International Decision Rights and Efficient Signaling*

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January 12, 2019

Abstract

The exchange of information is one of the proposed rationales for delegation to international organizations (IOs). But why would states be better off exchanging information in the presence of an IO? To study the signaling benefits from delegation, we develop and analyze a model in which multiple principals use costly signals to transmit information in the presence and absence of an initially uninformed agent. A key result is that, regardless of misalignment among states, IOs may be helpful for informational efficiency as long as inter-state externalities are sufficiently high. There are two countervailing forces for informational efficiency when states delegate. They incur (i) lower costs if a more aligned IO makes policy on behalf of another state, but (ii) higher costs if they delegate their own policy to a misaligned IO. Finally, we provide implications for the efficient selection of international bureaucrats and their level of discretion.

Word count: ≈ 6000 (max 8000)

*We thank Mark Fey, Jack Paine, and Randy Stone for helpful comments. All errors are our own.

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Sovereign states often delegate policy-making authority 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 rationale for delegation is that IOs facilitate information exchange among states. Indeed, there are many IOs that claim that one of their main goals is to provide a forum for communication to its member states. For example, consultation is important in NATO because member states "[...] are able to exchange views and information, and discuss issues prior to reaching agreement and taking action."[2] Similarly, the United Nations "[...] provides a forum for its members to express their views in the General Assembly, [...] and other bodies and committees."[3] However, we cannot conclude from these examples that the exchange of information in IOs is more efficient than its exchange outside IOs. That is, delegation could be inefficient for informational purposes, but states may still cooperate in IOs because it brings about other types of benefits. Moreover, it is not immediately obvious why states would not share information in the absence of IOs. What can IOs do for states that they cannot do just as well by themselves if they were to transmit information *ad hoc*? More broadly, what type of international institutions maximize the efficiency of information aggregation?

Scholars of international institutions 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).[4] Thus, the proposed answer is that states are more willing to reveal information if they delegate to IOs. Existing game theoretic work sees an informational role for IOs but typically conceptualizes these

[1] Existing scholarship explains delegation by thinking of IOs 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] `https://www.nato.int/cps/en/natolive/topics_49187.htm`.

[3] `http://www.un.org/en/sections/about-un/overview/`.

[4] 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). Similarly, see Thompson 2015: "Moreover, the exchange of information and discourse that takes place within an IO tends to reveal information about states' preferences and intended actions [...], leading to more effective monitoring and higher quality signaling at the international level" (p. 30).

organizations as a source of information rather than a receiver or forum for communication (Fang, 2008).[5] For example, focusing on the United Nations, Johns 2007 studies the selection of bureaucrats who provide information to bargaining member states. Fang and Stone 2012 analyze when and how IOs strategically provide influential policy recommendations to member states, with applications to the WHO and IMF. 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 European Parliament and member states in the Council.

In every aforementioned theoretical model, IOs are better informed than member states. However, although states have an obvious incentive to delegate to better informed IOs, it is an open question whether delegation to *uninformed* IOs can be efficient from an informational perspective.

Our model focuses on this exact setting. We are interested in the design of institutions that allow states to learn new information as efficiently as possible. In the model, two states have private information and may make policy individually or delegate authority to an initially uninformed IO that makes policy on their behalf. Both states use costly signals to provide information to each other or to the IO. That is, substantively, states talk with each other, but also use other ways to signal their information to others, such as implementing certain policies domestically. We then study how efficiently states learn new information with and without IOs. The efficiency of information aggregation can be categorized into two parts. First, how much uncertainty remains after states signal information to each other? And second, how many costs are incurred to signal this information? The model shows that there is no change in the amount of information that is aggregated when authority is delegated to an IO. Regardless, even if states have incentives to lie to each other, due to the fact that states use costly signals, the results demonstrate that they can be completely truthful. Instead, the welfare effect of delegation to IOs stems from the size of the costs that

[5] In a formal model of influence by states over IOs, Urpelainen 2012 is an exception, albeit in a complete information framework.

are incurred by both states to achieve full information aggregation.

We identify and study a key trade-off that states face in delegating and centralizing authority. On the benefit side of delegation is the well-known efficiency gain of improved information transmission between more aligned actors. 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. This is because it has weaker incentives to misrepresent its information. The less intuitive effect, however, is a potential decrease in efficiency. Without delegation, states do not need to send costly signals to alter their own policy because they have authority over it and can freely choose their most preferred policy. 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 centralization. Thus, the conclusion is that the informational efficiency gains due to delegation to IOs are not guaranteed to exist.

Beyond a comparison between decentralization and centralization, we also study how IOs are designed if the goal is to maximize efficiency from the perspective of both states. In our setting, if there were no informational asymmetries, the IO's preference should be in the middle of the two. This conclusion remains to hold if both states have private information with the same level of uncertainty. But if there is one state that has information which is more uncertain, then the IO should be biased in favor of that state. In the extreme, when one state's information becomes much more important than the other's, authority should effectively be put in the hands of the state that faces more uncertainty. Furthermore, we show that the efficient amount of discretion that is given to the IO depends on both on how misaligned states are, as well as how important their information is.

Our focus on efficiency does not imply that we aim to predict how organizations are actually designed.[6] There are many reasons for why IOs are not organized in a way that is socially optimal for all member states. Instead, states bargain over institutional design,

[6]Stone 2011: Abbott and Snidal 1998, Koremenos, Lipson and Snidal 2001.

and those that have better outside options often have a greater say in the design process.[7] However, it is important to note that the informational rationale for delegation to international institutions is an efficiency rationale, not an empirical prediction. Thus, we are not so much interested in how states bargain over institutional design, but instead take institutional design as given, and study its implications for the strategic incentives of states and their welfare.

There are two main issues for efficiency in principal-agent relations. First, from the perspective of the principals, the agent often has divergent preferences, and must be kept in check. That is, without limiting the agent, principals fear that implemented policies are too far away from those that they prefer. A large theoretical literature on delegation has focused on this issue. The second issue relates to too much influence from the principal(s) on the agent. Although principals could be best off leaving the agent alone *ex-ante*, for example because it incentivizes the agent to exert more effort or acquire more information, *ex-post* they have incentives to renege. This second issue is less well explored, and is part of our main interest in this paper. Recent work on the performance of IOs emphasizes this exact issue. It is not so much deviant IO-behavior that is problematic, but more states using influence to follow narrow national interests (Lall, 2017).

