Efficient Learning through International Delegation*

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Abstract

Sharing information is one of the proposed rationales for international delegation. But why would information exchange outside international organizations not be as efficient? To study the potential signaling benefits from delegation, we develop a formal model where multiple principals use costly signals to transmit information in the presence and absence of an uninformed agent. States face a trade-off in delegating: Moderate international organizations allow states to waste fewer resources in signaling, but the higher stakes of centralized policies leads to stronger signaling incentives – especially if little weight is placed on policies made by other states. We provide an informational rationale for delegation even if international organizations are uninformed.

Latest version

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Sovereign states often delegate to international organizations (IOs) (Abbott and Snidal, 1998; Hawkins et al., 2006; Bradley and Kelley, 2008; Koremenos, 2008; Hooghe and Marks, 2015).[1] One proposed reason is that IOs facilitate information exchange among states. However, it is not immediately obvious why states would not share it bilaterally. Does international delegation yield signaling benefits? Scholars of IOs argue that formalized cooperation allows states to reduce uncertainty by sharing information that they otherwise would not share (Keohane, 1982, 1984; Morrow, 1994; Koremenos, Lipson and Snidal, 2001).[2] Thus, the proposed answer is that states are willing to reveal more information if they delegate to IOs.

Existing work sees a role for learning and information exchange but typically conceptualizes IOs as a source of information rather than a receiver (Fang, 2008). Focusing on the United Nations, Johns 2007 studies the selection of bureaucrats who provide information to bargaining member states. Fang and Stone 2012 look at how IOs provide policy recommendations that governments follow. Crombez, Huysmans and Van Gestel 2017 study the appointment of the Commission in the European Union and their role as an agenda setter that provides information to the Parliament and member states.

Although states have an obvious incentive to delegate to better informed IOs, it is an open question whether they would delegate to uninformed IOs to share information.

Our model focuses on this exact setting. We are interested in the design of institutions that allow states to learn information as efficiently as possible. In particular, two states have private information and may make policy individually or delegate authority to an initially uninformed IO that makes policy on their behalf. We then study how efficiently states learn new information with and without IOs. One of the key elements of the model is an informational and policy spillover. One state's information affects an other's optimal policy

[1] Existing scholarship explains delegation by thinking of international organizations as agents that solve collective action problems, allow for credible commitments, and reduce transaction costs in decision-making, see Hawkins et al. 2006 and Hooghe and Marks 2015, p. 307.

[2] See Keohane 1984: "Regimes may also include international organizations whose secretariats act not only as mediators but as providers of unbiased information that is made available, more or less equally to all members. By reducing asymmetries of information through a process of upgrading the general level of available information, international regimes reduce uncertainty" (p. 94).

and payoff, and one's policy affects an other's payoff as well.

One point of departure from most of the related literature on delegation is that we allow states to use costly signals in addition to costless ones.[3] In one sense, we are more flexible by allowing multiple channels of information transmission. And, indeed, in many strategic situations, political actors use costly signals (Austen-Smith and Banks, 2002). In another sense, the departure from the classical cheap talk setting may be unwarranted because communication is typically understood to be cheap talk (Crawford and Sobel, 1982; Green and Stokey, 2007). Thus, we also devote some attention to information transmission without costly signals.

There are two potential efficiency losses in information transmission if preferences are misaligned. First, incentives to misrepresent may lead to more noisy communication because actors have incentives to exaggerate their information (Crawford and Sobel, 1982). This is one of the driving forces in many theories of delegation. It also has immediate implications for the design of IOs because it determines how much information can be transmitted (Johns, 2007; Crombez, Huysmans and Van Gestel, 2017). Second, although models of cheap talk predict that disagreement prevents full information revelation, this conclusion does not hold if informed parties can willfully impose costs on themselves (Austen-Smith and Banks, 2000).[4] These costs naturally impose a welfare loss on states. The size of these costs depends on preference misalignment and on how much informed parties care about policies.

We identify and study a key trade-off that states face in delegating authority. On the benefit side of delegation is the well-known result of efficiency gains in communication between more aligned parties (Crawford and Sobel, 1982). That is, if an IO is more moderate than state B is, then state A incurs fewer costs to influence the decision that was originally made by B. The less intuitive effect, however, is a potential decrease in efficiency. Without delegation, states do not need to incur influence costs to alter their own policy because they

[3]But, outside the IO-literature, see Amador and Bagwell 2012, 2013; Ambrus and Egorov 2017.

[4]Alternatively, costless full revelation is possible in models with, for example, free transmission of verifiable information as in Milgrom 1981; Grossman 1981, Bayesian persuasion as in Rayo and Segal 2010; Gentzkow and Kamenica 2011, or with sufficiently high lying costs as in Kartik 2009.

have authority over it. With delegation, each state incurs costs due to incentives to misrepresent its information vis-à-vis the IO. Information transmission is thus efficient from a state's perspective if the benefits from moderation outweigh the increased costs of signaling due to the higher stakes of the IO's centralized decision. But these efficiency gains are not guaranteed to exist.

We reiterate that the informational rationale for delegation is different in our model. Others show that states delegate authority because IOs are better informed. For these theories, there is no reason to delegate if states are better informed. In contrast, we assume that these organizations have no private information whatsoever. In our model, IOs endogenously receive information from states. Delegation can still be beneficial for states because IOs also receive relevant information from others.

In the main extension to this paper, we study the efficiency implications of providing discretion to IOs. Perhaps surprisingly, although limited discretion reduces the scope for information aggregation, it also reduces the anticipated influence costs. As a result, when an IO has little room to maneuver, states have fewer incentives to misrepresent information, which could yield welfare gains. We provide results on optimal delegation to IOs as a function of preference alignment and spillovers among states.

We proceed as follows. Section 1 discusses the related literature. Section 2 presents the model and section 3 studies information aggregation with and without an IO. Finally, in section 4 we discuss the results and conclude.

1 Related Literature

Our model is related to several strands of the literature in IOs and organizational economics. One set of papers studies the role of mediators in information transmission between states in bargaining models of conflict. One strand of the literature in organizational economics studies the allocation of decision-rights and its efficiency implications with incomplete information.

Although our principal focus is not on inter-state conflict, a literature on mediation is related to our model.[5] The main interest of this literature is how mediators, which could be conceptualized as IOs, can help states to achieve peaceful outcomes. A substantial literature finds that, indeed, IOs can successfully prevent war. Fey and Ramsay 2010 survey this literature, but cast doubt on this possibility and show that the IO needs private information to be successful. Uninformed mediators cannot help states do something that these states cannot do by themselves. As Fey and Ramsay 2010, we focus on the case in which IOs are uninformed but do allow states to delegate formal decision-making power. Together with the absence of conflict in our model, this means that their results on the informational role of IOs do not necessarily carry over.

Our findings are related to a literature in organizational economics that studies communication and delegation. In a setting with a principal and a better informed agent, Dessein 2002 finds that the benefits of delegation outweigh the costs as long as the agent's preferences are sufficiently congruent relative to the principal's uncertainty. We consider the opposite case, where the principals—which may delegate decisions to the agent—are privately informed but not the agent.[6] Alonso, Dessein and Matouschek 2008 study an organization with a headquarters (agent) and two privately informed divisions (principals) who communicate through cheap talk. Decentralized authority allows divisions to optimally adapt their decisions to local conditions, while centralized authority allows for more coordination at the cost of a loss in information. They find that under certain conditions, decentralization dominates centralization even when coordination is extremely important. One main difference with our model is the additional possibility of using costly signals. In a similar setup, but with asymmetric principals' payoffs, Rantakari 2008 shows that it may be better to allocate decision rights to either principal. Lima, Moreira and Verdier 2017 consider a different approach in the context of lobbying influence over public decision makers. Instead of cheap

[5] See also Goltsman et al. 2009.

