5: Life and Time

“Our new Constitution is now established and has an appearance that promises permanency; but in this world nothing can be said to be certain except death and taxes.”

February 12, 2018

MARKET FAILURE AND GOVERNMENT FAILURE: COERCION FOR THE PUBLIC GOOD

http://rasmusen.org/g406/reg-rasmusen.htm,

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If the government is trying to design a regulation, it must compare the costs and benefits. Very commonly, the costs and benefits are timed differently— costs early, benefits later, typically— so the analysis needs to take time into account. It is also common for the cost or the benefit to consist partly of more people or fewer people dying. In choosing a speed limit, for example, a higher limit will have the cost that more people will die in traffic accidents, but the benefit that people will save time in their journeys. This chapter is on those two topics: time, and life.

5.1: Time

Consider the following three assets.

- Bond A pays out \$10,000 plus inflation to be received 1 year from today.
- Bond B pays out \$10,000 plus inflation to be received 50 years from today.
- Bond C pays out \$1,000 plus inflation each year forever, with the first payment one year from today.

If I gave each bond to you right now, how much would you sell it to me for?

Clearly, Bond A is more valuable than Bond B. It is better to have money sooner rather than later. Having it sooner, you can at least put the money in the bank for 49 years and be no worse off than if you had been holding Bond B all along.

Bond C's valuation is trickier. It will pay out an infinite amount of money, but not right away. It is definitely more valuable than Bond B, because by 50 years from today it will have paid out \$49,000, which is better than Bond B's \$10,000 even if we ignore the interest you can earn on the earlier payout. But it is not clear whether it is better than Bond A. That depends on the **discount rate**, the rate at which you trade off future against present wealth.

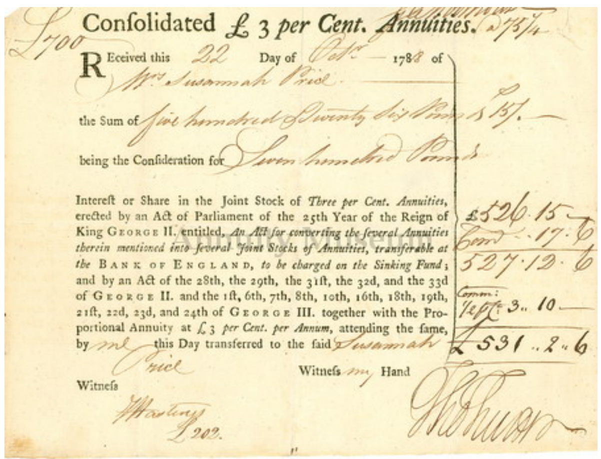
The **present discounted value** or **present value** of X dollars received t years from today is, if the discount rate is constant at t,

$$PDV = X\left(\frac{1}{1+r}\right)^t \tag{1}$$

The present value is the amount of immediate cash that equals the value of a future stream of payments, in this case the stream consisting of one drip in t years.

BOX 5.1: CONSOLS

In 1752, the Chancellor of the Exchequer converted all outstanding redeemable government securities into “Consolidated 3.5% Annuities” to reduce the interest rate.



£700

Consolidated £ 3 per Cent. Annuities.

REceived this 22 Day of Oct. 178 of Mrs. Susannah Price

the Sum of five hundred & twenty six Pounds 15/.

being the Consideration for Seven hundred Pounds

Intereſt or Share in the Joint Stock of *Three per Cent. Annuities*, erected by an Act of Parliament of the 25th Year of the Reign of King GEORGE II. entitled, *An Act for converting the ſeveral Annuities therein mentioned into ſeveral Joint Stocks of Annuities, transferable at the* BANK OF ENGLAND, *to be charged on the Sinking Fund*; and by an Act of the 28th, the 29th, the 31ſt, the 32d, and the 33d of GEORGE II. and the 1ſt, 6th, 7th, 8th, 10th, 16th, 18th, 19th, 21ſt, 22d, 23d, and 24th of GEORGE III. together with the Proportional Annuity at £ 3 *per Cent. per Annum*, attending the ſame, by me this Day transferred to the ſaid Susannah Price

Witneſs my Hand

Witneſs

£526.15.–
17.6
527.12.6
3..10.–
£531..2..6

Consols still exist today; as “2.5% Consolidated Stock (1923 or after)” they remain part of the UK’s debt portfolio. The bonds have a low coupon, so the government is not eager to redeem it.

If the discount rate is r_t during year t, the present discounted value of X dollars received in t years is:

$$PDV = X\left(\frac{1}{1+r_1}\right)\cdot\left(\frac{1}{1+r_2}\right)\cdots\left(\frac{1}{1+r_t}\right) \tag{2}$$

The present value of X dollars at the end of each year forever, the bond known as a **perpetuity** or a **consol** is

$$PDV = X\left(\frac{1}{r}\right) \tag{3}$$

If the X dollars is received at the beginning of each year, the value is simply

$$PDV = X + X\left(\frac{1}{r}\right) \tag{4}$$

because it is the same as the stream of X dollars at the end of the each year plus a bonus of X dollars received immediately.

Table 5.1 uses Equations (1) and (3) to show the values of Bonds A, B, and C for various discount rates.

TABLE 5.1
PRESENT DISCOUNTED VALUES ROUNDED TO THE NEAREST $100

Asset		Discount Rate 0.01%	1%	2%	3%	5%	7%	10%
A: $10,000 next year	$\frac{10K}{1+r}$	10,000	9,900	9,800	9,700	9,500	9,300	9,100
B: $10,000 in 50 years	$\frac{10K}{(1+r)^{50}}$	10,000	6,500	3,700	2,300	900	300	85
C: $1,000/year forever	$\frac{K}{r}$	10 million	100,000	50,000	33,300	20,000	14,300	10,000

Discount rates are like interest rates. Indeed, if you can sell the bond on the open market, the market interest rate will be the discount rate you should use, since you will be a price taker. Interest rates do differ across time, however, and even across bonds with the same **maturity** (the same date at which the bond makes its final payment). Bonds issued by companies or governments which might **default**— not making the promised payments— will pay a higher interest rate to account for the extra risk. **Rating agencies** such as Moody's are private companies that issue reports on how likely different issuers are to default on bonds of various maturities, giving them ratings such as AAA (the best) or B (quite risky). Bonds that are traded more commonly will pay lower interest rates because they are easier to buy and sell. Bonds may have special provisions that affect their value too. Some bonds, for instance, can be recalled early by the issuer, paid off at some pre-specified price. Since the issuer has this valuable option, he has to pay a higher interest rate in order to compete with simple bonds.