Unlike other work, we do not conceive of influence being completely inefficient, nor do we conceive of it as vote-buying or transferring money (Vreeland and Dreher, 2014). However, incurring influence costs and sending costly signals has an informational role.[8] The fact that a state tries its best to influence policies in IOs harms the organization's independence, but it also reveals information about what the state knows or wants. This information can then be used to more effectively tailor policies to the situation at hand.

Although many models of IOs grant it more information than their member states, it is unclear whether this is generally the case. (Stone, 2009, p. 35/36) argues this and provides

[7] Johns 2007; Lipscy 2017. Additionally, states are not in complete control over institutional design when they delegate, and international bureaucrats play an important role, see e.g., Johnson 2013, 2014; Johnson and Urpelainen 2014.

[8] Discussion about influence costs Milgrom and Roberts 1988.

examples in which states are better informed than IOs (long quote in footnote).[9]

Related Theoretical Literature

Our model is related to traditional principal-agent theories in which the principal has formal authority, but may grant a better informed agent the ability to take decisions, as long as preferences do not diverge too much (Aghion and Tirole, 1997; Dessein, 2002). One difference is that we study a situation in which there are multiple principals. But more importantly, one of the main differences with the traditional literature is that we assume that the principals are better informed than the agent. The principals, however, could still gain from delegation to an agent because each individual principal has private information that is relevant for the other. The agent can then serve as a receiver of information and make policies on the principals' behalf. However, the principals could also choose to retain authority and simply transmit information bilaterally.

Another 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.[10] In a 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). Typically, however, information transmission is modeled within the classical cheap talk setting in which costly signals are absent (Crawford and Sobel, 1982; Green and Stokey, 2007). As a result,

[9] The influence of multiple principals is the most convincing account, because alternative agency arguments must assume that international bureaucrats have substantial information advantages over national authorities. This seems consistent with the widespread assumption that international institutions provide information that facilitates cooperation. [...] There are not many examples where institutions really have superior information. Most intergovernmental organizations, as for example the WTO, rely upon member states to put violations of rules on the agenda: they rely on "fire alarm" rather than "police patrols". Even the European Union, the most impressive international institution in terms of its bureaucratic capacity, cannot rival the analytic and data collection capacities of its member states. The IMF does not have an information advantage over borrowers, which filter and often falsify the data that they feed to it, and arguable has no advantage over international financial markets, where major investors have the resources and incentives to produce information. Although it has subsequently modernized and made significant strides in creating incentives for members to provide it with quality data, during the Mexican crisis of 1994-95 the IMF relied on incomplete data reported by the Mexican Central Bank with a three- to four-month lag, when more complete data were available daily from Reuters and Bloomberg's.

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

we devote some attention to cheap talk as well.

Our findings are related to a strand of the organization economics literature that studies communication and delegation. Both Alonso, Dessein and Matouschek 2008 and Rantakari 2008 are especially close to our setup.[11] Their interest is in the trade-off between the coordination of decisions and adaption to local conditions in the context of multi-product firms. Alonso, Dessein and Matouschek 2008 study an organization with a headquarters and two privately informed divisions who communicate through cheap talk in which both divisions care symmetrically about the importance of coordination. Decentralized authority allows divisions to optimally adapt their decisions to local conditions, while centralized authority in the hands of the headquarters 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. In a similar setup, but with asymmetric division payoffs, Rantakari 2008 shows that it may be better to allocate decision rights to either division if the need for coordination differs among them.

In addition, although our main focus is not on inter-state conflict, a literature on mediation is related to our model.[12] The main interest of this literature is how mediators, which could be conceptualized as IOs, can help states to achieve peaceful outcomes. Indeed, a substantial literature finds that IOs can successfully prevent war. However, Fey and Ramsay 2010 survey this literature, and cast doubt on this possibility. They show that IOs require private information to be successful, and uninformed mediators cannot help states do something that these states cannot do by themselves. Similar to Fey and Ramsay 2010, we focus on uninformed IOs, but we do allow states to formally delegate decision-making power and study a model where conflict is absent. This means that their results on the informational role of IOs do not necessarily carry over.

[11] But there is a larger set of papers that deals with related issues. See Athey and Roberts 2001; Dessein, Garicano and Gertner 2010; Friebel and Raith 2010; Rantakari 2013; Alonso, Dessein and Matouschek 2015; Liu and Migrow 2018; Bils 2018. Roberts and Saloner 2012 survey this literature.

[12] See also Goltsman et al. 2009 and Hörner, Morelli and Squintani 2015.

The 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 within the standard principal-agent framework. States perform the role of the principals, and the IO is the potential agent. In the first game, with *separated authority*, two privately informed principals make policies individually. In the second one, with *delegated authority*, an initially uninformed agent makes policy on the principals' behalf. As in Alonso, Dessein and Matouschek 2008; Rantakari 2008, after actors observe their private information, both games start with a round of information transmission and end with policy-making. The difference is only in the final stage of the game, and our interest is in how the allocation of decision-rights affects information transmission.

Both games have three stages in which the first two are the same. In stage 1 of each game, Nature draws Principal 1's type t_1 and Principal 2's type t_2 independently and uniformly. Principal 1's type t_1 is drawn from $T_1 = [-s_1, s_1]$ and Principal 2's type is drawn from $T_2 = [-s_2, s_2]$, with both s_1 and $s_2 \in \mathbb{R}_+$. This type represents each Principal's private information that is relevant for policy-making from the perspective of both Principals. Additionally, the greater is s_1 or s_2, the more uncertainty there is about t_1 and t_2 respectively.

In stage 2, after observing its private information t_i, Principal i sends a costly signal. Since each Principal is privately informed, this may be informative for others. This is known as *burning money* in information economics.[13] 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, just to signal one's intentions to others. It is important to note that money burning is completely wasteful, but because it may be informative, there is a potential welfare benefit

[13] See Austen-Smith and Banks 2000 and Kartik 2007.