[6] See Bils 2017 for an analysis of a principal that decides whether to delegate to better informed agencies in a setting with acquisition and transmission of verifiable information.

talk, lobbyists reveal their private information by offering a contribution schedule to decision makers. This is close to our paper because lobbyists incur costs within this interaction.

Finally, our paper is related to the literature on property rights and contracting (Grossman and Hart, 1986; Hart and Moore, 1990). In our model, we assume that contracts are highly incomplete, in the sense that countries can commit only to an ex-ante allocation of decision rights. It is not possible to contract over the decisions themselves or the protocol to share information. Unlike the mechanism design approach, the lack of commitment implies that the principals and agent are not able to commit their decisions on received information.

2 Model

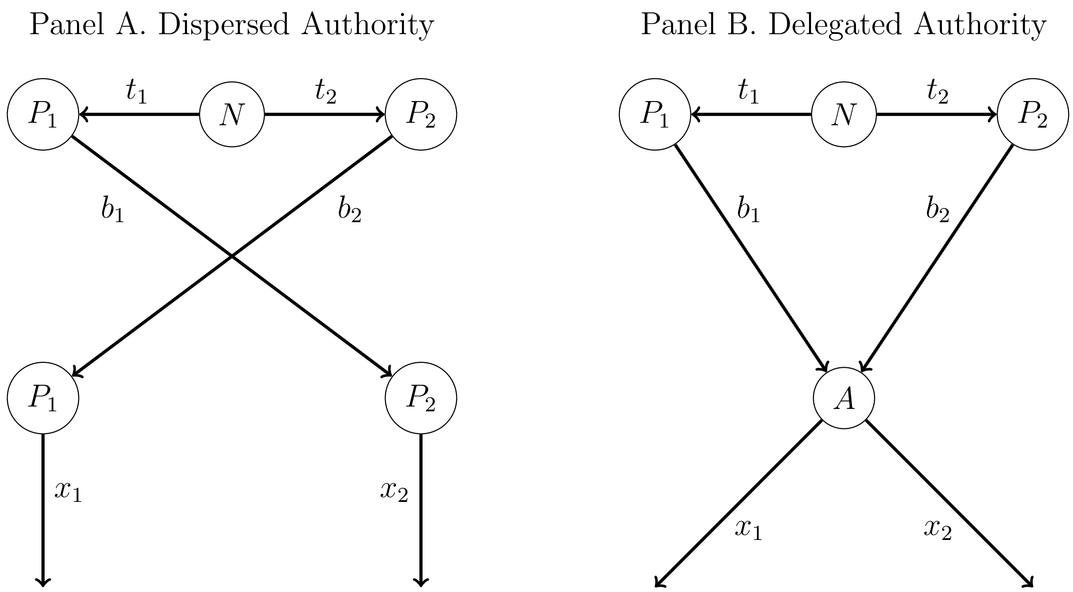
In many international interactions, states have the authority to make decisions domestically, but voluntarily choose to delegate this authority to IOs. We seek to explain this phenomenon from an informational perspective. Our goal is to analyze how IOs affect the endogenous costs and benefits of information transmission.

We set up two games. In the first one, with *dispersed authority*, two privately informed principals make policies individually. In the second one, with *delegated authority*, an uninformed agent makes policy on the principals' behalf. States perform the role of the principals, and the IO serves as the agent.

Both games have three stages. In stage 1, Nature draws the type $t = (t_1, t_2)$ of each principal P_i independently according to the probability density function $f(t) > 0$, where the support is the unit square $T_1 \times T_2 = T = [0, 1]^2$. In stage 2, after observing its private information t_i, principal P_i takes a costly action. Since each principal is privately informed, this wasteful action may signal information to others. This is known as *burning money* in information economics.[7] Concretely, P_i chooses to burn an amount $b_i \geq 0$ which enters

[7]More broadly, in the context of organizations, money burning is fighting through red tape and bureaucratic sclerosis. In the international sphere, money burning could be choosing unpopular policies that lead to lower reelection chances.

Figure 1: Signaling and Policy-Making



Note: In Panel A, authority is dispersed and each state burns money to influence the other state's policy. In Panel B, authority is delegated to an international organization, and states burn money to influence the centralized policy made by the organization.

negatively in P_i's payoff.[8]

In stage 3, with *dispersed authority* (Figure 1.A), each P_i observes the profile of burned money $b = (b_1, b_2)$ and implements a policy x_i, after which payoffs are realized. As a function of the realized types $t = (t_1, t_2)$, policies $x = (x_1, x_2)$, and burned money b_1, P_1 obtains a payoff of $u_1(x, t) - b_1$, where the first term takes the form

$$u_1(x,t) = -w_1 \left(x_1 - [t_1 + t_2 + \delta_1]\right)^2 - (1 - w_1)\left(x_2 - [t_1 + t_2 + \delta_1]\right)^2, \tag{1}$$

where $\delta_1 \in \mathbb{R}$ is principal 1's bias, $w_1 \in (0, 1)$ is the weight of principal 1's own decision on its payoff, and $(1 - w_1)$ is the weight of principal 2's decision. This weight parameter can be conceptualized as the exposure of a country to decisions made in the international arena. For example, small countries would have a small value for w_i and care a lot about decisions

[8] The signaling technology is similar to Austen-Smith and Banks 2000, but because we anticipate that cheap talk is not influential, we remove this option for ease of exposition.

made in bigger countries, and vice versa for big countries. Similarly, the payoff for P_2 is given by $u_2(x,t) - b_2$, where the first term equals

$$u_2(x,t) = -(1-w_2)\left(x_1 - [t_1+t_2+\delta_2]\right)^2 - w_2\left(x_2 - [t_1+t_2+\delta_2]\right)^2, \tag{2}$$

where $\delta_2 < \delta_1$ is the second principal's bias, and $w_2 \in (0,1)$ is the weight of principal 2's own policy x_2, and the remainder $(1-w_2)$ is put on the first principal's policy x_1.

Instead, with *delegated authority* (Figure 1.B), an agent makes both policies $x = (x_1, x_2)$. The agent A has a bias[9] of $\delta_A \in (\delta_2, \delta_1)$ and a payoff that equals

$$u_A(x,t) = -\left(x_1 - [t_1+t_2+\delta_A]\right)^2 - \left(x_2 - [t_1+t_2+\delta_A]\right)^2. \tag{3}$$

The interest is in the welfare of both states from an ex-ante perspective. We focus on pure-strategy equilibria. In the equilibria of both games, there is a mapping from the set of types into the set of actions. Formally, given each type profile $t = (t_1, t_2) \in [0,1]^2$, both principals burn $b^*(t) = (b_1^*(t), b_2^*(t))$ and have policies $x^*(t) = (x_1^*(t), x_2^*(t))$. Thus, in expected terms, each principal obtains a payoff of

$$\begin{aligned} V_i(x^*, b_i^*) = & \int_{[0,1]^2} (u_i(x^*,t) - b_1^*(t_1)) f(t) dt \\ = & - w_i \left(E[x_1^*(t) - (t_1+t_2+\delta_i)]\right)^2 - (1-w_i)\left(E[x_2^*(t) - (t_1+t_2+\delta_i)]\right)^2 \\ & - Var[t_1+t_2] \\ & - E[b_i^*(t_i)] \end{aligned}$$

Because payoffs are quadratic, V_i can be decomposed into three parts. The first part is driven by preference misalignment, the second by uncertainty, and the third by the costs of burned money. Given our interest in the costs and benefits of delegation for information aggregation, we focus mostly on the latter two parts. The results formally establish the size

[9] Since the agent exists to weigh both principals' interests, this is the relevant case.

of the costs and benefits of these three parts.

