

# An Option Value Problem from *Seinfeld*

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## Abstract

This is a paper about nothing.

## 1 Introduction

In an episode of the sitcom *Seinfeld* (season 7, episode 9, original air date December 7, 1995), Elaine Benes uses a contraceptive sponge that gets taken off the market. She scours pharmacies in the neighborhood to stock a large supply, but it is finite. So she must “re-evaluate her whole screening process.” Every time she dates a new man, which happens very frequently, she has to consider a new issue: Is he “spongeworthy”? The purpose of this article is to quantify this concept of spongeworthiness.

When Elaine uses up a sponge, she is giving up the option to have it available when an even better man comes along. Therefore using the sponge amounts to exercising a real option to wait, and spongeworthiness is an option value. It can be calculated using standard option-pricing techniques. However, unlike the standard theory of financial or many real options, there are no complete markets and no replicating portfolios. Stochastic dynamic programming methods must be used.

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## 2 The model

Suppose Elaine believes herself to be infinitely lived; this is a good approximation in relation to the number of sponges she has and her time-discount factor or impatience. She meets a new man every day. Define the quality  $Q$  of each man as Elaine's utility from having sex with him. This is independently and identically distributed, and drawn each day from a distribution which I assume to be uniform over  $[0,1]$ . Each day she observes the  $Q$  of that day's date. Actually this is only her estimate formed from observing and closely questioning the man (which is what she does in the episode), not the ex post facto outcome. But I assume that she has sufficient experience and expertise to make a very accurate estimate. Having observed  $Q$ , she makes her yes/no decision. Elaine's per-day discount factor is  $\beta$ . All these assumptions are to simplify the calculations; the method is perfectly general and many bells and whistles can be added to the analysis. I mention a few of them at the end.

If sponges were freely available for purchase at a constant price (which is small in relation to the potential value so I will ignore it), then Elaine's decision would be yes for any quality greater than zero. But when she has a finite stock and cannot buy any more, her optimal decision will be based on a "spongeworthiness threshold" of quality,  $Q_m$ , such that her decision will be yes if  $Q > Q_m$ . The threshold depends on the number  $m$  of sponges she has: the fewer sponges left, the higher the threshold needed to justify using up one of them.

Let  $V_m$  denote Elaine's expected present value of utility when she has a stock of  $m$  sponges. She meets a man and observes his quality  $Q$ . If she decides to use one of her sponges, she gets the immediate payoff  $Q$  and has continuation value  $V_{m-1}$  on the second day, which has present value  $\beta V_{m-1}$ . If she decides not to, there is no immediate payoff, only the present value of continuation with  $m$  sponges, namely  $\beta V_m$ . Therefore her decision rule is

$$\begin{aligned} \text{Spongeworthy if} \quad & Q + \beta V_{m-1} > \beta V_m \\ \text{that is, if} \quad & Q > Q_m \equiv \beta (V_m - V_{m-1}), \end{aligned} \tag{1}$$

and the value recursion formula of dynamic programming is

$$V_m = \mathbf{E} [ \max\{ Q + \beta V_{m-1}, \beta V_m \} ] . \tag{2}$$

Although (1) gives an expression for the spongworthiness threshold, it is not a full solution since the  $(V_m - V_{m-1})$  that appears on its right hand side is endogenous. We must obtain the solution using (2).

The expectation on the right hand side of (2) is found by integrating over the range of  $Q$ , which splits into two parts, depending on which of the two expressions yields the max. Therefore

$$\begin{aligned}
V_m &= \int_0^{Q_m} \beta V_m dq + \int_{Q_m}^1 (q + \beta V_{m-1}) dq \\
&= \beta V_m Q_m + \frac{1}{2} [1 - (Q_m)^2] + \beta V_{m-1} (1 - Q_m) \\
&= \beta (V_m - V_{m-1}) Q_m + \frac{1}{2} - \frac{1}{2} (Q_m)^2 + \beta V_{m-1} \\
&= (Q_m)^2 + \frac{1}{2} - \frac{1}{2} (Q_m)^2 + \beta V_{m-1} \\
&= \frac{1}{2} + \frac{1}{2} (Q_m)^2 + \beta V_{m-1} \\
&= \frac{1}{2} + \frac{1}{2} \beta^2 (V_m - V_{m-1})^2 + \beta V_{m-1}.
\end{aligned}$$

Write this as

$$V_m - V_{m-1} = \frac{1}{2} + \frac{1}{2} \beta^2 (V_m - V_{m-1})^2 - (1 - \beta) V_{m-1},$$

or

$$\beta^2 (V_m - V_{m-1})^2 - 2 (V_m - V_{m-1}) + [1 - 2(1 - \beta) V_{m-1}] = 0.$$