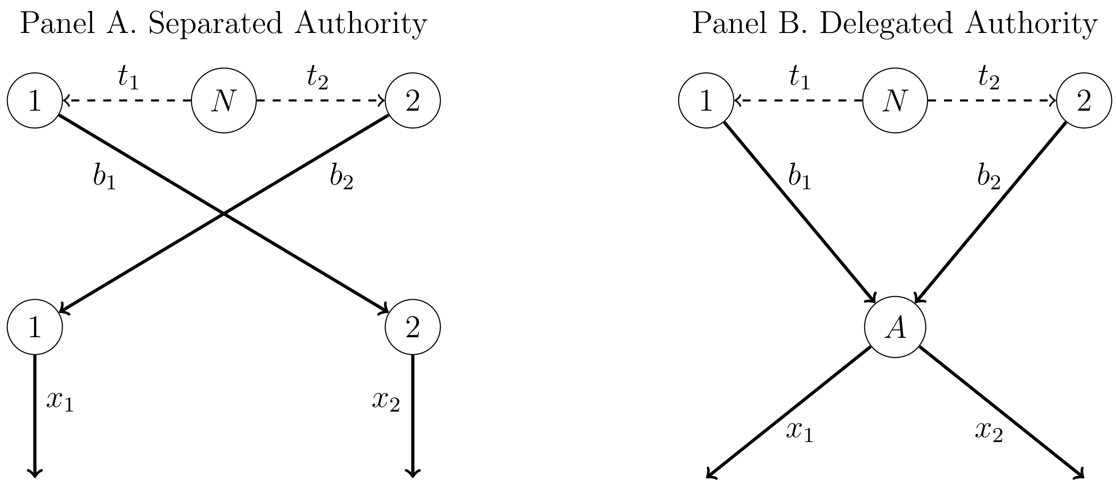

Figure 1: Signaling and Policy-Making. In both panels, Nature (N) reveals private information to each individual Principal. In Panel A, authority is separated and each Principal burns money to influence the other Principal's policy. In Panel B, authority is delegated to Agent A, and Principals burn money to influence the centralized policy made by the Agent, where $x_1 = x_2$ in equilibrium.

from doing it. Concretely, Principal i chooses to burn an amount $b_i \geq 0$ which enters negatively in the Principal's payoff.[14]

In the third and final stage, how policies are made is determined by the institutional structure. With *separated authority* (Figure 1, Panel A), each Principal i observes how much the other Principal j has burned and simultaneously[15] implements a policy x_i, after which payoffs are realized. Instead, with *delegated authority* (Figure 1, Panel B), an Agent makes both policies $x = (x_1, x_2)$.

As a function of the realized types $t = (t_1, t_2)$, policies $x = (x_1, x_2)$, and burned money b_1, Principal 1 obtains a payoff of $u_1(x, t) - b_1$. The first term takes the form

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

where $\delta_1 \in \mathbb{R}$ is Principal 1's bias, $w_1 \in (0, 1)$ is the weight of Principal 1's own policy on

[14]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.

[15]Without this assumption, each Principal could learn another Principal's information from its chosen policy, as in the model of Hermalin (1998) about leading by example.

its payoff, and $(1 - w_1)$ is the weight of Principal 2's policy. This weight parameter can be conceptualized as the exposure of a country to policies made in the international arena. For example, small countries would have a small value for w_i and care a lot about decisions made in bigger countries, and vice versa for big countries. Similarly, the payoff for Principal 2 is given by $u_2(x,t) - b_2$. The first term equals

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

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 the weight of the first Principal's policy x_1.

The Agent A's bias is δ_A, with $\delta_2 \leq \delta_A \leq \delta_1$ and her payoff equals

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

Note that ideal policies for both Principals and the Agent are ordered in a simple way. Given their types t_1 and t_2, Principal 1 and 2 have respective ideal policies $\hat{x}^1 = \delta_1 + t_1 + t_2$ and $\hat{x}^2 = \delta_2 + t_1 + t_2$. Similarly, the Agent is somewhere in the middle because $\delta_2 \leq \delta_A \leq \delta_1$, with ideal policy $\hat{x}^A = \delta_A + t_1 + t_2$.

We are ultimately interested in the welfare of both Principals with separated and delegated authority. Before studying efficiency, however, we first analyze equilibrium strategies under both institutional arrangements. All proofs are collected in the appendix.

Equilibrium Signals and Policies

We study perfect Bayesian equilibria (PBE). 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).[16] In a share of signaling models, refinements can delete a large set of these equilibria, potentially to the point of guaranteeing a unique one (Cho and Kreps, 1987; Chen, Kartik and Sobel, 2008). This is true as well in our setting, where the refinement of monotonic D1 (Bernheim and Severinov, 2003)[17] ensures a unique separating equilibrium (Kartik, 2005).[18] From now on, we simply call the unique PBE that survives the refinement of monotonic D1 an *mD1-equilibrium*.

Lemma 1. *With both separated and delegated authority, there is a unique PBE that survives monotonic D1 and it is fully separating.*

This first result implies that every policy-maker, whether it is a Principal or the Agent, makes policies under full information. At the final stage in equilibrium, each policy-maker knows exactly what the private information of each Principal is, i.e., t_1 and t_2 are known. This means that we already know that the answer is not that IOs lead to *more* information transmission. Regardless of the institutional arrangement, all information is revealed in equilibrium, which means that the type of equilibrium is essentially the same. But what is different, are the policies that are made, and potentially, the kind of signals that are sent.

This result is different than the standard results in models with cheap talk. In those models, if preferences are sufficiently aligned, information can be transmitted because different types send different messages. The more aligned preferences are, the more messages can be sent in equilibrium, and the less residual uncertainty remains after communication. But as long as there is some level of misalignment, fully informative cheap talk is impossible. Thus, there will always be some residual uncertainty. These models are, however, sensitive

[16]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. See also Kolotilin and Li 2018.

[17]Monotonic D1 puts more restrictions on equilibrium behavior and beliefs off the path of play than D1. Most importantly, money burning strategies need to be monotonic. 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.