3 Results

With dispersed authority, both principals have authority to make their own policy. However, these policies are made in the face of uncertainty. To analyze the value of information transmission, first consider the strategies and welfare of principals in a *benchmark* case where neither principal takes costly actions to signal its information.

There are two possible inefficiencies. On the one hand, from the perspective of P_1, if the other principal does not provide information, then P_1 cannot condition its policy x_1 on that information. As a result, P_1 chooses a policy that is optimal given its own private information t_1 and its prior belief about P_2's information t_2. In particular, P_1 chooses a policy of $x_1(t_1) = \delta_1 + t_1 + E[t_2]$. P_1 would ideally choose a policy of $x_1(t) = \delta_1 + t_1 + t_2$, but P_1 does not know the other's information. Therefore, P_1 would benefit if the other principal provides its private information.

The same holds for the second principal P_2, who would ideally choose a policy of $x_2(t) = \delta_2 + t_1 + t_2$, but without information about t_1 it chooses $x_2(t_2) = \delta_2 + E[t_1] + t_2$. Although P_1 prefers higher policies than the other principal, it would still prefer that the other principal makes informed policy choices. This is the second possible benefit of information transmission in comparison with the benchmark case. The size of the welfare gains from information transmission depend on the level of uncertainty about each other's information, measured by the variance of the distributions of t_1 and t_2. Lemma 1 summarizes the unique equilibrium in the benchmark case.

Lemma 1. *In the unique equilibrium of the benchmark, for all $t \in T$, P_1 chooses $x_1(t_1) = \delta_1 + t_1 + E[t_2]$ and P_2 chooses $x_2(t_2) = \delta_2 + E[t_1] + t_2$. The expected welfare of P_1 and P_2*

respectively are

$$V_1^0 = -w_1\sigma_2^2 - (1-w_1)\Big((\Delta_{12})^2 + \sigma_1^2\Big),$$
$$V_2^0 = -w_2\sigma_1^2 - (1-w_2)\Big((\Delta_{12})^2 + \sigma_2^2\Big),$$

where σ_1^2 is the variance of $f(t_1)$, σ_2^2 is the variance of $f(t_2)$, and $\Delta_{12} = \delta_1 - \delta_2$ measures the preference misalignment between principals.

3.1 The Value of Signaling

Principals could do better by information transmission because of uncertainty. However, because preferences are misaligned, they have reasons to exaggerate their private information. Note that for all types t_1, P_1 wants to push P_2's policy upward, and vice versa for P_2, who wants to push P_1's policy downward. This implies that full information revelation is impossible if countries communicate through cheap talk (Crawford and Sobel, 1982).

A general issue in signaling models is the existence of multiple equilibria. This is already problematic in sender-receiver models of cheap talk but even more so if money burning is an additional option, yielding infinitely many equilibria (Karamychev and Visser, 2016).[10] In a share of signaling models, refinements can delete a large set of these equilibria, sometimes to the point of guaranteeing a unique one (Cho and Kreps, 1987). This is true as well in our setting, where the refinement of monotonic D1 (Bernheim and Severinov, 2003)[11] ensures a unique separating equilibrium (Kartik, 2005).[12]

[10] Karamychev and Visser 2016 study equilibria that are optimal for the sender from an ex-ante perspective. In proposition 1, they show that existence of equilibria requires a partitional structure as in Austen-Smith and Banks 2000, and that any arbitrary partitioning of the state-space can be generated through the use of cheap talk and burned money.

[11] Monotonic D1 puts more restrictions on equilibrium behavior and beliefs than D1. Both are formally defined in the appendix. We show that with only D1, and in the presence of small bias differences between a sender and receiver, some non-separating equilibria may survive for particular type distributions.

[12] A straightforward application of Theorem 3 in Kartik 2005 absent an upper bound on burned money implies that every type separates.

Lemma 2. *With both dispersed and delegated authority, every PBE that satisfies monotonic D1 is fully separating. Furthermore, there exists a unique separating PBE.*

This means that at any decision-maker chooses policies based on full information. This allows us to easily compare welfare in the presence and absence of delegation, where equilibria are essentially the same. Information is lost in neither situation, but the potential inefficiency comes from the fact that principals may incur different signaling costs.

In a separating equilibrium, principals incur costs so that they never have incentives to lie about their private information. Because P_1 has incentives to say its type t_1 is higher than it actually is, it has to burn greater amounts if its type is greater. Vice versa, P_2 wants to lie in the other direction, and thus burns more money if its type is lower. The benefit of information transmission is that both principals can make policies based on full information. The downside, however, is that such information transmission is costly. From an ex-ante perspective, this cost increases both in the preference misalignment between the principals $\Delta_{12} = (\delta_1 - \delta_2)$, and the weight w_i that P_i places on policies made by the other principal. The equilibrium strategies and ex-ante welfare of both principals are summarized in Lemma 3.

Lemma 3. *Consider the separating equilibrium with dispersed authority. For all $t \in T$, P_1 chooses policy $x_1(t) = \delta_1 + t_1 + t_2$ and burns $b_1(t_1) = 2(1 - w_1)t_1\Delta_{12}$, and P_2 chooses policy $x_2(t) = \delta_2 + t_1 + t_2$ and burns $b_2(t_2) = 2(1 - w_2)(1 - t_2)\Delta_{12}$. The ex-ante welfare for P_1 and P_2 respectively are*

$$V_1^C = -(1 - w_1)((\Delta_{12})^2 + 2E[t_1]\Delta_{12}),$$
$$V_2^C = -(1 - w_2)((\Delta_{12})^2 + 2(1 - E[t_2])\Delta_{12}).$$

Comparing Lemma 1 and 3, the following proposition provides a condition under which information transmission is welfare enhancing. In particular, we study the joint welfare of both principals.

Proposition 1. *A principal benefits from information aggregation if the gains from reducing uncertainty outweigh the losses of burned money. P_1 and P_2 jointly benefit if $V_1^C + V_2^C \geq V_1^0 + V_2^0$, which reduces to*

$$\overbrace{(w_1 + 1 - w_2)\sigma_2^2 + (w_2 + 1 - w_1)\sigma_1^2}^{\text{gains of reduced uncertainty}} \geq \overbrace{2(1 - w_1)\Delta_{12}E[t_1] + 2(1 - w_2)\Delta_{12}(1 - E[t_2])}^{\text{costs of burned money}}.$$

Notably, information transmission is not always beneficial. The welfare gains of reducing uncertainty do not necessarily exceed the losses from money burning. Most importantly, greater preference misalignment makes information aggregation more costly. For example, when both types are distributed uniformly, we have that $E[t_1] = E[t_2] = \frac{1}{2}$ and $\sigma_1^2 = \sigma_2^2 = \frac{1}{12}$. When both states equally weight both policies, the two inequalities simplify to $\Delta_{12} \leq \frac{1}{6}$. If the difference in biases is greater than this value, then both states would be better off without money burning if the alternative is full separation.[13]

3.2 The Value of Delegation

After having analyzed information transmission in a decentralized setting, we now examine equilibrium strategies and welfare in the presence of an agent (the IO). Recall that the agent now sets both policies x_1 and x_2. With full information, the agent chooses the same centralized policy $x_1(t) = x_2(t) = \delta_A + t_1 + t_2$ for all $t \in [0,1]^2$. Our main result is that it is possible that delegation can lead to more efficient information transmission. Recall that without delegation, a principal burns money to influence the policy made by the other principal. With delegation, states burn money to influence the policy made by the agent. There are two countervailing effects. Consider P_1's decision to burn an amount of money. On the one hand, the policy that was previously made by P_2 is now made by the agent. Given that $\Delta_{1A} = (\delta_1 - \delta_A) < (\delta_1 - \delta_2) = \Delta_{12}$, the agent is closer to P_1 than P_2 is, and this leads to less money burned in equilibrium for that policy.