The Rule of 72.[1]

Suppose you start with X and it doubles in t years if compounded at interest rate r. The doubled value is $2X$ and the compounded value in t years is Xe^{rt}, where e is Euler's number, $e \approx 2.7$, defined as the value e which solves $\frac{d}{dx}e^x \equiv e^x$ for any x.[2] Thus,

$$2X = Xe^{rt}. \tag{5}$$

[1]See Moneychip.com, "The Rule of 72 - Why it Works."

[2]The number e vies with π for the status of "most important strange number in mathematics". It is the limit as n goes to infinity of the amount would get if you were paid an annual rate of interest of r=100% compounded n times per year: $\lim_{n\to\infty}(1+r/n)^n$. Its most wonderful feature, Euler's identity of $e^{i\pi} = -1$ where $i \equiv \sqrt{-1}$, is not used in economics,.

Simplifying yields $ln(2) = rt$, so since the natural log of 2 is about .69,

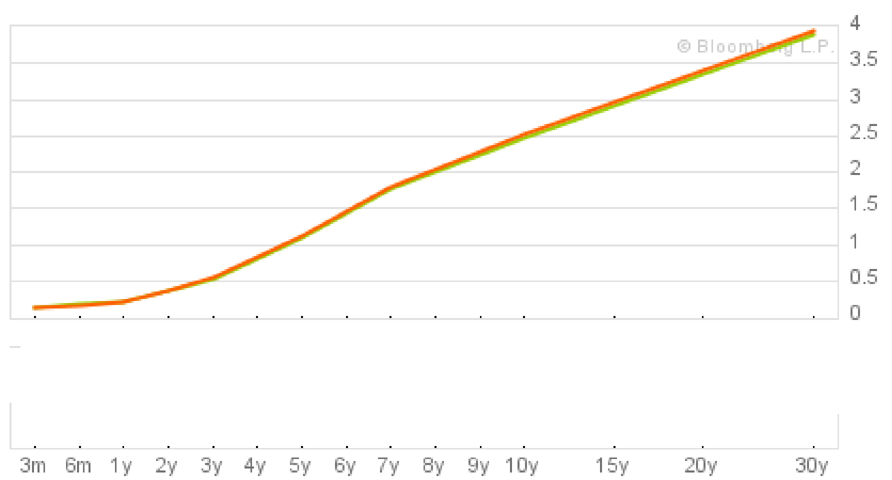
$$t \approx \frac{.69}{r}. \tag{6}$$

The number 69 isn't 72, of course, but 72 is pretty close, and it divides evenly by a lot of numbers. Thus, if $r = 36\%$ it takes about 2 years to double your money; if $r = 18\%$ it takes 4 years; if $r = 9\%$ it takes 8 years; if $r = 10\%$ it takes about 7.2 years, if $r = 6\%$ it takes about 12 years; if $r = 3\%$ it takes about 24 years; if $r = 2\%$ it takes about 36 years; and if $r = 1\%$ it takes about 72 years. This last shows how far off the Rule of 72 will take you, because the true number is closer to 69 years than to 72. But the whole point is to make the arithmetic easy to do in your head.

What Value Should Be Chosen for the Discount Rate?

Table 5.2 shows the market **yields to maturity**— the average interest rate you would earn if you bought the bond at the current market price and held it till its last payment— on a variety of bonds. Much of the interest rate is simply compensation for expected inflation. If inflation is expected to increase, people expect future interest rates to be higher than present interest rates, and the yields on long-term bonds will be higher than on short-term bonds, as shown in Figure 5.1.

FIGURE 5.1
THE YIELD CURVE



The U.S. Treasury issues **TIPS**— bonds that pay an interest rate that varies with inflation— for investors who do not want to take the risk that inflation will affect the value of their bonds. Another consideration is that state and local bonds are **tax-exempt bonds**. Their owners do not have to pay federal income tax on the interest (and often can reduce their state income tax too, as a California resident can by holding

California government bonds). Naturally, tax-exempt bonds pay lower interest rates, since demand for them is higher.

TABLE 5.2
PERCENTAGE YIELDS ON FEDERAL GOVERNMENT DEBT

Asset	Term (rating)	Yield to Maturity	Inflation-Indexed
U.S. Treasury	3-Month	0.13	
U.S. Treasury	6-Month	0.17	
U.S. Treasury	12-Month	0.21	
U.S. Treasury	2-Year	0.35	
U.S. Treasury	3-Year	0.53	
U.S. Treasury	5-Year	1.09	-0.52
U.S. Treasury	7-Year	1.77	
U.S. Treasury	10-Year	2.47	0.39
U.S. Treasury	30-Year	3.90	1.34

TABLE 5.3
PERCENTAGE YIELDS ON PRIVATE AND MUNICIPAL DEBT

Asset	Term (rating)	Yield to Maturity
Fixed-rate mortage	30-year	4.29
Prime rate		3.25
LIBOR	1-Month	0.26
Microsoft	30-year (AAA)	4.44
Johnson & Johnson	7-year (AAA)	1.94
Toys R Us	3-year (B)	4.63
Lucent	19-year (B)	8.02
Brookstone	1-year (CCC)	19.25
Indiana University	7-year (AAA)	1.68
East Chicago	19-year (B)	5.91

Market yields fluctuate. Those shown in Table 5.2 are from 2010. Table 5.3 shows the average returns over two periods of time: the long interval from 1926 to 2007, which covers the Great Depression, World War II, the 1970's Stagnation, the 90's Boom, and the 2001 Telecom Bubble, and the more recent interval from 1970 to 2007, which avoids the Depression and World War II. Table 5.3 also shows the yields on the stocks of large and small companies, which are riskier and hence must be higher for people to be willing to hold them.

TABLE 5.4
PERCENTAGE YIELDS ON STOCKS AND BONDS

	1926–2007		1970–2007	
Asset	Nominal	Real	Nominal	Real
Stocks:				
Large Firms (S&P 500)	12.3	**9.2**	12.4	7.7
Smal Firms	17.1	**14.0**	15.6	10.9
Bonds:				
Long-Term Corporate	6.2	**3.1**	9.4	4.7
Long-Term Treasury	5.8	**2.7**	9.4	4.7
Intermediate-Term Treasury	5.5	**2.4**	8.4	3,7
30-Day Treasury Bills	3.8	**0.7**	6.0	1.3
Currency	0.0	**-3.1**	0.0	-4.7

The returns are arithmetic means. Boldface indicates numbers I tell my students to memorize for their quiz.