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

to the inavailability of costly signals. With the application of our mD1-refinement, if some types were to pool, then at least one type has a profitable deviation to send an off-path costly signal to separate from other types if such a signal were available. Substantively, this means that if states are communicating with each other, they take costly actions that serve as a signal and add additional credibility to a state's message. Implicitly, states are always able to prove what information they have by choosing different signal.[19]

Separated Authority

When authority is separated between the two Principals, Principal 1 chooses policy x_1 and Principal 2 chooses policy x_2. Due to Lemma 1, all information is revealed in equilibrium, which means that each Principal can simply choose his most preferred policy under full information. That is, when authority is separated, Principal 1 chooses a policy of $x_1^S(t) = \delta_1 + t_1 + t_2$, while Principal 2 chooses $x_2^S(t) = \delta_2 + t_1 + t_2$.

Why is money burning necessary to ensure full information aggregation? This is because each Principal has incentives to exaggerate its information. Principal 1 wants to say its type t_1 is *higher* than it actually is, while Principal 2 wants to say its type t_2 is *lower* than it actually is. If lying is free, as is the case with cheap talk, then specific lies always lead to more preferred policies, which means that an informed party deviates from always telling the truth. As a result, fully informative equilibria with only cheap talk fail to exist. Instead, with money burning, lying becomes expensive, and although an informed party would like that the other implements a more preferred policy, the higher cost of the different signal prevents him from deviating.

How much does each Principal need to burn to sustain an equilibrium? Money burning helps to influence the other Principal's policy. Given a separating equilibrium, no two types

[19] It is important to note that this equilibrium is not the most efficient. See Karamychev and Visser 2016 for a discussion on *ex-ante* socially optimal equilibria. Under general conditions, full separation is never efficient. Although the receiver's preferred equilibrium is fully separating, the sender prefers to reveal information through a finite number of intervals. Thus, if the receiver's payoff becomes sufficiently important compared to the sender's, only then is full separation efficient.

must prefer to mimic each other. For Principal 1 for instance, for two types $t_1 < t_1'$, neither type must be willing to send the signal that the other type sends. That is, if Principal 1 has type t_1, he must not prefer to deviate to burn $b_1(t_1')$, and vice versa, Principal 1 of type t_1' must not prefer to burn $b_1(t_1)$ instead. Principal 2 chooses a policy that is based on his own type t_2, and based on the costly signal b_1 of Principal 1. Because $b_1(t_1)$ is a separating function, there are no two types that burn the same amount. That means that $b_1(t_1)$ is invertible, where $b_1^{-1}(t_1) = t_1$ is the type that burns on-path $b_1(t_1)$. Let Principal 2's policy choice be $x_2^*(t_1) := \delta_2 + b_1^{-1}(t_1) + t_2$ for short. Then the incentive constraints of the two types t_1, t_1' of Principal 1 respectively equal

$$u_1(x_2^*(t_1), t_1) - b_1(t_1) \geq u_1(x_2^*(t_1'), t_1) - b_1(t_1'), \tag{4}$$

$$u_1(x_2^*(t_1'), t_1') - b_1(t_1') \geq u_1(x_2^*(t_1), t_1') - b_1(t_1). \tag{5}$$

We are interested in how much money is burned in equilibrium. After some rearranging, we have that the difference between the amount of burned money by type t_1 and t_1' is bounded below and above by the willingness of each type to imitate another, where

$$u_1(x_2^*(t_1'), t_1') - u_1(x_2^*(t_1), t_1') \geq b_1(t_1') - b_1(t_1) \geq u_1(x_2^*(t_1'), t_1) - u_1(x_2^*(t_1), t_1). \tag{6}$$

After some calculus, and together with the insight that at least one type burns nothing in equilibrium, this gives us the money burning function of each Principal. The following lemma summarizes the equilibrium strategies, where beliefs are formally defined in the appendix.

Lemma 2. *For all $(t_1, t_2) \in T$ in the mD1-equilibrium with separated authority,*

- *Principal 1 chooses $x_1^S(t) = \delta_1 + t_1 + t_2$ and burns $b_1^S(t_1) = 2(1 - w_1)(t_1 + s_1)(\delta_1 - \delta_2)$,*
- *Principal 2 chooses $x_2^S(t) = \delta_2 + t_1 + t_2$ and burns $b_2^S(t_2) = 2(1 - w_2)(s_2 - t_2)(\delta_1 - \delta_2)$.*

As can be seen, there are a couple of parameters that affect how much money is burned in equilibrium. Consider for example Principal 1 who burns $b_1^S(t_1) = 2(1 - w_1)(t_1 + s_1)(\delta_1 - \delta_2)$.

Holding fixed a type $t_1 > -s_1$ who burns a positive amount, first we see that the higher is w_1, the more Principal 1 cares about its own policy, and the less it cares about Principal 2's policy. Thus, it has fewer incentives to misrepresent its information because it cares less about what policy Principal 2 will choose. Notice here, again, that both Principals burn money to affect the other Principal's policy, but not to influence their own policy, because they have authority over that. This will be an important difference with delegated authority. Second, the amount of burned money increases in the preference misalignment between the two principals. The quadratic form of the payoffs imply that the more extreme another Principal's policy is, the more its policy affects Principal 1, and thus the more it has to gain from lying. These lies have to be prevented with more burned money in equilibrium. Notice also that Principal 1's money burning function is increasing in t_1, while Principal 2's function is decreasing in t_2. This is because Principal 1 wants to lie in the positive direction, it wants to claim its type is higher than it actually is, because $\delta_1 > \delta_2$. The reverse is true for Principal 2, who wants to say its type is lower than it is, because $\delta_2 < \delta_1$.

Delegated Authority

When authority is delegated to the Agent, she chooses her most preferred policy under full information. In this case, each Principal burns money to influence the Agent's policy. Although the Agent is choosing both x_1 and x_2, she has the same ideal policy for both policy, which means she chooses $x_1^D(t) = x_2^D(t) = \delta_A + t_1 + t_2$. From the perspective of each Principal, the centralized policy chosen by the Agent has a total weight of 1. Similar to the case of separated authority, how much money is burned is determined by a Principal's willingness to lie about its information. The following lemma establishes equilibrium strategies when authority is delegated to the agent.