[13] This conclusion does not hold if principals can play other equilibria than the fully revealing one. See Karamychev and Visser 2016 for a discussion on socially optimal equilibria.

On the other hand, the policy that was previously made by P_1 is now made by the agent. That means that P_1 has incentives to lie against the agent about what was originally its own policy. To counter incentives to misrepresent information, it has to burn money. This leads to an inefficiency in additional burned money because $\Delta_{1A} > 0$. This amount increases in the distance between the biases of P_1 and the agent. Lemma 4 describes equilibrium strategies with delegation and money burning.

Lemma 4. *Consider the separating equilibrium with delegated authority. For all $t \in [0,1]^2$, the agent chooses $x_1(t) = x_2(t) = \delta_A + t_1 + t_2$. P_1 burns $b_1(t_1) = 2t_1\Delta_{1A}$, and P_2 burns $b_2(t_2) = 2(1-t_2)\Delta_{2A}$. The ex-ante welfare of P_1 and P_2 equal*

$$V_1^D = -(\Delta_{1A})^2 - 2E[t_1]\Delta_{1A},$$
$$V_2^D = -(\Delta_{2A})^2 - 2(1-E[t_2])\Delta_{2A}.$$

Finally, holding the possibility of information transmission fixed, the comparison between lemma 3 and 4 establishes the value of delegation. In particular, it disentangles two different effects: (i) the expected costs or benefits from different policies, and (ii) the expected costs or benefits from changes in the costs of signaling. The following proposition summarizes our main result.

Proposition 2. *P_1 and P_2 jointly benefit from delegation if $V_1^D + V_2^D \geq V_1^C + V_2^C$:*

(i) P_1 gains from more preferred policies if $(\Delta_{1A})^2 < (1-w_1)(\Delta_{12})^2$, and
P_2 gains from more preferred policies if $(\Delta_{2A})^2 < (1-w_2)(\Delta_{12})^2$.

(ii) P_1 gains from cheaper signaling if $\Delta_{1A} < (1-w_1)\Delta_{12}$, and
P_2 gains from cheaper signaling if $\Delta_{2A} < (1-w_2)\Delta_{12}$.

Importantly, states do not always benefit from delegation. There are two separate trade-offs. In one trade-off, principals weigh the costs and benefits of policy adjustment. A principal gains because the other delegates to a more moderate agent, but loses because it delegates its own decision. This loss becomes more severe when a principal weighs its own policy relatively high.

In the second trade-off, principals weigh the costs and benefits of marginal changes in the amount of money burned in equilibrium. They gain under delegation because it allows a principal to more cheaply signal its information to a less biased agent. They lose because they delegate their own decision in the presence of preference misalignment with the agent. Again, this loss becomes more severe in the weight of a principal's own policy.

When is there an agent that makes delegation welfare enhancing? As a result of the welfare analysis of proposition 2, an immediate corollary follows. The main factor is the weight that principals put on their own policy. That is, regardless of initial bias difference among principals, as long as principals strongly value policies made by others, agents with particular preferences can yield joint welfare gains to principals.

Corollary 1. *There exists an agent with bias δ_A that makes delegation welfare enhancing for both principals through policy benefits if $\sqrt{1-w_1}+\sqrt{1-w_2}>1$. Additionally, there exists an agent with bias δ_A that makes delegation welfare enhancing through signaling benefits if $w_1+w_2<1$.*

3.3 Limited Discretion

The previous section considered a case in which the agent has full discretion if authority is delegated. This means that the agent always gets to make her most preferred policy based on full information. Although such an institution is optimal from the agent's perspective, the principals are potentially less well off. Given our focus on institutions that are optimal for the principals, we now study additional tools these principals could use to more efficiently cooperation with each other. One way is to limit the agent's discretion.

In particular, we study the efficiency implications of letting the agent pick a policy from an interval $[\underline{x},\bar{x}]\subseteq\mathbb{R}$, with $\underline{x}\leq\bar{x}$. We simplify the problem and study the symmetric case in which types are uniformly distributed. First, both principals place an equal weight on their own and the other's policy, with $w_1 = w_2 = \frac{1}{2}$. Second the agent's ideal point is normalized to $\delta_A = 0$, and the ideal points of both principals are equidistant from the agent's ideal point, with $\delta_1 = -\delta_2 = \delta > 0$.

Given a level of discretion, the agent still makes its decision based on full information. Its ideal policy is always $\hat{x}^A(t_1, t_2) = t_1 + t_2$. Whether it can implement its ideal policy depends on the constraints imposed by the principals. Thus, equilibrium policies are determined as follows

$$x^*(t_1, t_2) = \begin{cases} \underline{x} & \text{if } t_1 + t_2 \leq \underline{x}, \\ t_1 + t_2 & \text{if } \underline{x} < t_1 + t_2 < \bar{x}, \\ \bar{x} & \text{if } t_1 + t_2 \geq \bar{x}. \end{cases} \tag{4}$$

Both principals differ in opinion on how to constraint the agent, if at all. Because the first principal has a positive ideal point, it always prefers the agent chooses higher policies. Thus, it benefits from putting a more restrictive lower bound $\underline{x}$ on the agent. The opposite is true for the second principal, who always prefers that the agent chooses lower policies. Thus, it wishes to put a more restrictive upper bound $\bar{x}$ on the agent.

On the other hand, both principals gain from information aggregation through the reduction of uncertainty. However, such information aggregation is costly due to incentives to misrepresent information. By limiting discretion and giving the agent less leeway, both principals know that their information is less likely to be pivotal. This reduces their incentives to exaggerate their information and leads to a lower need for money burning to offset this incentive.

From an ex-ante perspective, each principal earns an expected utility that is a function of equilibrium policies, residual variance, and money burned. What type of institutional arrangement maximizes the joint welfare of these principals? Without limits to discretion, the previous section has established that each principal earns a payoff of

$$V_1^D = V_2^D = -\delta^2 - \delta. \tag{5}$$

Are principals better restricting the possible set of policies that the agent can choose? Our next proposition shows that this is the case in some cases.

Proposition 3. *P_1 and P_2 can jointly benefit from limited discretion. In particular, there are $\epsilon_1, \epsilon_2 > 0$ sufficiently small such that if principals restrict the agent to pick policies from the interval $[\epsilon_1, 2-\epsilon_2]$, both principals improve their ex-ante payoffs separately compared with full discretion.*

4 Conclusion

International organizations play an important role in settings of incomplete information. A significant share of the literature attests to this, but views international organizations as the source of information. In that case, as in standard models of delegation, states have incentives to delegate authority to international organizations for informational purposes.

