A Communication Model with Limited Information-Processing Capacity of Recipients

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Abstract

This paper offers a computational model of profit-driven communication, when information-processing capacity of recipients is limited. Even though the model was inspired by the present situation in the direct online marketing industry, it has a wide applicability. In the model, profit-seeking communication firms exploit freely-available attention of recipients, while recipients allocate their limited cognitive capacity between competing tasks. We run numerical experiments to test various technical, market and regulatory proposals that aim at improving the social outcome. The paper makes a theoretical contribution to the economic literature and it also elucidates the current public policy debate about direct online marketing industry.

Introduction

In 1947, Herbert Simon (Simon, 1947) wrote about the need to recognize that the rationality of human decision makers is imperfect and that individuals possess limited attention capacity. At the time, the idea that human performance could be compromised by too much information, instead of not enough information, was novel. However, Simon’s work was later supported by seminal work in cognitive science on information processing limitations in human memory (Miller 1956; Atkinson and Shiffrin 1968; Baddeley and Hitch 1974) and attention (Broadbent 1958; Treisman and Gelade 1980). Today the notion of human cognition as bounded by at times severe limitations on cognitive capacity and processing is the dominant view in cognitive science.

Such findings have direct practical applicability. For example, Shimp and Gresham (Shimp and Gresham, 1983) took a cognitive-perspective look at marketing communication; they identified eight stages of processing of an advertisement. An ad is information that must be processed and hence requires the customer to dedicate the processing capacity to it. Often individuals choose not to. For example, an individual typically watches TV at most 70 percent of the time that the TV is on (Harris 2004: 40). For advertisers the greatest challenge is to get the attention of viewers (Harris 2004: 105). This is true in general for all modern organizations, which operate in the new information-rich economy. For them, customer attention is the most valuable resource (Davenport and Beck, 2001).

This paper offers a model of profit-driven communication, when information-processing capacity of recipients is limited. The basis of our analysis is the limited capacity information-processing view in cognitive research (Lang, 2000).

Direct online marketing

Presently, about 73 percent of the American population, or 147 million people, use the Internet (Madden, 2006). Among them, 91 percent use electronic mail (Emaillabs, 2006). Over the years, unsolicited commercial email, or spam, has been a growing problem. Even though the majority of the population still finds email useful (Strader *et al.*, 2005), the sentiment is strongly against spam. Some of us feel that “spam has ruined the Internet” (Fallows, 2003).

It is not likely, however, that spam will go away for economic and political reasons. There is a strong opinion that spam should not be banned (e.g. Dai and Li, 2004; Goldman, 2006). From the economic viewpoint, the Internet has had a revolutionary impact on practice of marketing (Chittenden and Rettie, 2003). Return on investment for direct online marketing is much superior to any other type of a marketing campaign. Economic forces drive spam beyond email to other platforms, including instant messaging (spim), blogs, and mobile text messaging. Now even cell-phones are affected by spam (Verizon filed a law suit in 2006 against a spam company). Spam also provided an inexpensive communication tool for political and grass-roots organizations (Sweet, 2003).

Theoretical arguments about spam policies have been based on works that offer a comparative static analysis of the situation. Anderson and de Palma (2005) offer an economic model of spam that utilizes attention as a scarce resource. Khong (2004) also identifies email mailbox as a common resource. In Khong’s framework, message processing has direct costs and “second order” costs, which occur when useful messages are filtered out. Khong looks at the utility of a recipient. Loder et al. (Loder *et al.*, 2004) review spam policies from the standpoint of total surplus, which is a sum of sender and recipient surplus.

On the practical side, there are private, public and market fixes to the market failures caused by the negative externality associated with the direct online marketing (see Table 1). In this section we review some of them.