In determining the present value of an asset, the investor must think carefully about the risk from inflation, default, and business success in order to decide which interest rates to use for the discount rate. Even bigger problems arise, however, if the asset is not tradeable in a market. Suppose I ask you at what price you would sell Bonds A, B, and C to me, but we specify that I am the only possible buyer. Now you can't look at market yields to figure out the price by seeing how much you could sell the bond for in the open market. If I am the only buyer, you must ask yourself how much the stream of payments is worth to you personally, given your own need for money each year in the future. You can't use the market interst rate for the discount rate—you need to look inside your heart and find your personal discount rate.

Box 5.2
Circular No. A-94

1. Base-Case Analysis. Constant-dollar benefit-cost analyses of proposed investments and regulations should report net present value and other outcomes determined using a real discount rate of 7 percent. This rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years. Significant changes in this rate will be reflected in future updates of this Circular.

2. Other Discount Rates. Analyses should show the sensitivity of the discounted net present value and other outcomes to variations in the discount rate. The importance of these alternative calculations will depend on the specific economic characteristics of the program under analysis. For example, in analyzing a regulatory proposal whose main cost is to reduce business investment, net present value should also be calculated using a higher discount rate than 7 percent . . .

It might be, for example, that you will badly need money in two years to repay a loan shark who has threatened to break both of your legs if you don't pay him. In that case, Bond A would be most attractive to you since it pays out in one year, even if the yield on 50-year bonds were as low as 0.01% so that Bond C, the consol, had a market value of ten million dollars. If you're not allowed to sell your asset, its market value doesn't matter to you— you have to focus on the cash flows.[3]

This is an important decision in public policy. In business finance, the focus is on matching your own discount rate with market interest rates. In public policy, the focus is on figuring out what discount rate to use, because the decisions are about cash flows that aren't traded in a market. The Office of Management and Budget issued the memo *Circular A-94* in 1994 to lay out general policies to be used by agencies in choosing discount rates for cost-benefit analysis. The excerpt in Box 5.2 establishes 7% as the rate to be used for most analyses, saying

> "This rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years."

What is the relevance of "the marginal pretax rate of return on an average investment in the private sector"? Put briefly, this is the opportunity cost of using the funds for a government project or for complying with a regulation as opposed to investing it privately or consuming it. The idea is that we want to know if citizens kept the money for themselves, what return would make them willing to forego consumption

[3]Companies also have to decide what discount rate to use. Most simply, they can use their cost of capital— but that will change in the future if they take on more risky or less risky projects. Companies, like people, often use extremely simple rules such as computing the pay-back period (ignoring the time value of money!) as a first step in making their decisions. See "The Theory and Practice of Corporate Finance: Evidence from the Field," John R. Graham & Campbell R. Harvey, *Journal of Financial Economics*, 60: 187–243 (2001).

in exchange for future benefits. That will be the return that people are willing to accept on the investments they actually make. The adjectives in the quotation above are carefully chosen to clarify this idea. The return is on "the average investment in the private sector" because returns on investments with different risks will be very different. We could try matching the risk of the particular government project or regulation to the discount rate needed, but OMB decided that was more complexity (and ability to twist the analysis to get the result the agency desired) than was justified, so it just uses the average rate across all investments. The return is "the marginal rate of return" because investors will first snap up the private investment projects that yield the highest returns for given risk, but when we look at the opportunity cost of using the funds for government purposes, it is the private projects that have the lowest returns of all those adopted that will disappear. It is "the pretax rate of return" because actually private investors are not looking at the social rate of return on projects. The total benefit to society from a project with a pre-tax return of 10% and an after-tax return of 7% is 10%, not 7%. The benefit to the investor is only 7%, but society gets the additional 3% to spend for some worthy government cause. (You may think the government wastes it, but since our political process produces the spending we actually have, it would be improper for OMB to make a judgement like that.)

The excerpt in Box 5.2 also says that 7% is the discount rate for "constant-dollar benefit-cost analyses of proposed investments and regulations." That means 7% is the discount rate to use if the future costs and benefits are measured in present-day dollars, rather than being higher because of expected future inflation. If the agency uses nominal dollars, it should add the expected inflation rate to the 7%. For example, if the agency measures benefit flows as rising because of inflation from $100 million in the first year to $104 million in the second year, $108 million in the third year, and so forth, it should use a discount rate of 11%, not 7%. Of course, a cost-benefit analysis must also be careful to measure costs and benefits either both in constant dollars or both in nominal dollars.

Not all projects cost the government money, however, so the logic of the 7% private return does not always apply. Circular A-94 distinguishes ordinary cost-benefit analysis from **cost-effectiveness analysis**, cost-benefit analysis for a project, a project that actually reduces government spending:

> **3. Cost-Effectiveness Analysis.** Analyses that involve constant-dollar costs should use the real Treasury borrowing rate on marketable securities of comparable maturity to the period of analysis....
> b. Cost-Effectiveness Analysis. A program is cost-effective if, on the basis of life cycle cost analysis of competing alternatives, it is determined to have the lowest costs expressed in present value terms for a given amount of benefits. Cost-effectiveness analysis is appropriate whenever it is unnec-

> essary or impractical to consider the dollar value of the benefits provided by the alternatives under consideration. This is the case whenever (i) each alternative has the same annual benefits expressed in monetary terms; or (ii) each alternative has the same annual effects, but dollar values cannot be assigned to their benefits. Analysis of alternative defense systems often falls in this category.

Remember why 7% was chosen for most projects. It was the opportunity cost of taking funds away from the private sector. Suppose, though, we are spending $100 million per year maintaining jet fighters, and the Department of Defence is considering investing in a new training program for air force technicians that would cost $120 million for initial retraining but would reduce the maintenance cost to $80 million per year. We will want to have the jet fighters maintained whether we change the training or not; the only question is whether we can save money. If we can save money, then taxes can actually be reduced, so there will be more investment in the private sector, not less. In this case, the government should look to its own cost of borrowing, the interest rate on government bonds. That will be much lower than the private return on investment because the government pays a very low risk premium. (At least, the U.S. federal government pays a low risk premium— for some governments, near insolvency, government bonds might be riskier than private investment.)