Lemma 3. *For all $(t_1, t_2) \in T$ in the mD1-equilibrium with delegated authority,*

- *The Agent chooses $x_1^D(t) = x_2^D(t) = \delta_A + t_1 + t_2$,*

- *Principal* 1 *burns* $b_1^D(t_1) = 2(t_1 + s_1)(\delta_1 - \delta_A)$,
- *Principal* 2 *burns* $b_2^D(t_2) = 2(s_2 - t_2)(\delta_A - \delta_2)$.

A number of parts stand out. First, as mentioned before, the weights do not appear in the money burning function. This is because each Principal burns money to affect both x_1 and x_2, which has a total weight of 1. Second, what matters now is the bias difference between a Principal and the Agent, instead of the bias difference between both Principals. This is because the Agent is choosing the policy. Similar to before, the more players disagree about policies, the greater are incentives to lie, and the more money is burned to offset these incentives. In the following section, we discuss the welfare differences between the equilibrium with separated authority and the one with delegated authority.

Centralization versus Decentralization

Are states better off delegating authority to an Agent (centralization) or if they keep authority separated among themselves (decentralization)? To answer this question, we evaluate the welfare of both Principals in an *ex-ante* sense, that is, before the game is played. Formally, each Principal's welfare is

$$V_i(x^*, b_i^*) = \int_T u_i(x^*(t), t) - b_i^*(t_i) f(t) dt = Eu_i(x^*(t), t) - E[b_i^*(t_i)]. \tag{7}$$

This calculation can be performed both when authority is separate and when it is delegated. In the first case, Lemma 2 shows that Principals 1 and 2 choose their most preferred policies and burn $b_1^S(t_1)$ and $b_2^S(t_2)$ respectively. Define V_1^S and V_2^S as the welfare of Principal 1 and 2 if authority is separated, where

$$V_1^S := V_1(x_1^S, x_2^S, b_1^S) = -(1 - w_1)\Big((\delta_1 - \delta_2)^2 + 2s_1^3(\delta_1 - \delta_2)\Big), \tag{8}$$

$$V_2^S := V_2(x_1^S, x_2^S, b_2^S) = -(1 - w_2)\Big((\delta_1 - \delta_2)^2 + 2s_2^3(\delta_1 - \delta_2)\Big). \tag{9}$$

Similarly, taking into account Lemma 3, define V_1^D and V_2^D as the welfare of the Principals if authority is delegated to the Agent, where

$$V_1^D := V_1(x_1^D, x_2^D, b_1^D) = -(\delta_1 - \delta_A)^2 - 2s_1^3(\delta_1 - \delta_A), \tag{10}$$

$$V_2^D := V_2(x_1^D, x_2^D, b_2^D) = -(\delta_A - \delta_2)^2 - 2s_2^3(\delta_A - \delta_2). \tag{11}$$

Our notion of efficiency is that if the sum of utilities of the two Principals with delegation is higher than without the Agent, we say that delegation is efficient. However, we want to separate the welfare benefits of delegation due to informational reasons from those that would exist even without incomplete information. That is, even with complete information, both Principals could gain from delegation to an Agent because of the quadratic nature of payoffs. Each Principal could, if they weigh the other Principal's payoff sufficiently high, gain from delegation because they prefer a certain payoff over a lottery of payoffs, which depends on the Agent's bias δ_A. This part is captured by the first term in $V_i(x^*, b_i^*)$.

Instead, we care about the informational parts of the welfare of both Principals. We already know that the variance (or uncertainty) is zero in both cases. But the thing that is different is how much money is burned to achieve full information aggregation. The following proposition summarizes the welfare differences with and without delegation, decomposed into a policy component and an informational component.

Proposition 1. *Principal 1 and 2 jointly benefit from delegation if $V_1^D + V_2^D \geq V_1^S + V_2^S$:*

(i) Principal 1 gains from more preferred policies if $(\delta_1 - \delta_A)^2 < (1 - w_1)(\delta_1 - \delta_2)^2$, and Principal 2 gains from more preferred policies if $(\delta_A - \delta_2)^2 < (1 - w_2)(\delta_1 - \delta_2)^2$.

(ii) Principal 1 gains from cheaper signaling if $\delta_1 - \delta_A < (1 - w_1)(\delta_1 - \delta_2)$, and Principal 2 gains from cheaper signaling if $\delta_A - \delta_2 < (1 - w_2)(\delta_1 - \delta_2)$.

When is there an Agent that makes delegation welfare enhancing? As a result of the welfare analysis of Proposition 1, 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

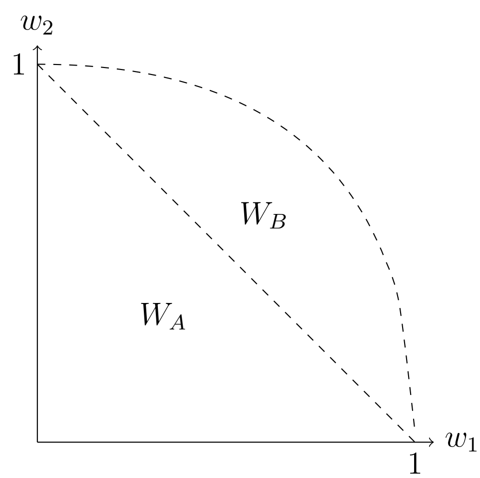

Figure 2: Existence of an Efficient Agent. In region W_A, there exists an Agent that allows for more efficient signaling. In regions W_A and W_B, there exists an Agent that provides policy benefits to both Principals.

Principals, as long as they strongly value policies made by others, Agents with particular biases can yield joint welfare gains to the Principals.

Corollary 1. *The existence of an Agent with some bias $\delta_A \in \mathbb{R}$ only depends on the level of externalities (w_1, w_2):*

- *If $\sqrt{1-w_1} + \sqrt{1-w_2} > 1$ (region W_A and W_B in Figure 2), there exists an Agent with bias δ_A that makes delegation welfare enhancing for both Principals through policy benefits.*
- *If $w_1 + w_2 < 1$ (region W_A in Figure 2), there exists an Agent with bias δ_A that makes delegation welfare enhancing for both Principals through signaling benefits.*

Figure 2 displays these two conditions as a function of the weights w_1 and w_2 that Principals 1 and 2 put on their own policy. The Figure shows that an Agent with a certain bias δ_A can be found such that both Principals would benefit from delegation through improved signaling or through policy benefits.

