4 Choosing when to act

> The only way to get rid of a temptation is to yield to it.
> I can resist everything except temptation.
>
> Oscar Wilde

Time is important in most economic decisions because the choices we make will have future consequences. Should a person do the shopping today, or tomorrow? Should she buy a new TV, or save for retirement? Should she look for a new job? Should she go to university and get a qualification? Should she eat healthily and join a gym? The answer to all these questions involves weighing future benefits and costs with present benefits and costs. We need to think about how people do that, and that's the focus of this chapter.

4.1 Exponential discounting

To illustrate some of the issues, consider Maria planning when to do her homework. The homework was set on Friday and must be handed in on Monday morning. She can do it on Friday, Saturday, Sunday, or Monday. Table 4.1 gives her day-by-day utility, depending on when she does the homework. For example, if she does it on Friday she pays a cost on Friday, gets to enjoy Saturday and Sunday, and on Monday gets to know how well she did. Doing the homework on a weekend is more costly but also means she does it better. When should Maria do the homework?

Clearly she has to weigh up the benefits and costs of doing the homework on each possible day. Before we see how she might do this, it is worth introducing some general notation for thinking about choice over time. We can think of time as running from period one to period T. In the example, period one is Friday and period $T = 4$ is Monday. Maria needs to plan what she will do in each period between now and T, and, given a plan, she can work out what her utility will be in each period. We can think of the utility in a period as determined by the same utility function that we came across in Chapters two and three, and I will use u_t to denote the utility in period t. (Just to clarify, in some parts of the book I have used u_i to denote the utility of person i, but not in this chapter.) In the example, a plan

Table 4.1 The day-by-day utility for Maria of doing her homework on different days

Plan	*Utility on*			
	Friday	*Saturday*	*Sunday*	*Monday*
Do it Friday	−5	5	10	4
Do it Saturday	0	−5	10	10
Do it Sunday	0	5	−5	10
Do it Monday	0	5	10	−5

is when to do the homework, and we see, for example, that the utility in period three is $u_3 = 10$ if Maria plans to do the homework on Friday.

To try and model Maria's choice we can use an **inter-temporal utility function** that combines utility from each period to one measure of overall utility. The simplest way to do this would be to just add together the utility from each time period. Generally, however, she might want to **discount**, that is, give less weight to future utility. This suggests a **utility function with exponential discounting**. The inter-temporal utility of getting u_1 in period 1, u_2 in period 2, and so on is then:

$$u^T(u_1, u_2, \ldots, u_T) = u_1 + \delta u_2 + \delta^2 u_3 + \ldots, + \delta^{T-1} u_T = \sum_{t=1}^{T} \delta^{t-1} u_t \tag{4.1}$$

where δ is a number called the **discount factor**. Inter-temporal utility is, therefore, a simple weighted sum of the utility in each period. If $\delta < 1$ then less weight is given to the utility in a period the further away that period is. So, the smaller is δ, the more future utility is discounted.

If we know the utility in each period of each plan then we can work out the inter-temporal utility of each plan. A prediction would be that Maria should choose the plan with highest inter-temporal utility. Table 4.2 illustrates what happens when we do this for three different discount factors. We can see that, the higher is δ, the more impatient Maria becomes. If $\delta = 1$, she is willing to sacrifice an enjoyable Saturday in order to get a higher mark on Monday. If $\delta = 0.7$, she is more impatient to enjoy herself and does not do the homework until Monday.

Table 4.2 The inter-temporal utility of each plan for three different discount factors

Plan	*Inter-temporal utility*		
	$\delta = 1$	*$\delta = 0.9$*	*$\delta = 0.7$*
Do it Friday	14	10.5	4.7
Do it Saturday	15	10.9	4.8
Do it Sunday	10	7.7	4.5
Do it Monday	10	9.0	6.7

Exponential discounting is a very simple way to model choice over time. All we need to know is the discount factor, and then we can easily predict choice. For that reason exponential discounting is by far the most common way used in economics to model choice over time. What we need to do is ask whether it is sophisticated enough to capture all the things we observe. Before we do that, it is important that we fully understand what the model and, in particular, the discount factor, implies, and so there are a couple of things I want to mention.

The first thing I want you to think about is the units of measurement: a period and utility. Maria's choice is going to have a stream of future consequences, and we somehow need to measure those consequences. What I have done is split the future into days and say what her utility will be on each day, but there is inevitably something arbitrary about how we split things up. For instance, I could have split into hours and said what her utility will be in each hour, or seconds, etc. One sensible approach is to split things up as Maria perceives them, and so, if she thinks in terms of what will happen each day, then that is how we should split things. How Maria perceives things will, however, likely depend on the context. This is already enough to suggest important context effects.

The second thing I want to clarify is the distinction between discount factor and discount rate. If the **discount factor** is 0.8, then '\$10 worth of utility' next period is equivalent to \$8 today. More generally, \$10 next period is equivalent to δ\$10 today. The smaller the discount factor, the more impatient Maria is. Given a discount factor δ, we can work out a **discount rate** ρ using the relation:

$$\delta = \frac{1}{1+\rho} \text{ or } \rho = \frac{1-\delta}{\delta}.$$

For example, if the discount factor is 0.8, then the discount rate is 0.25. In interpretation a discount rate of 0.25 means Maria would require an interest rate of 25 percent to delay until next period. So, instead of \$8 today she would want $1.25 \times \$8 = \$10$ next period. The higher the discount rate, the more impatient she is. It does not matter whether we use discount rate or discount factor, and so to be consistent I will use discount factor throughout this book. If you follow up the further reading, however, expect many to use the term discount rate. [Extra] If you are wondering why the name 'exponential discounting': in continuous time, equation (4.1) becomes:

$$u^T = \int_0^T e^{-\rho t} u_t$$

where ρ is the discount rate.

4.1.1 The discount factor

To better understand exponential discounting we need to see what values for the discount factor seem most appropriate. In the experimental lab the discount factor can be estimated by giving subjects questions of the form: 'Would you prefer $100 today or $150 in a year's time?' If they answer $100 today then the discount factor is smaller than 0.66 (but see Review question 4.1!). I will look next at a study by Benzion and co-authors (1989), where subjects were asked questions a bit like this. More precisely, subjects were asked questions of the four basic types given below. As you look through these questions, please think about what your answer would be.

- **Postpone receipt**: You have just earned $200 but have the possibility to delay receiving it by one year. How much money would you need to get after a year in order to want to delay payment?
- **Postpone payment**: You need to pay back a debt of $200 but have the possibility to delay payment by one year. How much money would you be willing to pay back after a year if payment is delayed?
- **Expedite receipt**: You will get $200 in one year but have the chance to receive the money immediately. How much money would you accept now rather than have to wait a year?
- **Expedite payment**: You need to pay back a debt of $200 in one year but can pay it now. How much would you be willing to pay now rather than pay off the debt after one year?

In specific questions the time period was changed from six months to four years and the amount of money from $40 to $5,000. Figure 4.1 summarizes the implied annual discount factor that we get from subjects' responses to each question. There is a lot to look at in Figure 4.1. One thing, however, stands out immediately and that's that the discount factor appears to depend a lot on context. We can see this in how the discount factor varies a lot depending on the length of time, amount of money, payment versus receipt, and expedite versus postpone.

In looking in a little more detail at Figure 4.1 I want to point out five things. First, notice that the discount factor is relatively low, around 0.8–0.9, suggesting that the subjects were relatively impatient. Next, notice that the discount factor is higher, the longer it is necessary to wait, suggesting **short-term impatience**. For example, subjects wanted on average almost as much compensation to postpone receipt by six months as to postpone by four years. A third thing to note is that the larger the sum of money, the larger the estimated discount factor, suggesting people are more patient for larger amounts. This is called the **absolute magnitude effect**.

Next I want to compare payment versus receipt and loss versus gain. If you look from top to bottom in Figure 4.1, then you can see a **gain-loss asymmetry** where the estimated discount factor is smaller for gains than for losses. For example, the discount factor is higher in the case of postponing payment (which would require a loss of money) than for postponing receipt (which would involve a gain of money). Similarly, the discount factor is higher in the case of expediting receipt (which would require a loss of money) than for expediting payment (which would involve a gain of money). This is consistent with loss aversion because it suggests that subjects were reluctant to lose money in order to postpone or expedite.

The final thing I want you to do is compare postponing versus expediting. If you look from left to right in Figure 4.1 then you can see a **delay-speed-up asymmetry** where the estimated discount factor is higher to postpone than to expedite payment, and higher to expedite than postpone receipt. This is because subjects were willing to pay relatively less money to postpone a payment than they demanded to expedite payment. Similarly, they demanded relatively more to postpone receipt than they were willing to pay to expedite receipt.

To really work well, exponential discounting requires that the discount factor should not change depending on context. In other words, in Figure 4.1 we should see overlaying horizontal lines all at the same discount factor. We clearly do not, and this is not good news for anyone wanting to use exponential discounting. By now, however, you should be getting used to the idea that context matters. Indeed, the gain-loss asymmetry is consistent with loss aversion, and the delay-speed-up asymmetry is suggestive of mental accounting.

The existence of such large context effects does not mean that exponential discounting is necessarily a bad way to model choice. What it does mean is that we have to be very careful in thinking about what the appropriate discount factor should be for a particular situation. There is no such thing as 'Maria's discount

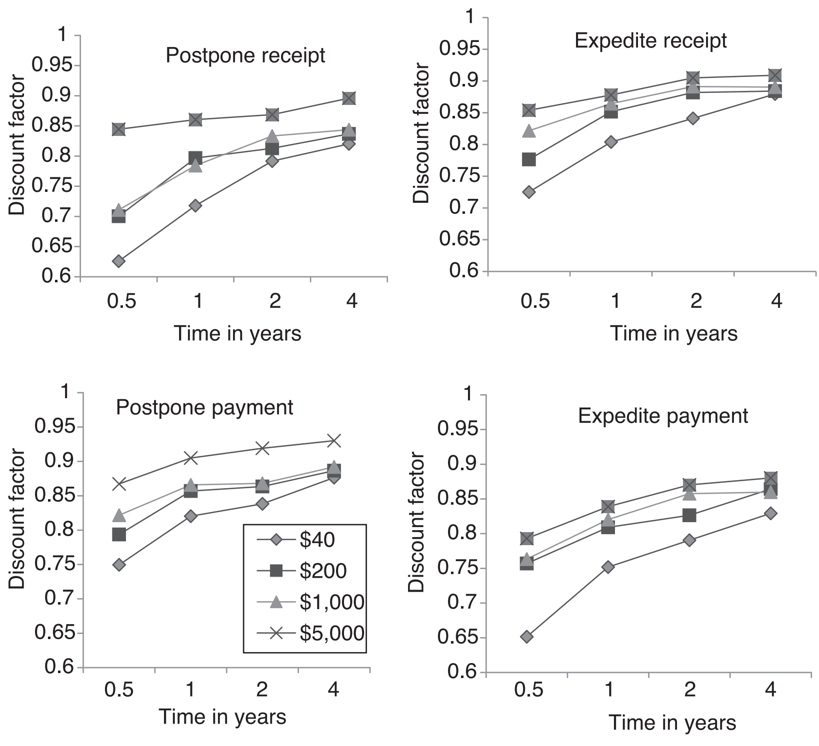

Figure 4.1 Estimated discount factors for four types of choices.

