Inflationary Collapses, or The NPV of Grandchildren

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Suppose you own a forest. You'd like to make some money from the trees and you are considering two options. One is to clearcut the whole thing and sell the timber, which will net you $\$X$. This particular forest happens to be on a steep erodable slope such that the soil will probably wash off and no more trees will grow after one clearcutting.

Your other option is to manage the forest sustainably. You consult a sustainable forestry expert who estimates that you could cut an amount of timber that would net you $\$kX$ this year, where k is some number much less than one, and the same amount of timber year after year in perpetuity (which would produce more $$ when adjusted for inflation). Thus k is roughly the fraction of the timber you'd get in one go from the clearcut that you could cut each year on a sustainable basis (the "roughly" comes from correcting for harvesting and management expenses, etc). The expert believes in sustainable forestry and emphasizes to you the benefits for the wildlife (who live in the trees), downstream neighbors (who won't get flooded with rivers choked with your silt), and fish (who can spawn in the unsullied gravels of the streams).

Before acceding to these persuasive arguments, you check with your accountant. What would she recommend?

I should say at the outset: yes I know this is a gross oversimplification of the tradeoffs present in real forestry. But bear with me - let's just take this premise and see what your accountant would recommend.

He or she would probably perform what's called a *net present value* calculation to determine what was economically rational. The idea is as follows. Somehow we'd like to compare the value of getting a one time payment of $\$X$ with an infinite stream of smaller $\$kX$ dollar payments from now into the indefinite future. Clearly we'd like to somehow add up the benefits of all the future payments into a single number that we can compare to $\$X$ (the sum we'd net if we just clearcut the forest).

It might seem that this sum will be infinite if the forest lasts forever, but it isn't so. Let's take it step by step. Clearly, this year's $\$kX$ of sustainable income from the forest is money that is directly comparable to this year's $\$X$ of clearcut payment. However, next year's payment seems to be somehow not quite as good, since we won't get it till next year. The trick to comparing is to notice what money we would have to invest now to get $\$kX$ next year. If interest rates are currently $i\%$, then it would seem like if we invest $\$kX/(1+i)$ now, we would have $\$kX$ next year. So the net present value (NPV) of $\$kX$ next year is $\$kX/(1+i)$ (which is smaller than $\$kX$).

Which interest rate should we use? Well, a sensible thing (since we are overall making a long term comparision) is to use a safe investment like a long US treasury bond. Right now, the nominal yield on those is about 5.25%. However, it's a little tricky because next year we'll have the same amount of **wood**, not dollars. And the wood will be worth more in dollars because of inflation. We can correct for this, however, by using real interest rates (minus inflation), rather than nominal ones. The treasury also issues 30 year inflation indexed bonds. The yield on those is a decent estimate of what the market thinks inflation-adjusted yields will be over the long haul. That number is about 2.5% presently.

You might think you should compare against something with a higher yield than treasury bonds, but assuming all those hedge fund managers, investment banks, and credit rating agencies have done their homework right on setting bond price/yields in the bond market, any bond that yields more should mainly be doing so because it's riskier and the extra yield should exactly take into account the extra risk. So let's stick with treasury bond yields. Then *i*, the interest rate, is presently 2.5%. (And let's assume that the *$kX* is net of insuring the forest so we don't have to worry about the risk in our future income stream from fire etc - in reality companies use higher internal discount rates to account for the various risks/uncertainties that plague projects).

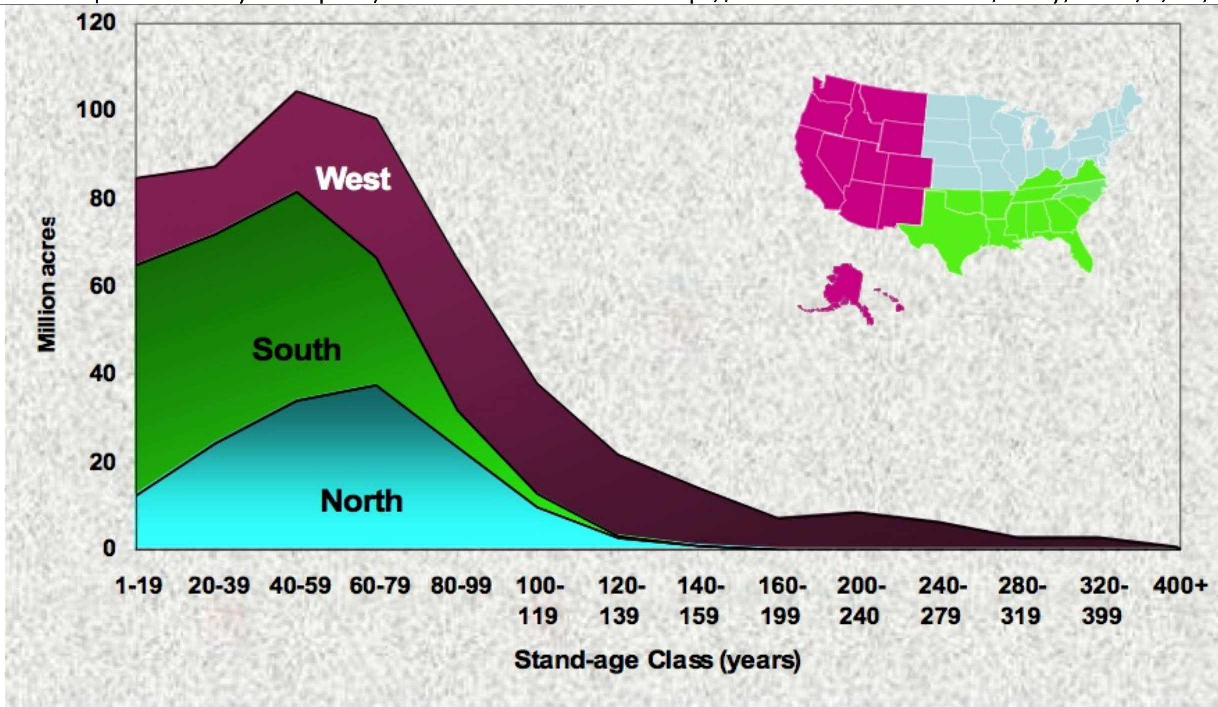
You might also think that perhaps wood will get more valuable in future, more so than the general rise in prices embodied in the inflation rate. But let's assume for simplicity now that the real price of wood is anticipated to stay fixed (eg by the lumber futures market). (Uncertainty in future wood prices would tend to make us choose a higher interest rate to compensate for the risk). We'll take up price changes in a later thought experiment.