Table 1: Approaches to the Management of the Email Common

APPROACH	STRENGTH	DRAWBACK	STATUS
PRIVATE SOLUTIONS			
SELF-REGULATION, RESPONSIBLE USE, ETHICAL BEHAVIOR, SELF-HELP	• Simplicity • No new technology or regulatory changes.	• Unlikely to work in practice. • Too strong an incentive to break (prisoner's dilemma). • Limited effectiveness • Vigilantism	• Worked in the beginning, but popularity of Web beyond techies has changed online culture. • There is an active community of anti-spam enthusiasts
LITIGATION	• Effective way to shut down spam operations	• Costly • Lengthy	• ISPs and government bring lawsuits against spammers
EMAIL FILTERING (OSI NETWORK LAYER 7) SERVER BLACK LIST, SIGNATURE-BASED, HEURISTIC, BAYESIAN, CHALLENGE-RESPONSE	• May reduce the amount of SPAM for the user. • No need for complicated third-party schemes and systems. • Inexpensive systems available. • Can be implemented by ISPs.	• May increase the amount of SPAM due to an arms race scenario. • Local solution so global network impacts and associated economic drain not mitigated. • Cost may be borne by senders in the form of challenge-response and false positives.	• SPAM blocking industry has mushroomed. • Large ISPs all filter SPAM. • Many vendors.
TARGETED UCE	• Only relevant UCE arrives	• Lists are more costly for spammers	
REQUEST AND RETURN	•	•	
PUBLIC SOLUTIONS			
REGULATION	• No need for technical changes. • Can be applied uniformly across a state or nation. • Specify precisely what is allowed and what is not.	• Enforceability is questionable. • Regulation of offshore operators in doubt. • Technical schemes to avoid prosecution. • May have perverse impact to drive out more legitimate UCE originators and raise proportion of illegal/illicit SPAM.	• US CAN-SPAM act (1/1/2004) requires labeling, bans deception, includes opt-out instructions. • Active debate on merits of the bill and efficacy of regulation in general. • National limitation
MARKET SOLUTIONS			
EMAIL POSTAGE	• Imposes a cost on SPAM, to lower profit of SPAMMERS. • Analog to physical mail. • Attacks economic model of SPAM senders.	• Much technical change needed. • Much administrative change needed. • Much standards change needed (SMTP changes). • Some popular resistance.	• Many proposals. • Supported by Bill Gates.
WARRANTY	• Sender must guarantee the email by posting a bond or warranty. • If mail is not worth sending, no warranty posted.	• Much technical change needed. • Much administrative change needed. • Much standards change needed.	• Loder et al. (2004)
INFORMATION SOLUTIONS			
DATABASE OF VALIDATED ACCOUNTS	• Eliminates spammers' advantages due to informational asymmetries	• A possible surge of spam	• Plice, Pavlov, Melville 2006
	•	•	

Filtering

Filtering can be very effective, as is acknowledged by spammers themselves (Mcwilliams, 2005: 89). Filtering reduces demand for attention. Users report a lesser burden of spam at work than on their personal e-mail accounts because of active e-mail screening at work (Fallows, 2003). The popularity of this solution feeds the growth of a new and active anti-spam software industry.

Filtering does the work of targeting for spammers. By setting a filter we in effect do the work for the information supplier – we remove email that is of no interest to us. Hence, filtering resolves a problem due to information asymmetry (the spammer does not know our preferences).

The method, however, is flawed. Many inbox users fear that aggressive filtering may lead to some legitimate e-mail being discarded. A 2003 survey by the Pew Internet Project (Fallows, 2003: 29) found that about one third of the respondents feared their incoming e-mail might be blocked, and 13 percent were convinced that it happened to them. About a quarter of respondents feared that their outgoing e-mails might be filtered out by the intended recipient.

Electronic postage

Currently, sending a spam message costs about one hundredth of a cent (Goodman *et al.*, 2005). But this cost does not capture the cost borne by the information recipient. Electronic stamps (e.g. Kraut *et al.*, 2002) fixes this negative production externality by moving the private cost more closely to the social cost.

There are some problems with electronic postage. Electronic postage is similar to the Pigovian tax, with all the problems of the Pigovian tax. Additionally, it may eliminate "good" spam, such as political spam by grass-root organizations (Sweet, 2003).

Sender warranty system

Fahlman (Fahlman, 2002) advanced a concept of interrupt rights for email or phone calls. Loder et al. (Loder *et al.*, 2004) propose a similar system, which they called a sender warranty system. The economic logic of this approach is to offer monetary compensation to the person who bears the cost of the interruption due to communication. Such a system has been implemented and is offered by Return Path under the name Bonded Sender Program. Return Path says that on average response rates for marketers who participate in the program improved by 21 percent (Return Path, 2006).