Instead, we start off with the observation that information initially comes from states, and that international organizations receive information from better informed states. In that case, it is not immediately obvious why delegation could still be beneficial, especially given that states can simply share information bilaterally. And indeed, this is exactly what some states do in particular policy areas.

The results demonstrate that if states can use both costless and costly signals, full information aggregation requires states to only be influential with costly signals. In contrast to the standard argument about the value of international organizations, we do not find that *more* information is shared if states delegate, but that the aggregation of information is more efficient with delegation. This, however, requires that states are relatively exposed to policies made by other states. Regardless of the level of uncertainty and preference misalignment among states, as long as states are significantly affected by others, they can design an institution that allows them to aggregate information more cheaply.

A Appendix (incomplete)

In the appendix, we formally derive the results of the main text. The first step is to analyze the model without money burning and delegation. Second, we add the possibility of money burning, but still without delegation. Third, we allow for money burning, where the agent chooses both policies.

A.1 Benchmark

In the model without money burning there are two stages. First, Nature draws types $t = (t_1, t_2) \in [0,1]^2$. Both types t_1 and t_2 are independently drawn according to $F(t) = F_1(t_1)F_2(t_2)$ with strictly positive and continuously differentiable density function $f_1(t_1) := F_1'(t_1)$ and $f_2(t_2) := F_2'(t_2)$, where $f(t) = f_1(t_1)f_2(t_2)$. Second, both principals observe their private information. Principal 1 chooses x_1 after observing t_1, and principal 2 chooses x_2 after observing t_2, simultaneously. The following lemma shows the expected payoffs for each principal from playing the game from an ex-ante perspective.

Proof of Lemma 1. Each principal i chooses its decisions after observing t_i, but without information about t_j. Each principal i has a belief that puts probability 1 on the true t_i, and a (prior) belief $F_j(t_j)$ about t_j. Consider decision x_i for principal i, with the following maximization problem.

$$U_i(t_i) = -\int_{[0,1]} (x_i - (t_i + t_j + \delta_i))^2 f_j(t_j)dt_j. \tag{6}$$

Taking the first order condition with respect to x_i and setting it equal to zero gives

$$\frac{d}{dx_i}U_i(t_i) = -\int_{[0,1]} 2(x_i - (t_i + t_j + \delta_i))f(t_j)dt_j = 0 \tag{7}$$

$$\iff x_i^*(t_i) = t_i + \delta_i + \int_{[0,1]} t_j f(t_j)dt_j \tag{8}$$

$$= t_i + E[t_j] + \delta_i. \tag{9}$$

This is the unique maximizer. Now consider the ex-ante welfare of principal 1 and 2 respectively by plugging in $x_1^*(t_1)$ and $x_2^*(t_2)$, which equal

$$V_1^0 = \iint_T \Bigg(- w_1 \left(E[t_2] - t_2\right)^2 - (1 - w_1) \left(\delta_2 - \delta_1 + E[t_1] - t_1\right)^2 \Bigg) f(t)dt, \tag{10}$$

$$V_2^0 = \iint_T \Bigg(- w_2 \left(E[t_1] - t_1\right)^2 - (1 - w_1) \left(\delta_1 - \delta_2 + E[t_2] - t_2\right)^2 \Bigg) f(t)dt. \tag{11}$$

Note that

$$\iint_T -(E[t_i] - t_i)^2 f(t)dt = \iint_T -(E[t_i]^2 + t_i^2 - 2E[t_i]t_i)f(t)dt, \tag{12}$$

$$= -E[t_i]^2 - E[t_i^2] + 2E[t_i]^2, \tag{13}$$

$$= E[t_i]^2 - E[t_i^2], \tag{14}$$

$$= Var[t_i]. \tag{15}$$

Then it follows finally that

$$V_1^0 = -w_1\sigma_2^2 - (1 - w_1)\Bigg((\Delta_{12})^2 + \sigma_1^2\Bigg), \tag{16}$$

$$V_2^0 = -w_2\sigma_1^2 - (1 - w_2)\Bigg((\Delta_{12})^2 + \sigma_2^2\Bigg), \tag{17}$$

as required. □

A.2 Monotonic D1

Now we have the model as described in the main text without delegation to the agent. First, Nature draws types $t = (t_1, t_2) \in [0, 1]^2$ as before. Second, both principals observe their private information and choose to burn b_1 and b_2 individually and simultaneously. Third, principal 1 chooses x_1 after observing t_1 and (b_1, b_2), and principal 2 chooses x_2 after observing t_2 and (b_1, b_2), simultaneously.

Our claim is that the use of cheap talk is irrelevant in PBE that satisfy monotonic D1. Thus, we first move to a more general model that also allows for cheap talk and then show that the application of monotonic D1 generates a separating equilibrium that is unique. Our notation is similar to Karamychev and Visser 2016.

In stage 1, Nature draws $t = (t_1, t_2)$ under the same conditions as above. In stage 2, principal 1 observes t_1 and chooses $\sigma_1(t_1) = (m_1, b_1)$, while principal 2 observes t_2 and chooses $\sigma_2(t_2) = (m_2, b_2)$, and these actions are chosen simultaneously. Each $m_i \in M_i$ is a cheap talk message, while $b_i \geq 0$ is a non-negative amount of burned money. In stage 3, after observing (m_i, b_i), j forms posterior denoted by CDF $G_j(z|m_i, b_i) := Pr(t_i \leq z|m_i, b_i)$. Then j takes action x_j. Let $\alpha_j(m_i, b_i, t_j)$ be his pure strategy.

An equilibrium is $\Omega = \big(\sigma_1(t_1), \sigma_2(t_2), \alpha_1(m_2, b_2, t_1), \alpha_2(m_1, b_1, t_2), G_1(t_2|m_2, b_2), G_2(t_1|m_1, b_1)\big)$ is (i) a signaling strategy for principal $i = 1, 2$ $\sigma_i(t_i)$ given j's action strategy $\alpha_j(m_i, b_i, t_j)$, (ii) an action strategy for principal $i = 1, 2$ that is optimal given t_i and given beliefs $G_i(t_j|m_j, b_j)$, and (iii) principal $i = 1, 2$'s beliefs $G_i(t_j|m_j, b_j)$ that are consistent with $\sigma_j(t_j)$ for signals (m_j, b_j) on the equilibrium path.

In this model, there is no unique equilibrium. In fact, there are infinite of those. This follows directly from proposition 1 in Karamychev and Visser 2016. Before analyzing the separating equilibrium of the game (among separating equilibria, there is a unique one), we define and apply the refinements of D1 and monotonic D1 to our game. We show below that D1 allows for multiple equilibria, while monotonic D1 guarantees a unique separating equilibrium.

Note first that it is never a best response for any decision-maker to mix over different actions, as there always is a unique maximizer following every belief. By previous results, the beliefs of P_i about t_j either have degenerate support $\{t_j\}$, or form an interval with bounds t_j and t'_j. Thus with $t'_j \geq t_j$, define

$$y_i(t_j, t'_j) := \begin{cases} \arg\max_{x_i} \int_{t_j}^{t'_j} -(x_i - [\delta_i + t_i + \tau])^2 f(\tau) d\tau & \text{if } t'_j > t_j \\ \delta_i + t_i + t_j & \text{if } t'_j = t_j. \end{cases} \tag{18}$$

For short, let $y_i(t_j) := y_i(t_j, t_j)$. Then, define $BR_i := [y_i(0), y_i(1)]$ as the set of best responses for some possible belief $G_i(t_j|m_j, b_j)$. With some changes in notation, the following definition of D1 comes from Kartik 2005.