Source: Benzion *et al*. (1989).

factor'. Instead, Maria will likely have different discount factors for different things. For example, she might be impatient to repay \$10 she borrowed from one friend, but more patient to get back a CD she lent to another friend. Before we explore the implications of this there is one more important context effect that we have yet to consider.

Research Methods 4.1

Empirical versus lab evidence

Inter-temporal choice is one area where the experimental lab does seem inadequate to answer many of the questions we are interested in, because we want to know how people trade off money over relatively large time periods. How can we create delay over relatively large time periods in the experimental lab? One option is to use hypothetical scenarios, as in the study by Benzion and co-authors. This, however, leads to the objection that subjects are not making real choices. If we do use real choices, then we cannot realistically delay payment beyond a few months, and certainly not years. It is also questionable whether subjects would find delayed payment credible.

This means that empirical studies in which we observe people making choices with long-term trade-offs are very useful. We can illustrate with a study by Warner and Pleeter (2001). In 1992 the US Department of Defense needed to reduce the size of the US military. They offered selected servicemen two possible packages for leaving the military: (i) a lump sum payment of around \$25,000 for privates and NCOs, and \$50,000 for officers; (ii) an annuity that would pay some fraction of current basic pay for twice the length the person had worked for the military.

Serviceman had, therefore, the choice between a one-off payment and deferred payments. For a particular serviceman it is possible to work out the discount factor such that the serviceman should be indifferent between the two options. Formally, we find the δ^* such that:

$$LS(1-T_{LS}) = \sum_{t=1}^{2YOS} \delta^{*t-1} A(1-T_A)$$

where *LS* is the lump sum payment, *A* the annuity payment, *YOS* the years of service, and *T* the respective tax rates. A serviceman should choose the lump sum payment if and only if they are more impatient than is implied by δ^*, i.e. only if their discount factor is $\delta < \delta^*$. With data on what a person chose and by calculating δ^*, we can therefore estimate a person's discount factor. This is what Warner and Pleeter do. Estimates of the mean discount factor were around 0.85.

The estimate of 0.85 is consistent with what we see in Figure 4.1, which provides reassurance that the numbers obtained from the study by Benzion and co-authors are not unrealistic. I think this nicely illustrates how empirical studies can complement experimental studies. Experimental studies allow us to investigate relatively easily the comparative statics of changing things like the amount of money and time frame. This is simply not possible with empirical studies because events such as the US military downsizing are rare and only give a point estimate of the discount factor. Empirical studies do, though, serve as a useful check that results obtained in the lab are meaningful.

4.1.2 The utility of sequences

Imagine now that instead of asking someone whether they would prefer \$100 today or \$150 in a year's time, we ask them whether they would prefer \$100 today and \$150 in a year's time, or \$150 today and \$100 in a year's time. This gets us thinking how people interpret **sequences** of events. To illustrate how people tend to respond to such questions, I will look at how subjects answered two questions asked in a study by Loewenstein and Prelec (1993).

In the first question people were asked to imagine two planned trips to a city they once lived in but do not plan to visit again after these two trips. During one trip they need to visit an aunt they do not like, and in the other visit friends they do like. Those asked were given three scenarios for when the trips might be (e.g. one this weekend and the other in 26 weeks) and asked to say who they would rather visit first. The results are in Figure 4.2.

One thing to pick out from Figure 4.2 is a **preference for an improving sequence** in which subjects visit the aunt first and then friends later. This might seem natural, but is the opposite of what exponential discounting would predict. If someone uses exponential discounting, with a discount factor less than one, then they would maximize their inter-temporal utility by visiting the friends first because they are impatient for higher utility. This impatience does become apparent when the gap between the trips is made bigger because then more subjects wanted to visit friends first.

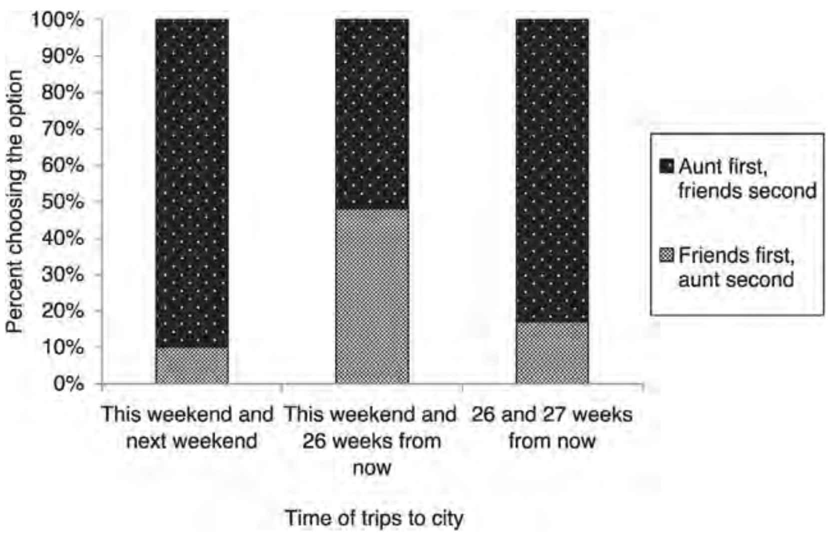

Figure 4.2 Choice of when to visit an aunt and friends. If the two trips were close together, most subjects chose to visit the aunt first. If the two trips were far apart, more subjects chose to visit friends first.

Source: Loewenstein and Prelec (1993).

In the second question I want to look at people who were asked to choose when over the next three weeks they would like to eat out at restaurants called Fancy French and Fancy Lobster. The results are in Table 4.3. When asked to choose between options A and B, we see the same preference for an improving sequence that we saw for the previous question. When asked to choose between options C and D, however, many subjects preferred to spread the good events over the sequence. Again, this might seem natural, but is not consistent with exponential discounting. This switch in choices should not happen because the utility in period three should not affect the optimal choice in periods one and two. It clearly may do.

Overall, therefore, we see a preference for improving sequences coupled with a preference for spreading events evenly throughout the sequence. None of this seems consistent with exponential discounting. The only way to make it consistent is to distinguish sequences from disjoint events. This can work. For instance, we could say that the relevant time period for deciding when to visit the aunt and friends is one month. If, therefore, the two trips are consecutive weekends they should be bundled together and seen as a sequence, while if they are 26 weeks away they should be seen as disjoint events and discounted. Table 4.4 illustrates how this might work to explain what we see in Figure 4.2.

Table 4.3 Choice of when to eat at a restaurant. When asked to choose between options A and B, most subjects prefer to delay eating at Fancy French restaurant. When asked to choose between options C and D, most subjects prefer not to delay eating at Fancy French restaurant

Option	*This weekend*	*Next weekend*	*Two weekends away*	*Choices (%)*
A	Fancy French	Eat at home	Eat at home	16
B	Eat at home	Fancy French	Eat at home	84
C	Fancy French	Eat at home	Fancy Lobster	54
D	Eat at home	Fancy French	Fancy Lobster	46

Source: Loewenstein and Prelec (1993).

Table 4.4 Maria deciding when to visit an aunt and friends. Events in weeks one to four and weeks 24 to 28 are bundled together as a sequence. Events in weeks 24 to 28 are seen as disjoint from those in weeks one to four and discounted with a factor of 0.8

Events		*Inter-temporal utility*
Weeks 1–4	*Weeks 24–28*	
Visit aunt then friends		10
Visit friends then aunt		5
Visit aunt		0
Visit friends		15
Visit aunt	Visit friends	12
Visit friends	Visit aunt	15
	Visit aunt then friends	8
	Visit friends then aunt	4

This approach works perfectly if we can distinguish a length of time and say that events happening over a shorter period of time are a sequence and everything happening over a larger period of time are separate events. In general, however, this is not going to be easy, because we need to know how the person perceives things. Does Maria perceive the events before she hands in her homework as separate, or a sequence? Will she be thinking, 'Today I want to play sport so other things can wait till tomorrow', or 'If I do my homework today, then tomorrow I can go out and play sport'? It will likely affect her choice, but it is not obvious how she might think. There is certainly no simple rule to say when something is a sequence or not. It is more likely to depend on the context.

Clearly, context will matter in thinking about and modeling inter-temporal choice. What I want to do now is question what the implications of this may be, and whether we need a different model to that of exponential discounting in order to capture it.

4.2 Hyperbolic discounting

We clearly see in Figure 4.1 that the discount factor is larger for longer time intervals. This means that people are impatient over the short term but more patient over the long term. To give another example, in a study by Thaler (1981), subjects were asked the amount of money they would require in one month, one year or ten years to make them indifferent to receiving \$15 now. The average responses of \$20, \$50, and \$100 seem entirely sensible, but imply an annual discount factor of 0.22, 0.45, and 0.84 respectively. Relatively speaking, therefore, subjects were asking a lot to wait one month but not very much to wait ten years. Such decreasing impatience is called **hyperbolic discounting**.

One way to capture hyperbolic discounting is to modify the model of exponential discounting and allow for different discount factors in different periods. In equation (4.1) we assume exponential discounting where payment in t time periods from now is discounted by an amount:

$$D(t) = \delta^{t-1}.$$

One of many possible alternatives is to assume:

$$D(t) = \frac{1}{1-\alpha(t-1)} \tag{4.2}$$

where α is a parameter that can capture changes in the discount factor over time. I will call this a **model of hyperbolic discounting**. In either case equation (4.1) is generalized to:

$$U^T(x_1, x_2, \ldots, x_T) = \sum_{t=1}^{T} D(t)\, x_t. \tag{4.3}$$

To illustrate, Figure 4.3 plots $D(t)$ and the annualized discount factor assuming exponential discounting with factor $\delta = 0.85$ and hyperbolic discounting with $\alpha = 0.25$. We see that hyperbolic discounting does give a higher discount factor for longer periods and looks a bit more like what we saw in Figure 4.1.

We are, therefore, able to accommodate a changing discount factor without too much change to a standard exponential discounting model. But are we really capturing decreasing impatience? To explain why we might not be, consider the following set of choices:

> Do you want \$100 today or \$110 tomorrow?
>
> Do you want \$100 in 30 days or \$110 in 31 days?

