The Economics of Two-Party Communication: Increasing Welfare across Media. *

Extended Abstract

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Communications media, typically useful, are nevertheless imperfect. Email, for example, is highly cost effective for many purposes yet participants are troubled by unsolicited communication – often regarded as spam. To increase the value of participation, those using the medium can employ various mediating mechanisms. These mechanisms have economic consequences, both for participants and for general welfare.

To compare the effects and effectiveness of competing mechanisms, we develop a media independent model of two-party communications, one suitable for analyzing welfare effects in email, telecom, SMS, or similar media. After a short discussion of participation constraints, we examine participants' values and costs (for senders and receivers) under a baseline "null mechanism," the case of no intervention for the medium. For comparison, we then introduce both an idealized or 'perfect' filter, as well as a signaling mechanism that allows side payments via a bond. We find that the bond mechanism has many favorable properties and can beat the perfect filter in certain circumstances for both individual surplus and for overall welfare.

A Model of Communications

We model communications as a multi-period game between two participants. There is a stream of communications from sender to receiver, where each period has one message. The message at time t will have value s_t to the sender and r_t to the recipient. The total discounted value of a stream of communications will be $\sum_{i=0}^{\infty} \delta^t s_t$ and $\sum_{i=0}^{\infty} \delta^t r_t$ for the sender and receiver respectively, assuming a discount factor of δ. These values $s_0, \ldots$ and $r_0, \ldots$ are distributed probabilistically.

Assume there are two possible types of senders, for exposition called G and B (good and bad, respectively). The primary difference between these two types is that the expected value of the stream for type G is positive, while the expected value for type B is negative:

$$E\left[r^G\right] = \sum_{i=0}^{\infty} \delta^t E\left[r_t^G\right] \geq 0$$

$$E\left[r^B\right] = \sum_{i=0}^{\infty} \delta^t E\left[r_t^B\right] \leq 0$$

First we consider only initial communications, representing time $t = 0$. Let α be the fraction of these messages from type B (and $1-\alpha$ be the fraction from type G). The expected value of the first message in a stream is then

$$\alpha E\left[r_0^B\right] + (1-\alpha) E\left[r_0^G\right] \leq 0$$

This expected value is negative representing the preponderance of spam currently.

Next, let β be the fraction of all messages that represent initial or unsolicited communications. Since the bad types have a negative expected lifetime value, a recipient would not continue communications with them. Therefore, they would receive the value from subsequent messages only for senders of type G. The total value of being open to communication (having a mailbox, etc.) is

$$\beta\left(\alpha E\left[r_0^B\right] + (1-\alpha) E\left[r_0^G\right]\right) + (1-\beta))\left(\sum_{i=1}^{\infty} \delta^t E\left[r_t^G\right]\right) \geq 0 \quad (1)$$

This value must be positive for a recipient to participate at all (individual rationality).

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	Baseline	Perfect Filter	ABM
RS	$k \cdot \int_{\underline{r}}^{\overline{r}} \int_{c_s}^{\overline{s}} (r - c_r)\ ds\ dr$	$k \cdot \int_{c_r}^{\overline{r}} \int_{\frac{c_s}{\eta}}^{\overline{s}} (r - c_r)\ ds\ dr$	$k \cdot \int_{\underline{r}}^{\overline{r}} \int_{c_s+b}^{\overline{s}} (r - c_r + b)\ ds\ dr$
SS	$k \cdot \int_{\underline{r}}^{\overline{r}} \int_{c_s}^{\overline{s}} (s - c_s)\ ds\ dr$	$k \cdot \int_{c_r}^{\overline{r}} \int_{\frac{c_s}{\eta}}^{\overline{s}} (s)\ ds\ dr$ - $k \cdot \int_{\underline{r}}^{\overline{r}} \int_{\frac{c_s}{\eta}}^{\overline{s}} (c_s)\ ds\ dr$	$k \cdot \int_{\underline{r}}^{\overline{r}} \int_{c_s+b}^{\overline{s}} (s - c_s - b)\ ds\ dr$

Table 1: Sender and Recipient Surpluses

Unsolicited Communications

Since the second term of Equation (1) is expected to be positive (by the IR constraint), we focus only on the initial message in communications.