So then we can just proceed out to further years. So far, the value of the income stream is *$kX* (for this year), plus *$kX/(1+i)* for next year. For the year after that, the amount of money we would need to have to get $kX in two years (in current dollars) is *$kX/(1+i)^2* (because that amount would get multiplied in a compounded manner by *(1+i)* on two years to give the *$kX* payment). Clearly, we can keep doing this for all the years.

I'll spare you the algebraic detail, but if you work out the series it sums up that the net present value of the future income stream is *$X* x *k(1+i)/i*.

So the condition that the net present value of the sustainably managed forest would be higher than profit from clearcutting it is that *k > i/(1+i)*. Now, remembering that the proper *i* right now is 2.5%, we see that the equation is equivalent to k > 1/41. In other words, if we have more than 41 years worth of forest growth on the land, then we are definitely financially better off clearcutting the forest than managing it sustainably forever.

I note that in translating profit ratios to forest age directly, we are making a crude approximation. In reality, it's worse than this because the economies of scale in doing the harvesting and managing will be greater if we clearcut, and not only that, but it's likely there will be **some** regrowth after the clearcut and young trees create wood faster than mature trees. Thus where trees take a long time to regrow, you can see why there's a financial advantage to clearcutting as fast as the regulators will allow. And that's why lumber companies often do it: they have a fiduciary duty to provide their shareholders with the maximum possible return on shareholder capital, and clearcutting frequently provides it.



Age structure of US forests. Source: [USDA Forest Service](#).

If it seems like this net present value calculation is some kind of complex technical accounting rule that ought to be changed for the benefit of forests, I'd like to try to disabuse you of that idea. As far I can see, any economic system in which:

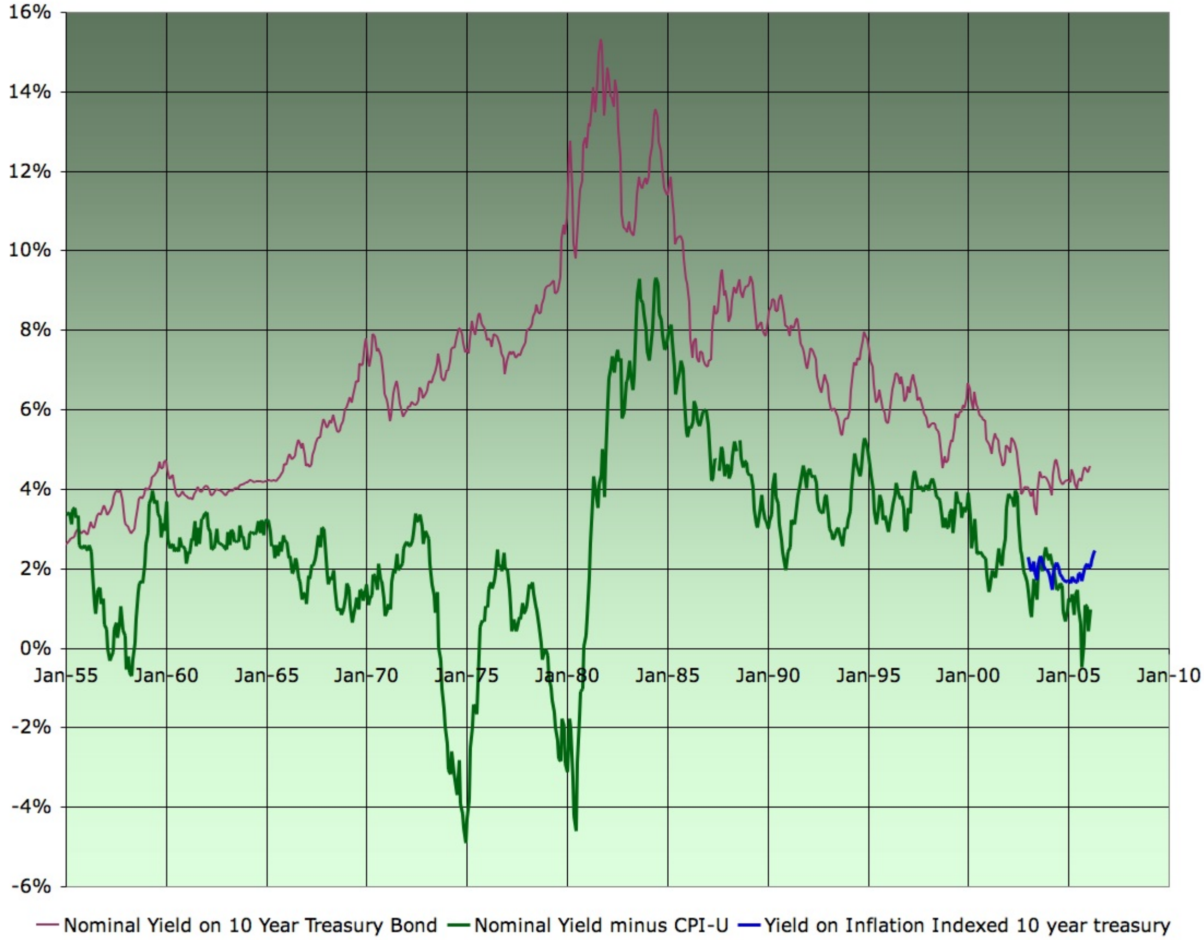
1. natural ecosystems like forests are private property and can be traded for money
2. people are allowed and encouraged to maximize their own self interest
3. interest is paid on loans