Thus, government agencies use "the real Treasury borrowing rate on marketable securities" for cost-effectiveness analysis. It should be the real rate (the after-inflation rate) used in Treasury bonds that must be paid back at the same time as the project's costs—that have "comparable maturity" to "the period of analysis." Thus, if the cost saving from the project wouldn't start until 10 years from now, the discount rate should be the rate on inflation-indexed bonds maturing in 10 years or more, not the rate on 3-month Treasury bills, which is not guaranteed to stay the same over that time.

Not everyone believes that the government should use the opportunity cost of funds as the discount rate, especially for projects with benefits very far in the future. To some extent this is just because people who like the project for other reasons don't want to believe that it's not worthwhile to spend $10,000 today to get a benefit of $100 million in 200 years (it's only worth $132 using $r = .07$). In fact, it's not even worth spending $10,000 today to get a benefit of $2 million/year for eternity but starting 200 years from now (that's worth $38). Why should we be so selfish towards future generations? A little sacrifice on our part would bring them a huge benefit.

This comes up in the context of global warming or space catastrophes. Suppose that a comet might hit the earth 300 years from now and destroy all humans and most animals and plants because of the resulting debris blocking the sun. Cost-benefit analysis would say that since the world's total wealth is only $200 trillion, we shouldn't spend more than about $300,000 on space equipment to block the comet.

So why not adopt a different discount rate for very distant costs and benefits? Well, my comet example is wrong, to begin with. The raw benefit from stopping the comet should be the dollar value (in constant dollars) of wealth 300 years from now, not the value now. If it grows by 3%/year, that comes to a 36,900% increase in wealth and we'd pay $111 million— but that's still a relatively small amount. Another consideration is whether people now, who have only 1/369 as much wealth as the future generation, ought to bear the burden. We could invest $100 million now to double their wealth in 200 years, but people do not seem to feel inclined to subsidize their wealthy descendants that way. Of course, that's not the same as letting them all die, but it does show that we must be careful about incurring costs now to help people in the future. We will consider the value of human life later in this chapter, but for now, note that we should add the values of all the lost lives and the non-wealth destruction to the benefit from our comet-stopper.

What is perhaps more important is the huge uncertainty about what will happen in the world over the next 200 years. What if the United States is conquered by a foreign country, or there is a revolution? Would the space equipment survive? Or what if in 120 years a President is elected who decides to scrap the idea? There is also flexibility in waiting– **option value**. It seems implausible that we really would have to build the spaceship now to be ready in 200 years. If we wait, maybe the comet's path will change, or we'll discover a better way to move it. We at least would not have to incur the cost now and could not only invest the saved money in the meantime but leave it to a richer generation.

The comet prevention program is a special case because the people 200 years in the future who would die would not be compensated for that by having their wealth increased from current investment. Ordinarily, though, the best way to think about discounting investment for the far distant future is to use the idea of opportunity cost. Take the example of spending $10,000 today to get a benefit of $100 million in 200 years. You may not think 7% is the right discount rate, but it does give us one way to look at the opportunity cost of using the $10,000 for that project. The opportunity cost doesn't have to be to selfishly spend the money on ice cream for the current generation. It can be losing the opportunity to invest the $10,000 instead of spending it on the project. If we invest it and earn 7% per year, then in 200 years we'd be able to make a present of $7.5 billion to our descendants. That beats $100 million. Thus, any project that fails cost-benefit using present discounted value and a discount rate equal to the rate at which we can invest money is dominated by just investing the money and giving the resulting sum to whoever would have benefitted from the project. [4]

[4] Here are a variety of references on the social discount rate if you wish to explore further: Mark A. Moore et al., " 'Just Give Me a Number!' Practical Values for the Social Discount Rate," *Journal of Policy Analysis and Management*, 23: 789–812 (2004). "Intertemporal Equity and Discounting," Kenneth J. Arrow, et al., in M. Munasinghe (Ed.), *Global Climate Change: Economic and Policy Issues,* World Bank

5.2: What Is the Value of Life?

In moving from time to life, the natural bridge is the value of your time. If a regulation requires you to spend 2 hours filling out a form, what is the loss in your surplus? What we really want to know is how much the government would have to pay you to make you willing, but just barely willing, to spend the 2 hours filling out the form. Unless you are very bored when you're not at work, you'd need to be paid something for the two hours whether you use leisure time or spend 2 fewer hours earning money. Let's take your wage to be $20/hour. Then you would be $40 poorer as a result of filling out the form if you had to work 2 fewer hours. How to incorporate the cost of leisure time into cost-benefit analysis is then straightforward: measure the cost as $40 even though it wasn't taken from work time. If you have flexible hours, at least, your marginal opportunity cost of leisure is $20/hour, because you could have been earning $20, even though you chose leisure instead. Many people have their hours fixed at 40 hours per week, so the connection is less direct, but if you earn $20/hour it still seems reasonable to estimate the wage at which you'd work one more hour at $20, even if it may be that you'd rather work fewer than 40 hours if you could (in which case your marginal value of time might be $23) or you'd rather work more hours if you could (in which case it might be $18).

We can use the same method for short periods of time. Suppose it only take 15 minutes to fill out the form. At how much should we estimate the cost to you? Our method would say the cost is $20/hour times 1/4 hour, which is $5. In actuality, you'd probably would need to be paid more than $5 to spend the quarter hour, since there's a fixed cost to planning out the time and starting a task, but for government planning we want to keep the estimation simple.

Is it really any cost to spending just five minutes filling out a form, though? Five minutes is a trivial amount of time. This method, though, would estimate the cost of the regulation when applied to a thousand people as five thousand dollars, even though nobody is very inconvenienced by it.

Such thinking is deceptive, even though we don't usually fret much over the loss of five minutes. We're right not to fret, since getting aggravated would probably be a bigger cost than the five minutes itself. What we have to avoid, though, is **the Paradox of the Heap.**[5] The paradox is this. Suppose we start with a heap of sand. If

Environment Paper Number 12. "Valuing the Future: Recent Advances in Social Discounting," David Pearce et al., *World Economics* 4: 121–141 (2003). "Introduction," in P. R. Portney and J.P. Weyant (eds), *Discounting and Intergenerational Equity*, Paul R. Portney and John P. Weyant , (1999). "Reassessing the Government's Discount Rate Policy in Light of New Theory and Data in a World Economy with a High Degree of Capital Mobility," Robert C. Lind, *Journal of Environmental Economics and Managment*, 18: s8–s28 (1990). "On the Social Rate of Discount," Willam J. Baumol, *American Economic Review* 58: 788–802 (1968).