The problem with this solution may be that the identity of the sender is often not clear. Among other drawbacks of this system: much technical change needed, much administrative change needed, and much standards change needed.

Model

The spam value chain includes the following major participants:

1. Recipients which receive unwanted commercial e-mail in their mailboxes;
2. Harvesters are in the business of discovering inboxes and compiling them into lists of e-mail addresses, which they sell to spammers;
3. Spammers administer spam campaigns, which promote products from sponsors.
4. Sponsors use direct online marketing as a marketing channel; they finance spam campaigns.
5. Technology companies provide filtering software.
6. Internet Service Providers (ISPs) transmit email traffic from spammers to the recipients; spammers pay ISPs for this service.

Our model is organized as shown in Figure 1. The model was built in Vensim DSS and was simulated using Runge-Kutta integration. In the following sections we describe the sectors of the model.

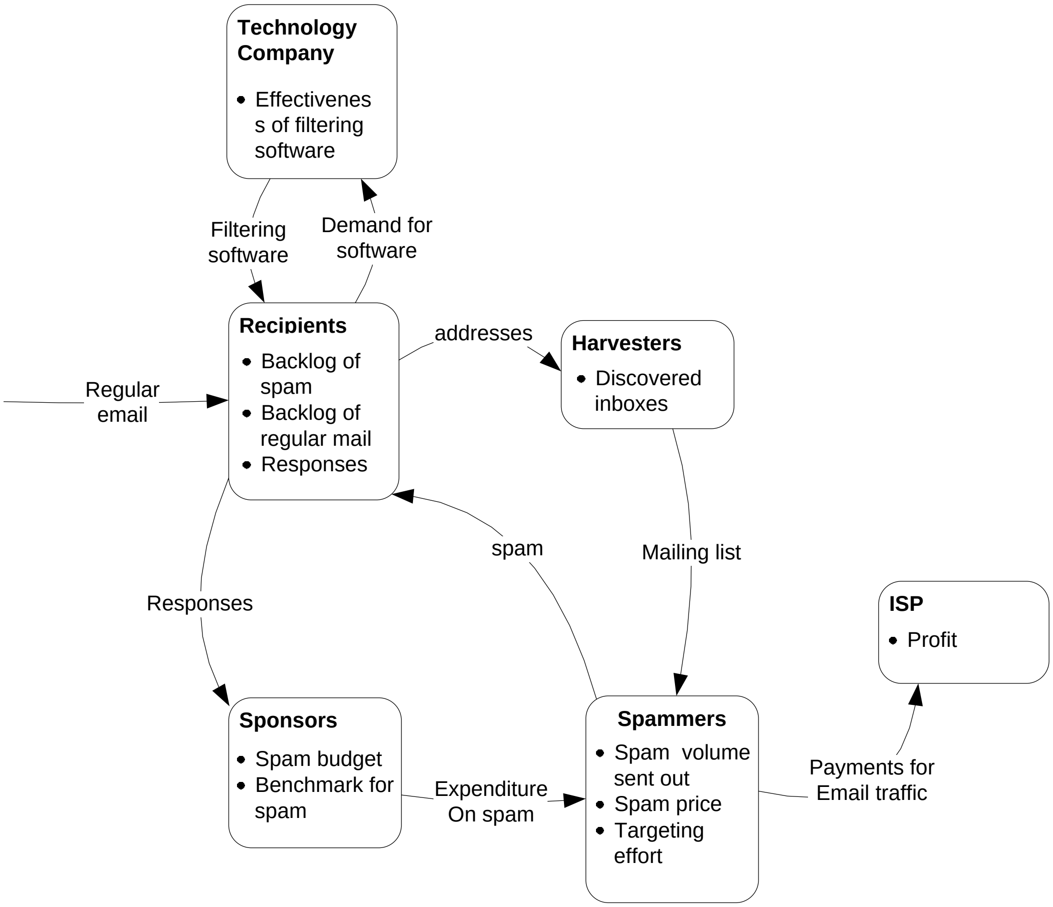


Figure 1: Sectors of the model

Recipients

In our model, the attention capacity of agents devoted to email is divided between two types of email: regular email and spam. Individuals prioritize, putting a higher priority on regular email. Our formulation is inspired by the economic attention allocation model of Gabaix et al. (Gabaix *et al.*, 2003).