When asked such questions, many people choose the \$100 today and \$110 in 31 days. This can be consistent with a model of hyperbolic discounting. The

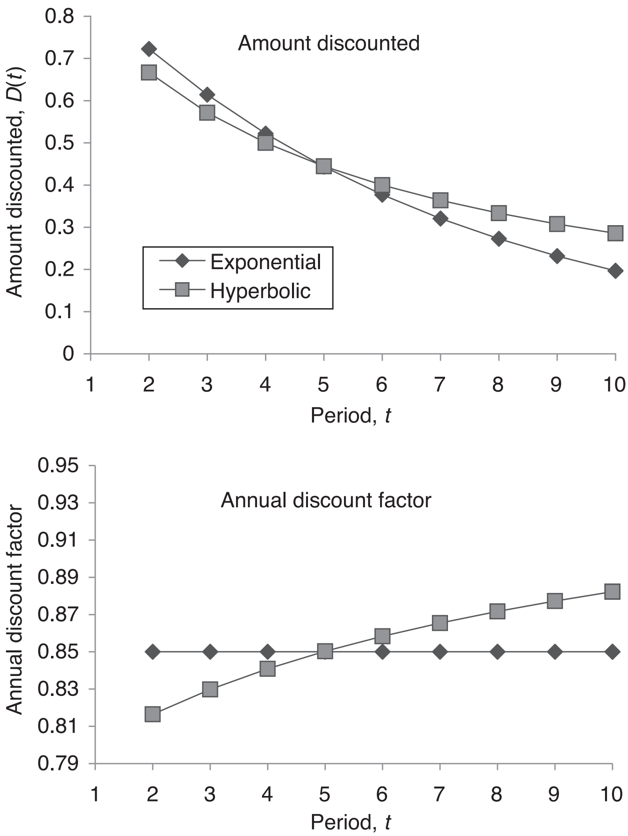

Figure 4.3 Hyperbolic discounting compared to exponential discounting. With hyperbolic discounting, the discount factor is lower for shorter time periods.

potential problem comes if we ask the same question after 30 days and get the same answer. That is, suppose Maria says she would prefer \$110 in 31 days to \$100 in 30 days, but then after 30 days says that she prefers \$100 today to \$110 tomorrow. This is not consistent with a model of hyperbolic discounting, because the model requires choices to be consistent over time. Maria should not change her mind. If she says that she prefers \$110 in 31 days' time to \$100 today, then after 30 days she should still prefer \$110 tomorrow to \$100 today.

[Extra] To illustrate this with some numbers, let me first explain why it can be consistent with a model of hyperbolic discounting to choose the \$100 today and \$110 in 31 days' time. Suppose the time period is a day and $D(2) = 0.9$, $D(30) = 0.85$, and $D(31) = 0.84$. Then \$110 tomorrow is worth \$99 today, \$100 in 30 days is worth \$85 today, and \$110 in 31 days is worth \$92.4 today, so it makes sense to choose \$100 today and \$110 in 31 days' time. What happens after 30 days? Given that $D(30) = 0.85$ and $D(31) = 0.84$ we should, after 30 days, calculate a revised discount factor of $D(2) = 0.99$. With this value of $D(2)$ it is optimal to choose the \$110 tomorrow rather than \$100 today.

It seems plausible that someone who chooses the \$100 today and \$110 in 31 days might also choose the \$100 today and \$110 in 31 days when asked 30 days later. We need, therefore, a different model to that of hyperbolic discounting.

4.2.1 Quasi-hyperbolic discounting

With exponential and hyperbolic discounting, a time period should be interpreted as a specific date. For instance, in the homework example we thought of period one as Friday and period four as Monday. If today is Friday then the discount factors $D(t)$ are specific to that day, and on Saturday we need to update them. For example, if $D(2) = 0.9$ and $D(3) = 0.9$ on Friday, then Maria does not discount between Saturday and Sunday, and on Saturday we should get $D(2) = 1$. Consequently, in a model of hyperbolic discounting, decreasing impatience means that a person gets less impatient as they get older, even if only by a few days.

An alternative interpretation of decreasing impatience is that a person is more impatient for short-term gains relative to long-term gains, and this has nothing to do with age. We can capture this by interpreting $D(2) = 0.9$ and $D(3) = 0.9$ as constant over time and showing how much future amounts are discounted relative to today. So, if today is Friday, then $D(2) = 0.9$, and if today is Saturday, then $D(2) = 0.9$. In this interpretation Maria chooses the \$100 today because she is always impatient for a possible immediate gain. The distinction is illustrated in Figure 4.4.

If it makes more sense to think of the discount factor as relative to today rather than calendar time, we say that there are **present-biased preferences**. In this case Maria does not postpone her homework today, or choose the \$100 today, because today is Friday, 1 May and on Friday, 1 May she is impatient; she is always impatient for immediate gains.

To model present biased preferences we can reuse equation (4.2) but now interpret t as how many time periods from today rather than a specific point in

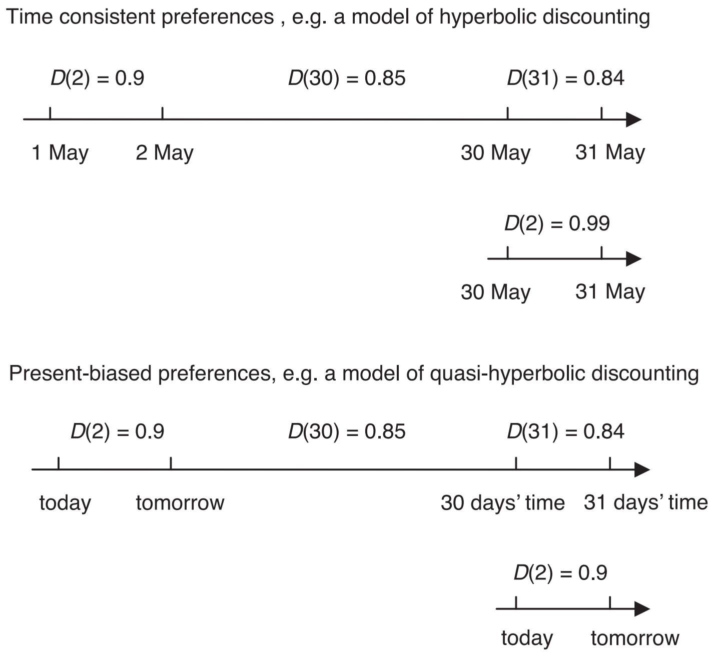

Figure 4.4 The difference between time-consistent and present-biased preferences. In the model of hyperbolic discounting, period refers to a specific moment of calendar time. In the model of quasi-hyperbolic discounting, period refers to a delay from now.

time. But, we still need to capture decreasing impatience. A simple way to do this is to use a model of **quasi-hyperbolic discounting** or (β,δ) **preferences** where:

$$U^T(x_1, x_2, \ldots, x_T) = x_1 + \beta \sum_{t=2}^{T} \delta^{t-1} x_t \tag{4.4}$$

and where β is some number between zero and one. The β is crucial here because it measures **present bias**. If $\beta = 1$, then there is no bias, and equation (4.4) is equivalent to (4.1). If $\beta < 1$, then more weight is given to today than to the future. This means that there is a present bias and decreasing impatience. For instance, if $\beta = 0.7$ and $\delta = 0.99$, then \$110 in 31 days is always preferred to \$100 in 30 days, but \$100 today is always preferred to \$110 tomorrow.

To see how (β, δ) preferences work, we can return to the example of Maria deciding when to do her homework. Table 4.5 summarizes the payoffs that she gets if she does or does not have a present bias. First, look at what happens if $\beta = 1$ and so she does not have a present bias. On Friday, she should plan to do her homework on Saturday, and on Saturday, she also thinks this way, and so would do the homework. The same is true when $\beta = 0.9$. Next, look at what happens if

Table 4.5 Quasi-hyperbolic discounting in the homework example. If the present bias is high, Maria plans to do the homework on Saturday, but on Saturday would rather do it on Monday

	$\beta = 1, \delta = 0.9$		$\beta = 0.9, \delta = 0.9$		$\beta = 0.8, \delta = 0.9$	
Plan	*On Friday*	*Saturday*	*On Friday*	*Saturday*	*On Friday*	*Saturday*
Do it Friday	10.5	—	9.0	—	7.4	—
Saturday	10.9	12.1	9.8	10.4	8.7	8.7
Do it Sunday	7.7	8.6	7.0	8.2	6.2	7.9
Monday	9.0	10.0	8.1	9.5	7.2	9.0

$\beta = 0.8$ and so the present bias is relatively large. On Friday she would plan to do the homework on Saturday. The interesting thing is that, when Saturday comes, she would rather do it on Monday.

We say that there is a **time inconsistency** if someone plans to do something in the future but subsequently changes her mind. Planning to do the homework on Saturday but then on Saturday deciding to do it on Monday, and planning to wait an extra day for \$110 but when the time comes taking the \$100, are examples of time inconsistency. There cannot be time inconsistency in a model of exponential or hyperbolic discounting, but there can be in a model of quasi-hyperbolic discounting. Time inconsistency is potentially very important in terms of welfare and policy because it suggests that people plan to do something but then end up doing something else. I am, therefore, going to spend some time on the issue in Chapters ten and eleven when we look at welfare and policy. At this point I want to show you how time inconsistency can have important consequences for behavior.

4.2.2 The consequences of time inconsistency

The consequences of time inconsistency will depend on whether people know they are time inconsistent or not. For example, does Maria realize on Friday that, if she plans to do the homework on Saturday, when Saturday comes she might think differently? This could clearly be important in deciding what she does do on the Friday.

We say that someone is **naïve** if they are unaware that they have present-biased preferences. In this case, Maria would plan on Friday to do the homework on Saturday and not expect to think differently on Saturday. By contrast, we say that someone is **sophisticated** if they know that they have present-biased preferences. In this case Maria will realize on Friday that if she leaves the homework until Saturday she will probably end up doing it on Monday.

I'll look first at what happens if Maria is naïve. It's easiest to start with cases where the costs of an activity precede the benefits, as in the homework example.

We saw in the example that on Friday Maria will expect to do the homework on Saturday, but on Saturday might decide to do it on Monday. This means that she can end up doing the homework later than she expected and later than she would have done without a present bias. To delay doing something in this way is called **procrastination**. Maria procrastinates because she puts off doing the costly thing. What happens if the benefits come before the costs?

To help illustrate, I will use a second example. Imagine it costs \$10 to go to the movies and Maria only has \$11 spending money. There are movies on Friday, Saturday, and Sunday. Table 4.6 shows that she will prefer the movie on Sunday to that on Saturday and that on Saturday to that on Friday. Table 4.7 summarizes her inter-temporal utility (these tables can be compared to 4.1 and 4.5). If Maria has time-consistent preferences then she would plan to go to the movie on Sunday. If she has present-biased preferences, then on Friday she would to plan to go on Sunday, but on Saturday would change her mind and go that day. Again we see a time inconsistency. The difference is that this time Maria does something earlier than she expected and earlier than she would have done with no present bias. To bring forward something in this way we can call to **preproperate**.

In both the homework and the movie example, Maria is impatient for benefits. In the homework example this causes her to put off something that is costly. In the movie example it causes her to do early something that is pleasurable. Will someone who is sophisticated and knows they are time inconsistent avoid such problems? The answer is a bit surprising.

The surprise is not in the homework example. If Maria knows that on Saturday she will delay until Monday, then on Friday she knows the real choice is between

Table 4.6 Payoffs from Maria going to watch a movie

	Payoff on		
Plan	*Friday*	*Saturday*	*Sunday*
Go on Friday	5	0	0
Go on Saturday	0	6	0
Go on Sunday	0	0	8

Table 4.7 Inter-temporal utility in the movie example with time-consistent and present-biased preferences

	$\beta = 1, \delta = 0.9$		$\beta = 0.8, \delta = 0.9$	
Plan	*On Friday*	*On Saturday*	*On Friday*	*On Saturday*
Go on Friday	5.0	—	5.0	—
Go on Saturday	5.4	6.0	4.3	6.0
Go on Sunday	6.5	7.2	5.2	5.8

doing her homework now, giving utility 7.4, or on Monday, giving utility 7.2. So, she will do the homework on Friday and behave as if time consistent. Being sophisticated thus allows Maria to avoid any time inconsistency. So far, so good. But what about the movie example? In this case Maria knows that if she does not go on Friday she will go on Saturday. On Friday she therefore knows that the real choice is between going today or tomorrow. She will go today. Being sophisticated, therefore, means that Maria preproperates more than if she was naïve. She knows that she will not be able to resist going to the movies and so goes even earlier!