Therefore

$$\begin{aligned}
V_m - V_{m-1} &= \frac{2 \pm \sqrt{4 - 4\beta^2 [1 - 2(1 - \beta) V_{m-1}]}}{2\beta^2} \\
&= \frac{1 \pm \sqrt{1 - \beta^2 + 2\beta^2 (1 - \beta) V_{m-1}}}{\beta^2}.
\end{aligned}$$

The initial condition is  $V_0 = 0$ . Keeping the positive root would make  $V_1 > 1/\beta^2 > 1$  which is impossible. Therefore keep the negative root and write the difference equation as

$$V_m = V_{m-1} + \frac{1 - \sqrt{1 - \beta^2 + 2\beta^2 (1 - \beta) V_{m-1}}}{\beta^2}. \quad (3)$$

### 3 Solution

To solve this, examine the function

$$f(x) = x + \frac{1 - \sqrt{1 - \beta^2 + 2\beta^2(1 - \beta)x}}{\beta^2}. \quad (4)$$

We have

$$f(0) = \frac{1 - \sqrt{1 - \beta^2}}{\beta^2} > 0,$$

and for large  $x$ , the second term (built-up fraction) on the right hand side of (4) becomes negative so eventually  $f(x) < x$ . (See Figure 1.) Also

$$\begin{aligned} f'(x) &= 1 - \frac{1}{\beta^2} \frac{1}{2} \left(1 - \beta^2 + 2\beta^2(1 - \beta)x\right)^{-1/2} 2\beta^2(1 - \beta) \\ &= 1 - (1 - \beta) \left(1 - \beta^2 + 2\beta^2(1 - \beta)x\right)^{-1/2}. \end{aligned}$$

This is increasing as  $x$  increases. At the extremes,

$$f'(0) = 1 - (1 - \beta) \left(1 - \beta^2\right)^{-1/2} = 1 - \left(\frac{1 - \beta}{1 + \beta}\right)^{1/2},$$

which is positive but less than one, and

$$f'(\infty) = 1.$$

Figure 2 shows the key portion of the graph in Figure 1. Starting at  $x = V_0 = 0$ , we successively read off  $V_1 = f(V_0)$ ,  $V_2 = f(V_1)$ , etc. As  $m \rightarrow \infty$ ,  $V_m \rightarrow V^*$ , the fixed point  $f(x) = x$ . Solving (4) we find

$$V^* = \frac{1}{2(1 - \beta)}. \quad (5)$$

This is obviously correct: with infinitely many sponges Elaine can use one every day to have an expected value of  $\frac{1}{2}$  each day, and  $V^*$  is just the capitalized value of this.

Table 1 shows some numerical calculations for the cases where Elaine has just one sponge left,

$$V_1 = \frac{1 - \sqrt{1 - \beta^2}}{\beta^2}, \quad (6)$$

Figure 1: The function  $y = f(x)$  for  $\beta = 0.5$ , together with  $y = x$ .

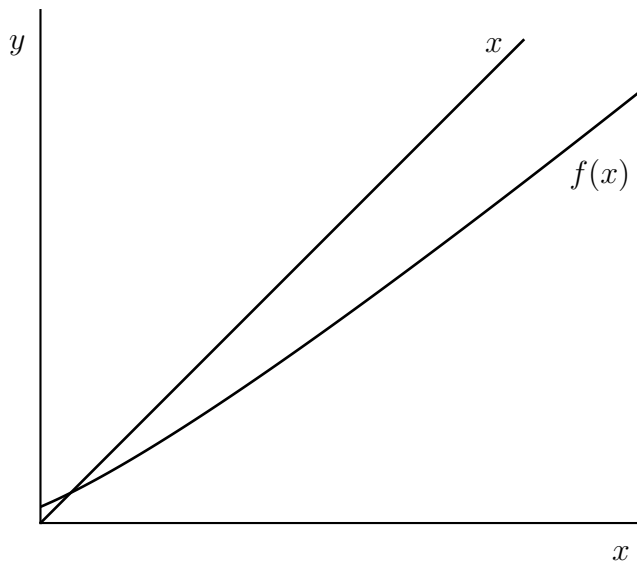


Figure 2: Graphical solution for  $\beta = 0.5$ , showing the key portion of Figure 1.