The dynamic equation for the backlog of regular email is:

$$(d/dt)R = r_n - r_o \tag{1}$$

Once there is too much e-marketing email, people tend to delete it (Emaillabs, 2006). Hence, spam backlog, S, can be either deleted, s_d, or opened and processed, s_o. The new spam rate, s_n, adds to the spam backlog. The dynamic equation for spam backlog is:

$$(d/dt)S = s_n - s_o - s_d \tag{2}$$

The new spam arrival rate is proportional to the spam volume sent by spammers, s, less the spam blocked by a filter, s_b:

$$s_n = s - s_b \tag{3}$$

The quantity of spam that is blocked by the filtering software is a function of the effectiveness of filtering software, Φ:

$$s_b = s \cdot \Phi \tag{4}$$

We assume that agents have some limited budget of time for reading email, which they allocate between reading regular email and reading spam. We assume that reading regular email, i.e. the one that is not qualified as spam, is of the higher priority among the two tasks. As a result, time available for processing spam is the difference between total time available for all email, T, and time allocated for reading regular email, T_r:

$$\overline{T_s} = T - T_r \tag{5}$$

The daily time required to process spam is determined by the magnitude of the spam backlog, the normal response delay, γ, and the average time it takes to process a typical spam message, τ_s:

$$T_s^* = \left(S/\gamma\right) \cdot \tau_s \tag{6}$$

The time allocated for processing spam is a function of the time required for processing spam, T_s^*, but it also cannot exceed the total time available for spam processing, $\overline{T_s}$. Rather than using a MIN function, we use a fuzzy MIN formulation (Sterman, 2000:

529), which allows to avoid the discontinuity of the MIN function. The fuzzy MIN formulation is:

$$T_s = T_s^* \cdot f\left(\overline{T_s}/T_s^*\right)\ , \qquad f\left(0\right)=0,\ f\left(\infty\right)=1,\ f^{'} \geq 0,\ f^{''} \leq 0 \tag{7}$$

The number of spam messages that is processed every day, s_o, depends on the time allocated for reading spam, T_s, the average time it takes to process a typical spam message, τ_s, and the normal delay of responding to an email, γ:

$$s_o = \mathrm{MIN}(T_s/\tau_s, S/\gamma) \tag{8}$$

We define spam overload as a fraction of time required to process spam to the time actually allocated for this task: $\lambda = T_s^*/T_s$. As spam overload increases, so does the number of spam messages that are deleted before they are opened:

$$\begin{aligned} s_d &= d_s \cdot S \\ d_s &= d_s^* \cdot \lambda \end{aligned} \tag{9}$$

Here, d_s is the adjusted spam deletion fraction, and d_s^* is the normal spam deletion fraction.

The opening rate and the average relevance of spam email, ρ, determine the number of responses to spam:

$$Q = s_o \cdot \rho \tag{10}$$

As recipients process spam messages, they form a perception about the share of relevant spam messages:

$$\tilde{\rho} = \mathrm{SMOOTHI}(Q/s_o, \tau, \tilde{\rho}_0) \tag{11}$$

Here, τ is the perception formation delay, and $\tilde{\rho}_0$ is some initial value of the perception.

Harvesters

Considering the many ways in which harvesters identify e-mail addresses that are later sold to spammers, it is reasonable to assume that it is only a matter of time before an e-mail account is discovered. So we assume that there is some number of listed email accounts, L. The harvesters make combined profit of $\pi_h = p_h \cdot L$, where p_h is the harvester's marginal profit when the harvester sells an email address to spammers.