The value of this message to a sender is s and is known to the sender. The value of that same communication to the recipient is r, and she does not learn this until after receiving the message and incurring her receipt cost. We assume these lie within a range of values. $s \in [\underline{s}, \overline{s}]$ and $r \in [\underline{r}, \overline{r}]$, uniformly distributed. To insure participation, we assume maximum values are net positive $\overline{s} > c_s, \overline{r} > c_r$. Minimum values may range arbitrarily below maximum values, and may be negative, representing offensive communication.

In addition to the value, there are marginal costs for initiating and receiving a communication. Let c_s represent total cost of initiating a communication, and c_r be total cost of receiving and processing this message. Both sender and receiver know these costs. We assume all parties have quasi-linear utilities, which allows for the direct transfer of utility as money.

Baseline Case

For the baseline case we add no further rules. We assume that the sender can walk away at any time, implying that he only sends if $s \geq c_s$. This is interim individual rationality for the sender, since he knows his value and costs. Recipients, however, can only opt in or out of communications generally (have a cell phone, have an email box, etc.); she cannot opt out of individual messages without first incurring the costs of reading them. This is *ex ante* individual rationality for the recipient. The difference in when each party makes his or her participation decision is made is the fundamental problem with initiating communication.

With these model parameters defined, we can determine the sender and recipient surplus (SS_0 and RS_0) for the baseline case where no mechanism is employed. The exact equations can be found in Table 1. Both equations have a uniform distribution constant k given by $k = \frac{1}{\overline{s}-\underline{s}} \cdot \frac{1}{\overline{r}-\underline{r}}$.

A Perfect Filter

As a point of comparison, consider an idealized mechanism. Define a “perfect filter” as a mechanism that accepts communications on behalf of a recipient iff a fully informed recipient would rationally accept based on net message value. It costs nothing to operate, and makes no mistakes. Accordingly, the perfect filter provides interim individual rationality for the recipient, giving her the same balanced veto on participation in any single communication.

To incorporate the perfect filter into the model, we assume it eliminates any email where $r < c_r$ before the receiver receives it, the value to the recipient for such email is zero. Should the sender still send, their surplus is decreased by c_s, and any value s he might have gained from delivery is lost.

In addition, we expect senders to notice that only a fraction η of their messages reach their destination. Senders will suffer a corresponding reduction in surplus to ηs. If initially senders choose to send messages of value $s > c_s$, application of the perfect filter limits this choice to $\eta \cdot s > c_s$. Equivalently, higher proportional costs imply a choice of $s > \frac{c_s}{\eta}$. *eta* will be $\frac{\overline{s}-c_s}{\overline{s}-\underline{s}}$.

The definitions of sender and recipient surplus are found in Table 1. The second term in SS_{PF} represents the sender losses due to emails sent but subsequently filtered before receipt. These losses, in effect, drive up the threshold value on marginal cost $\frac{c_s}{\eta}$.

Attention Bond Mechanism

Analogous to a standard bond, delivering email to an inbox requires an unknown sender to place a small pledge b into escrow with a third party. In the case of screening, recipients determine the size of this bond *ex ante*, which can dynamically adjust to opportunity costs. The email is delivered only after the recipient receives suitable confirmation that the bond has been posted. When the recipient opens the email, she may act solely at her discretion to seize the pledge. Taking no action releases the escrow after a period of time.

The cost increase from paying the bond value has the secondary effect of reducing total emails sent to those where $s > c_s + E[b]$ where $E[b]$ is the expected amount per email that is seized. As before, we have interim individual rationality for the sender but only *ex ante* individual rationality for the recipient.

Figure 1 then serves as a visual comparison of the no-intervention baseline, perfect filter, and attention bond. This figure shows the space of all possible message values, with all communications to the northeast of line W representing communications that makes a positive contribution to social welfare.

Single Distribution Results

We start with results where the sender and recipient values are drawn from a single distribution, which forms the basis of later analysis. First, we must calculate what bond the recipient should charge to receive the maximal utility.

Lemma 1 *The recipient optimal bond b^+ is*

$$b^+ = \frac{1}{2}\left((\overline{s} - c_s) - \left(\frac{\overline{r} + \underline{r}}{2} - c_r\right)\right)$$

This optimal bond is exactly one half of the total sender surplus minus the average recipient surplus. This makes sense, as it forces the sender to split his surplus with the recipient.