D1 Refinement (Kartik, 2005) A perfect Bayesian equilibrium satisfies the D1 criterion if for any off-the-equilibrium signal $(\tilde{m}_i, \tilde{b}_i)$:

If there is a nonempty set $\Omega \subseteq [0,1]$ such that for each $t_i \notin \Omega$, there exists some $t'_i \in \Omega$ such that for all $x_j \in BR_j$,

$$u_i(x, t_i, t_j) - \tilde{b}_i \geq u_i(\alpha_j(m_i(t_i), b_i(t_i), t_j), t_i, t_j) - b_i(t_i)$$
$$\Downarrow$$
$$u_i(x, t'_i, t_j) - \tilde{b}_i > u_i(\alpha_j(m_i(t'_i), b_i(t'_i), t_j), t'_i, t_j) - b_i(t'_i)$$

Then Supp $G_j(t_i|\tilde{m}_i, \tilde{b}_i) \subseteq \Omega$.

We first show by example that a pooling equilibrium cannot be ruled out by D1 under certain type distributions and preferences.

Claim 1. *There exist type distributions $f(t)$ and bias differences $\Delta_{12} > 0$ such that a pooling equilibrium survives the refinement of D1.*

Proof of Claim 1. Consider a pooling equilibrium, where both principals pool and choose $b_1(t_1) = b_2(t_2) = 0$ for all $t_1 \in [0,1]$ and $t_2 \in [0,1]$. As in Lemma 3, P_1 chooses $x_1^*(t_1) =$

$\delta_1 + t_1 + E[t_2]$ and P_2 chooses $x_2^*(t_2) = \delta_2 + E[t_1] + t_2$. It suffices to focus on P_1 and the influence on P_2's policy. Let $\Delta_{12} \to 0$ be arbitrarily close to 0. In equilibrium, P_1's expected payoff is

$$Eu_1^*(t_1) = \int_{[0,1]} (-w_1(t_2 - E[t_2])^2 - (1 - w_1)(\delta_2 - \delta_1 - t_1 + E[t_1])^2) f(t_2) dt_2. \tag{19}$$

Now invoke D1. Any $\tilde{b}_1 > 0$ is off the equilibrium path. For the second principal, the set of best responses equals

$$BR_2 = [\delta_2 + t_2, \delta_2 + t_2 + 1]. \tag{20}$$

If P_1 of type t_1 would deviate to some $\tilde{b}_1 > 0$, its payoff as a function of $x_2' \in BR_2$ would be

$$Eu_1(x_1, x_2, \tilde{b}_1, t_1) = \int_{[0,1]} (-w_1(t_2 - E[t_2])^2 - (1 - w_1)(x_2' - \delta_1 - t_1)^2) f(t_2) dt_2 - \tilde{b}_1. \tag{21}$$

Then, define the set of possible best responses of P_2, which is any $x_2' \in BR_2$ that would make deviating to $\tilde{b}_1 > 0$ profitable for P_1 as

$$D(t_1, \tilde{b}_1) = [x_2' \in BR_2 : -(1 - w_1)(\delta_2 + E[t_1] - \delta_1 - t_1)^2 < -(1 - w_1)(x_2' - \delta_1 - t_1)^2 - \tilde{b}_1]. \tag{22}$$

For each $t_1 > E[t_1]$, P_1 could potentially have a profitable deviation as long as P_2 chooses $x_2' > \delta_2 + E[t_1]$. Note that by D1, each type t_1' such that $t_1' > t_1 \geq E[t_1]$ has stronger incentives to deviate than t_1, which implies that $\mu_{\tilde{b}_1}^*(t_1) = 0$. Similarly, for each $t_1 < E[t_1]$, P_1 could potentially have a profitable deviation as long as P_2 chooses $x_2' < \delta_2 + E[t_1]$. But again, by D1, each type t_1' such that $t_1' < t_1 < E[t_1]$ has stronger incentives to deviate than t_1, which implies that $\mu_{\tilde{b}_1}^*(t_1) = 0$. Thus, beliefs only put positive probability on boundary types $t_1 = 0$ and $t_1 = 1$.

Finally, define $\hat{b}_1$ such that

$$\hat{b}_1 = -(1 - w_1)(\delta_2 - \delta_1)^2 + (1 - w_1)(\delta_2 - \delta_1 + E[t_1] - 1)^2, \tag{23}$$

$$\hat{b}_1 = (1 - w_1)(\delta_2 - \delta_1 + E[t_1])^2. \tag{24}$$

If P_1 given types $t_1 = 1$ and $t_1 = 0$ respectively above deviates to $\hat{b}_1$, P_1 gets its highest possible payoff by deviating, rendering it indifferent. This amount of burned money is chosen in such a way that neither types $t_1 = 0$ and $t_1 = 1$ can be ruled out by indifferent. The above equation has a solution if

$$E[t_1] = \Delta_{12} + \frac{1}{2}[1 - (\Delta_{12})^2], \tag{25}$$

which is in between 0 and 1 as required as long as Δ_{12} is sufficiently small. Given that neither 0 nor 1 can be ruled out, there exists off-path beliefs that put weights on 0 and 1 in such a way that yields an expected belief of $E[t_1]$ as given above. As a result, there exists some type distribution such that the pooling equilibrium cannot be pruned by the D1-refinement. $\square$

Second, we define monotonic D1 and invoke a result by Kartik 2005.

Monotonic D1 An equilibrium with beliefs G satisfies monotonic D1 if

1. (Signal monotonicity) $b_i(t_i)$ is weakly increasing or weakly decreasing for $i = \{1, 2\}$
2. (Belief monotonicity) For $i = \{1, 2\}$ and all t_i and $b_i > b'_i$, $G(t_i|b_i) \leq G(t_i|b'_i)$ or $G(t_i|b_i) \geq G(t_i|b'_i)$.
3. For any off-path signal $\tilde{b}_i$, if there is a nonempty set $\Omega \subseteq [0, 1]$ such that for each $t_i \notin \Omega$, there exists some $t_i \in \Omega$ such that for all $x_j \in [\xi_l(\tilde{b}_i), \xi_h(\tilde{b}_i)]$[14]

[14]See page 14 on Kartik's working paper

A.3 The Value of Signaling

Proof of Lemma 3. Consider a separating equilibrium. Principal i's belief μ_i puts probability 1 on t. It is obvious that $x_i(t) = \delta_i + t_i + t_j$ maximizes $u_i(x, t, b_i)$ for all $t \in [0,1]^2$. Now consider the money burning function $b_i(t_i)$. Principal i burns money to affect the other principal's policy x_j. By reporting t_i', principal i obtains

$$U_i(t_i') = \int_{[0,1]} -(1-w_i)(\delta_j - \delta_i + t_j + t_i' - t_i - t_j)^2 f(t_j) dt_j - b_i(t_i') \tag{26}$$

$$= -(1-w_i)(\delta_j - \delta_i + t_i' - t_i)^2 - b_i(t_i') \tag{27}$$

By reporting truthfully, the following first order condition has to be satisfied, evaluated at $t_i' = t_i$.

