Incentives to innovate

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1. TOC {:toc}

Profits!

This isn't hard. We think innovation occurs because people want to get *paid*. Companies get started with new products because the founders want to make money. Existing comparies hire R&D workers to invent or improve products so that they can make more money. Individual workers will generate new ideas and ways of doing things to get noticed by a boss and ... make more money.

The motivation is straightforward, but there are some subtleties to it, which in this clip the underpants gnomes don't quite get. Warning, salty language at the end:

Let's generalize this. The first step, "collect underpants" is a highly specific activity that may or may not generate innovation (who knows?). Think of this first step instead as "do research and development", or even more generally "exert some effort to try and come up with a new idea". The gnomes are putting in that effort.

The second step is where things break down for these guys, and where we need to fill in more information. What allows the generator of a new idea get to stage 3 and profit from that idea? The answer is that they need some form of ownership. They need to make that idea *exclusive* to them, so they can force others to *pay* them for using that idea.

Excludable things

This notion of exclusivity is the key to generating profits from innovation. If refers to a property of goods, services, or ideas. Something is *excludable* if you have some legal or physical way of preventing someone from using that something (i.e. excluding them). In practice, this means that you can force someone to *pay* your to use that something. In order for you to make money selling *anything*, it has to be excludable. Non-excludable means the opposite, and refers to things that it is hard or impossible to prevent people from using, and therefore hard or impossible to charge them for.

You might be thinking of the concept of rivalry and non-rivalry right now. But be careful, excludability and rivalry are *different*. I like this video because Rohen (who does a lot of good economics tutoring videos) does a nice quick job of explaining the distinction, and in giving you some idea of how the two concepts of rivalry and excludability interact.

The key square for us here is the non-rival, excludable square, which are "artifically scarce" goods. The ideas that generate productivity growth are non-rival, as discussed before. That non-rivalry is what allows growth to occur. But to provide incentives for people to spend effort (R&D spending and time) those non-rival ideas have to be made excludable, or artifically scarce.

How do we do that? The most obvious answer is intellectual property (IP) law: patents, copyrights, trademarks, and the like. This video is an explainer from out of the UK, so some of the minor details are not

going to be true for the US. However, it gives you a good introduction to the separate types of intellectual property rights that create excludability for non-rival ideas.

We could go deep down the rabbit hole of IP and innovation. For the moment, though, we're just interested in the idea that IP creates the excludable characteristic of non-rival ideas. Note that nothing here says that *more* IP or *stronger* IP necessarily increases innovation. We probably need *some* IP to incent innovation, but it is an open question of how much. We'll come back to that later.

Economic implications

Instead of getting into the weeds of IP here, let's work out some of the economic implications of having IP in order to generate growth.

First, from a pure accounting perspective, remember that we can always break GDP down into three income streams,

$$Y = wL + RK + \Pi$$

where wL are the wages paid to labor, RK are the returns paid to capital, and Π are the total economic profits paid out.

Second, a constant returns to scale production function (like the Cobb-Douglas) has the interesting property that

$$Y = MPK \times K + MPL \times L.$$

Third, we just said above that productivity growth could only occur if there were economic profits that got paid to innovators, or $\Pi > 0$.

Put all three of these together, and you get an intriguing result. It *must* be that $w \leq MPL$ and/or $R \leq MPK$. How do you find this? The first two properties imply that $wL + RK + \Pi = MPK \times K + MPL \times L$. If $\Pi > 0$, then $wL + RK < MPK \times K + MPL \times L$, and the only way for that to work is if either (or both) the wage is less than the MPL or the rental rate is less than the MPK.

Growth requires innovation, which requires profits, which requires that rival inputs like labor and capital are paid *less* than their marginal product. This is important enough to warrant a little label

Growth and rival inputs {: .label .label-green } **Economic growth in a constant-returns to scale economy implies that rival inputs are not paid their marginal products.**

Based on this, rival inputs like labor and capital need to be "underpaid" relative to their contribution to producing GDP so that we can provide incentives to innovators to come up with better ways to do things. That doesn't mean this must be unfair to labor or capital. It depends on their outlook. It may be that labor and capital are agreeing to take a smaller slice of the pie, in return for the pie growing even faster over time.