Spammers

Spammers are hired by sponsors to send spam. The volume of spam that is sent by the spammer is proportional to the expenditure by sponsors on the spamming campaign, e_s, and inversely proportional to the price of spam, p_s:

$$s = e_s / p_s \tag{12}$$

Price of spam may deviate from its base value, $\overline{p}_s$ by the value b, which is due to e-postage or bond that the spammer may need to post. Hence, the final spam price is:

$$p_s = \overline{p}_s + b \tag{13}$$

Sponsors

Sponsors provide money for spamming campaigns. The dynamic equation for the spam budget, B, is set by the difference between the new budget allocations i and the expenditure on spam, e_s:

$$\left(d/dt\right) B = i - e_s \tag{14}$$

The budget is spent over a budget duration period λ_B:

$$e_s = B/\lambda_B \tag{15}$$

Optimal marketing expenditure is a topic of active research (see, e.g., Feichtinger *et al.*, 1994 for a review). For example, a conclusion from the classical Nerlove and Arrow (1962) model of advertising expenditures is that spending on advertising should be proportional to sales. But real Internet companies use various approaches in allocating the budget for direct emailing (see Emaillabs, 2006: 26). Here we assume that sponsors will allocate more to the online ad campaign if the average response rate, r^{av}, is better than some benchmark response rate, $\overline{r}$:

$$i = \left(B/\lambda_B\right) \cdot f\left(r^{av}, \overline{r}\right) \tag{16}$$

Technology companies

Spam is blocked by the filtering software. The “ideal” filter would catch all the spam. We say that such a filter has the effectiveness of one, i.e. $\Phi = 1$. When the filtering software is turned off, the effectiveness of the filtering software is zero, i.e. $\Phi = 0$. As the filtering software improves, the software effectiveness Φ improves by ϕ_{in}. As spammers invent new ways to circumvent the filters, the effectiveness of a given filter drops by ϕ_{out}. The effectiveness of filtering software changes according to the equation:

$$\left(d/dt\right)\Phi = \phi_{in} - \phi_{out} \tag{17}$$

Improvements to the effectiveness of the filtering software are driven by the gap between the desired filtering effectiveness, Φ^*, the current effectiveness of the software, Φ, and the software improvement delay, λ_ϕ:

$$\phi_{in} = \left(\Phi^* - \Phi\right)/\lambda_\phi$$

Internet service providers

ISPs earn profit by trafficking the spam volume. Their profit is proportional to the total volume of spam, s, and the profit of the unit of traffic, υ_s:

$$\left(d/dt\right)\pi_{ISP} = s \cdot \upsilon_s \tag{18}$$

Analysis

As more commercial messages arrive in the mailbox of a recipient, more responses will be given, which will, in turn encourage greater spam budget (Figure 2). Greater spam budget leads to additional expenditures on spam. More money for spam increases spam volume. This completes the Budget Growth Loop R1, which is a reinforcing loop. The exponential growth is checked by the Deletion Pressure Loop B1 and the More Time Loop B2. The Deletion Pressure Loop B1 acts through the spam overload, which increases as the backlog of spam increases. As the recipients feels overburdened with spam, they delete an increasing share of spam before opening it. As backlog grows, the recipients may choose to allocate more time to processing spam (the More Time Loop B2). This coping mechanism will, however, be limited by the time available for spam processing.

In the following sections we present experiments that show the effects of various policies. All experiments start in the steady state when no anti-spam policy is active.