$$\frac{d}{dt_i'} U_i(t_i') = -2(1-w_i)(\delta_j - \delta_i + t_i' - t_i) - b_i'(t_i') = 0 \tag{28}$$

Now imposing that $t_i = t_i'$, and integrating out principal i's private information t_i, this yields

$$b_i(t_i) = -2t_i(1-w_i)(\delta_j - \delta_i) + C, \tag{29}$$

where C is a constant. Now consider principal 1, who has a money burning function of $b_i(t_i) = -2t_1(1-w_1)(\delta_2 - \delta_1) + C = 2t_1(1-w_1)(\delta_1 - \delta_2) = C$. As $\delta_1 > \delta_2$, this function is increasing in t_1. Evaluated at $t_1 = 0$, principal 1 burns $b_1(0) = C$. Suppose, for a proof by contradiction that $C > 0$. Because $b_1(t_1)$ is increasing, there exists no $t_1 \in [0,1]$ such that $b_1(t_1) < C$. Suppose principal 2 observes $b_1 = 0$, which is off-path. Then principal 2 can have any arbitrary posterior belief $\mu_2(0)$ over t_1 after observing $b_1 = 0$. For any such $\mu_2(0)$, principal 2 takes an action of $x_2(0, t_2) = \delta_2 + E[t_1|\mu_2(0)] + t_2$, where $0 \leq E[t_1|\mu_2(0)] \leq 1$. Now consider principal 1's payoff given type $t_1 = E[t_1|\mu_2(0)]$ if he were to deviate to $\tilde{b}_1(t_1) = 0$, which is

$$U_1(t_1, \tilde{b}_1) = -(1 - w_1)(\delta_2 + E[t_1|\mu_2(0)] - t_1 - \delta_1)^2 - \tilde{b}_1(t_1), \tag{30}$$

$$= -(1 - w_1)(\delta_2 - \delta_1)^2. \tag{31}$$

Clearly this deviation is profitable, as it is higher than t_1's payoff in the proposed equilibrium, which is $U_1(t_1, b_1^*(t_1)) = -(1 - w_1)(\delta_2 - \delta_1)^2 - b_1^*(t_1)$, where $b_1^*(t_1) \geq C > 0$, a contradiction. This implies that we need that $C = 0$, which means that for principal 1,

$$b_1^*(t_1) = 2t_1(1 - w_1)(\delta_1 - \delta_2), \tag{32}$$

as required.

Now consider principal 2 with a money burning function of

$$b_2(t_2) = -2t_2(1 - w_2)(\delta_1 - \delta_2) + C. \tag{33}$$

Note that this function is decreasing in t_2. By a similar argument, there must be some type t_2' that burns $b_2(t_2') = 0$. In particular, because b_2 is decreasing in t_2, to ensure non-negative amounts of burned money, we need that $b_2(1) = 0$. Plugging this into P_2's money burning function yields

$$C = 2(1 - w_2)(\delta_1 - \delta_2). \tag{34}$$

Plugging in this constant yields

$$b_2^*(t_2) = 2(1 - t_2)(1 - w_2)(\delta_1 - \delta_2), \tag{35}$$

as required. This concludes the proof. □

Proof of Proposition 1. Follows from Lemma 1 and 3. □

A.4 The Value of Delegation

Proof of Lemma 4. Consider the separating equilibrium in the presence of delegation. It is straightforward to see that A takes an action of $x_1^*(t) = x_2^*(t) = \delta_A + t_1 + t_2$ because A perfectly infers t in a separating equilibrium. The only thing that remains is to establish the money-burning functions of principals P_1 and P_2. The steps are similar to the Proof of Lemma 3 and are not completely copied.

Consider P_1. By reporting truthfully, the following first order condition has to be satisfied, evaluated at $t_1' = t_1$.

$$\frac{d}{dt_1'}U_1(t_1') = -2(\delta_A - \delta_1 + t_1' - t_1) - b_1'(t_1') = 0. \tag{36}$$

Imposing that $t_1 = t_1'$ and integrating out P_1's private information yields

$$b_1^*(t_1) = 2t_1(\delta_1 - \delta_A), \tag{37}$$

where the constant is 0, by a similar argument as above. □

Proof of Proposition 2. Follows from Lemma 3 and 4 □

A.5 Limited Discretion

Proof of Proposition 3. Suppose $w_1 = w_2 = \frac{1}{2}$, $\delta_1 = -\delta_2 = \delta$, $\delta_A = 0$.

$$\begin{aligned} u_1 = &-\frac{1}{2}(x_1 - (t_1 + t_2 + \delta))^2 \\ &-\frac{1}{2}(x_2 - (t_1 + t_2 + \delta))^2 - b_1 \end{aligned}$$

$$\begin{aligned} u_2 = & -\frac{1}{2}(x_1 - (t_1 + t_2 - \delta))^2 \\ & -\frac{1}{2}(x_2 - (t_1 + t_2 - \delta))^2 - b_2 \end{aligned}$$

$$\begin{aligned} u_A = & -(x_1 - (t_1 + t_2))^2 \\ & -(x_2 - (t_1 + t_2))^2 \end{aligned}$$

Suppose both policies are restricted to the same interval $[\underline{x}, \overline{x}]$. Assume the agent observe the type of each principal. Thus, the policies chooses by the principal are:

$x_1 = x_2 = t_1 + t_2$ when $t_1 + t_2 \in [\underline{x}, \overline{x}]$

$x_1 = x_2 = \underline{x}$ when $t_1 + t_2 \leq [\underline{x}, \overline{x}]$

$x_1 = x_2 = \overline{x}$ when $t_1 + t_2 \geq [\underline{x}, \overline{x}]$

Interim-payoffs for a principal t_1 that pretends to be type t_1' is:

$$\begin{aligned} U(t_1, t_1') = & -\int_0^{\min\{\max\{\underline{x}-t_1',0\},1\}} (\underline{x} - (t_1 + t_2 + \delta))^2 dF(t_2) \\ & -\int_{\min\{\max\{\overline{x}-t_1',0\},1\}}^1 (\overline{x} - (t_1 + t_2 + \delta))^2 dF(t_2) \\ & -\int_{\min\{\max\{\underline{x}-t_1',0\},1\}}^{\min\{\max\{\overline{x}-t_1',0\},1\}} (t_1' + t_2 - (t_1 + t_2 + \delta))^2 dF(t_2) \\ & -b(t_1') \end{aligned}$$

Taking first order conditions w.r.t. t_1' and making $t_1' = t_1$:

$$b'(t_1) = 2\delta \int_{\min\{\max\{\underline{x}-t_1,0\},1\}}^{\min\{\max\{\overline{x}-t_1,0\},1\}} dF(t_2) = 2\delta(F(\min\{\max\{\overline{x}-t_1, 0\}, 1\}) - F(\min\{\max\{\underline{x}-t_1, 0\}, 1\}))$$

In the uniform case:

$$b'(t_1) = 2\delta \min\{(\overline{x} - \underline{x}), 1\}$$

Solving the ODE:

$$b(t_1) = 2\delta \min\{(\overline{x} - \underline{x}), 1\}t_1 + C$$

Where it must be that $C = 0$.