With the optimal bond calculated as above, Recipient surplus under the ABM is always at least that of the baseline case, that $\mathrm{RS}_{b^+} \geq \mathrm{RS}_0$. Since $b^+ = 0$ reproduces the baseline case, the added degree of freedom ensures the left hand side weakly dominates the right. This means that the recipient is always at least as well off using the attention bond mechanism.

Next, we begin our comparisons with the perfect filter.

Proposition 1 *Using the ABM creates greater recipient surplus than using a perfect filter,* $\mathrm{RS}_{b^+} \geq \mathrm{RS}_{PF}$*, if and only if*

$$\left[(\overline{s} - c_s) + \left(\frac{\overline{r} + \underline{r}}{2} - c_r\right)\right]^2 \geq 2\eta\left(\overline{s} - \frac{c_s}{\eta}\right)(\overline{r} - c_r)$$

Social Welfare

To consider the welfare effects, let welfare $\mathrm{W} = \mathrm{SS} + \mathrm{RS}$, the sum of recipient and sender surpluses.

Proposition 2 *The total social welfare with a recipient-chosen bond is greater than that of a perfect filter* $\mathrm{W}_{b^+} > \mathrm{W}_{PF}$ *if and only if the following is true:*

$$\left[(\overline{s} - c_s) + \left(\frac{\overline{r} + \underline{r}}{2} - c_r\right)\right]^2 \geq 3\eta\left(\overline{s} - \frac{c_s}{\eta}\right)\left[(\overline{r} - c_r) + \left(\overline{s} - \frac{c_s}{\eta}\right)\right] \quad (2)$$

An alternative method of choosing the bond is to attempt to maximize total social welfare. This is the bond that a social planner would choose for the recipient.

Lemma 2 *The social welfare maximizing bond size is*

$$b^\star = \left(c_r - \frac{\overline{r} + \underline{r}}{2}\right)$$

Note that the result for $b^\star$ is proportional to the average recipient surplus, but unrelated to sender surplus. The bond essentially compensates the recipient for their inconvenience. Also note that if the recipient receives positive average value communications relative to cost, then the socially optimal bond becomes a subsidy that increases good communications sent.

Knowing the welfare maximizing bond, we can ask when and if this bond produces greater social welfare than the perfect filter.

Corollary 1 *The total social welfare with a socially-optimal bond is greater that of a perfect filter,* $\mathrm{W}_{b^\star} > \mathrm{W}_{PF}$*, if and only if the following is true:*

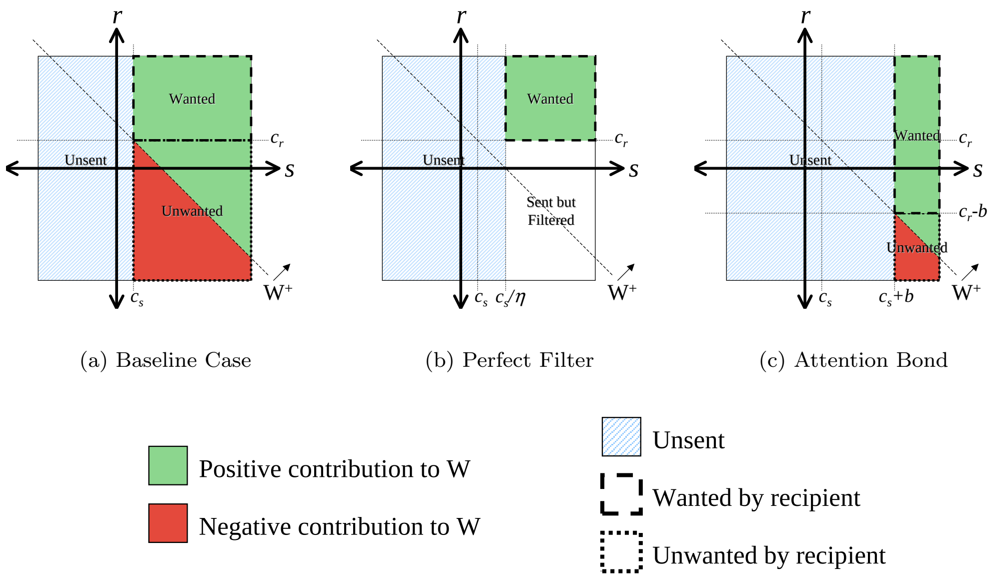
$$\left[(\overline{s} - c_s) + \left(\frac{\overline{r} + \underline{r}}{2} - c_r\right)\right]^2 \geq \eta\left(\overline{s} - \frac{c_s}{\eta}\right)\left[(\overline{r} - c_r) + \left(\overline{s} - \frac{c_s}{\eta}\right)\right] \quad (3)$$