will have this property. In particular, an equivalent way of looking at it is this. If $k < 1/41$, you would make more money by cutting down the forest and investing the money in treasury bonds. (Of course, regulations could, and do, limit what landowners can do, but the finances dictate what self-interested landowners would **like** to do, if they can).

We've been running our civilization on those three rules for many centuries now, so the NPV logic is very deeply embedded in the whole way Western culture works. To change it would be a massive cultural wrench.

An important point is that the actual current price of lumber should make no difference to our decision criterion. Unless we can predict changes in prices in the future, the economics of our decision should mainly be sensitive to interest rates.

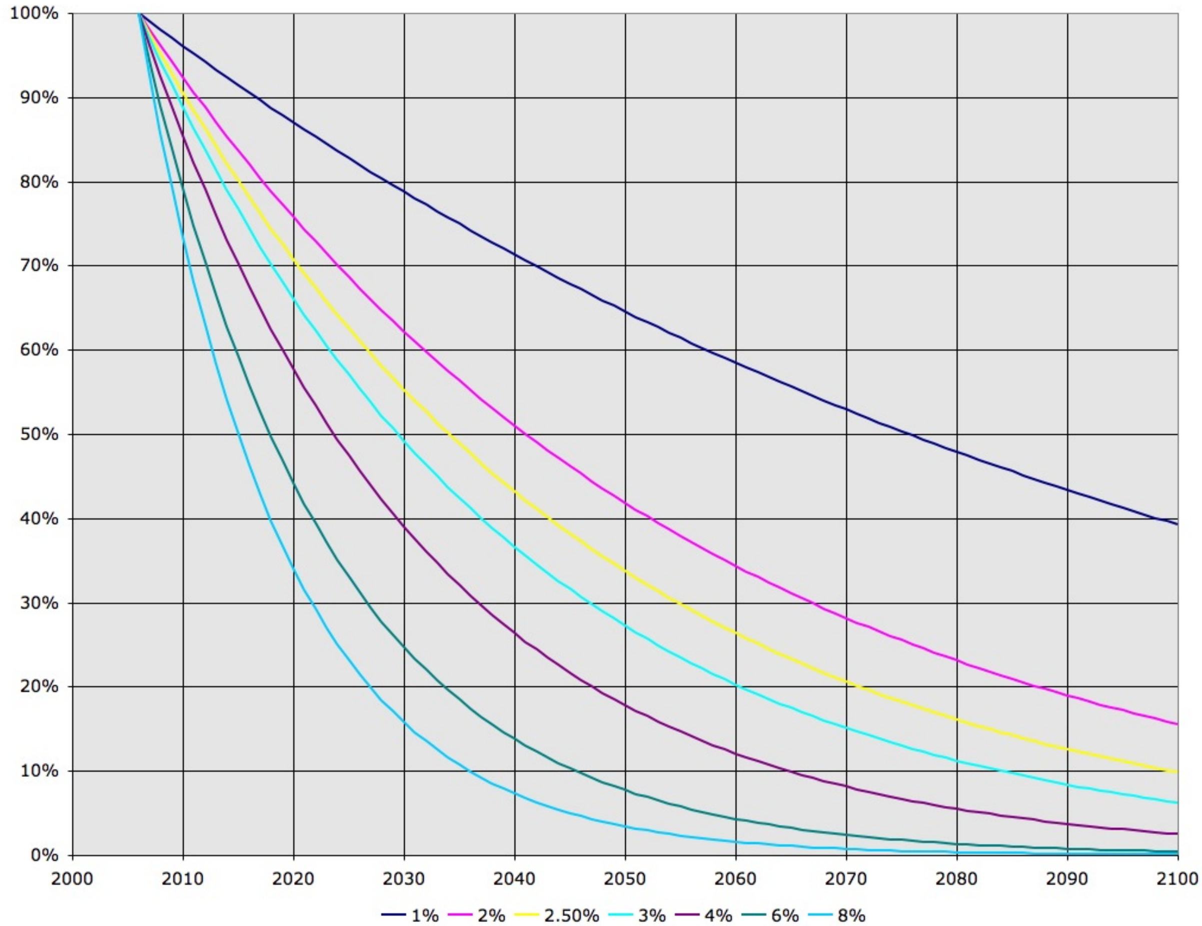
Now, in this condition of whether sustainable management of the forest makes economic sense or not, recall $k > i/(1+i)$, the variable k is more-or-less a property of the forest - the speed with which it grows (modulo some correction for the cost of managing it). However, the interest rate i is a property of the economy, and indeed is somewhat under the control of the central bank (the Federal Reserve in the US). (I say somewhat because the Fed targets short-term rates and long-term rates don't move exactly with short-term rates, though mostly so). Because of it's importance to these kinds of NPV calculations, interest rates basically set how much society cares about the future. Specifically, let's first look at some history of real interest rates to get a feeling for the range they vary in:



Nominal yields on ten year treasuries (1955-Feb 2006), nominal rates minus CPI-U inflation over the prior 12 months, and inflation adjusted ten year treasury yield. Source: Federal Reserve Bank.

Note that the best estimate of long-term real interest rates is the yield of the inflation-adjusted treasury (the blue line). However, this series only goes back to 2003, so I've also included an estimate of real rates constructed by subtracting the consumer price index change over the prior 12 months from the nominal rate on regular 10 year treasury bonds. That line (green) goes back to 1955, but should only be viewed as a rough approximation of anticipated real interest rates (since long term expectations of future inflation could vary somewhat from the value the CPI happened to take over the last 12 months). In particular, it's probably never been the case that long term expectations of real interest rates were negative.

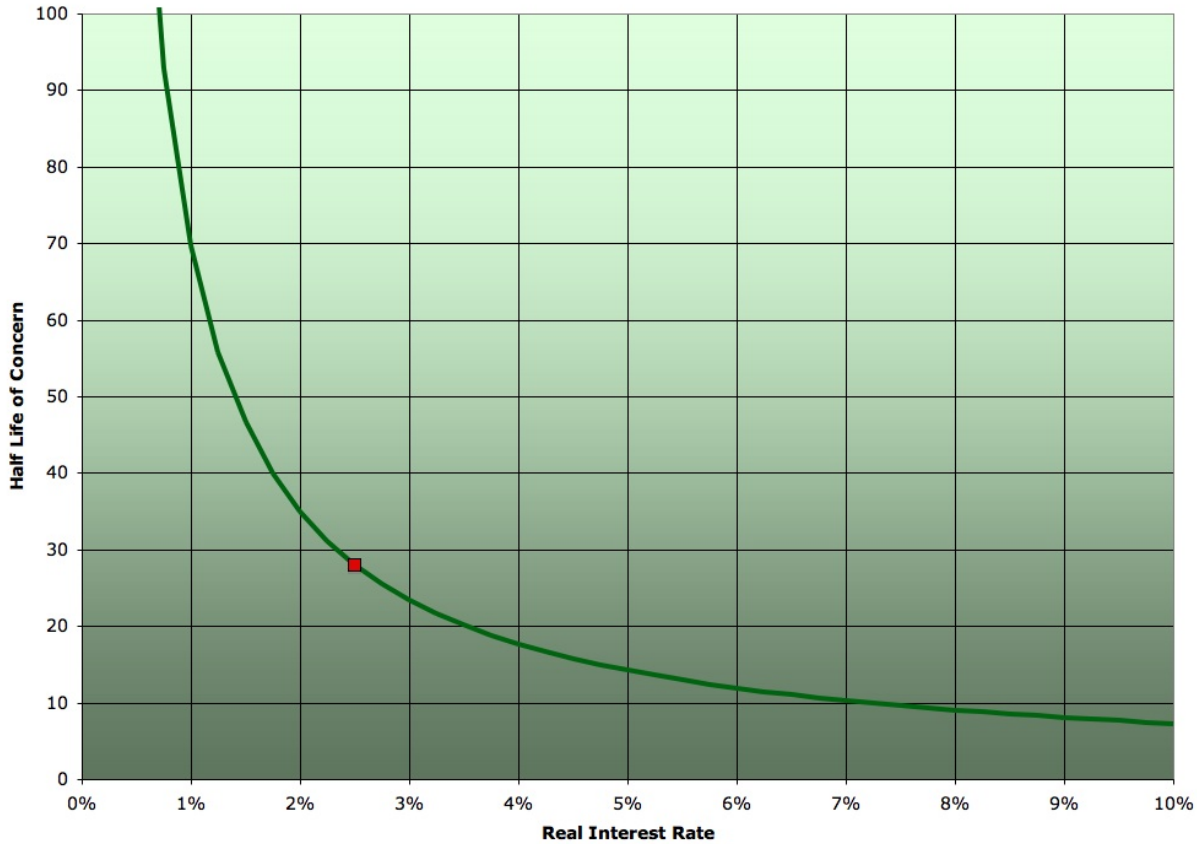
Anyway, the graph gives us the sense that real rates vary from 0%-8% or so over the course of recent history. Let's have a look at the shape of the net value function for the rest of the century as a function of those interest rates. Ie what I'm about to plot is how much the cashflow from the forest (or anything else) would contribute to NPV in year Y relative to how much it contributes in 2006.