A type t_1 payoff before money burning:

$$\begin{aligned} U(t_1) = &- \int_0^{\min\{\max\{\underline{x}-t_1,0\},1\}} (\underline{x} - (t_1 + t_2 + \delta))^2 dF(t_2) \\ &- \int_{\min\{\max\{\overline{x}-t_1,0\},1\}}^{1} (\overline{x} - (t_1 + t_2 + \delta))^2 dF(t_2) \\ &- \int_{\min\{\max\{\underline{x}-t_1,0\},1\}}^{\min\{\max\{\overline{x}-t_1,0\},1\}} (t_1 + t_2 - (t_1 + t_2 + \delta))^2 dF(t_2) \\ &-2\delta \min\{(\overline{x} - \underline{x}), 1\}t_1 \end{aligned}$$

The third term is:

$$- \int_{\min\{\max\{\underline{x}-t_1,0\},1\}}^{\min\{\max\{\overline{x}-t_1,0\},1\}} (t_1 + t_2 - (t_1 + t_2 + \delta))^2 dF(t_2) = -\delta^2 \min\{(\overline{x} - \underline{x}), 1\}$$

Summing the third and the fourth terms:

$$(3) + (4) = -\min\{(\overline{x} - \underline{x}), 1\}\delta[2t_1 + \delta]$$

Taking expectations w.r.t. t_1:

$$\int_{T_1} [(3) + (4)] = -\min\{(\overline{x} - \underline{x}), 1\}\delta[1 + \delta]$$

We can express the ex-ante payoffs for principal in the following way:

$$\begin{aligned} U_1 = &- \int_0^1 \int_0^{\min\{\max\{\underline{x}-t_1,0\},1\}} (\underline{x} - (t_1 + t_2 + \delta))^2 dF(t_2) dF(t_1) \\ &- \int_0^1 \int_{\min\{\max\{\overline{x}-t_1,0\},1\}}^1 (\overline{x} - (t_1 + t_2 + \delta))^2 dF(t_2) dF(t_1) \\ &- \min\{(\overline{x} - \underline{x}), 1\}\delta[1 + \delta] \end{aligned}$$

Note that we can assume w.l.o.g. that $0 \leq [\overline{x} - \underline{x}] \leq 2$. Our main model is equivalent to assume that $[\overline{x} - \underline{x}] \geq 2$. We know that $\delta_1 > \delta_A$. It is always true that $1 > (\delta_A - \delta_1)$. Thus, In any other case, as $[\overline{x} - \underline{x}]$ decreases, the fifth term is increasing. This term represents the net-benefit of signaling the information to the agent conditions on the agent to choose a policy $x_1 = x_2 \in (\overline{x} - \underline{x})$. Intuitively, as this term decreases, there is less need for the principal to signal his information to the agent, whenever he uses to take a decision. Also, the second and fourth terms are decreasing on $[\overline{x} - \underline{x}]$. Intuitively, a smaller interval of policies restricts the set of possible values of $t_1 + t_2$. However, how the first and third term change is not possible to determine.(?)

Consider the case of full discretion. This case is equivalent to have $\underline{x} \leq 0$ and $\overline{x} \geq 2$. Assume for simplicity that $\underline{x} = 0$ and $\overline{x} = 2$. Note that $t_2 \geq \underline{x} - t_1$ and $t_2 \leq \overline{x} - t_1$. In this case, the ex-ante payoffs for principal one is the following.

$$U_1^{FD} = -\delta[1 + \delta]$$

Suppose instead we give limited discretion $[0 + \epsilon, 2]$, with $\epsilon > 0$. In this case, the ex-ante payoffs for principal one is the following:

$$U_1^{LD} = -\int_0^1 \int_0^{\min\{\max\{\epsilon - t_1, 0\},1\}} (\epsilon - (t_1 + t_2 + \delta))^2 dF(t_2)dF(t_1)$$
$$-\int_0^1 \int_{\min\{\max\{2-t_1,0\},1\}}^1 (2 - (t_1 + t_2 + \delta))^2 dF(t_2)dF(t_1)$$
$$-(2-\epsilon)\delta[1+\delta]$$

The second term is zero. Thus:

$$U_1^{LD} - U_1^{FD} = -\int_0^1 \int_0^{\epsilon - t_1} (\epsilon - (t_1 + t_2 + \delta))^2 dF(t_2)dF(t_1)$$
$$+\epsilon\delta[1+\delta]$$

Consider $\epsilon \leq \delta$. Thus $(\epsilon - (t_1 + t_2 + \delta)) \leq 0$. In that case we have that:

$$\int_0^1 \int_0^{\epsilon - t_1} (\epsilon - (t_1 + t_2 + \delta))^2 dF(t_2)dF(t_1) < \delta^2 \frac{\epsilon^2}{2}$$

Then

$$U_1^{LD} - U_1^{FD} > -\delta^2 \frac{\epsilon^2}{2} + \epsilon\delta[1+\delta]$$
$$= \epsilon\delta + \epsilon\delta^2(1 - \frac{\epsilon}{2})$$
$$> 0$$

So principal one ex-ante payoffs increases when $\underline{x}$ increases from 0 to ϵ whenever $\epsilon \leq \min\{\delta_1, 2\}$

Suppose instead we give limited discretion $[0 + \epsilon_1, 2 - \epsilon_2]$, with $\epsilon_1, \epsilon_2 > 0$. In this case, the ex-ante payoffs for principal one is the following:

$$\begin{aligned} U_1^{LD} &= -\int_0^1 \int_0^{\epsilon_1 - t_1} (\epsilon_1 - (t_1 + t_2 + \delta))^2 dF(t_2) dF(t_1) \\ &\quad - \int_0^1 \int_{2-\epsilon_2-t_1}^1 (2 - \epsilon_2 - (t_1 + t_2 + \delta))^2 dF(t_2) dF(t_1) \\ &\quad -(2 - \epsilon_2 - \epsilon_1)\delta[1+\delta] \\ &= -\int_0^1 \int_0^{\epsilon_1 - t_1} (\epsilon_1 - (t_1 + t_2 + \delta))^2 dF(t_2) dF(t_1) - (2-\epsilon_1)\delta[1+\delta] \\ &\quad - \int_0^1 \int_{2-\epsilon_2-t_1}^1 (2 - \epsilon_2 - (t_1 + t_2 + \delta))^2 dF(t_2) dF(t_1) + \epsilon_2\delta[1+\delta] \end{aligned}$$

Note that $2 - \epsilon_2 - (t_1 + t_2 + \delta) < 0$. Thus, for $\epsilon_2 \leq 1$:

$$\int_0^1 \int_{2-\epsilon_2-t_1}^1 (2 - \epsilon_2 - (t_1 + t_2 + \delta))^2 dF(t_2) dF(t_1) < (\epsilon_2 + \delta)^2 \frac{\epsilon_2^2}{2}$$

Thus, for small enough ϵ_1, ϵ_2 such that $(1 - \frac{\epsilon_1}{2}) \geq 0$ and $(\delta^2 - (\epsilon_2 + \delta)^2 \frac{\epsilon_2}{2}) \geq 0$.

$$\begin{aligned} U_1^{LD} - U_1^{FD} &> -\delta^2 \frac{\epsilon_1^2}{2} + \epsilon_1\delta[1+\delta] - (\epsilon_2 + \delta)^2 \frac{\epsilon_2^2}{2} + \epsilon_2\delta[1+\delta] \\ &= \epsilon\delta + \epsilon\delta^2(1 - \frac{\epsilon_1}{2}) + \epsilon_2\delta + \epsilon_2(\delta^2 - (\epsilon_2 + \delta)^2 \frac{\epsilon_2}{2}) \\ &> 0 \end{aligned}$$

□

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