Table 4.8 summarizes the choices made. We see that, in the case of delayed benefits, sophistication helps overcome the problems associated with present bias, but in the case of delayed costs it makes things worse. It is not obvious what is better or worse in terms of utility because it is not clear whether to take into account the present bias or not. What we do see, however, is that a present bias has important implications for choice, even if someone is sophisticated.

The movie example shows that being sophisticated can make things worse because Maria anticipates her future present bias. This, however, misses part of the story. That is because someone who is sophisticated may use **commitment** to constrain her future choice. For instance, Maria could pre-order her movie ticket on Friday for Sunday. She would be willing to pay to do such a thing because it means she is committed to making the best choice. If she was naïve, she would see no need to do so. Someone who is sophisticated will thus be looking for ways that they can commit and avoid future temptation.

4.2.3 Temptation and self-control

The model of quasi-hyperbolic discounting is a nice simple model that has allowed us to capture important aspects of inter-temporal choice. One thing that it does not capture so well is the potential benefits of commitment. An approach suggested by Gul and Pesendorfer (2001) provides us with a more elegant way to capture this. To illustrate how it works I will continue the homework example.

On Saturday Maria can either do the homework or play sport. What I want you to imagine now is the possibility that on Friday Maria can commit to what she will do on Saturday. So, she can commit to doing the homework or to playing sport by,

Table 4.8 A summary of the two examples: choice and utility (calculated as inter-temporal payoff on Friday with no present bias)

	Delayed benefits (homework)		*Delayed costs (movie)*	
	Choice	*Payoff*	*Choice*	*Payoff*
Time consistent	Saturday	10.9	Sunday	6.5
Sophisticated	Saturday	10.9	Friday	5.0
Naïve	Monday	9.0	Saturday	5.4

for example, arranging things with friends. This means that on Friday Maria has three choices: commit to doing the homework on Saturday, commit to playing sport on Saturday, or not commit and decide what to do on Saturday.

If Maria has time-consistent preferences then the possibility to commit is irrelevant. If she thinks it is best to do the homework on Saturday then she will be indifferent between committing to do the homework on Saturday and not committing, because she will do the homework on Saturday either way. If Maria has present-biased preferences then things are different.

If Maria thinks it is best that she does the homework on Saturday but knows that on Saturday she may not do it, then it may be good for her to commit on the Friday to doing the homework on Saturday. What's interesting is that we can now distinguish two distinct reasons for her to commit. Most obvious is that Maria knows on Saturday she will choose to play sport and wants to stop this happening. Looking back at Table 4.5 this makes sense if $\beta = 0.8$. The second possibility is that Maria knows she would do the homework on Saturday but only after overcoming the temptation to play sport. That is, she would do the homework but only after exercising **self-control**, which is psychologically costly. She may be able to avoid this cost by committing on Friday to do the homework on Saturday. This fits the case where $\beta = 0.9$.

We can formalize this in a simple model. We already have u_2 to measure the utility of Maria on Saturday. If she does her homework, she gets utility $u_2(H) = -5$, and if she plays sport she gets utility $u_2(S) = 5$. We are now going to add to this a cost of temptation. The cost of temptation should reflect Maria's psychological cost of not doing something she might have wanted to do. So, let $m(H)$ denote the **temptation** to do homework and $m(S)$ the temptation to do sport. The **cost of temptation** from doing action a is then calculated as follows:

$$C(a) = m(a) - max_{b=H,S}m(b).$$

For instance, if the temptation to do sport is greater than that of doing homework, then $m(S) \geq m(H)$ and so the cost of temptation from doing the homework is $C(H) = m(H) - m(S)$. This is the psychological cost of doing the homework when Maria would rather be playing sport.

What if we add together Maria's basic utility plus the cost of temptation? Then we get that if she has not committed on Friday to do something on Saturday, her overall utility on Saturday can be of two forms. First, Maria could exercise self-control, and so the payoff from not committing includes the cost of overcoming temptation. We can write this:

$$u_2^m(H,S) = max_{a=H,S}\{u(a) + m(a)\} - max_{b=H,S}\, m(b). \tag{4.5}$$

Or, it could be that Maria has not exercised self-control and so chooses the action that gives highest utility. We can write this:

$$u_2^m(H,S) = max_{a=H,S}u(a) \text{ subject to } m(a) \geq max_{b=H,S}\, m(b). \tag{4.6}$$

We can, therefore, distinguish the two reasons that Maria may want to commit.

Equations (4.5) and (4.6) might look a little over the top for what we need. The neat thing, though, is that, if Maria would want to pre-commit, we can say for certain that her overall utility must be like that in (4.5) or (4.6). More generally, if someone wants to be able to pre-commit then we must be able to represent their preferences with a utility function u and temptation function m like this (see Research Methods 4.2). This means that a desire to pre-commit must come hand in hand with temptation.

Research Methods 4.2

Axioms and behavior

Gul and Pesendorfer analyzed a much more general setting than that which we have discussed here and obtained a stronger result than I have suggested so far. They showed that preferences satisfy four 'intuitive' axioms if and only if preferences can be represented by functions like u,m and u^m. As well as being a beautiful mathematical result, this is also an interesting illustration of the axiomatic approach to modeling choice.

In an axiomatic approach a researcher basically questions what properties of preferences are consistent with a particular way of modeling choice. Gul and Pesendorfer look at four axioms. Informally these are that preferences (i) be complete and transitive, (ii) be continuous, (iii) satisfy independence, in the sense that a third option would not change the choice between two others, and (iv) satisfy a preference for commitment, meaning that if someone would rather they did one action than another, then they prefer to commit to doing that action. Their results show that, if you think a person's preferences satisfy these axioms, then you have to think functions u,m and u^m are a good way to model choice. Similarly, if you think u,m and u^m are a good way to model choice, then you have to think these axioms are reasonable.

The axiomatic approach has a very long history in economics. In principle, it seems entirely consistent with behavioral economics in trying to match plausible assumptions on preferences with observed choices. In reality, something of a divide has emerged between behavioral economics and the axiomatic approach. This is probably because axioms that seemed sensible have not held up to scrutiny in the experimental laboratory, transitivity being one example. The axiomatic approach does, however, give definitive answers about when ways of modeling choice are appropriate and so clearly does have its place, as Gul and Pesendorfer show.

To illustrate, Table 4.9 follows through what Maria's preferences may look like. If there is no present bias, then there is no temptation, and so it is natural to think that $m(S) = m(H) = 0$. It does not matter whether she commits or not. If there is a relatively small present bias, $\beta = 0.9$, then Maria will do the homework on Saturday. If she does not pre-commit, however, she will have a cost of temptation. If $m(S) = 0.5$ and $m(H) = 0$ then by pre-committing to do her homework she can avoid the cost of this temptation and increase the utility she gets on Saturday.

Table 4.9 The utility of Maria on Saturday. The basic utility u^T is the same as in Table 4.5, the temptation is given by m, and the overall utility, taking into account the cost of temptation, is given by u^{T^m}. By committing to the homework, she avoids the cost of temptation when $\beta = 0.9$ and avoids procrastinating when $\beta = 0.8$

	$\beta = 1, \delta = 0.9$			$\beta = 0.9, \delta = 0.9$			$\beta = 0.8, \delta = 0.9$		
	u^T	m	u^{T^m}	u^T	m	u^{T^m}	u^T	m	u^{T^m}
Committed to homework	12.1	0	12.1	10.4	0	10.4	8.7	0	8.7
Committed to sport	10.0	0	10.0	9.5	0.5	9.5	9.0	0.5	9.0
Decide on Saturday	12.1	—	12.1	10.4	—	9.9	9.0	—	9.0

If there is a larger present bias, $\beta = 0.8$, then Maria will delay doing the homework unless she commits to doing it on Saturday. This is motive enough to commit.

This model allows us to nicely capture the benefits of commitment. In particular, it illustrates how someone may make consistent choices yet still desire commitment, in order to avoid the psychological costs of temptation. Altogether,therefore, we now have some useful ways to model decreasing impatience and present bias. We have, however, only addressed one of the issues raised in section 4.1. Now, it is time to consider some of the others.

4.3 Loss aversion and sequences

What I want to do now is look back on things like the delay-speed-up asymmetry and see if we can better understand them. In doing so, I will draw heavily on work by Loewenstein and Prelec (1992, 1993).

4.3.1 Reference dependence

We can begin by applying the idea of reference dependence to inter-temporal choice. This means writing the inter-temporal utility function as:

$$u^T(x_1, x_2, \ldots, x_T) = \sum_{t=1}^{T} D(t)v(x_t - r_t)$$

where $D(t)$ is the discount factor, $v(x)$ is some value function, and r_t is the reference point in period t. We shall not say much about the discount factor because everything we did in section 4.2 is relevant here. Our focus, therefore, will be on the value function.

As we saw in Chapters two and three, the most important thing about the value function is that it measures consumption relative to some reference point. So, instead of thinking of x_t as the payoff in period t we need to think of $x_t - r_t$ as the loss or gain relative to the reference point. This raises familiar questions about what the reference point should be, but we can assume for now that the reference point is current income. What does the value function need to look like for us to capture the behavior I talked about in section 4.1.1?

To answer that question, suppose that Maria is indifferent between getting \$$q$ now rather than \$$y > q$ in some future period t. This means $v(q) = D(t)v(y)$. Recall that the **gain-loss asymmetry** implies that she should be relatively reluctant to postpone payment compared to postponing receipt. So, she should prefer to pay \$$q$ now instead of having to pay \$$y$ in period t. For instance, if she is indifferent between getting \$10 today or \$11 tomorrow, she would prefer to pay \$10 today than \$11 tomorrow. This means $v(-q) > D(t)v(-y)$. The gain-loss asymmetry requires, therefore, that:

$$\frac{v(q)}{v(y)} < \frac{v(-q)}{v(-y)}. \tag{4.7}$$

Recall that the **absolute magnitude effect** means that the larger the amount, the more patient she is. So, Maria should prefer getting \$$\alpha y$ in period t rather than \$$\alpha q$ now, if $\alpha > 1$ captures some proportional increase in the amounts to be paid. This means that $v(\alpha q) < D(t)v(\alpha y)$. The absolute magnitude effect requires, therefore, that:

$$\frac{v(q)}{v(y)} > \frac{v(\alpha q)}{v(\alpha y)}. \tag{4.8}$$

Finally, we come to the **delay-speed-up asymmetry**. Speed-up is naturally thought of as expediting a receipt, in order to get \$$q > 0$ now rather than \$$y > 0$ in some future period t. One can think of the reference level as zero now and \$$y$ in the future. By expediting the receipt Maria loses, therefore, \$$y$ in the future but gains \$$q$ now. If she is indifferent between doing this, then $-D(t)v(-y) = v(q)$. We can estimate a discount factor for speeding up t periods using $q = \delta^{speed\ up} y$ to give:

$$\delta^{speed\ up} = \frac{q}{y} = \frac{v^{-1}(-D(t)v(-y))}{y}.$$

Delay is naturally thought of as delaying a receipt so as to get \$$y > 0$ at some future period t rather than \$$q > 0$ now. This time we can think of the reference level as \$$q$ now and zero in the future. By delaying receipt Maria loses \$$q$ now but gains \$$y$ in the future. If she is indifferent to do this, then $-D(t)v(y) = v(-q)$. We can estimate a discount factor for delaying t periods using $q = \delta^{delay} y$ to give:

$$\delta^{delay} = \frac{q}{y} = \frac{v^{-1}(-D(t)v(y))}{y}.$$

Suppose we compare these two discount factors and, for simplicity, assume that $D(t) = 1$. Then, $\delta^{speed\ up} > \delta^{delay}$ if:

$$v^{-1}(-v(-y)) > -v^{-1}(-v(y)).$$

If you stare at this long enough you might see that we require $-v(-y) > v(y)$, but this is what we get with loss aversion. So, all we need to explain the delay-speed-up asymmetry is loss aversion.

