. It follows that, when cooperation must be self-enforcing, countries may voluntarily forgo the use of institutional mechanisms for achieving partial binding coordination even if such mechanisms are available.

It has been argued that a lack of policy commitment can make a country more willing to enter into international agreements because a country that faces a domestic commitment problem has comparatively more to gain from securing efficient policies. This paper shows that what matters for the sustainability of international cooperation is not only how much a country has to gain from solving its policy commitment problem, but also whether the miscoordination between policymakers and investors helps or impedes gainful defections. The problems of sustaining policy cooperation internationally and policy reputation domestically can thus complement each other in helping to support overall coordination to efficient policies: not only do countries with weaker domestic institutions have a greater need for international agreements, but they can also be better at sustaining such agreements.

Our analysis has shown that the relationship between domestic and international policy commitment is a priori ambiguous and should vary according to the size of the international spillovers. In particular, lack of domestic policy commitment is more likely to boost international cooperation in policy dimensions where international spillovers are comparatively larger (e.g., in the case of transboundary environmental emissions, the more "global" emissions are). Moreover, since a lack of commitment impedes deviations through a lack of coordination in private investment choices but encourages defections through the direct gains it generates, it will be more likely to help in cases where the direct effects of policies are comparatively smaller (e.g., the smaller are the adverse distributional impacts of environmental policies).

Evidence on the relationship between domestic policy commitment and international policy cooperation is indeed mixed. For example, if we look at the main environmental, trade or security agreements and compare their member countries against non-members according to the World Bank indicator of institutional credibility (Brunetti et al., 1998), we find that, although members score higher on average, credibility scores vary widely within each group.[37] However, it is difficult to draw conclusions from these patterns, given that the World Bank indicator does not reflect domestic policy credibility in specific policy areas. For example, in countries with generally "strong" institutions such as the United States, policy delegation mechanisms are in place with respect to trade policies (e.g., Anderson and Zanardi, 2004; Destler, 2005), but none exist in the area of environmental policy.

Appendix A. Deviation gains in the environmental policy application

In the model with linear spillovers presented in Section 4, corner solutions are possible with respect to optimal deviation policies. We must then distinguish between two cases:

– For $\alpha < \tilde{\alpha} \equiv 1 - \beta\phi/\mu$ (implying $t^V > t^N$), the deviation gain is equal to

$$\Phi^V = \frac{\alpha^2 \mu^2}{2\phi}; \tag{33}$$

– For $\alpha \geq \tilde{\alpha}$ (implying $t^V = t^V = 0$), the deviation gain is given by

$$\Phi^V = \frac{(\mu - \beta\phi)((2\alpha - 1)\mu + \beta\phi)}{2\phi}. \tag{34}$$

Comparing deviation incentives under no coordination with those under vertical coordination, we thus have two scenarios:

– For $\alpha < \tilde{\alpha}$ (and thus $t^V > t^N$), the difference in deviation gains is given by

$$\Phi^N - \Phi^V = \beta(\mu - \beta\phi) - \frac{\alpha^2 \mu^2}{2\phi}, \tag{35}$$

which is negative for $\alpha > \alpha'$;

– For $\alpha \geq \tilde{\alpha}$ (and thus $t^V = t^N = 0$), the difference becomes

$$\Phi^N - \Phi^V = (\mu - \beta\phi)((1 - 2\alpha)\mu + \beta\phi)/(2\phi), \tag{36}$$

which is negative for $\alpha > \alpha''$;

where α' and α'' are as defined in the main text. It is then straightforward to show that, in line with the result obtained in Lemma 1, if the international spillover is sufficiently large, $\Phi^N - \Phi^V$ is negative, implying that a lack of domestic commitment will reduce

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[36] Krugman (1991), for example, applies this idea to preferential international trade policy coordination, showing that the simultaneous formation of customs unions can lower welfare.

[37] This index—ranging from a minimum of 1 to a maximum of 6—is meant to measure the credibility of governments' policy announcements. It was constructed by the World Bank and the International Finance Corporation on the basis of a private sector survey conducted during 1996–1998 in seventy-four countries. The average credibility index of the countries that have ratified the Kyoto Protocol is 3.9, with a standard deviation of 0.6; for non-ratifiers the average index is 3.6, with a standard deviation of 0.6. The average credibility index is 3.6 for WTO members and 3.0 for non-members, with a standard deviation of 0.7 and 0.6, respectively. In the case of the Non-Proliferation Treaty, the average credibility index for ratifying countries is 3.8, with a standard deviation of 0.6; the average index for non-ratifiers is 3.7, with a standard deviation of 0.9.

the incentives to deviate from efficient policies. To see this, notice that, depending on the size of β, we have two scenarios:

– For $\beta \leq \mu/(3\phi)$, the following ranking applies: $\alpha' \leq \alpha'' \leq \tilde{\alpha}$. In this parameter range, we thus have: (i) $t^V > t^N$ and $\Phi^N > \Phi^V$ up until α'; (ii) $t^V > t^N$ and $\Phi^N < \Phi^V$ between α' and $\tilde{\alpha}$; (iii) $t^V = t^N$ and $\Phi^N < \Phi^V$ above $\tilde{\alpha}$;

– For $\beta > \mu/(3\phi)$, the following ranking applies: $\tilde{\alpha} < \alpha' < \alpha''$. In this parameter range, we have: (i) $t^V > t^N$ and $\Phi^N > \Phi^V$ up until $\tilde{\alpha}$; (ii) $t^V = t^N$ and $\Phi^N > \Phi^V$ between $\tilde{\alpha}$ and α''; (iii) $t^V = t^N$ and $\Phi^N < \Phi^V$ above α''.

We can thus conclude that the minimum level of international spillovers above in which a lack of domestic commitment makes it easier to sustain efficient policies is identified by $\underline{\alpha} = \alpha'$ for $\beta \leq \mu/(3\phi)$ and by $\underline{\alpha} = \alpha''$ for $\beta > \mu/(3\phi)$. A result equivalent to Lemma 1 is then obtained for any parameter configuration for which $\mu > \beta\phi$.

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