Discount applied to future cash flows (in present dollars) as a function of year for varying real interest rates.

In general, as you can see, the degree to which future cash flows contribute to present value is highly dependent on interest rates. When interest rates are high, the degree to which future cashflows contribute is very small and it's very unlikely that it would make financial sense to manage the forest sustainably. On the other hand, when interest rates are low, the discount function is still non-negligible far out into the century, and managing the forest sustainably is more likely to be the profitable option.

A way to summarize the situation is the half life (the point at which the contribution from a future cash-flow drops to half), which is given by log(2)/log(1+i). If we plot that, it looks like this:

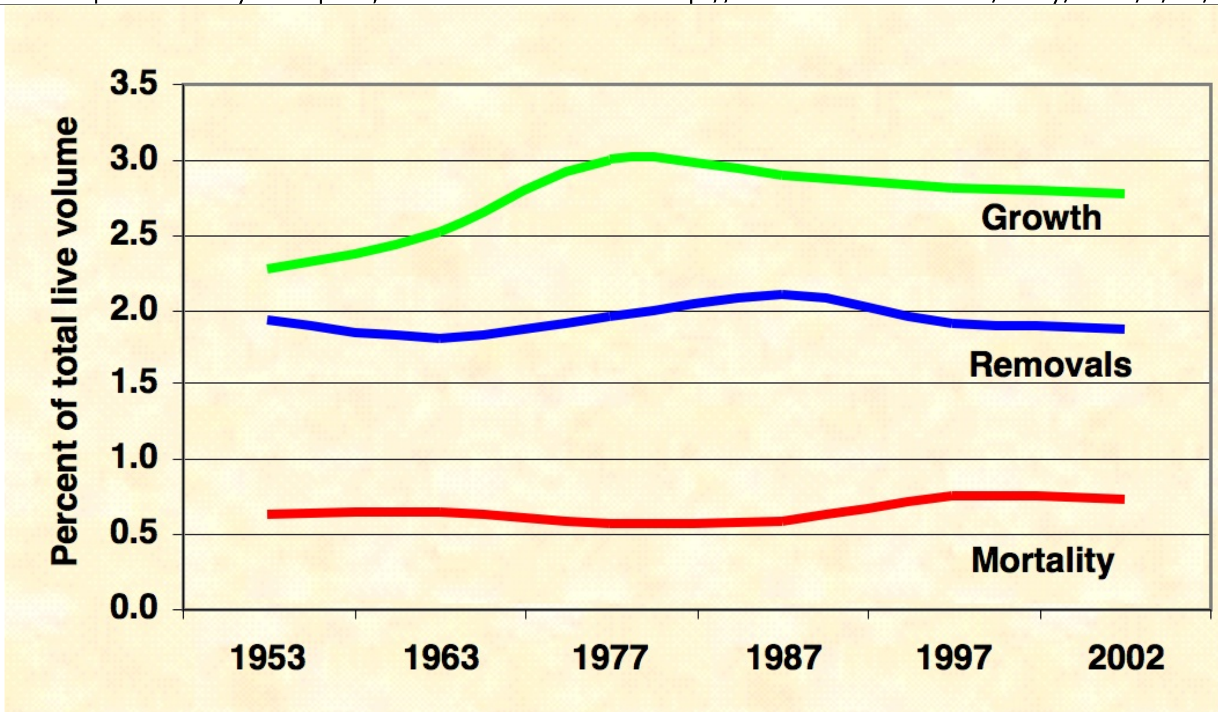


Half life of discount function as it depends on interest rate. The red square is based on interest rates as of this writing.

Again, when interest rates are low (below 1%), the half life of our interest in future cash-flows gets up around a century. However, when they are high, it drops down to only a decade or two, and the poor trees have no chance.

As an aside, it's interesting to note that the very controversial acquisition of Pacific Lumber (then owners of the Headwaters Forest) by Maxxam, which was financed almost entirely by junk bonds and led to greatly increased cutting of Pacific Lumber's timber holdings (and a long litany of litigation), took place in 1985. If you look back up at my first graph of interest rates, you'll see that real interest rates in 1985 were just about at their peak of around 8% (on the nominal-CPI method of estimation). This suggests that the influence of high real interest rates on unsustainable cutting of forests is a real effect.

Also, during the era of high interest rates in the 1970s and 1980s, forest cut rates increased. Since then they have been reduced, and we are importing more timber instead. So this is at least consistent with the hypothesis that interest rates are important in affecting the desire to liquidate natural resources more quickly.