[5]Another name for it could be the "Just One More Drink Fallacy," or the "I'll Stop Tomorrow Trap."

you take away one grain, do you still have a heap of sand? Yes, of course. If you take away another grain from the heap, is it still a heap? Yes. But if you do this until there is just one grain of sand left, is it a heap? No. But when did it change from being a heap to being less than a heap?

We fall into the paradox for two reasons. First, it is hard to notice the difference when one grain of sand is removed, even though it does make a difference. Second, definitions often face a **line-drawing problem**. Where do you draw the line between the pile of sand being big enough to call "a heap" and being too small? We can tell the difference when it is a million grains versus one, but somewhere in the middle we aren't sure what to do. Yet there has to be some dividing point. The line-drawing problem comes up constantly in law and regulation. Is it really worse to drive 55.1 miles per hour than 55.0? Not much worse, but a line has to be drawn somewhere if we are to have a speed limit.

Thus, it makes sense for regulators to count the cost of small losses in time. Indeed, this is a lesson employers should learn too. If a company makes its 500 employees spend 5 minutes per day reading memos, and the average employee is paid $20/hour, that is a cost of 500*1/12*$20 $\approx$ $833/day, which is about the cost of two extra full-time employees.

When someone spends five minutes reading a memo, that is five minutes of their life gone, and perhaps that is just as bad as dying five minutes sooner. Premature death has something more to it than lost time, though, and the value of human life is a deep puzzle for philosophy. Long before Hamlet considered suicide and asked himself "To be or not to be," people wondered about the value of their lives and the value of the lives of strangers. Confucius considered the question of whether a man should save his wife or his mother, if he is in a crisis situation and can only save one of them. More recently, philosophy's **Trolley Problem** asks whether if a trolley is speeding out of control down a track about to kill five people, you should switch the tracks to save them even if you know that by switching the trolley to another track you will kill one other person.[6] Those are hard questions, and as I've said earlier, economics tries to avoid deep questions when it can. Yet we want economics to tell us about how people will behave when they can buy products that reduce the risk of death, and how the government should behave when it decides whether to impose safety regulations.

We can start with a simpler problem: measuring how much a person values *his own* life. Suppose that Joe is buying a car with a base cost of $20,000, and the salesman tells him that for $2,000 extra the car can have special brakes, which might save his life some day in a highway emergency. How does he decide whether to pay that much to avoid a risk to his life? It's a difficult decision, because he doesn't know the exact

[6]See Philippa Foot, "The Problem of Abortion and the Doctrine of the Double Effect," *Oxford Review* 5: 5-15 (1967). "The Trolley Problem," *Wikipedia*, has a summary.

risk avoided, and even if he did, it's hard to visualize the cost of one's own death. But people make the decision. Some buy the special brakes, and some do not.

Economics can say something about this. There is no reason that brake safety shouldn't follow the usual law of demand. If the price goes up to $2,500, we can predict that fewer people will buy the brakes. Whatever decision process they are using, dollar cost is a part of it. We can also, only a bit less definitely, predict that more rich people than poor people will decide to buy the brakes. In paying the price, the buyer is making a tradeoff between safety and money— which is to say, the ability to buy other things. There will be a tradeoff between saving money and avoiding risk in practice, even if people cannot vocalize how they decide it.

Safety tradeoffs are part of our daily life, notably in transportation. Someone who drives a car is deciding every moment how much attention to give to the driving, and how much to the radio, conversation, or plans for the day. It seems crazy to say that people risk their life so they can listen to the radio, but they do: the driver would have lower risk if he had absolutely his full attention on the road. If you think you are driving as safely as you can, think again. Suppose we attached a short razor-sharp spike to your steering wheel, aimed straight at your heart. Wouldn't you change your driving habits.[7]

The government faces the same kind of choice, on a wide scale. Every life-saving regulation has a cost that can be measured in dollars and an estimate of the number of lives saved. That means we can compute a cost per life saved. As Table 5.5 shows, the cost varies wildly across regulations. Steering column protections standards have a cost of about 100,000 dollars per life saved, and the benzene occupational hazard standard has a cost of 10.6 million dollars per life. Surplus would rise if we made steering column standards more strict but relaxed benzene standards. Think of each regulation as a way to buy human lives. The steering column regulation is a cheap way to buy a life, and the benzene regulation is an expensive way. We could relax the benzene standard to lose, say, 10 lives per year because of cancer from the extra exposure, and tighten the steering column regulation enough to save 10 more lives per year in traffic accidents.

[7]The spike hypothetical is attributed to Armen Alchian of the UCLA economics department.

TABLE 5.5
THE COST OF RISK-REDUCING REGULATIONS PER LIFE SAVED

Regulation	Year	Agency	Cost per life saved	Cost per year of life saved
Unvented space heater ban	1980	CPSC	0.1	< 0.1
Steering column protection standards	1967	NHTSA	0.1	< 0.1
Children's sleepware flammability ban	1973	CPSC	1.0	0.1
Rear lap/shoulder belts	1989	NHTSA	3.8	0.2
Ethylene dibromide in drinking water	1991	EPAA	6.8	0.8
Benzene occupational exposure	1987	OSHA	10.6	1.3
Asbestos ban	1989	EPA	131.8	15.8
Atrazine/alachor in drinking water	1991	EPA	109,608.0	13,126.0

Notes: Viscusi et al., Table 20.4. Costs are in millions of 1995 dollars.

Oddly enough, we can reach this conclusion even if we don't know the value of a human life. What I've said is that surplus would rise if we tightened up on steering columns and loosened up on benzene. In the example above, we saved on cost while maintaining the same overall safety level. Or, we keep the total cost the same by relaxing the benzene standard while tightening the steering column standard, in the process saving more lives because so few extra lives would be lost from benzene exposure but many more would be saved in traffic accidents,

If human lives are valuable enough— over 10.6 million dollars per life— then we could do even better by tightening up on both steering columns and benzene. If human lives are valued little— less than \$100,000 per life— then we could do even better by loosening up on both Steering and Atrazine.[8]

5.3: The Forensic Approach to Valuing Life

One approach to valuing a life is the one used in the courts to find the compensation someone has to pay if their negligence kills someone else: find the present value of the person's lifetime earnings. This is called the **forensic approach** since forensics is the application of science to the legal system.