A model with reference-dependent preferences can, therefore, capture a lot of the things we observe in inter-temporal choice. Unfortunately, things do not work out as perfectly as we might hope, because the formula for the value function we looked at in Chapter three (see equation (3.7)) does not satisfy either relations (4.7) or (4.8)! But we could easily tweak it and sort that out. As in Chapters two and three, therefore, reference dependence helps a lot in understanding behavior.

As you might expect, however, by now we do need to think a bit more about the reference point. To illustrate why, let's return to the homework example and suppose Maria must do the homework on Saturday or Monday. Furthermore, suppose that it is rare for homework to be set over the weekend, and so this is not her reference point. Instead, her reference point is to doing something on Saturday. One possibility is that on a Saturday she usually plays sport. Another is that she usually has to visit an aunt she does not like. This gives the reference-dependent utility in Table 4.10.

Irrespective of the reference point, Maria faces the same trade-off between a relatively large drop in utility on Saturday, a difference of 10, for a gain on Monday, a difference of 15. The reference point will matter in how she perceives this trade-off. Let's go through each reference point in turn. If she normally plays sport on Saturday, then doing the homework on Saturday will feel like a loss. This might make her reluctant to do the homework. If:

$$D(2)v(-10) + D(4)v(10) < D(4)v(-5)$$

Table 4.10 The homework example with reference-dependent preferences. If the reference point is to play sport, doing the homework on Saturday feels like a loss, but if the reference point is to visit an aunt, doing the homework on Saturday feels like a gain

	Utility on		
	Saturday	*Sunday*	*Monday*
Payoff x_t if do homework Saturday	−5	10	10
Payoff x_t if do homework Monday	5	10	−5
Reference point is to play sport			
Reference payoff r_t	5	10	0
Reference-dependent utility if do homework Saturday	−10	0	10
If do homework Monday	0	0	−5
Reference point is to visit aunt			
Reference payoff r_t	−10	10	0
Reference-dependent utility if do homework Saturday	5	0	10
If do homework Monday	15	0	−5

then she will leave the homework until Monday. If she normally visits her aunt on Saturday, then doing the homework on Saturday will feel like a gain. This might make her more likely to the homework. If:

$$D(2)v(5) + D(4)v(10) > D(2)v(15) + D(4)v(-5)$$

then she would want to do the homework on Saturday.

To focus on the issue at hand, suppose that $D(2) = D(4) = 1$. Then we need to know whether $v(-10) + v(10) < v(-5)$ and whether $v(5) + v(10) > v(15) + v(-5)$. These equations may or may not be satisfied but suppose, by way of illustration, that $v(5) = 3, v(10) = 5, v(15) = 6, v(-5) = -7$, and $v(-10) = -13$. Then she would not do her homework on Saturday if the reference point is playing sport, but she would do her homework on Saturday if the reference point is to visit her aunt. The reference point and context can, therefore, influence behavior.

4.3.2 Preferences for sequences

What I want to look at next is how to model preferences over sequences. For now we shall ignore the question of when a set of events is viewed as a sequence rather than separate. So, what we need to do is measure the overall utility of a sequence of payoffs such as $\{x_1, x_2, \ldots, x_T\}$.

One way we do so is to compare this sequence with one that gives the same payoff in each period. That is, we compare the actual sequence to the smoothed sequence $\{\bar{x}, \bar{x} \ldots, \bar{x}\}$ where:

$$\bar{x} = \frac{1}{T}\sum_{t=1}^{T} x_t.$$

For every period t let:

$$d_t = t\bar{x} - \sum_{t=1}^{t} x_i$$

be the difference in utility, up to and including period t, between the smoothed sequence and actual sequence. We then get a nice way to think about the utility of a sequence by saying that utility is given by:

$$u^q(\{x_1, x_2, \ldots, x_T\}) = \sum_{t=1}^{T} x_t + \beta \sum_{t=1}^{T} d_t + \sigma \sum_{t=1}^{T} | d_t | \quad (4.9)$$

To see why this is a nice way to think about things I need to introduce two further concepts.

We say that the **anticipated utility** of receiving sequence $\{x_1, x_2, \ldots, x_T\}$ is given by:

$$AU = \sum_{t=1}^{T} (t-1)x_t.$$

The story is that if Maria is going to receive payoff x_t in period t then she spends $t-1$ periods anticipating this. So, she gets $(t-1)x_t$ anticipated utility. Summing this over all periods gives total anticipated utility.

Following a similar logic we say that the **recollected utility** of the sequence is:

$$RU = \sum_{t=1}^{T} (T-t)x_t.$$

If Maria received payoff x_t in period t then she has $T-t$ periods to recollect it, and so gets $(T-t)x_t$ recollected utility.

A bit of rearranging shows that:

$$\sum_{t=1}^{T} d_t = 0.5(AU - RU).$$

So, positive values of Σd_t are associated with more anticipated than recollected utility. This means that a high Σd_t goes hand in hand with an improving sequence in which the x*t*s increase with t.

Now we can go back to equation (4.9) and make some sense of it. We can see that a $\beta > 0$ means a preference for an improving sequence and a $\beta < 0$ a preference for a worsening sequence. We also see that $\sigma < 0$ indicates a preference for a smoothed sequence while $\sigma > 0$ indicates a preference for a one-sided sequence. To illustrate what this means, Table 4.11 has some example sequences. If σ is small and β positive, then Maria would prefer sequence C with lots of anticipation utility. If σ is negative and β positive, then she may prefer sequence E which still has anticipation utility but is more smoothed over time.

Table 4.11 Preference over sequences of outcomes with the anticipated and recollected utility

	Period					*AU*	*RU*	Σd_t
	1	*2*	*3*	*4*	*5*			
Sequence A	1	1	1	1	1	10	10	0
Sequence B	5	0	0	0	0	0	20	−10
Sequence C	0	0	0	0	5	20	0	10
Sequence D	2	1	1	1	0	6	14	−4
Sequence E	0	1	1	1	2	14	6	4
Sequence F	2	0	1	0	2	10	10	0

The evidence we looked at in section 4.1.2 would suggest that $\beta > 0$ and $\sigma < 0$. With the help of Table 4.12 we can see what this means in the homework example. Doing the homework on Saturday gives the most improving sequence, but not a very smooth one. To do the homework on Friday or Sunday may, therefore, be optimal. Indeed, if σ is very negative, Monday may be optimal as it gives the most smooth sequence.

The homework example brings us back to the troubling question of when period payoffs are seen as part of a sequence and when they are not. Will Maria think of the weekend as one sequence of events, or think of each day as separate from another? We see now that this might affect her choice. Unfortunately, there is no simple rule as to when a person will think of periods as separate or part of a sequence. The further apart are two events, then the more likely it intuitively seems that they will be seen as two separate events rather than as a sequence of events. This logic can only take us so far, however, as we shall see shortly in looking at habit formation.

4.4 Summary

I began by looking at a utility function with exponential discounting. The basic idea here is that inter-temporal utility, and choice, can by captured by assuming people discount the future at a constant rate. If true, this would make our life easier. Unfortunately, we saw that preferences seem to depend a lot on context, and exponential discounting is not well placed to pick this up. For example, we observe things like a gain-loss asymmetry, delay-speed-up asymmetry, absolute magnitude effect, and preference for improving sequences.

In looking at alternatives to exponential discounting we focused first on the fact that people seem impatient for short-term gain. We saw that there are two distinct ways to think about this. We can think in terms of a model of hyperbolic discounting with time-consistent preferences, or we can think in terms of quasi-hyperbolic discounting with time-inconsistent or present-biased preferences. The latter looked the better way to go.

Present bias, and time inconsistency, raises some interesting possibilities. A person may procrastinate by putting off doing something costly, preproperate by doing early something pleasant, or fight to overcome temptation. What happens

Table 4.12 Preferences over sequences in the homework example

	Payoff on:				*AU*	*RU*	Σd_t
Plan	*Friday*	*Saturday*	*Sunday*	*Monday*			
Do it Friday	−5	5	10	4	37	5	16
Do it Saturday	0	−5	10	10	45	0	22.5
Do it Sunday	0	5	−5	10	25	5	10
Do it Monday	0	5	10	−5	10	20	−5

can depend on whether the person is naïve or sophisticated in knowing about their present bias.

We next added reference dependence and loss aversion to the mix and showed this can explain things like the delay-speed-up asymmetry and gain-loss asymmetry. We also saw that perceptions of the reference point can influence choice.

Finally, we looked at how we can capture the utility from a sequence of events using anticipated and recollected utility.

A recurring theme in Chapters two and three was that context mattered. It would influence perceptions which would then influence choice because of things like the reference point. In thinking about inter-temporal choice we can come up with many other good reasons why context will matter. For instance, whether someone perceives a series of events as a sequence or separated can have a huge impact on behavior; in the one they are impatient for gain and in the other they want to delay for the future. Context effects will be less of a theme in the rest of the book (although they will crop up again in Chapter seven). So, before we move on I do want to emphasize their importance.

Most economic choices involve choice arbitrariness, risk, and time, all mixed up together. The potential context effects are, therefore, huge, and behavior will depend a lot on the context, and perceptions of the context. It's vital to be aware of and try to account for this. It's a key part of being a behavioral economist. What this means in practice is questioning things like what is the reference point, and what is a loss or a gain, in the different contexts that you are interested in understanding. This is a matter of judgment.

4.5 Borrowing and saving

In Chapter two we spent some time looking at the life cycle hypothesis and saving. Clearly these are inter-temporal issues, and so it is natural to think back to them now that we have a means to model inter-temporal choice. In doing so there are two new issues I want to pick out: habit formation and consumer debt.

4.5.1 Saving equals growth or growth equals saving?

A high savings rate usually goes together with a high growth rate. What is not so clear is why. A standard life cycle model of consumption predicts that higher expected income should lead to less saving, because the higher expected income means less income needs to be saved now in order to smooth future consumption. The prediction, therefore, would be that high saving causes high growth, and not the other way around. A lot of evidence, however, tends to suggest that things do go the other way around. It seems that high growth tends to proceed and cause high saving.

Habit formation is one possible way to account for this, as shown by Carroll and co-authors (2000). I am going to look at habit in more detail in Chapter ten, but the basics are all we need here. In a **model of habit formation** the utility of today's consumption depends on past consumption. One possible reason for this is that a person wants to maintain consumption at past levels. They have got used to a certain standard of living and would rather keep to, or improve upon, that standard. This fits with the idea that people want an improving sequence. People want to see their income and standard of living improving and not getting worse.