First, consider region W_A, where the weights w_1 and w_2 are sufficiently small. Under these parameters, whenever there are signaling benefits, both Principals would also delegate with complete information because of policy benefits. Thus, if delegation has no exogenous cost, and the IO is free to create, then the improved efficiency of signaling cannot be a reason for delegation by itself.

However, in region W_B, both Principals could benefit from delegation because of better policies, but signaling becomes more expensive. As a result, the presence of incomplete information and signaling may prevent states from delegating, because even though there are benefits from moderation, the increased costs of money burning may be too high. More broadly, IOs may be created by Principals, but not because information is exchanged in a better way, even if all information is revealed in the presence of an IO.

The opposite may also happen, however, if delegation has some exogenous cost. In region W_A, when each Principal cares sufficiently much about the other Principal's policy, delegation may be too costly in settings with complete information. But the fact that states aggregation information through burned money may provide additional benefits if it is done within an IO, and that may push states to efficiently delegate authority.

Efficient Delegation

Among the types of institutions in which authority is delegated to the Agent, which one is the most efficient? We explore two main institutional design choices separately: The Agent's ideal policy δ_A and the amount of discretion that the Agent has in policy-making. To simplify exposition, let there be a single policy $x \in \mathbb{R}$ that is made by the Agent. Principal 1 and 2 have a policy payoff of

$$u_1(x,t) = -(x - [\delta_1 + t_1 + t_2])^2 \qquad u_2(x,t) = -(x - [\delta_2 + t_1 + t_2])^2, \tag{12}$$

and a total payoff of $u_1(x,t) - b_1$ and $u_2(x,t) - b_2$ that also includes the cost of burned money. The Agent's payoff is simply

$$u_A(x,t) = -(x - [\delta_A + t_1 + t_2])^2. \tag{13}$$

First consider what type of Agent should be selected if she were also given full discretion.

Proposition 2. *An efficient Agent has an ideal policy of* $\hat{\delta}_A = \frac{1}{2}(\delta_1 + \delta_2 + s_1^3 - s_2^3)$ *as long as* $\hat{\delta}_A \in [\delta_2, \delta_1]$. *If this value is lower than* δ_2, *then the efficient Agent has the same ideal policy as Principal* 2. *If this value is higher than* δ_1, *then the efficient Agent has the same ideal policy as Principal* 1.

Efficiency requires that if the two Principals face the same level of uncertainty, the Agent should be exactly in the middle. This is, however, also the case if there were no uncertainty at all. However, if one Principal faces more uncertainty in terms of s_1 or s_2, then the Agent should be more aligned to that Principal. This is because this Principal has the greatest incentives to misrepresent its information and incur costs to signal. Thus, to minimize the total costs of signaling, it is preferable to align the Agent to the Principal who has the strongest incentives to misrepresent. In the extreme, the Agent should be perfectly aligned with the Principal that faces the most uncertainty. More strongly, if the only goal of an IO is to minimize the costs of money burning, then the Agent should always have the exact same ideal point as the Principal that faces greater uncertainty.[20]

Second, for a fixed bias δ_A, how much discretion should the Principals give if their goal is to maximize efficiency? We model an Agent's discretion as the size of an interval $X = [\underline{x}, \bar{x}]$ from which the Agent can pick a policy. Without loss of generality, we normalize $\delta_A = 0$ and let $\delta_2 < 0$ and $\delta_1 > 0$ be arbitrary but finite. In this case, the Agent's policy-making strategy is very simple. She either picks her ideal policy if it is feasible, or the closest possible policy given her level of discretion. Her ideal policy is $\hat{x}^A(t_1, t_2) = t_1 + t_2$. Thus, equilibrium

[20]This result is related to the model of Rantakari 2008 with cheap talk, in which it may be efficient to put all authority in the hands of either Principal.

policies are determined as follows

$$x^*(t_1, t_2) = \begin{cases} \underline{x} & \text{if } t_1 + t_2 \leq \underline{x}, \\ t_1 + t_2 & \text{if } \underline{x} < t_1 + t_2 < \bar{x}, \\ \bar{x} & \text{if } t_1 + t_2 \geq \bar{x}. \end{cases} \tag{14}$$

Even with full discretion, the Agent never takes an action outside the interval $Y = [-s_1 - s_2, s_1 + s_2]$. As a result, we only consider non-empty delegation intervals $X \subseteq Y$. If X is a strict subset of Y, then for some values of $t_1 + t_2$, the Agent cannot make full use of its information. This also imposes a potential loss on the Principals. On the other hand, if the length of the interval X decreases, then Principals have a smaller influence on policies that are chosen by the Agent. As a result, their incentives to strategically misrepresent their information weakens, which means that there is a less of a need for money burning.

Both Principals differ in opinion on how to constraint the Agent, if at all. Because the first Principal has a higher ideal point than the Agent, it always prefers that 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.

Proposition 3. *(conjecture) Principal* 1 *and* 2 *can jointly benefit from limited discretion compared to full discretion. For any Agent's bias, the size of the delegation interval weakly increases in preference alignment between the Principals. Additionally, the size of the delegation increases in the amount of uncertainty about each Principal's information.*

Applications

- Environmental policy[21]

[21] Mansouri and Youssef 2000.

- States have private information about the marginal costs of domestic firms that produce goods, but pollute. States only want to tax those with low marginal costs (?)
- So there are externalities that affect states.
- Each state's private information affects optimal environmental policies in both states (the amount of taxes on pollution, etc.)
- But each state has incentives to misrepresent its information and induce the other country to pollute less.
- So states talk with each other, but they also implement some policies domestically to influence policy-making in other states. That is, some domestic policies are chosen in such a way that they are not 'first-best' domestically, only to signal one's 'resolve' or 'willingness' to implement further policies that affect environmental outcomes.

Other applications? Alliances? Trade-policy? Military parades as a costly signal? ...