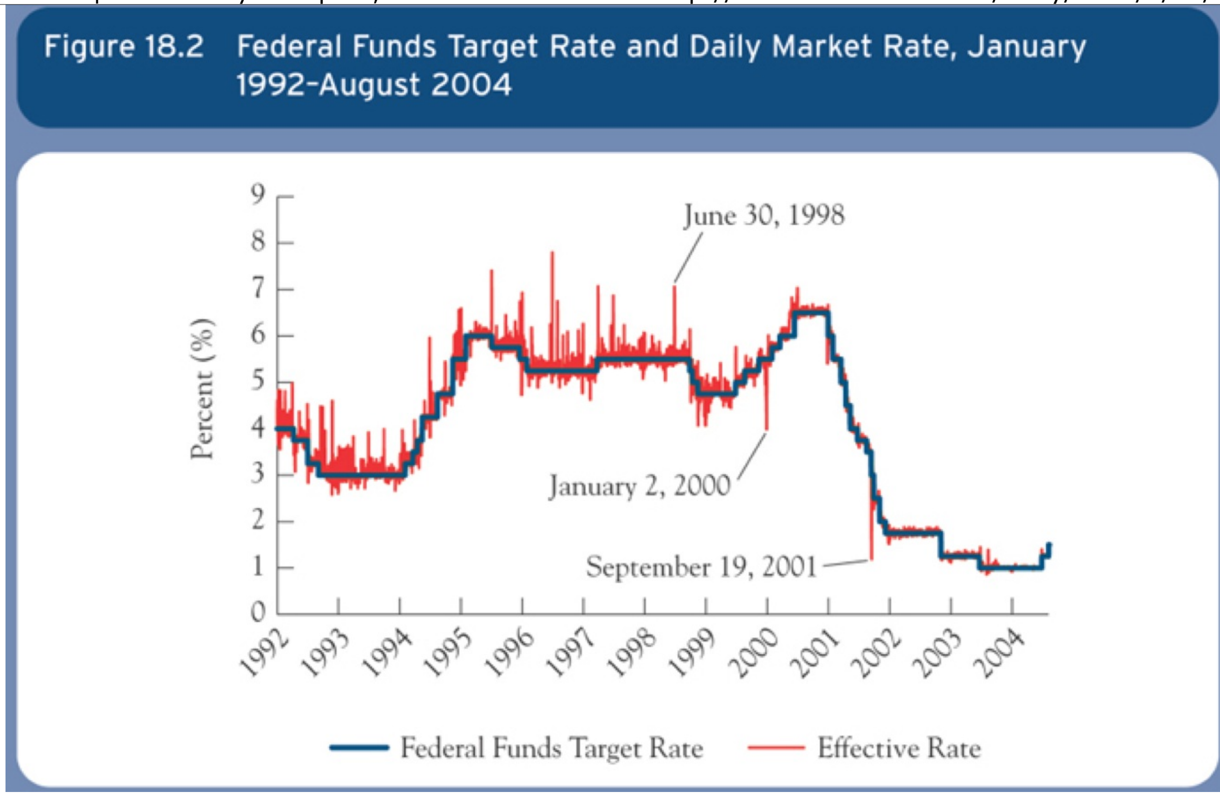
Rates of growing stock growth, removals, and mortality on productive unreserved forest, 1953-2002. Source: USDA Forest Service.

So in summary, real interest rates control how far project finances are sensitive to cashflow into the future (what economists call inter-temporal preferences). In a sense, they control how much the economy cares about the future.

Now, this is not usually the main focus that the business community places on interest rates. Instead, the focus is on the effects of interest rates on the short term growth of the economy and on inflation. Generally speaking, when the central bank wants to accelerate the economy (or prop up an ailling one), it targets a lower interest rates. This makes it cheaper for businesses and households to borrow, thus encouraging them to do so, which can increase both consumption and capital investment. It also makes it less rewarding to save, and this also encourages consumption. This tends to increase the amount of economic activity in the near term.

Correspondingly, when the central bank is concerned about inflation (which economist frequently view as aggregate demand for goods and services (and/or labor) growing faster than businesses can supply those goods and services, or trained labor can become available), it is likely to increase interest rates which has the reverse effect and slows the economy. This, eventually, will reduce inflationary pressures.

Note that the Fed does not directly control interest rates - what it directly controls is the size of the *monetary base*, the amount of currency in circulation and the quantity of bank reserves on deposit with the Fed. However, what it does with that power is adjust the monetary base via open market operations in such a way as to maintain short term interest rates as near as possible to a stated target. And it has got increasingly good at that:



Fed target and actual daily market rate for Fed funds. Source: This is Figure 18.2 of [Money, Banking, and Financial Markets] by Stephen Cecchetti (a book I highly recommend).

In short, the interest rate is viewed as a big lever that roughly controls the speed of the economy. Push it down (lower rates) and the economy goes faster, but if it goes too fast, inflation is likely to ensue. Pull it up, and the economy slows down. You cannot read the business press or economics blogs for any length of time without reading constant discussion of what the Fed is likely to do to interest rates and how that will affect the economy.

And herein lies the paradox. On the face of it, the question of whether the economy should care about the far future or not is fairly unrelated to the question of whether the economy should be sped up or slowed down in the near future. But in fact, the same lever manages both things. And it seems to me that there is a potential problem there.