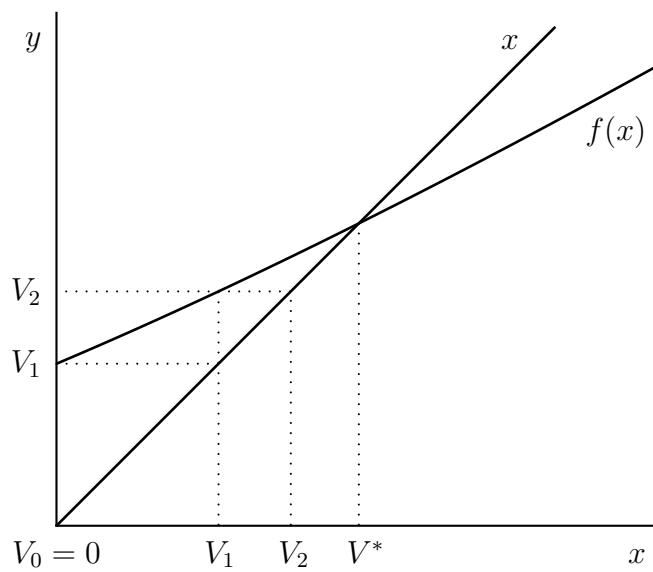


Table 1: Numerical calculations

$\beta$	$\beta^{365}$	$V_1$	$Q_1$	$V_{10}$	$Q_{10}$	$V_{100}$	$Q_{100}$
0.999999	0.999635	0.998	0.998	9.968	0.996	99.054	0.986
0.999	0.694	0.957	0.956	9.044	0.866	73.333	0.617
0.990	0.026	0.876	0.868	7.272	0.619	35.416	0.168
0.900	$1.988 \times 10^{-17}$	0.696	0.627	3.571	0.155	4.999	$1.73 \times 10^{-5}$
0.500	0	0.536	0.268	0.999	$4.27 \times 10^{-4}$	1.000	0.000

where she has ten sponges left ( $V_{10}$ ), and 100 left ( $V_{100}$ )—there are no simple explicit formulas for the latter two—and the implied spongeworthiness thresholds for each case for various discount factors. Note that  $\beta$  is the daily discount factor; therefore for better intuition I also show the annual discount factor  $\beta^{365}$  in each case.

Some limiting cases should be noted. First, suppose Elaine is very patient, and take the limit as  $\beta \rightarrow 1$ . From (3) we have  $V_m - V_{m-1} \rightarrow 1$ . Then  $V_m \rightarrow m$ . Therefore (1) gives  $Q_m \rightarrow 1$ : a completely patient Elaine will accept no one except the best possible man. The first line of the table is a close approximation to this. Second, consider the other extreme case, where Elaine is very impatient. As  $\beta \rightarrow 0$ , expanding the square root in (6) in its binomial series, we have  $V_1 \rightarrow 1/2$  and then  $Q_1 \rightarrow 0$ . Third, suppose Elaine's stock of sponges is large. For the low values of  $\beta$ —namely 0.9 and 0.5, where events one year out are negligible— $V_{100}$  is a very close approximation to the  $V^*$  in (5).

## 4 Some extensions

First, suppose Elaine has a finite life of  $n$  days, where  $n > m$  (the number of sponges). Defining the value function  $V(m, n)$  in the obvious way, the Bellman equation is

$$V(m, n) = \mathbf{E} [ \max\{ Q + \beta V(m-1, n-1), \beta V(m, n-1) \} ] .$$

This yields the threshold

$$Q(m, n) = \beta [ V(m, n-1) - V(m-1, n-1) ] .$$

The boundary conditions are  $V(0, n) = V(m, 0) = 0$  for all  $m, n$ . At least for small  $m$  and  $n$ , this can be solved numerically quite easily.

Second, suppose Elaine's estimation procedure is error-prone. She can calculate conditional probabilities and expectations based on her estimate of  $Q$ , and the dynamic programming set-up works as before. Other complexities such as a non-uniformity or serial correlation (positive or negative) in the distribution of  $Q$  can be handled using numerical methods for calculation.

Third, Elaine may have time-inconsistent preferences; for example, she may be a hyperbolic discounter, either naive or sophisticated (aware that next period she will have a different preference over the remaining time profile). The modifications to the analysis are relatively easy to make.

Finally, I mention applications of the basic model to two incidents in the episode:

George asks Elaine for one of her sponges, and she refuses. In fact, she should be willing to sell it for the price  $V(m) - V(m - 1)$ , or—in the finite life case— $V(m, n) - V(m - 1, n)$ .

At the end of the episode, when the man she has accepted for the night asks for a second helping, she says "Sorry, I can't afford two of them." This pins down the man's spongeworthiness quite precisely: greater than  $Q_m$  but less than  $Q_{m-1}$ . For example, if  $m = 10$  and  $\beta = 0.999$ , the interval is  $[0.866, 0.872]$ .