Discussion

It is important to understand the scope of the model, and to discuss what happens if some of our assumptions do not hold. In particular, the presence or absence of certain assumptions affects whether the existence of an IO can be efficient from the perspective of the states.

Throughout the analysis, we have focused on a specific setting of communication among states. The main goal was to study the informational role of IOs in a 'hard' case. First, we assumed that information is essentially soft. This means that states cannot verify information that is provided to them. Instead, they send messages and incur costs to signal their information. This assumption is important for our main results, because with hard information, states can provide verifiable evidence about their privately held information. In that case, even though there is an incentive to misrepresent information, lies are detectable, and in our setting, this guarantees full information transmission. This would by and large remove the strategic tension in our model, as regardless of whether authority is delegated to an IO, information is fully aggregated at zero cost. Thus, there is no informational reason to delegate to IOs in the first place.

Second, we assumed that there is no shadow of the future. Typically, models of communication predict that more information can be transmitted if actors operate in a repeated setting. The fact that lies are detected in future rounds of play means that punishments can induce truth-telling in the present. Thus, by not allowing for reputation building, we have made it harder to ensure truthful communication. It is, however, unclear why IOs would help more if there is a shadow of the future. A possibility is that IOs allow states to better monitor each other, potentially providing an informational rational for delegation to IOs.

Third, the IO in our model has no private information itself. This assumption was made to ensure that states do not delegate to obtain information that they otherwise would not be able to get. Substantively, it is unclear as to why it could ever be the case that IOs would ever know more than its member states combined. It seems that if interested parties (other than states) provide information to IOs, they would also provide it to states.

Moreover, we have assumed that the presence of IOs allows for some sort of commitment ability on the part of states. That is, IOs are granted independence to make policies, while other formal mechanisms are unable to ensure that states commit to their policies. The IO is therefore not just a mediator or forum for communication, instead, it also serves as a mechanism through which both principals ensure that certain policies are implemented.

Alternatively, IOs may have the ability to monitor and independently acquire the information of states. However, this may be too costly, or it may simply not work because of strategic considerations.[22]

[22]Sanchez and Urpelainen 2014.

Conclusion

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

Instead, we start off with the observation that information initially comes from states, and that IOs endogenously 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.

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 institutions that allow them to aggregate information more cheaply.

A Supplemental Appendix (incomplete)

One of our claims is that the presence of cheap talk is irrelevant when we apply the refinement of monotonic D1. For the sake of exposition, we have only allowed Principals to burn money to signal their information. To prove this claim, we first describe the full model with cheap talk and burned money. We then show that the application of monotonic D1 generates a separating equilibrium that is unique, in which only burned money is used to separate types. Our notation is similar to Karamychev and Visser 2016.

A.1 Full Model and Equilibrium

In stage 1, Nature draws $t = (t_1, t_2)$. 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), every player other than i forms posterior about t_i denoted by CDF $G_i(z|m_i, b_i) := Pr(t_i \leq z|m_i, b_i)$. With separated authority, Principal j takes action x_j. Let $\alpha_j(m_i, b_i, t_j)$ be his pure strategy. With delegated authority, Agent A takes action x_i and x_j. Let $\alpha_A(m_i, b_i, m_j, b_j)$ be his pure strategy.

An equilibrium is $\Omega = \langle \sigma_1(t_1), \sigma_2(t_2), \alpha_1(m_2, b_2, t_1), \alpha_2(m_1, b_1, t_2), G_1(t_2|m_2, b_2), G_2(t_1|m_1, b_1) \rangle$ 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) Beliefs about Principal $i = 1, 2$'s type t_i, denoted by $G_i(t_i|m_i, b_i)$ that are consistent with $\sigma_i(t_i)$ for signals (m_i, b_i) on the equilibrium path.

The existence of an infinite number of equilibria follows directly from Proposition 1 in Karamychev and Visser 2016. Before analyzing the separating equilibrium of the game, we define monotonic D1 and apply it to our game. We show in Appendix B.1 that D1 potentially allows for multiple equilibria, while monotonic D1 guarantees a unique separating equilibrium, shown in Appendix A.2.

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 about Principal j's type 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

$$y_i(t_j, t_j') := \begin{cases} \arg\max_{x_i} \int_{t_j}^{t_j'} -(x_i - [\delta_i + t_i + \tau])^2 f(\tau) d\tau & \text{if } t_j' > t_j \\ \delta_i + t_i + t_j & \text{if } t_j' = t_j. \end{cases} \quad (15)$$

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 $G_j(t_j|m_j, b_j)$. With some changes in notation, the following definition of D1 comes from Kartik 2005.

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 $x_j \in [\xi_l(\tilde{b}_i), \xi_h(\tilde{b}_i)]$[23]

A.2 Proof of Lemma 1

Lemma 1. With both separated and delegated authority, there is a unique PBE that survives monotonic D1 and it is fully separating.

Proof. Suppose not. Then there exists a PBE that survives monotonic D1 that is not fully separating. By Proposition 1 in Karamychev and Visser 2016, a PBE can be characterized completely by a set of pooling intervals. Suppose without loss of generality that Principal 1 is not fully separating. Because the PBE satisfies monotonic D1, we have that $b_1(t_1)$ is weakly increasing or weakly decreasing.

Suppose first it is weakly increasing.