Multiple Distributions

Up to this point, we have modeled a single value distribution. As lost acquaintances and spammers may represent different distributions, we extend this model to handle multiple sender types, such as the good and bad above. Let value distributions $V_1, \ldots, V_n$, have bounds $\overline{s}_i, \underline{s}_i, \overline{r}_i, \underline{r}_i$ with $k_i = \frac{1}{\overline{s}_i - \underline{s}_i} \cdot \frac{1}{\overline{r}_i - \underline{r}_i}$. We make the additional assumption that a sender knows in which distribution their anticipated communication belongs (knows his type).

A recipient cannot know the source type of a message *ex ante*, and while she does know the relative likelihood α_i of an email coming from a given distribution i, she can only choose a single bond size ϕ for use across all messages.

After she has read an email, the recipient then has the choice to seize the bond or return the bond to the sender. Previously this choice was implicit in defining b as the expected bond value. Here we analyze two parts: ϕ is the bond, and p_i is the probability that the recipient seizes it for value distribution i. *Ex ante*, bonds ϕ must be the same for all senders, but



(a) Baseline Case (b) Perfect Filter (c) Attention Bond

Figure 1: Comparison of Three Mechanisms

ex post p_i may differ by distribution. For a single distribution, $b = p\phi$.

Surpluses are

$$\mathrm{SS}_{\phi,p_1,\ldots,p_N} = \sum_{i=1}^{N} \alpha_i k_i \cdot \int_{\underline{r}_i}^{\overline{r}_i} \int_{c_s+p_i\phi}^{\overline{s}_i} (s - c_s - p_i\phi)\, ds\, dr \quad (4)$$

$$\mathrm{RS}_{\phi,p_1,\ldots,p_N} = \sum_{i=1}^{N} \alpha_i k_i \cdot \int_{\underline{r}_i}^{\overline{r}_i} \int_{c_s+p_i\phi}^{\overline{s}_i} (r - c_r + p_i\phi)\, ds\, dr \quad (5)$$

The ABM in Multiple Distributions

Here we present results for multiple possible value distributions.

Lemma 3 *Given N value distributions $V_1, \ldots, V_N$, the recipient-chosen optimal bond ϕ^+ is*

$$\phi_N^+ = \frac{\sum_{i=1}^{N} \frac{\alpha_i}{\overline{s}_i - \underline{s}_i} \cdot p_i \cdot \left(\overline{s}_i - c_s - \left(\frac{\overline{r}_i + \underline{r}_i}{2} - c_r\right)\right)}{\sum_{i=1}^{N} \frac{\alpha_i}{\overline{s}_i - \underline{s}_i} p_i^2}$$

Note that this is a weighted average of bonds from the single distribution case.

Lemma 4 *For any distribution V_i, given a bond ϕ, the optimal policy p_i^+ is*

$$p_i^+ = \frac{1}{2\phi}\left(\overline{s}_i - c_s - \left(\frac{\overline{r}_i + \underline{r}_i}{2} - c_r\right)\right)$$

Differential Costs

For comparison, consider the special case of two distributions, the "good" communications G and the "bad" communications B. Qualitatively, the difference between these two distributions is that the expected value of communications to the recipient for B is significantly lower than for G: $\frac{\overline{r}_G + \underline{r}_G}{2} < \frac{\overline{r}_B + \underline{r}_B}{2}$.

Proposition 3 *Under the ABM, if the difference in mean recipient values exceeds the difference in maximum sender surplus, there exists a separating equilibrium in which less desirable senders incur higher costs*

$$E[r_G] - E[r_B] > \overline{s}_G - \overline{s}_B$$

if and only if $c_s + p_G^+\phi^+ < c_s + p_B^+\phi^+$.

Increased Information

Here we consider the case where both the sender and recipient know each other's values. The sender knows the value to the recipient *ex ante*, but the recipient does not learn the sender's value until she learns her own private r after receiving and incurring costs c_r.