Thus, suppose we take a man aged 40 who will earn \$80,000 per year for 25 years.[9]

[8]"Provenge is a treatment that involves collecting a patient's blood and processing it, in order to train the patient's immune system to attack the tumor. In clinical trials, it extended median survival by about four months compared to a control group. Dendreon is charging \$93,000 for each patient's treatment. Some private insurance companies and some Medicare carriers are already covering it." That comes to a value of life of \$279,000 per year. Would most patients prefer to have the drug (which is a risky asset) or the cash? "Medicare Panel Backs Prostate Drug," *New York Times*, Andrew Pollack, (November 17, 2010).

[9]Should we subtract income taxes from the \$80,000? No. That would affect the amount he would be willing to pay, to be sure, but those taxes are a positive pecuniary externality for the rest of us, and so should count if we are calculating the social value of his life, for regulatory purposes, rather than his

The present value would be, if we use a discount rate of .10 (which I like because it makes the arithmetic easier) and units of thousands of dollars:

$$PDV = \frac{80}{.10} - \left(\frac{1}{1+.10}\right)^{25}\frac{80}{.10} = 800 - .092(800) = 726 \tag{7}$$

since this is like owning a consol for 25 years and then having to give it up.

Note that this does not represent how much the person would pay to avoid dying. On the one hand, he will not be able to borrow the value of his entire future income— indeed, perhaps nobody will trust him enough to lend anything at all to him. On the other hand, he may have inherited wealth that he would be willing to pay as well as the value of his earnings. Rather than being what he is willing or able to pay, the present value of $726,000 represents the value of his earning power. This means also that the forensic valuation method does not work for retirees or children.

The forensic approach also is ill-suited to deciding what to do if the probability of death is not 100%. Government regulatory decisions are ordinarily about what to do in advance to reduce the probability of death by 1% or some smaller number. How much is it worth spending to reduce risk by that much? One's first thought is that the government could just take 1% of the 100%-death value. Thus, the man in our example above would pay $7,260 to avoid a 1% chance of death. But he would probably be willing to pay more than $7,260. This is easiest to understand by starting with asking him how much he would pay to eliminate a 50% chance of death, say, by a heart transplant that would cut his probability of death in the next year from 99% to 49%. Would his cutoff surgeon's fee be $363,000, half of his lifetime earnings? That depends on his taste for risk and on how much he values consumption as opposed to living by itself. Similarly, he might pay more or pay less than $7,260 to avoid that 1% chance of death.

An approach like this is used in lawsuits nonetheless, since the aim of the law is to look after the damage has occurred (so the probability has become 100%) and ask how much the victim should be compensated. In a **wrongful death** suit, the family of someone killed in a car accident must establish two things. First, they need to show **liability**: that the driver was enough at fault to have to pay any compensation at all. Second, they need to show the dollar value of the damage. A central part is showing the present value of the deceased's future earnings.[10]

personal value of life.

[10]Details of both steps become complex and vary by state and country. One possibility is to rule that the defendant driver has either zero or full liability, so the plaintiff victim must prove at least 51%. Another is **comparative negligence**: to rule on the percentage fault of each side. What damages should be added on top of future earnings is equally complex. Since the payment is to the deceased's relative, not him, his assets— which were not destroyed— are not considered. Pain and suffering and companionship are trickier issues, though.

5.4: The Value of a Statistical Life

We now come to the method commonly used by the U.S. government in valuing life, a method which gets around the problem that the value of reducing risk by 100% is not 100 times the value of reducing risk by 1%.

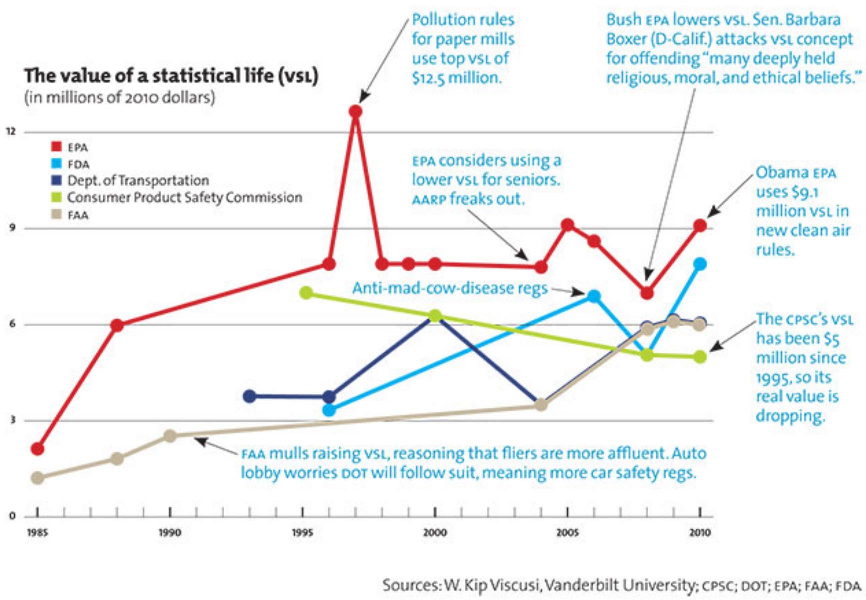
Suppose this evening you will be crossing the street and you have one chance in 10,000 of being hit by a bus and killed instantly. You may buy out of this risk for a cash payment now, and you may borrow to make the payment, at the government's rate of borrowing— say, the T-bill rate. This risk is about the same as the average yearly fatality rate for construction workers. How much would you pay?

If you would pay X, we say your **value of a statistical life** is 10,000X.

This approach makes sense for risks to a large group of people that can be prevented by prompt action. Consider a group of 10,000 people who know that one of them, picked randomly, will die next year in a car accident unless we each pay amount X now to strengthen safety rails on the highway. If each person is willing to pay 1,000 dollars, the total payment is 10,000 times that, which is 10 million dollars. We can say that is the value of a life. In aggregate, the group will pay 10 million dollars to purchase one life.

A problem is how to discover X, of course. How much would people really spend to avoid the 1 in 10,000 risk? We could simply ask a large sample of people and take the average for use in regulatory cost-benefit analysis. People's answers to hypothetical questions about low risks probably are not very informative, however, just as it is hard to get reliable answers in marketing surveys of how much people would pay to buy new products. Thus, the usual approach is to look at how much employers have to pay for people to accept risky jobs or how much consumers actually pay for extra safety features in cars or other risky products. Figure 5.**??** shows the values government agencies have adopted from statistical studies of that kind, and how the values have changed over time. The variation has been huge, but by 2010 was 5.1 to 9 million dollars.