To capture this, assume that Maria has a habit level of consumption h. The habit evolves over time according to:

$$\frac{dh}{dt} = \rho(c - h)$$

where c is consumption and ρ determines to what extent habit depends on the recent past. The larger ρ is, the more quickly Maria's habits adapt to recent consumption.

A simple utility function we could use would be:

$$u(c, h) = \frac{c}{h^{\gamma}}$$

where γ measures the importance of habit. If $\gamma = 0$, then habits are irrelevant and we have a standard model where utility depends on consumption. If $\gamma = 1$, then utility depends only on whether consumption is more or less than the habit level. For intermediate γ, utility depends on both the absolute level of consumption and whether it is more or less than the habit level. For example, if $\gamma = 0.5$, then consumption of two with a habit level of one gives the same utility as if both consumption and the habit level are four.

It is possible to show, with some reasonable assumptions, that savings will increase with income if and only if the importance of habit γ is sufficiently large. Thus, habit can cause high savings if there is a high growth rate of income. The intuition for this is that a habit level of consumption means less reason to devote any increase in income to consumption. As long as consumption is above the habit level and the standard of living is rising, Maria will get relatively high utility. So, she does best to increase her consumption slowly over time and always have a rising standard of living. What she would not want to do is devote all the increased income to consumption. This would risk a subsequent fall in consumption below her new habit level with a consequent fall in living standards and utility.

Table 4.13 illustrates how this may work. We can see that income is going to increase over the four periods and can compare a smoothed consumption schedule A to an increasing schedule B. The increasing schedule gives higher utility because Maria does relatively well compared to what she has become used to. It also guards against any potential fall in the income she might get in period four.

We see, therefore, that habit and a preference for an improving sequence can explain why people save rather than spend, even if they expect future income growth. That people may think about their lifetime earnings as a sequence also highlights the problems of trying to distinguish when events are seen as separated rather than as a sequence. Here we are thinking of someone potentially seeing year-to-year earnings as a sequence!

Table 4.13 Two sequences of consumption compared in a model of habit formation. Consumption schedule B gives the highest utility

	Period				*Total utility*
	1	*2*	*3*	*4*	
Income	15	15	30	100	
Consumption A	40	40	40	40	
Habit A	15.0	27.5	33.75	36.9	
Utility A	10.3	7.6	6.9	6.6	31.4
Consumption B	25	35	45	55	
Habit B	15.0	20.0	27.5	36.0	
Utility B	6.5	7.8	8.6	9.1	32.0

4.5.2 Why save when you have debts?

One of the more puzzling aspects of saving behavior is that many people borrow on credit cards at a high interest rate to buy consumer goods, while simultaneously saving for the future at lower interest rates. To give some figures, in March 2009, US consumer debt, made up primarily of credit card debt, was about $950 billion, and around 14 percent of disposable income went to paying off this debt. At the same time the savings rate was around 4 percent of disposable income. One might argue that some people are saving while others are borrowing, but this does not seem to be the case; many people are both saving and borrowing. Why?

In trying to explain this puzzle the key thing to recognize is that people typically borrow for the short term (i.e. to buy a new dress) while saving for the long term (i.e. to buy a new house or retire). This distinction between short term and long term leads naturally to thoughts of quasi-hyperbolic discounting and time inconsistency. Several studies have indeed shown that this can help explain what is going on. For example, Laibson and co-authors (2007) try fitting the (β, δ) preferences model to data from US households. Having taken account of risk attitudes, they find that the model with parameters $\beta = 0.90$ and $\delta = 0.96$ fits the data well. This equates to a long-run discount rate of 4.1 percent and a short-term rate of 14.6 percent.

Why does a model with (β, δ) preferences work? First, a consumer with a long-run discount rate of 4.1 percent would be happy to save over the long term at a savings rate of, say, 5 percent per year. Second, a consumer with a short-term discount rate of 14.6 percent would be happy to borrow money to buy something now if she can pay that back at a rate of, say, 14 percent per year. Basically, the consumer wants to save but because of time inconsistency may also be unwilling to wait to buy that new dress.

Clearly banks and credit card companies can profit from this, which brings us nicely on to the next topic.

4.6 Exploiting time inconsistency

We have seen that present-biased preferences and time inconsistency can result in someone procrastinating. They keep on delaying something they need to do. Could a company exploit this? To see why this question is pertinent I am going to look at a study by Della Vigna and Malmendier (2006). The study was published with the title 'Paying not to go to the gym', which somewhat gives away the punch line.

4.6.1 Time inconsistency and consumer behavior

DellaVigna and Malmendier look at attendance data for over 7,000 health club members at three health clubs in New England between April 1997 and July 2000. People going to the gym had four basic options: (i) pay $12 per visit, (ii) pay $100 every 10 visits, (iii) sign a monthly contract with a fee of around $85 per month, and (iv) sign an annual contract with a fee of around $850. One difference between the monthly and annual contract is that the monthly contract was automatically renewed, while the annual contract was not. Those on a monthly contract could cancel at any time, but needed to do so in person or in writing. Those on an annual contract needed to sign up again at the end of the term, or their membership would stop.

This difference between the monthly and annual contract is a difference of what happens if the member does nothing, or is in the **default position**. The default position with a monthly contract is that a member needs to **opt out** of being a member. With the annual contract a member needs to **opt in** to being a member. Why should we worry about this distinction? Possibly we should not, because it costs very little to make a phone call, or write a letter, to opt in or opt out. There is, however, potential for time inconsistency. A person may want to cancel, or rejoin, but put it off until tomorrow, and then put it off until the next day, and so on. Similarly, a person may think they will go to the gym often, but typically find some excuse to go tomorrow rather than today. Let's look at the data.

Any of the four payment options could make sense to a particular consumer. They may go rarely, so the pay per visit makes sense; they may know they will go often, so the annual contract makes sense; or they may be unsure how often they will go, so prefer the flexibility of the monthly option. The interesting question is whether consumers do choose the option that is best for them. The study finds that basically they do not. To give a first illustration of this, Figure 4.5 plots the average price per attendance of new members. We see that in the first six months of membership the average cost per visit was relatively high. Indeed, 80 percent of monthly members would have been better off paying for every ten visits.

Figure 4.5 is suggestive of customers not choosing the best option, but does not capture the whole picture. That is because we need to see whether people learn and readjust. It may have been optimal for someone to sign a monthly contract but then switch to paying per visit once they realized how much (or how little) they used the gym. There is little evidence, however, of readjustment. This

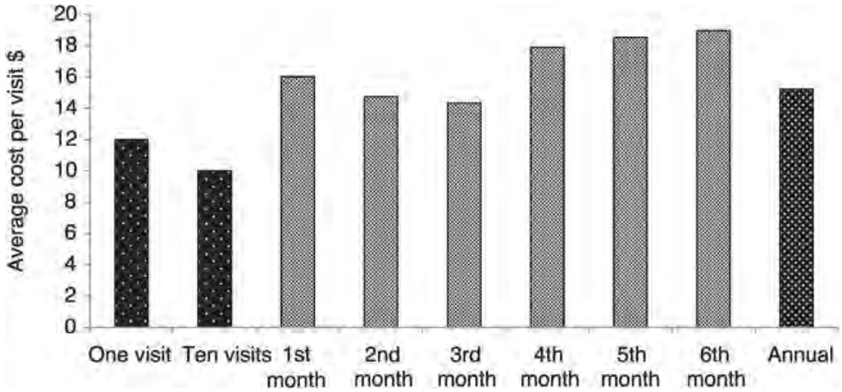

Figure 4.5 Average cost per visit to the gym for the first six months of monthly membership or year of annual membership. Monthly members pay on average more per visit than if they had paid per visit.

Source: DellaVigna and Malmendier (2006).

is particularly the case for those on the monthly contract. Many monthly members appeared to consistently overestimate their future usage and put off canceling their membership. Particularly telling is the average lag of over two months between the last time a person attends the gym and the moment they cancel membership! Such a delay is costly. Looking over the whole period of membership, the average loss for someone on the monthly contract was \$614. For those on the annual contract it was just \$1.

In trying to make sense of these results, DellaVigna and Malmendier suggest the most likely explanations are overestimation of future usage, time inconsistency, and naïvety. A model of naïve consumers with (β, δ) preferences where $\beta = 0.7$ and $\delta = 0.9995$ can explain the data, including the average delay of over two months in cancelation.

4.6.2 Firm pricing

In the gym example the loss made by a consumer on the monthly contract was the firm's gain. This raises the question of whether firms use a pricing strategy that maximizes the profit they can make from consumers. To answer this question we first need to know how firms should price if consumers have a present bias. To do so I will work through a model of gym membership based on that by DellaVigna and Malmendier (2004).

There are three periods. In period one the gym proposes a **two-part tariff** (L, p) that consists of a **lump sum membership fee** L and a **user fee** p that is paid every visit. If Maria joins the gym, then in period two she pays the membership fee and decides whether or not to use the gym. If she uses the gym then she pays the user fee, p plus some personal cost to attend, c. Maria does not know the personal cost until after joining. If she does go to the gym, then in period three she receives some benefit, B. Figure 4.6 summarizes what happens. The key to the model are the delays. There is a delay between joining and using the gym, so Maria needs to predict future usage when joining. There is also a delay between using the gym and benefitting from having used the gym.

This delay gives scope for present bias to matter. So, let's assume that Maria has (β, δ) preferences, but thinks she has $(\hat{\beta}, \delta)$ preferences. If $\hat{\beta} > \beta$, then she has a present bias but underestimates the strength of the bias.

To see what Maria will do we first need to imagine that we are in period one and Maria is predicting what she will do in period two. She expects that when period two comes she will think the payoff from using the gym is $\delta\hat{\beta} B - p - c$, the discounted benefit minus the cost. She, thus, expects that she will use the gym if $c < \delta\hat{\beta} B - p$. From the perspective of period one the benefit from using the gym is $\delta\hat{\beta}(\delta B - p - c)$. So, if Maria signs the contract, she should expect net benefit:

$$NB = \delta\hat{\beta}\left(-L + \int_0^{\delta\hat{\beta}B-p}(\delta B - p - c)dc\right). \tag{4.10}$$

The integral term captures her uncertainty about what the personal cost of using the gym could be.

The next thing we need to do is question what Maria will actually do in period two. She will only use the gym if $c < \delta\beta B - p$. If, therefore, $\hat{\beta} > \beta$ she is biased in overestimating her likelihood of going to the gym, and because of this overestimates the benefits of joining the gym. This is consistent with what we saw in Figure 4.5.

Now we can consider the firm. Suppose the firm pays production cost K whenever anyone joins and per-unit cost a if anyone uses the gym. They know that a consumer will use the gym in period two if $c < \delta\beta B - p$. The objective of the firm is to choose L and p to maximize profits,

$$max_{L,p}\left(L - K + \int_0^{\delta\beta B-p}(p-a)dc\right).$$

The one caveat is that the net benefit NB must be greater than zero, or no one would join. If you solve this maximization problem (see below) then the optimal price is:

$$p = a - \delta B(1 - \hat{\beta}) - \delta B(\hat{\beta} - \beta). \tag{4.11}$$

I'll look at this in three stages, summarized in Table 4.14.