Let me switch to another thought experiment. Suppose humanity were faced with the following dilemma. We could carry out a series of projects which would result in unsustainably consuming the entire biosphere to make food, fiber, and biofuels for the present and near-term human population, but which would mean that there would be no biosphere for our grandchildren (who would therefore all die). Under this alternative, we recklessly use up water, degrade soil, and throw away genetic diversity in such a way that plant productivity in future is irretrievably damaged. Alternatively, we could experience a decrease in our lifestyle now, which would mean that the fossil fuels would last longer, and the biosphere could continue to produce a fairly constant amount of food, fiber, and fuel indefinitely. Which should we do?

Again, I stress that this is a hypothetical thought experiment. I realize that the actual human dilemma in the 21st century is more complex and much less clear than this. However, bear with me. I'm making an extreme simplification of the situation because I want to explore what seem to me some less than optimal things about the decisions free market economics suggests in these cases. It's also not totally out of the question that we face a complicated variant of this choice: biologists do estimate that humans already appropriate 15%-25% of net primary productivity and those biologists are pretty concerned about it:

> Land use has generally been considered a local environmental issue, but it is becoming a force of global importance. Worldwide changes to forests, farmlands, waterways, and air are being driven by the need to provide food, fiber, water, and shelter to more than six billion people. Global croplands, pastures, plantations, and urban areas have expanded in recent decades, accompanied by large increases in energy, water, and fertilizer consumption, along with considerable losses of biodiversity. Such changes in land use have enabled humans to appropriate an increasing share of the planet's resources, but they also potentially undermine the capacity of ecosystems to sustain food production, maintain freshwater and forest resources, regulate climate and air quality, and ameliorate infectious diseases. We face the challenge of managing trade-offs between immediate human needs and maintaining the capacity of the biosphere to provide goods and services in the long term.

So the world is filling up in several senses, and peak oil is just one symptom of that. We can probably expect to be hitting a variety of resource constraints in this century, and having to work around all of them.

Anyway, whether you buy that or not, just suppose that the situation was as I describe it in my thought experiment. In a more-or-less free-market world, each individual decision to cut down this or that forest, or take all the straw from this or that field for biofuels, would be taken separately based on the profitability for the individual or company owning the land. Recall that a main control on whether you want to slash and burn something or manage it sustainably is real interest rates. The higher interest rates are, the faster your NPV discount function decays in future years, and the less sensitive economic decision-making becomes to anything that might happen in the future.

So the question becomes as the economy hits various resource constraints, what is likely to happen to interest rates?

Well both theory and past experience suggest that resource constraints are inflationary. The theoretical argument is that resource constraints reduce aggregate supply of goods and services, and unless aggregate demand is correspondingly reduced also, price levels will increase as people enter a bidding war for the goods and services that are still available. To manage this contraction (possibly in the face of people borrowing more aggressively to maintain their lifestyle) the central bank will have to increase interest rates.

The best empirical evidence of this comes from oil shocks. Major oil shocks have all caused a big spike in inflation over and above whatever the prevailing rate was beforehand (and indeed they've been the main cause of big spikes in inflation in the US in the last 50 years. This is not to discount that other factors have caused lower but longer-lasting inflation. Also, this is not to discount that there are some tempting arguments that we are overdue for a credit contraction - but I view that as something likely to be short-term (decade or sub-decade) if it occurs. Over the mid-to-long term, a cascade of resource constraints has got to be inflationary.