... □

A.3 Proof of Lemma 2

Consider a separating equilibrium. Principal i observes t_i and his belief $G_j(t_j)$ puts probability 1 on t_j. It is obvious that $x_i(t) = \delta_i + t_i + t_j$ maximizes $u_i(x, t, b_i)$ for all $t \in T_1 \times T_2$. 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' through burning $b_i(t_i')$, Principal i obtains

$$\begin{aligned} U_i(t_i') &= \int_{[-s_j,s_j]} -(1-w_i)(\delta_j - \delta_i + t_j + t_i' - t_i - t_j)^2 \frac{1}{2s_j} dt_j - b_i(t_i') \\ &= -(1-w_i)(\delta_j - \delta_i + t_i' - t_i)^2 - b_i(t_i') \end{aligned} \tag{16}$$

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

$$\frac{d}{dt_i'} U_i(t_i') = -2(1-w_i)(\delta_j - \delta_i + t_i' - t_i) - b_i'(t_i') = 0 \tag{17}$$

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

$$b_i(t_i) = -2t_i(1-w_i)(\delta_j - \delta_i) + C, \tag{18}$$

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 $t_1 = -s_1$, Principal 1 burns $b_1(-s_1) + C$. As Principal 1 cannot burn a negative amount of money, we have $C \geq 0$. Suppose, for a proof by contradiction that $C > 0$. Because $b_1(t_1)$ is increasing, there exists no $t_1 \in [-s_1, s_1]$ such

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

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 $G_1(t_1|0)$ over t_1 after observing $b_1 = 0$. For any such $G_1(t_1|0)$, Principal 2 takes an action of $x_2(0, t_2) = \delta_2 + E[t_1|G_1(t_1|0)] + t_2$, where $-s_1 \leq E[t_1|G_1(t_1|0)] \leq s_1$. Now consider Principal 1's payoff given type $t_1 = E[t_1|G_1(t_1|0)]$ if he were to deviate to $\tilde{b}_1 = 0$, which is

$$\begin{aligned} U_1(t_1, \tilde{b}_1) &= -(1 - w_1)(\delta_2 + E[t_1|G_1(t_1|0)] - t_1 - \delta_1)^2 - \tilde{b}_1(t_1), \\ &= -(1 - w_1)(\delta_2 - \delta_1)^2. \end{aligned} \tag{19}$$

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,

$$b_1^*(t_1) = 2(1 - w_1)(t_1 + s_1)(\delta_1 - \delta_2), \tag{20}$$

as required.

Now consider Principal 2 with a money burning function of

$$b_2(t_2) = -2t_2(1 - w_2)(\delta_1 - \delta_2) + C. \tag{21}$$

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 $b_2(s_2) = 0$. Plugging this into Principal 2's money burning function yields

$$C = 2s_2(1 - w_2)(\delta_1 - \delta_2). \tag{22}$$

Plugging in this constant yields

$$b_2^*(t_2) = 2(s_2 - t_2)(1 - w_2)(\delta_1 - \delta_2), \tag{23}$$

as required. This concludes the proof.

A.4 Proof of Lemma 3

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 1 and 2. The steps are similar to the Proof of Lemma 2 and are not completely copied.

Without loss of generality, consider Principal 1. By reporting truthfully, the following first order condition has to be satisfied, evaluated at $t_1' = t_1$.

$$\frac{d}{dt_1'} U_1(t_1') = -2(\delta_A - \delta_1 + t_1' - t_1) - b_1'(t_1') = 0. \tag{24}$$

Imposing that $t_1 = t_1'$ and integrating out Principal 1's private information yields

$$b_1^*(t_1) = 2(t_1 - s_1)(\delta_1 - \delta_A), \tag{25}$$

by a similar argument as in Lemma 2.

A.5 Proof of Proposition 1

Follows from the argument in the text.

A.6 Proof of Proposition 2

As a function of δ_A, the level of efficiency equals $V_1^D + V_2^D$, i.e.,

$$W(\delta_A) = -(\delta_1 - \delta_A)^2 - 2s_1^3(\delta_1 - \delta_A) - (\delta_A - \delta_2)^2 - 2s_2^3(\delta_A - \delta_2). \tag{26}$$

Maximizing this function subject to $\delta_A \in [\delta_2, \delta_1]$ yields the result.

A.7 Proof of Proposition 3

Consider Principal 1. In a separating equilibrium, each type t_1 earns

$$\begin{aligned} U_1(t_1) = &- \int_{-s_2}^{\underline{x}-t_1} (\underline{x} - [t_1 + t_2 + \delta_1])^2 dF(t_2) - \int_{\underline{x}-t_1}^{\bar{x}-t_1} \delta_1^2 dF(t_2) \\ &- \int_{\bar{x}-t_1}^{s_2} (\bar{x} - [t_1 + t_2 + \delta_1])^2 dF(t_2) - b_1(t_1) \end{aligned} \tag{27}$$

Due to the uniform distribution, this simplifies to

$$U_1(t_1) = \frac{1}{6s_2}\Big(- (\delta_1 + s_2 + t_1 - \underline{x})^3 + (\delta_1 - s_2 + t_1 - \underline{x})^3 - 3\delta_1^2(\bar{x} - \underline{x})\Big) - b_1(t_1). \tag{28}$$

...

B Secondary Results

B.1 D1 and multiple equilibria

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 **??**, 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

$$Eu_1^*(t_1) = \int_{[0,1]} (-w_1(t_2 - E[t_2])^2 - (1-w_1)(\delta_2 - \delta_1 - t_1 + E[t_1])^2) f(t_2) dt_2. \quad (29)$$

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

$$BR_2 = [\delta_2 + t_2, \delta_2 + t_2 + 1]. \quad (30)$$

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

$$Eu_1(x_1, x_2, \tilde{b}_1, t_1) = \int_{[0,1]} (-w_1(t_2 - E[t_2])^2 - (1-w_1)(x_2' - \delta_1 - t_1)^2) f(t_2) dt_2 - \tilde{b}_1. \quad (31)$$

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

$$D(t_1, \tilde{b}_1) = [x_2' \in BR_2 : -(1-w_1)(\delta_2 + E[t_1] - \delta_1 - t_1)^2 < -(1-w_1)(x_2' - \delta_1 - t_1)^2 - \tilde{b}_1]. \quad (32)$$

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 $\mu^*_{b_1}(t_1) = 0$. 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 $\mu^*_{b_1}(t_1) = 0$. Thus, beliefs only put positive probability on boundary types $t_1 = 0$ and $t_1 = 1$.

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

$$\begin{aligned} \hat{b}_1 &= -(1-w_1)(\delta_2-\delta_1)^2 + (1-w_1)(\delta_2-\delta_1+E[t_1]-1)^2, \\ &= (1-w_1)(\delta_2-\delta_1+E[t_1])^2. \end{aligned} \tag{33}$$

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

$$E[t_1] = \Delta_{12} + \frac{1}{2}[1 - (\Delta_{12})^2], \tag{34}$$

which is 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. □

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