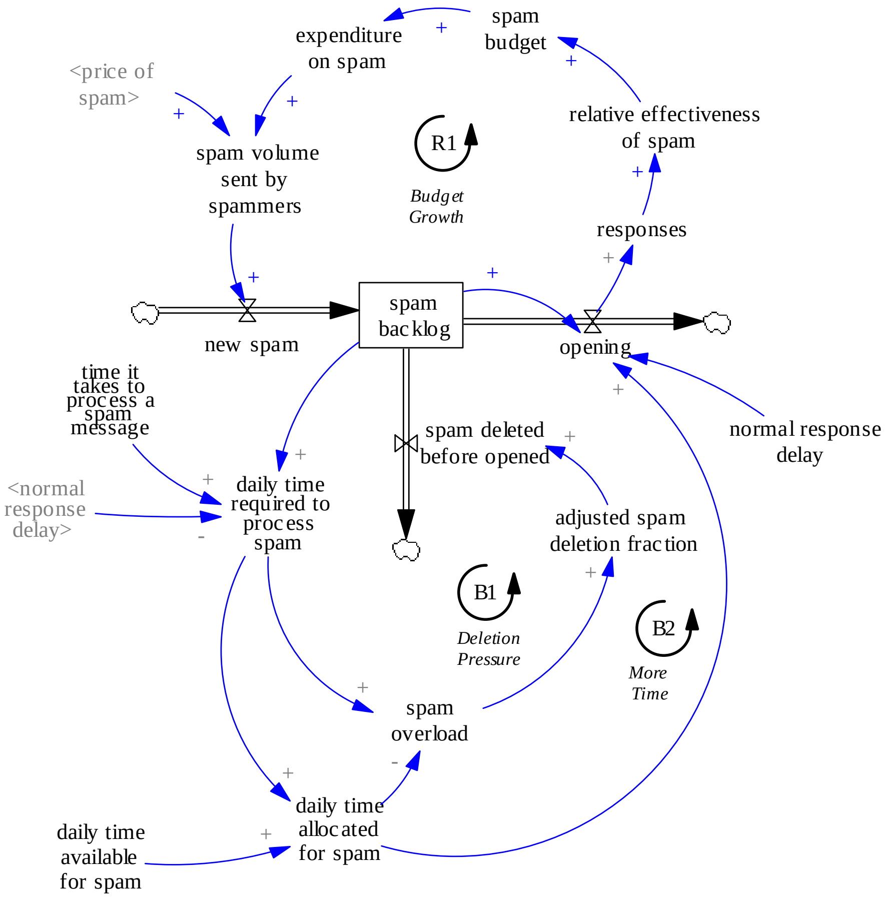
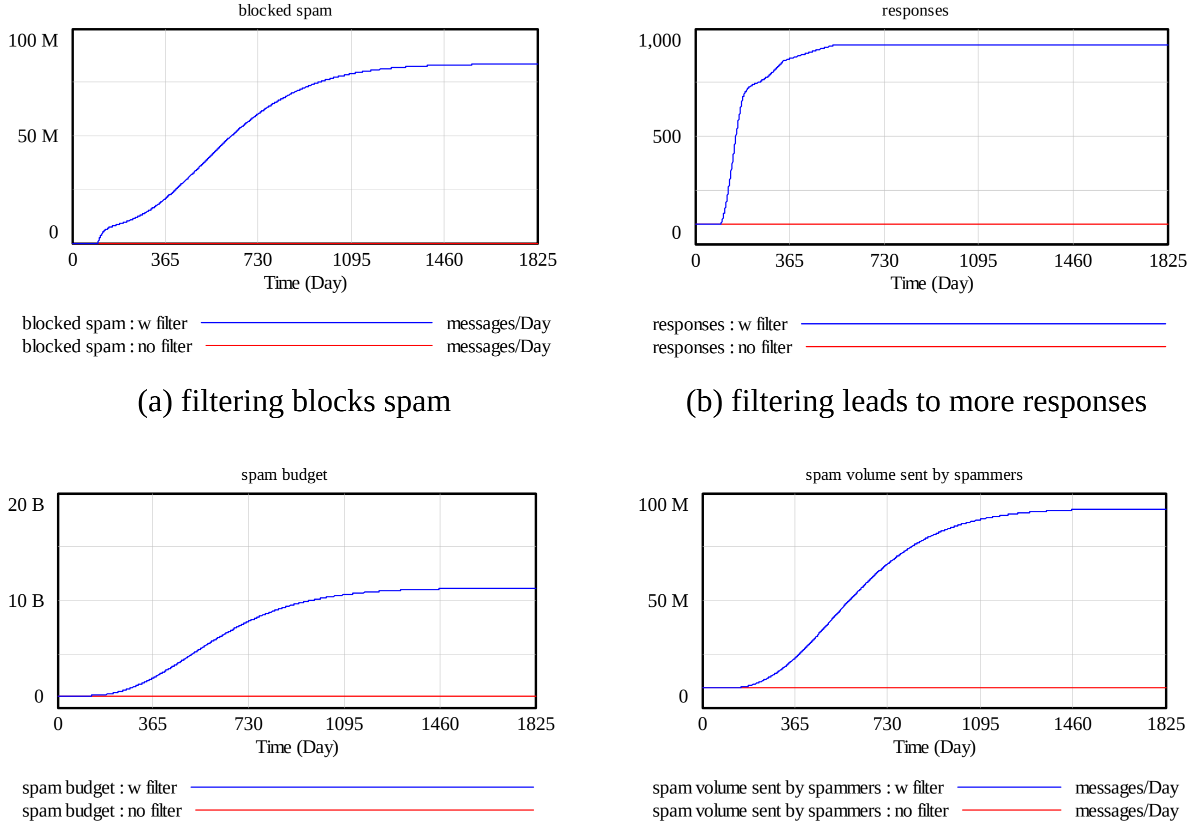