FIGURE 5.2
VALUE OF A LIFE



Source: Viscusi.

5.5: Occupational Hazards and Valuing Life

Workers intentionally choose unsafe jobs in the sense that they often prefer higher incomes to more safety. The extra amount of income in return for a risk or an unpleasantness is known as a **compensating differential**. Fishermen are an example, as the following *USA Today* story shows.[11]

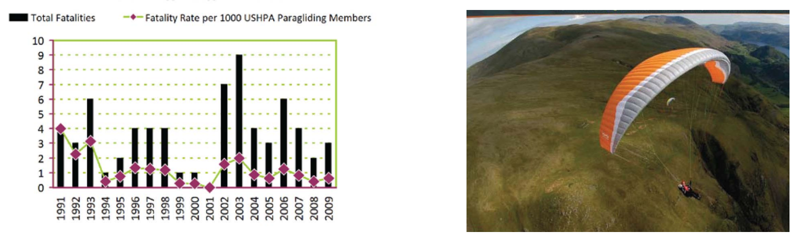
> "Fishermen are brought to the safety table kicking and screaming," says Jim Herbert, an Alaskan fisherman and chairman of an industry-dominated safety committee that advises the Coast Guard.. . .
>
> "Prevention of casualties will occur when we decide to require design, construction and maintenance standards for all fishing vessels and licensing standards for operators and crewmembers," says Richard Hiscock, a marine safety expert who was an adviser to the 1999 task force.
>
> McHugh, the maritime lawyer, says his stance may be unpopular with boat operators, the majority of his clients, but more could be done to make boats more seaworthy and less vulnerable to flooding. . .
>
> Today, most fishing boat operators aren't required to have a license or safety training. Yet, recreational boating operators in at least 33 states are required to have such training, according to the National Association of State Boating Law Administrators.

[11] "Commercial fishing is nation's most dangerous profession: Despite law, fishermen face deadliest job risks," *USA Today*, Gary Stoller, http://www.usatoday.com/money/industries/2003-03-11-fishing-safety_x.htm (March 13, 2003).

Fishing boat crewmembers also aren't certified, and most have little or no training, safety experts say. As for the boat itself, nearly all operate without safety standards for design, construction and maintenance.

Yet "many fishermen have strongly opposed standards that might save their own lives," the task force added. "Many of those harvesting the bounty of our ocean frontier staunchly defend the independent nature of their profession and vehemently oppose outside interference."

FIGURE 5.3
PARAGLIDING



On the other hand, some workers are more risk-averse than others, or more danger-averse, and they prefer safer but less remunerative jobs. A few years ago a young college graduate who wanted a high income would have done better as truck driver in Iraq than as an investment banker, though with less chances for advancement.[12][13]

When National Guardsman Gerald Harris was offered $120,000 in July to work as a truck driver in Iraq for Kellogg Brown & Root, it didn't take him long to make up his mind.

Harris was ending a six-month tour hauling battle tanks to the front line, and had spent his share of sleepless nights listening to the echo of weapons fire from the sweltering sand floor of his Army tent.

"I said, 'I don't care how much money you offer me, I won't do it,' " he said.

So far, 30 of Halliburton's 24,000 employees in the Iraq- Kuwait region have been killed since last spring, and seven civilian contractors are missing....

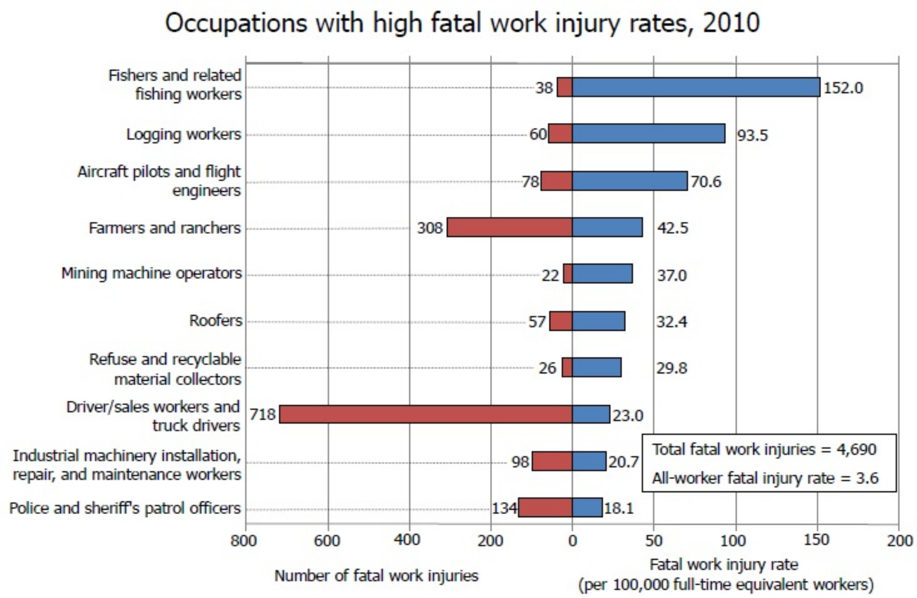
Judy Kelly said her husband [a truck driver] is making about $80,000 a year, a little more than they earned together when they worked as a truck driving team. Veronica Harris is earning $80,000 to $100,000 for managing recreational facilities for soldiers, about twice as much as she made in her former job in television, her husband said.

Notice the ratio of numbers in the story. Thirty killed plus 7 missing divided by 24,000 employees equals 0.00154, which is 154 per 100,000. Thus, working for Halliburton during the Iraq War was about as dangerous as being a fishermen (a rate of 152 in 2010).

[12]Not that most investment banking jobs taken by fresh graduates do not result in promotion. More often, the fast-tracker falls off the fast track onto a somewhat slower one. The danger not as physical as in Iraq, though still nerve-wracking.

[13]"Risky Business," *The Times-Picayune* (New Orleans) (April 18, 2004).

FIGURE 5.4
FATAL WORK INJURY RATE BY OCCUPATION IN 2010



Selected Other Occupations: Office and Administrative Support Occupations: 0.4. Electricians: 8.3. Cashiers: 2.1. Firefighters: 3.2. Janitors and building cleaners: 1.9.