If customers have no present bias, $\beta = 1$, the firm should set the per-usage fee equal to the cost, $p = a$. This result should be familiar to those who have studied price discrimination in a microeconomics course. The optimal thing for the gym to do is charge as high a membership fee as customers will pay and then make zero profit from customer use.

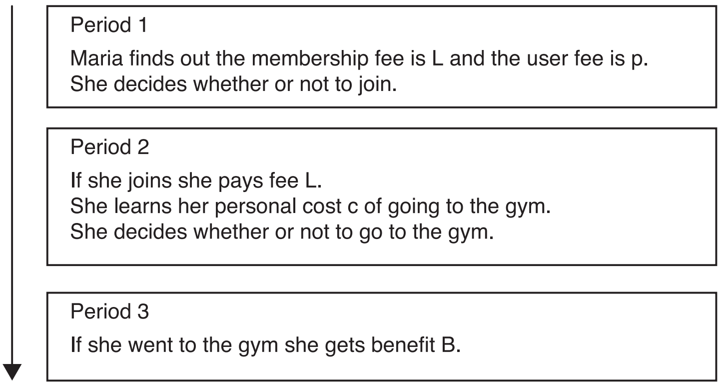

Figure 4.6 The timeline of the model of gym pricing.

If customers do have a present bias, $\beta < 1$, then the firm should set the per-usage fee below the cost, $p < a$. That means the gym makes a loss every time a customer uses the gym! Why would that make sense? It depends on whether the customer is sophisticated or naïve. If Maria is sophisticated, she knows that, because of her present bias, she may put off going to the gym. Thus, she wants something that makes it more likely she will go. A lower user fee serves that purpose. Maria would, therefore, be willing to pay a higher membership fee in order to have a lower usage fee. The gym does not profit from Maria having a present bias, but it does need to charge different prices.

If Maria is naïve, then she may overestimate how much she will use the gym. The lower the usage fee, the more she thinks she will use the gym, and consequently the higher the membership fee she is willing to pay. In this case the gym

Table 4.14 The consequences of optimal pricing in the gym example with present-biased preferences

Preferences	*Consumer*	*Firm*
No present bias, $\beta = 1$	Correctly predicts when will use the gym.	Makes a profit on membership fees. Makes no profit when members use the gym.
Present bias and sophisticated, $\beta = \hat{\beta}$	Knows will possibly not use the gym because of present bias.	Needs to charge a lower user fee to attract customers. Makes a loss when people use the gym but this is compensated for by a higher lump sum fee. Does not profit from consumers' present bias.
Present bias and naïve, $\beta < 1$ and $\hat{\beta} = 1$	Does not realize will possibly not go to the gym because of a present bias.	Charges a lower user fee to exploit customers. Makes a loss when people use the gym but this is compensated for by a higher lump sum fee and some customers not using the gym. Profits from consumers' naivety.

can profit from Maria's present bias. By offering a low usage fee it can charge a high membership fee and gain on people who join but subsequently do not use the gym. The larger the naïvety of consumers, the more profit the gym can make.

[Extra] To see how to get equation (4.11): If we set $NB = 0$, we can substitute in for L from equation (4.10) to rewrite the firm's problem as:

$$max_p\left(\int_0^{\delta\hat{\beta}B-p}(\delta B-p-c)dc-K+\int_0^{\delta\beta B-p}(p-a)dc\right).$$

This can be rewritten:

$$max_p\left(\int_0^{\delta\hat{\beta}B-p}(\delta B-a-c)dc-K+\int_{\delta\beta B-p}^{\delta\hat{\beta}B-p}(\delta B-p-c)dc\right)$$

and:

$$max_p\left((\delta\beta B-p)(\delta B-a)+\delta B(\hat{\beta}-\beta)(\delta B-p)-K-\int_0^{\delta\hat{\beta}B-p}cdc\right).$$

Evaluating the last integral and differentiating with respect to p gives the result!

There are two important lessons from this simple model. First, firms should take account of present bias when setting an optimal price. This is particularly pertinent if consumers are sophisticated. In this case, the firm cannot profit from the present bias but does need to price differently to make the same profits as without a present bias. Second, firms can profit by exploiting naïve consumers. They can charge a high membership fee and offer a low usage fee, knowing that some customers will not take advantage of the lower usage fee.

The data we have for gym membership would suggest that firms are aware of this. The user fee for members was zero, which must be below the gym's per-unit cost. We also did see underuse of the gym. Let's look at another example.

4.6.3 Choosing the correct calling plan

If the title of DellaVigna and Malmendier's paper, 'Paying not to go to the gym', gave away the punch line, the title of a paper by Miravete (2003), 'Choosing the wrong calling plan?,' leaves things more open.

Miravete looks at consumers' choice of telephone calling plans following a tariff change by company South Central Bell in 1986. Customers had the choice between a flat-rate tariff of \$18.70 per month, or a measured tariff of \$14.02 per month plus call charges. Such choices (and utility payments in general) are often suggested as fertile ground for present bias. That's because it may be best for a customer to switch tariff, and she may know that, but delays doing so because of present bias. This study aimed to put that anecdotal hunch to the test.

Key to the study was a survey of 5,000 customers that included questions on expected telephone usage. If we know how much customers expected to use the telephone then we can hope to identify customers who should have expected the other tariff to be less costly, but did not switch.

Around 30 percent of the consumers surveyed chose the measured option and 70 percent stayed with the flat rate. So, did consumers make the correct choice and, more importantly, did they switch if it looked like they had initially made a wrong choice? Table 4.15 provides some relevant data to see what happened. There was a high proportion of people over/underestimating the number of calls they would make. This should feed through to some making the wrong choice of calling plan. Of interest to us is how many of those who were in the wrong plan in October switched by December to the better plan. Overall, around 40 percent of customers were in the wrong plan in October, falling to 33 percent in December. There is also evidence that those with the most to gain from switching were the ones to switch.

This study gives an interesting contrast to the one on gym membership. Recall that, with gym membership, it was those opting for the 'flat' monthly tariff that were most often making the wrong choice. In this telephone example those choosing the flat rate are on average making the right choice. It is those choosing the 'variable' per-use tariff that are most often making the wrong choice. It would be hard, therefore, to argue that people are on average biased towards a flat versus variable tariff or vice versa. It just seems that people are bad at predicting future usage and therefore end up making the wrong choice.

Present bias can give a plausible explanation for all of this. People might over-estimate how much they will use the gym and underestimate how much they will use the telephone because of time inconsistency. Furthermore, they may put off changing plan once they have realized it's wrong because of procrastination. Present bias gives us a good story, but is it the whole story?

Probably not. In the gym case, those who are paying too much do eventually change their membership. Similarly, in the telephone case the number of customers choosing the wrong tariff does fall over time. What appears to be time inconsist-ency and procrastination may, therefore, just be people taking time to learn their

Table 4.15 Choices of calling plan, estimates of usage, and the proportion of customers making the wrong choice

Choice in October	*Flat*	*Flat*	*Measured*	*Measured*
Choice in December	*Flat*	*Measured*	*Flat*	*Measured*
Number of customers	953	43	41	375
Underestimated calls by 20% or more	26%	28%	32%	33%
Overestimated calls by 20% or more	59%	49%	61%	49%
Made wrong choice in October	11%	44%	100%	57%
Made wrong choice in December	6%	7%	0%	67%

Source: Miravete (2003).

preferences and make the best choice. This is not to say that present bias is not important, it is just to highlight that other things are clearly going on as well. These other things will be a theme of the next two chapters as we look at how people interpret new information and how they learn over time.

4.7 Environmental economics

Up until now we have focused on an individual making choices about her future. For example, when should Maria do the homework, or go to the cinema, or visit the aunt she does not like? Many important economic decisions, however, involve decisions that will affect future generations. For example, if Maria builds up too much debt, then her children, and grandchildren, may be expected to pay that off. In this section I want to briefly look at how we can understand such long-term trade-offs.

In doing so I shall focus on environmental protection. This is natural given that the most pressing examples of long-term trade-offs concern the environment. Many scientists paint a depressing picture of the future unless we reduce or control carbon emissions. Similar fears surround many related issues such as deforestation, overfishing, radioactive waste, pollution of rivers, etc. I will use, therefore, the example of protecting the environment to illustrate the more general ways that behavioral economics can inform debate on long-term trade-offs.

4.7.1 Inter-generational discount factor

Debate on climate change was blown open in 2006 by the Stern *Review on the Economics of Climate Change*. The *Review*, commissioned by the UK government, advocated immediate action to reduce CO_2 and other greenhouse emissions. It warned of dire long-run consequences unless we acted *now*. This advice was in stark contrast to conventional economic thinking. Most economists advocated a **climate-policy ramp** in which policies to slow global warming would increasingly ramp up over time. So, why did the *Review* reach such a radical conclusion?

To help explain the issues, consider the entirely made-up numbers in Table 4.16. These show the utility of an average person now and after 50 to 200 years, depending on the climate change policy enacted. If we do nothing we risk catastrophe. The climate-policy ramp advocates gradual action in the future. If we

Table 4.16 The long-run consequences of four climate change policies

	Utility				
Policy	*Now*	*50 years*	*100 years*	*150 years*	*200 years*
Do nothing	100	100	0	0	0
Climate-policy ramp	100	95	80	90	100
Immediate action	90	90	100	100	100

act immediately then we lower current utility for the sake of the future. Which policy should we choose?

Table 4.16 is similar to Tables 4.1 and 4.6, which detailed Maria's utility from doing her homework or going to the movies. The same techniques we used to analyze those choices can be used to decide on a climate change policy. But there is one fundamental difference. As Maria decides when to do her homework she is trading off her utility now for her utility in the future. We need to know her personal discount factor, present-day bias, preference for an increasing sequence, and so on. When society decides on a climate change policy we are trading off the utility of the current generation for the utility of future generations. This means we need some way of making inter-generational choices. We need a discount factor and preference over sequences that measure society's long-term desires (see Research Methods 4.3).

Research Methods 4.3

Inter-generational lab experiments

I have already remarked that long-run trade-offs are hard to measure in a laboratory experiment (see Research Methods 4.1). Looking at inter-generational trade-offs would seem even more impossible. Economists, however, are an ingenious bunch and inter-generational experiments have been run. Given that such experiments involve games that we are not going to look at until later in the book, I will not go through them in detail here, but the basic design can be illustrated with a study by Chaudhuri and co-authors (2009).

Groups of eight subjects were brought into the lab and played the weakest link game for ten rounds (see Chapter six for more on this game). Once the ten rounds were up, each subject was replaced by a new subject, her laboratory descendant. The new group of eight subjects played the weakest link game for a further ten rounds. This continued for up to nine generations. When a subject handed over to her descendant she was allowed to leave a message. Depending on the treatment, the descendant was allowed to see this message and the recent history of her parent. The final thing to point out is that a subject was paid based on her own performance and the performance of her descendant. A subject, thus, had an incentive to send a good message.

Experiments like this cannot tell us much about inter-generational discount factors. They can, however, tell us some interesting things about how advice is passed down and acted on from generation to generation. For example, subjects in the study tended to send pessimistic advice, which the next generation initially ignored but soon followed. The outcome was inefficiency. In terms of protecting the environment, this suggests that we need to be wary of a 'don't bother, it's hopeless' message being passed down the generations.