spam budget
expenditure on spam
<price of spam>
spam volume sent by spammers
R1
Budget Growth
relative effectiveness of spam
responses
spam backlog
new spam
opening
time it takes to process a spam message
<normal response delay>
daily time required to process spam
spam deleted before opened
normal response delay
adjusted spam deletion fraction
B1
Deletion Pressure
B2
More Time
spam overload
daily time available for spam
daily time allocated for spam
+
-

Figure 2: Balancing and reinforcing loops that affect spam backlog

Filtering

In this experiment, we simulate the introduction of filtering at time 100. As can be seen in Figure 3a, filters and their growing effectiveness are responsible for a growth in the amount of blocked email. The filter in effect eliminates all communication that is recognized as spam. Some of the spam, however, is still being delivered. This is the spam that is not the most “obvious” spam. As a result, a greater portion of these spam messages will be opened, as captured in Figure 3b. More responses encourage additional allocations to spam budgets (Figure 3c). Given constant price of spam, greater budgets result in greater total volume of spam (Figure 3d). Hence, an interesting conclusion from this experiment is that universal filtering is likely to lead to higher global volume of spam.



(a) filtering blocks spam

(b) filtering leads to more responses

(c) filtering encourages greater spam budgets

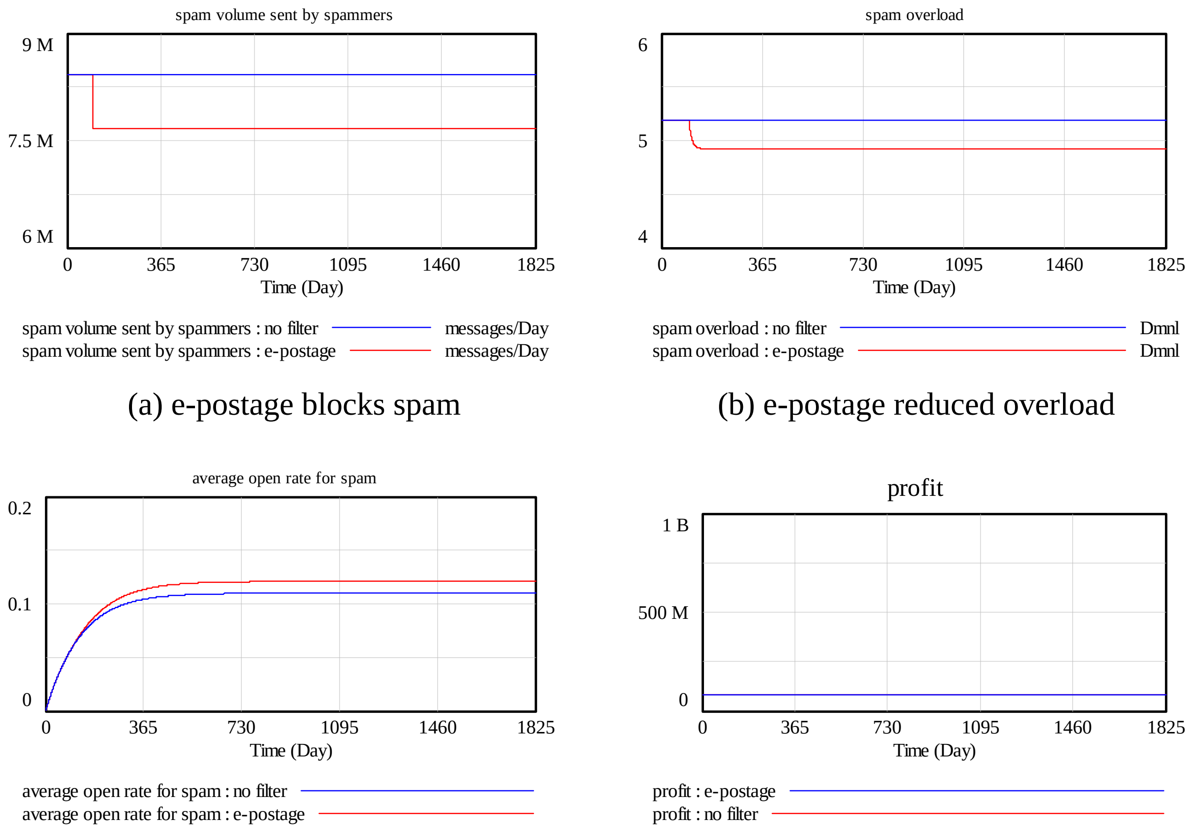
(d) filtering encourages more spam

Figure 3: Introduction of filtering at time 100

Electronic postage

In an effort to internalize the negative externality of unwanted email, electronic postage may be introduced. If electronic postage is levied on spammers, they will incorporate it in the price of spam. Hence, to test the effect of postage, we increase price of spam at time 100 by 10 percent.