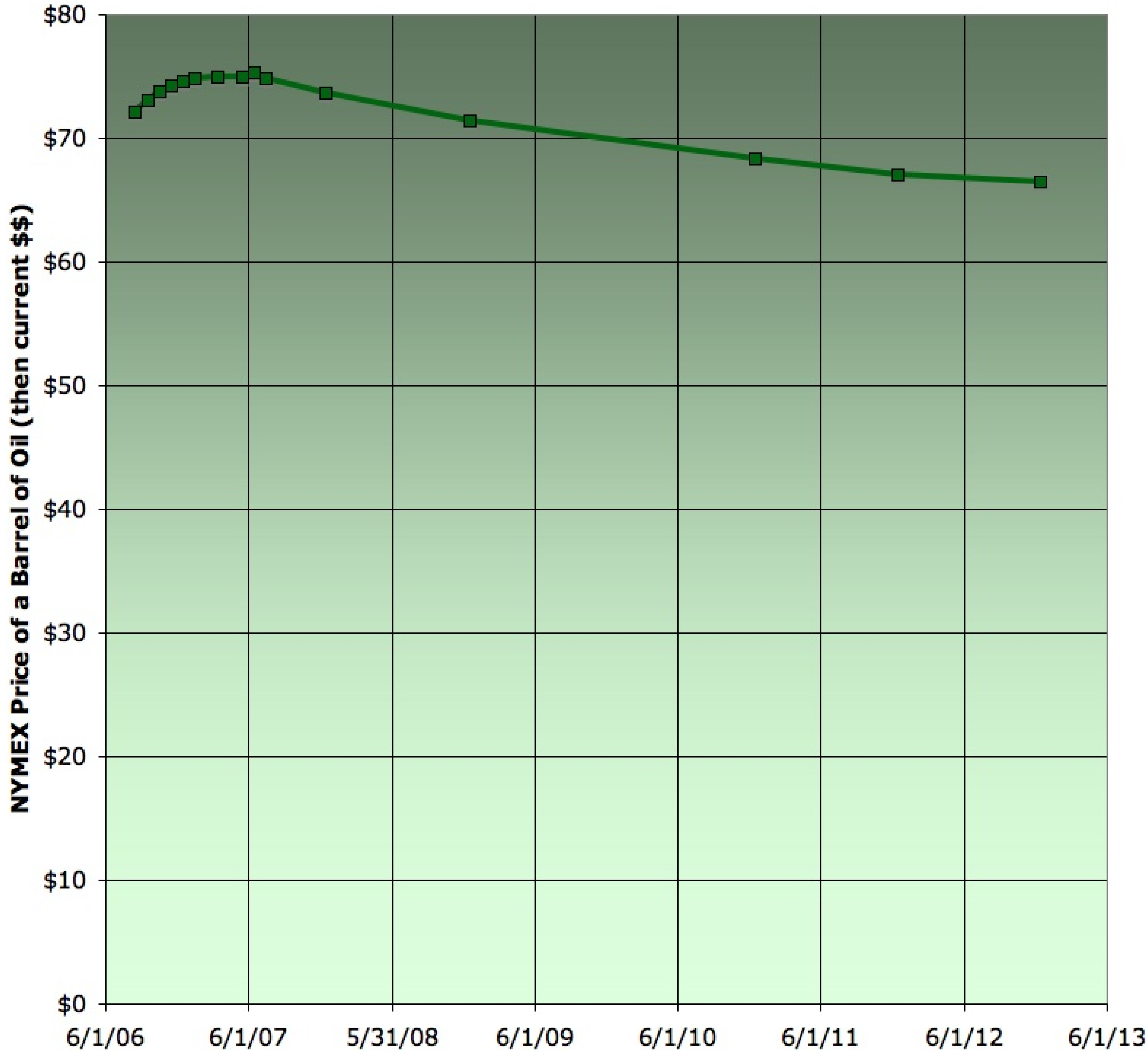
So if that's true, we might expect that a biosphere constraint (along with other resource constraints like peak oil) will tend to cause inflation. In the current economic consensus, the correct central bank response to that will be to increase interest rates with a view to throttling the economy back and reducing inflation.

And the problem with that is those higher interest rates will sway the balance of decision-making towards **less** sustainable management of the biosphere.

In other words, it appears to me that there is a potential for a nasty positive feedback here that could promote a downward spiral. One might call it an ***inflationary collapse***: the harder the resource constraint bites, the more tendency towards inflation in the economy, the higher interest rates will go, and the less incentive anyone will have to manage their piece of the biosphere sustainably.

Now, there's one dangling point here that I should clear up. In my first example (the individual forest) I assumed that price rises were not forseeable; prices were expected to stay flat. However, in this example of consuming the entire biosphere, someone might argue that the classic Hotelling analysis of a finite resource should apply (eg as discussed by Dave a while back). Basically, the Hotelling analysis says that if you know how much of a resource there is left, then as it becomes more scarce it's price should go up exponentially with the exponential constant being the interest rate. If that situation obtained, then the net present value analysis above (which assumed constant real prices) does not apply.

However, it does not seem that the Hotelling model is all that applicable to real resource constraints. In particular, if experience to date is any guide, it seems that we usually have terrible information about the amount of resource left. This is obviously true of oil (think OPEC reserve distortions, uncertainties over future recovery rates, undiscovered oil, etc). So the effect of this has been to make the futures price-curve more-or-less flat. As of yesterday, it looked like this:



Price of a barrel of oil on Nymex future contracts as of 6/28/06. Source: New York Mercantile Exchange.

However, over the course of the last few years, the shape of the back-end has been whipping up and down (in and out of contango) but always staying within $10 of the current price. Meanwhile, the current price has been rising exponentially at about 30% per year, much faster than interest rates. Thus the Hotelling theory really doesn't seem to help us: at any given time the futures curve has been more-or-less flat, because the information about the resource was too poor to constrain the price curve well, and so what the back end of it is probably doing is wandering up and down driven by momentum traders. In the meantime, the spot price has continued to rise, on average, much faster than interest rates.

Now, the situation in biosphere resource constraints is that the information is even poorer than on oil reserves (this will have to wait for future posts to flesh out, but aquifer volumes, etc are very poorly understood). And thus we might expect whatever resource constraints there are to show up in the same not-very-forseeable way that peak-oil seems to have been showing up.

And that's a problem. Because it means that the economy will not get the right signals to anticipate the problem, and then when it does hit the constraint, inflation and high interest rates will tend to promote exactly the wrong kind of choices.

I'm not saying that this is definitely going to happen - I don't know at present. But it seems plausible enough to be worth worrying about. It also reinforces two points:

- Improving the information available to the economy about the true situation with resource constraints is extremely valuable, environmentally as much as economically.
- Situations in the environment where there are lags between causing the damage and experiencing the consequence are exceptionally dangerous if the lags are long compared to the half-life of the discount function. The oceans warming up in response to carbon emissions and the melting of ice sheets come particularly to mind.