There are three basic approaches to tackling this problem. The approach taken by the Stern *Review* sees deciding on an appropriate discount factor and preference over sequences as a philosophical and ethical issue. What we know about personal discount factors is deemed irrelevant, because they are person specific. We need to think of future generations, and the *Review* argued that one generation should not unduly advantage itself at the cost of future generations. It, thus, advocated a discount factor near one and a smoothing of utility over time. Indeed, they argued that the only reason why the discount factor should differ from one is because of the threat of extinction; we need to take account of the fact that a meteor might wipe out humanity before 200 years are up.

Table 4.17 shows that, when we put in a discount factor of 0.999, immediate action is the optimal policy. The high discount factor means we should make immediate sacrifice for future generations. It did not take long, however, for economists to criticize such a high discount factor.

An alternative approach is based on revealed preference. This approach basically says that we should look to personal discount factors when deciding policy because these reveal how much we actually care about future generations. If Maria does not save for the future, then she reveals that she does not care too much about her children and grandchildren! Moreover, this approach argues that decisions to invest in climate change abatement technology should be based on current rates of return.

Table 4.17 shows that, if we put in a discount factor of 0.95, then the climate-policy ramp is optimal. If the discount factor is any lower, then doing nothing is optimal. The radical conclusions of the Stern *Review* follow, therefore, from the relatively high weight put on the future. Crisis over!

Well, the material in this chapter should leave you somewhat skeptical of the revealed preference approach. We have seen that personal discount factors are highly context dependent. We have also seen that people are time inconsistent and happy to pre-commit. They borrow at high interest rates while saving at low interest rates and buy gym memberships they do not need. Against this backdrop it seems hard to argue that current rates of return can be taken all that seriously when deciding on the optimal inter-generational discount factor. Indeed, the climate-policy ramp looks remarkably like present bias.

Fortunately, there is a third approach that can help reconcile views. This approach takes as its starting point the huge uncertainty about climate change. If we do not know what discount factor to choose, then let us build that into our thinking. This might sound like fudging the issue, but it turns out not to. To see

Table 4.17 The discount factor for which each policy is optimal, and the inter-temporal utility of each policy for different discount factors

Policy	*δ when optimal*	*Inter-temporal utility*			
		δ = 0.999	*0.95*	*0.9745*	*uncertain*
Do nothing	0.945 or less	195.1	107.7	127.5	151.4
Climate-policy ramp	0.945 to 0.996	422.1	107.8	134.6	264.9
Immediate action	0.996 to 1	434.0	97.6	124.9	265.8

why, let us say the appropriate discount factor is either 0.999 or 0.95. We put 50 percent probability on each possibility. At first glance this may seem equivalent to a discount factor half-way between 0.999 and 0.95, but Table 4.17 makes clear that it is not. If we are uncertain about the discount factor, then immediate action is the optimal policy. Basically, some probability that we should use a high discount factor is enough to advocate immediate action.

All three approaches summarized above have their critics, and it is up to you to decide which approach makes most sense to you. The point I would emphasize is that behavioral economics can inform your opinion, particularly about the reliability of using revealed preference. I want to show next that behavioral economics can also help us tackle climate change and reduce CO_2 emissions.

4.7.2 Reducing CO_2 emissions

Just about all economists agree that climate change requires action at some point in the future. That will require people to change their behavior. We need to pollute less, consume less, and so on. The standard economic model suggests that a change in behavior will only come about when there are changes in prices. Attention has, thus, focused on things like a carbon tax or subsidies for renewable energy. Behavioral economics, however, points to many ways in which behavior can be changed without disturbing economic fundamentals. I will look at two examples to illustrate the point. In Chapter eleven I shall look at the general approach to behavior change in more detail.

Suppose that Maria is persuaded by the need to protect the environment and is committed to reducing her CO_2 emissions. She needs a new car and decides to buy an environmentally friendly one. Suppose that she drives 10,000 miles per year for work, and this cannot be changed. The standard model of car she would like to buy does 15 miles per gallon and costs \$20,000. It is possible to buy alternative models that differ only in fuel efficiency, ranging from 20 miles per gallon up to 60 miles per gallon. How much should Maria pay for greater fuel efficiency?

Note that this question is partly about saving money. By buying a more fuel-efficient car Maria not only helps the environment but also can save money on fuel. It is potentially a win-win situation where no sacrifice is needed in order to reduce CO_2 emissions. But this is only going to happen if Maria makes the right choice. A study by Larrick and Soll (2008) put subjects in the position of Maria and asked them how much they would pay for the fuel savings. Figure 4.7 summarizes the results. We can see that the subjects' willingness to pay followed a linear pattern. They were willing to pay as much to reduce fuel consumption from 45 to 55 miles per gallon as they were to reduce consumption from 25 to 35 miles per gallon. This, however, is a basic misunderstanding of how the miles per gallon ratio works.

To see things more clearly it is convenient to convert miles per gallon into gallons per 100 miles. A change from 25 to 35 miles per gallon means a reduction from 4 to 2.86 gallons per 100 miles. A change from 45 to 55 miles per gallon means a reduction from only 2.22 to 1.81 gallons per 100 miles. Remember that Maria was going to do 10,000 miles per year. So, buying the model that does

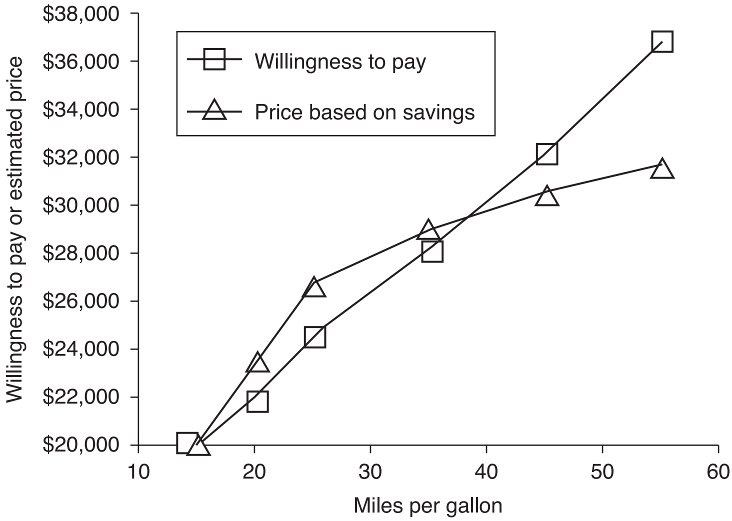

Figure 4.7 Willingness to pay for a more fuel-efficient car and the estimated price taking into account predicted fuel savings.

Source: Larrick and Soll (2008).

35 rather than 25 miles per gallon saves her 114 gallons of fuel. Buying the model that does 55 instead of 45 miles per gallon only saves 40 gallons of fuel. The linear willingness to pay schedule that we see in Figure 4.7 overestimates the benefit of going from 45 to 55 miles per gallon, while it underestimates the benefit of going from 25 to 35.

The bias we see here results from the use of simple heuristics. The framing in terms of miles per gallon makes most people think that any saving in ten miles per gallon is equivalent. If things are reframed in terms of gallons per 100 miles then people will be far less biased. The message, therefore, is simple. If we want people to make informed decisions we should use the amount of fuel per unit of output (as Europe typically does), rather than the amount of output per unit of fuel (as the US and UK typically do).

Having bought a fuel-efficient car, Maria now looks to cut down on her domestic energy usage. Her local utility company starts sending her Home Energy Report letters from a company called OPOWER. The report compares her energy use to that of 100 similar neighbors. She is rated as great, good, or below average and offered tips on energy reduction. Will this motivate, or inform her, to reduce energy consumption?

Allcott (2011) evaluated the consequences of sending such letters to over half a million energy customers across the US. In households that received the letters energy consumption was reduced by around 2 percent. That may not sound much, but it is a large reduction. For example, we can estimate that a price rise of around 11 to 20 percent would be needed to bring about such a fall in usage. Most of the reduction was caused by day-to-day changes such as turning off lights and adjusting thermostats. Again, we see that Maria can help the environment and save money at the same time.

These two examples illustrate once more the importance of framing and context effects. The new thing I want to emphasize is how such effects are amplified by procrastination. When it comes to reducing gas emissions, procrastination is potentially a very dangerous thing. If Maria, and everyone else, continually puts off protecting the environment until tomorrow, then it may not be long before there is no environment left to protect. This point makes clear that, for all the talk of the Stern *Review*, climate-policy ramps, and inter-generational discount factors, gas emissions will only be reduced if individuals change behavior. Procrastination is a major reason that people will not change behavior, even if they 'want' to.

Climate change policy, therefore, needs to look for ways of overcoming procrastination. A change in the way decisions are framed may help do that. For example, Maria may partly put off getting a fuel-efficient car because she underestimates the gains she would make from doing so. Similarly, receiving a letter with tips on energy reduction may help overcome her procrastination on reducing home energy usage. Small changes in framing can have big, long-run consequences!

4.8 Further reading

The survey article by Frederick *et al*. (2002) is a good place to start. The papers by O'Donoghue and Matthew Rabin (1999, 2000, 2006) are recommended reading on time inconsistency. As is the pioneering article by Strotz (1956). Note that we will return to time inconsistency in Chapter eleven, and so much of the further reading there is also relevant here. For an interesting look at the desire for wages to increase over time see Frank and Hutchens (1993). For more on applying behavioral economics in industrial organization see Ellison (2006). For more on behavioral environmental economics see Shogren and Taylor (2008) and Allcott and Mullainathan (2010).

4.9 Review questions

4.1 Inter-temporal utility (as defined in equation 4.1) is about measuring streams of utility over time. To make life easier for themselves, however, economists normally think about streams of money over time. This should be OK if we think in terms of, say, '\$10's worth of utility', but could be problematic if we really mean 'a \$10 note'. To illustrate, if someone says they are indifferent between \$150 in one year's time to \$100 today, what is the discount factor, when the utility function is $u(x) = x$ and $u(x) = \sqrt{x}$ and x is money? Think about the implications of this.

4.2 Explain the difference between time-consistent and present-biased preferences. Why is this distinction not important in a model of exponential discounting?

4.3 In section 4.3, I showed that $\delta^{speed\text{-}up} > \delta^{delay}$ in the case of a receipt. Show that $\delta^{speed\text{-}up} < \delta^{delay}$ in the case of a payment.
4.4 Looking back at Table 4.10, what would happen if Maria's reference point was to do her homework on Saturday, and what if it was to do it on Monday? How is this related to the concept of personal equilibrium that we looked at in the last chapter?
4.5 Looking back over this chapter and the previous two, come up with examples of context effects.
4.6 What is the expression for $D(t)$ with quasi-hyperbolic discounting?
4.7 What context effects do you think make it more likely that someone will think of a series of events as a sequence rather than separated?
4.8 What are the implications of habit formation for the life cycle hypothesis?
4.9 What is the relationship between a model of habit formation and reference-dependent utility?
4.10 Why do many firms, like gyms, charge a two-part tariff with a zero user fee?
4.11 Is there a difference between firms exploiting a customer's bias and changing their strategy to take account of a customer's bias?
4.12 What strategy can firms use to take account of other cognitive biases and heuristics that we have looked at, like loss aversion and risk aversion?
4.13 How can people overestimating how much they will use the gym and underestimating how much they will use the telephone both be caused by time inconsistency?
4.14 Compare the three approaches, looked at above, for deriving an intergenerational discount factor. Why is it so difficult to agree on the best approach?