An increase in price lowers the volume of spam (Figure 4a). This leads to lower spam backlog and, in turn, lower spam overload (Figure 4b). This lowers the pressure to delete. Less direct marketing email is deleted and open rates are improved (Figure 4c). If the response to the decline in incoming spam is proportional to the change in the spam volume, then the electronic postage is not likely to make a difference from the standpoint of the sponsors. Since open rates are improved, this will compensate for the higher price of spam. This experiment suggests that a situation with electronic postage may be Pareto superior to the case without it.



(a) e-postage blocks spam

(b) e-postage reduced overload

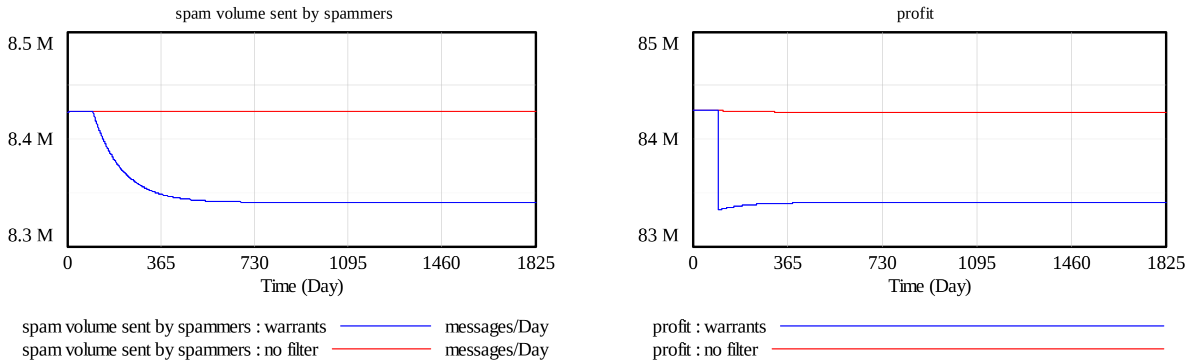
(c) electronic postage improves open rate

(d) electronic postage does not affect profit

Figure 4: Introduction of electronic postage at time 100

Sender warranty system

Sender warranty system can be simulated by assuming that the sponsor has to pay some fixed amount to the recipient each time a spam message is opened and not responded to. Assuming that the value of the warranty payment for each message is equal to the current price of a spam message, a simulation suggests that: (i) spam volume will drop (Figure 6a), and (ii) profit of sponsors will decrease (Figure 6b). This implies that while recipients are likely to embrace the warranty system, it may be against the interests of the sponsors.



(a) warranty decreases spam

(b) warranty cuts into profits

Figure 6: Introduction of warranty system at time 100

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