Don't endow this with some kind of mystic truth. It is a statement that *if* the economy is constant returns to scale, and *if* innovation requires profits, then rival inputs cannot be paid their marginal products. Those assumptions could be wrong.

But let's operate as if the assumptions are true, and think about more possible consequences. We've taken the supply of labor and capital to be fixed, for the most part. That is, we haven't provided any model

of why people would supply labor or capital to the market, they just do. But it isn't hard to imagine that the supply of these rival inputs would depend on what they are paid. So if wages and capital rents are pushed *down* in order to make room for profits for innovators, then this would presumably push *down* the willingness of people to supply labor and capital.

If this is true, then allowing profits for innovations doesn't just change the size of the slices of pie, it makes the pie smaller today. Again, this might be worth it. We might accept a smaller pie today, and labor and capital might accept smaller slices of that smaller pie today, if in return we get more innovation and a rapidly growing pie over time.

The amount of research

The general result of the prior sub-section indicates that the profits behind innovation necessitate some deviation from perfect factor markets. But that general result doesn't inform us about how much research and development effort will be put in. We can try and be a little more specific about that by thinking about the incentives for innovators.

Think of things from the perspective of a firm deciding whether to employ some workers in R&D, in the hopes of generating an innovation that will in turn generate profits. Our basic economic intuition is that they will employ R&D workers until the marginal benefit of R&D (the extra profits they could earn from their innovations) is equal to the marginal cost of those R&D workers, which is their wage.

We can use that condition to come up with a rough idea of how many R&D workers, R, firms will employ relative to the number of regular workers, L. To do that we have to describe the marginal benefit, profits, and the marginal cost, the wage.

Start with the profits. Let $s_\pi = \Pi/Y$ be profit's share of total GDP. Those are the total profits available to earn given the market power granted to innovators through IP rules and/or other means of making ideas excludable. To keep our lives simple, let's also assume that the profit each separate idea earns is equal to the total profits divided by the level of productivity, A. This is like saying that the size of productivity is exactly equal to the number of ideas. That isn't true, of course, but as long as they are proportional in some way, we are good. Put that together and we have a profits per idea in some given period t of $s_\pi Y_t/A_t$.

Hold onto that for a moment. Now, how many ideas would any given researcher - if hired - produce? Well, we modeled the total flow of ideas with $\Delta A_{t+1} = \theta R_t^\lambda A_t^\phi$. Note that this isn't the growth rate of ideas, this is the raw change in ideas given some total number of researchers and an initial value for productivity. The number of new ideas per researcher is this divided by R_t, or $\Delta A_{t+1}/R_t$.

Now hold onto *that* for a moment. What is the wage rate that you have to pay a researcher? We're assuming they are similar to everyone else, so they earn the regular wage. The wage per person is the total share of GDP earned by labor divided by the number of workers, or $w_t = s_L Y_t/L_t$. Note that I'm ignoring here any effect of moving researchers out of the labor force (which would presumably lower the number of workers and push wages up), because the fraction of R&D workers relative to the workforce is so small that it cannot matter that much.

Okay, we've got three pieces of information to work with. Put them together into this equilibrium condition,

$$\frac{s_\pi Y_t}{A_t} \frac{\Delta A_{t+1}}{R_t} = \frac{s_L Y_t}{L_t}.$$

The left-hand side has the profits-per-idea times the ideas-per-researcher, or profits-per-researcher. The right-hand side has wages per worker, and as we said above we expect these to be equal so that the marginal benefit to a firm (the left) is equal to the marginal cost (the right). This equation allows us to solve for the size of R_t relative to L_t.

Stary by noticing that the Y_t terms cancel. This is a little bit of a fudge, by the way. Note that the profits you earn for a new idea probably only come in the *future* (and we should have something like Y_{t+1} on the left side), but we're acting as if they arrive immediately. We can allow for that forward-looking behavior, and in some cases that will become interesting. But for starters we're ignoring it.