Note that perfect correlation of sender and receiver values (assuming invertibility) is a subset of the common knowledge case. In the analysis that follows, we make one additional assumption, that the recipient can credibly commit *ex ante* to a policy. This commitment can be enforced via external reputation systems or a trusted third party.

Proposition 4 *If the recipient can commit* ex ante *to a policy, senders know* ex ante *the value to the recipient, and the recipient learns or can infer s after learning r, then recipient surplus under the ABM is at least as great as that under the perfect filter:* $\mathrm{RS}_b \geq \mathrm{RS}_{PF}$*. In addition, maximum social surplus is achieved, with all surplus going to the recipient, meaning* $\mathrm{W}_b = \max W$*,* $\mathrm{SS}_b = 0$*, and* $\mathrm{RS}_b = \mathrm{W}_b$.

Proof: Consider the following mechanism. The recipient requests a bond of size $b = \max\{\overline{s} - c_s, c_r - \underline{r}\}$. She commits *ex ante* to refund $\rho(s,r)$ to the recipient, where

$$\rho(s,r) = b - \max\{s - c_s - \epsilon, c_r - r\}$$

where $\epsilon \geq 0$. The sender's strategy is to send if and only if $s - c_s - b + \rho(s,r) \geq 0$

This mechanism is budget balanced, individually rational for both parties, efficient, and is a dominant strategy equilibrium. Since this mechanism uses no outside funds, it is trivially budget balanced. Next we show that it is individually rational.

The bond is added to the recipient's net value, but the refund is then removed. This yields her total surplus.

$$\begin{aligned}\mathrm{RS}_b &= r - c_r + b - \rho(r,s)\\ &= r - c_r + b - (b - \max\{s - c_s - \epsilon, c_r - r\})\\ &= r - c_r + \max\{s - c_s - \epsilon, c_r - r\}\\ &= \max\{r - c_r + s - c_s - \epsilon, 0\}\\ &\geq 0\end{aligned}$$

Since $\mathrm{RS}_b \geq 0$, it is *ex ante* individually rational for the recipient to participate. As before, the sender's interim individual rationality allows him to choose per-message whether to send.

Next we show efficiency. First we must calculate sender willingness to send messages. The sender loses the value of the bond b and receives his net value plus the refund from the recipient:

$$\begin{aligned}\mathrm{SS}_b &= s - c_s - b + \rho(s,r)\\ &= s - c_s - b + b - \max\{s - c_s - \epsilon, c_r - r\}\\ &= s - c_s - \max\{s - c_s - \epsilon, c_r - r\}\\ &= \min\{(s - c_s) - (s - c_s - \epsilon), (s - c_s) - (c_r - r)\}\\ &= \min\{\epsilon, s - c_s + r - c_r\}\end{aligned}$$

Since $\epsilon \geq 0$, the only messages the sender will choose *not* to send are when $s - c_s + r - c_r < 0$. This is precisely the condition for positive welfare. Therefore, all positive welfare messages are sent, yielding the maximum possible total surplus.

Finally, we show that this mechanism is a dominant strategy equilibrium. Let $\epsilon \to 0$. This provides the recipient with all available surplus, and leaves zero surplus for the sender while still remaining individually rational. Since the sender has interim individual rationality, it is impossible for any mechanism to provide the recipient with greater surplus. Therefore, it is a dominant strategy for the recipient. Given this dominant strategy, the best response for the sender is to participate, as at worst he is indifferent between participation and non-participation. ■

Since communication itself is the negotiation problem, the ABM takes advantage of the fact that senders initiate contact. It avoids complex and costly negotiation and instead has the recipient implement a take-it-or-leave-it contact policy that shifts power to the recipient.

Conclusions

We explored a mechanism to screen unsolicited communications based on economic rather than technological or regulatory principles. Our first observation is that mechanisms designed to promote valuable communication can outperform those designed merely to block wasteful communication. Our second is to shift focus from the information in the message to the information known to the sender. Information revelation mechanisms can then be used to force people who knowingly misuse communication to incur higher costs than those who do not. Third, although private knowledge of message value might favor senders over receivers, the information rents disappear under a take-it-or-leave-it offer by recipients to refuse non-conforming communications. In certain cases we can show this approach leaves recipients better off than even an idealized or "perfect" filter that costs nothing and makes no mistakes.

WISE: A presentation at WISE will include several additional propositions, comparison against multiple competing spam proposals, as well as a literature review and complete references for this line of research.