The equation below shows how regression analysis is used to figure out the value of a statistical life. The analyst uses data on the salaries, jobs, and personal characteristics of different workers. The idea is that if workers with the same personal characteristics earn higher wages in more dangerous jobs, then we can see how much higher to gauge the price of danger.

$$\begin{aligned} Salary = \quad & \alpha + \beta(Probability\ of\ death) + \textstyle\sum_{i=1}^{n} \gamma_i(Job\ Characteristic\ i) \\ & + \textstyle\sum_{j=1}^{m} \delta_j(Personal\ Characteristic\ j) \end{aligned} \tag{8}$$

To actually do the statistical work, the analyst needs to be precise about what he means for each variable, taking into account that he has to be able to measure each variable too. Here is one way the equation above might be implemented:

$$\begin{aligned} Salary = \quad & \alpha + \beta(Probability\ of\ death) + \gamma_1(Weekly\ hours) \\ & +\gamma_2(Days\ away\ on\ business\ travel) + \delta_1(Years\ of\ education) \\ & +\delta_2(Years\ of\ experience) \end{aligned} \tag{9}$$

A problem with the simplest sort of hedonic regression is that people sort themselves into occupations by how much risk they are willing to tolerate. This means that if we were to calculate the value of a statistical life as $4 million using the wage premium in the fishing industry, that would underestimate the value most people put on safety. Those people who chose to be fishermen are the most willing to take on risk, and the wage premium would have to rise to attract the average person. The OMB warns about this:

> To value reductions in more voluntarily incurred risks (e.g., those related to motorcycling without a helmet) that are "high", agencies should consider using lower values than those applied to reductions in involuntary risk. When a higher-risk option is chosen voluntarily, those who assume the risk may be more risk-tolerant, i.e., they may place a relatively lower value on avoiding risks. Empirical studies of risk premiums in higher-risk occupations suggest that reductions in risks for voluntarily assumed high risk jobs . . . are valued less than equal risk reductions for lower-risk jobs.[14]

Using regressions on the size of compensating differentials in wages, Viscusi and Aldy found that the average worker valued a typical lost-workday injury at $47,900. Smokers valued it at $26,100. Workers who used seat belts valued it at $78,200.[15] Viscusi has estimated the value of a statistical life to be $8.7 million (in 2010 dollars). This is a debatable number, however. The Office of Management and Budget told agencies in 2004to pick a number between $1 and $10 million, though officials told a reporter that by 2011 it would not accept a number under $5 million.[16] Table 5.6 shows a variety of numbers that have been used.

TABLE 5.6
VARIOUS VALUES OF A STATISTICAL LIFE IN MILLIONS OF 2010 DOLLARS

Source	Year	Value
The Environmental Protection Agency (EPA)	2000	7.8
The Environmental Protection Agency (EPA)	2004	7.3
The Environmental Protection Agency (EPA)	2010	9.1
The Food and Drug Administration (FDA)	2008	5
The Food and Drug Administration (FDA)	2009	7.9
The Transportation Department	2005	3.5
The Transportation Department	2010	6.1
Professor W. Kip Viscusi	2003?	8.7

[14] Office of Management and the Budget, "Economic Analysis of Federal Regulations Under Executive Order 12866" (January 11, 1996), http://www.whitehouse.gov/omb/inforeg_riaguide.

[15] W. Kip Viscusi, and Joseph E. Aldy, "The Value of a Statistical Life: A Critical Review of Market Estimates throughout the World," 26 (Related Publication 03-2 AEI-Brookings 2003), http://ideas.repec.org/p/nbr/nberwo/9487.html.

[16] "As U.S. Agencies Put More Value on a Life, Businesses Fret," *The New York Times*, Binyamin Appelbaum (February 16, 2011).

The Bush Administration rejected regulation in 2005 to require car roofs to double in strength. It estimated that this would prevent 135 deaths in rollover accidents each year, but at a value of a life of $3.5 million the extra cost would exceed the extra value (which also included averted injuries) by $800 million. The agency therefore proposed a smaller increase in roof strength that was estimated to save 44 lives per year. In 2010 the Obama Administration imposed the stricter and more expensive standard, using a value of life of $6.1 million.[17]

The problem of valuing risk to life is difficult for both government and individuals. Usually, however, it comes down to valuing risk to life rather than the amount we would be willing to spend to save one life with certainty. The usual solution to the problem of government decisionmaking when lives are at stake is to use the concept of the statistical value of a life. This tries to replicate in government decisions the amount of risk to life that people take in their private decisions, to balance the expected cost against the expected benefit. Those risks are priced in the market, so we can see what people actually do in their own decisions.[18] The resulting value is useful in all manner of government decisions.

5.7: Concluding Remarks

Time and life are both hard to value. Value them we must, however, if we are to make sensible decisions either in private life or in public. Valuing them accurately has many difficulties. If the difficulties make your eyes glaze over, please do not respond by closing your eyes and choosing blindly. For those in a hurry, here is my recommendation: Discount any future cost and benefit by 10% per year, and value each human life at $5 million. But if you don't like things so crude and simple, feel completely free to read this chapter over again and make better estimates.

Review Questions

1. What are the formulas for discounting future payments and perpetuities?

[17] "As U.S. Agencies Put More Value on a Life, Businesses Fret," *The New York Times*, Binyamin Appelbaum (February 16, 2011). The article has links to the original sources.

[18] Yet another problem of valuation to solve is when goods aren't ever priced— such as the value of Yosemite Canyon as it is compared to the benefit from damming it up for water and power. See "Contingent Valuation: A Practical Alternative when Prices Aren't Available," Richard T. Carson, *Journal of Economic Perspectives*, 26: 27–42 (Fall 2012).

2. How should an individual or company choose which discount rate to use?
3. How should the government decide what discount rate to use?
4. How can surplus be raised by making the cost of life consistent across regulations?
5. What are the two ways of measuring the value of a life in money?

Readings

1. "Sustainability and the Discount Rate: An Economist's Perspective," Randall Pozdena *Oregon State Bar: Sustainable Future Section*.
2. "E.P.A. Drops Age-Based Cost Studies," Katharine Seeley and John Tierney. *The New York Times*.
3. "The Value of a Statistical Life Is Not the Value of Life," Mark Thoma, *The Economist's View*.
4. "What You Should Know About the Discount Rate," Rob Schmidt, *PropertyMetrics*.
5. "The Dimensions of Stock and Bond Returns," Mark Hebner.