Cancel the Y_t terms and then re-arrange the equation to

$$\frac{s_\pi}{s_L} \frac{\Delta A_{t+1}}{A_t} = \frac{R_t}{L_t}.$$

We've got what we want on the right-hand side now, the ratio of researchers to workers. And we can make one more substitution on the left. Note that we have the ratio $\Delta A_{t+1}/A_t$, which is just the growth rate of productivity. We could denote this g_A to keep things simpler, and find that

$$\frac{R_t}{L_t} = \frac{s_\pi}{s_L} g_A.$$

What does this tell us? It says that the number of people employed as researchers, relative to the labor force, depends on two things.

1. Profits relative to the cost of labor. The ratio s_π/s_L tells us about the benefits of innovation relative to the costs. The larger this ratio is, the more you get out of a researcher, in short. So the higher this ratio, the more researchers will be employed.

2. The growth rate of productivity. The g_A term is telling us how fast ideas arrive. If this is high, then it pays to invest in researchers, as they are likely to deliver a lot of new ideas to you, and hence profits. But if this is low, why bother hiring them?

Changes in IP laws or rules adjust the size of s_π relative to s_L, and thus affect the size of the research effort over time. The argument for IP is that by protecting the profits of innovators, it induces more innovation (higher R). The counter-argument is that by raising s_π relative to s_L, the share of GDP going to workers (or capital) is going down, and those workers are thus getting a smaller share of what may be a bigger pie. Whether that is good for the workers depends on whether the boost to innovation outweights the smaller slice.

This gives us one way of interpreting the growth of research effort over time in most developed countries, and in particular the growth in the fraction of workers involved in research. Our little model here suggests that this must have involved either an increase in the fruitfulness of research (g_A going up) or in a larger payoff to innovation (s_π going up).

Research growth over time

This section is a little speculative, but kind of fun to work through.

You'll recall (I hope) that we said g_A itself depends on the growth rate of researchers. So ultimately the fraction of researchers in the workforce depends on the growth rate of researchers? We can try and offer some idea about how the size of R_t evolves over time using the above toy model, at least along a balanced growth path.

Along a BGP, we know that $g_A = g_R \lambda/(1 - \phi)$, and since we see in the data that productivity growth is roughly constant it must be that g_R is roughly constant as well. In our model above this means we have

$$\frac{R_t}{L_t} = \frac{s_\pi}{s_L} \frac{\lambda}{1 - \phi} g_R$$

once we are on a BGP. Take logs

$$\ln R_t = \ln L_t + \ln s_\pi/s_L + \ln \lambda/(1 - \phi) + \ln g_R$$

and that tells us about the level of research effort. If we apply what we know already about how population growth works, that $L_t = L_0(1 + g_L)^t$, then we can get that

$$\ln R_t = \ln L_0 + \ln s_\pi/s_L + \ln \lambda/(1 - \phi) + \ln g_R + g_L t.$$

This is a big mathematical mess, so let's not lose sight of what it says. It says that research effort over time, R_t, depends on the size of the baseline population, L_0, and the growth rate of that population, g_L. A larger population will have more researchers, and a population that grows faster will have faster growth in researchers.

In addition, the *level* of research effort (the ratio of R relative to L) depends on the profit share and the parameters governing the accumulation of ideas like λ and ϕ. It also depends on how fast researchers are growing, because that dictates how fast we accumulate the ideas that put a drag on productivity growth.

Take this equation one step further, and ask yourself what it says about the growth rate of research effort. Careful, the g_R in the above equation is not what we're solving for. We're taking the slope of this line, so we care about the term involved with t. It says that

$$g_R = g_L$$

or that on a balanced growth path researchers grow at the same rate as the population. If you want to really round this off, then you could end up saying this

$$\ln R_t = \ln L_0 + \ln s_\pi/s_L + \ln \lambda/(1 - \phi) + \ln g_L + g_L t.$$

The growth rate of population determines the level *and* the growth rate of the level of research effort. Faster growth in population means the stock of possible researchers is growing, so that influences the growth rate of R_t. But faster population growth also means indirectly that the growth rate of research is fast, and thus it makes sense for people to put more people to work as researchers.