The productivity paradox, part I

Julien Garran & Andy Lees
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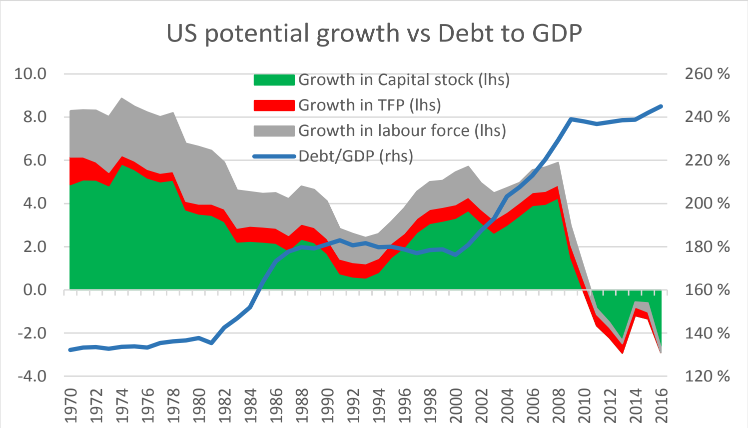
Introduction

In parts I & II of this note my colleague Andy Lees & I tackle some of the key questions that clients are asking on productivity and the capital stock. Consensus has it that GDP, the capital stock & productivity aren't measured properly, innovation is strong & and that potential growth in the US is solid.

We argue that a combination of physical constraints (and the constraints of physics), a lack of major innovation and misallocated capital have caused productivity to collapse and the capital stock to deteriorate. We believe that this has taken potential growth into negative territory, and it means that without massive liquidity injections from the Fed & other central banks, the US & the global economy will fall into a deflationary bust.

The key questions we'll answer in part me (in green) & part II (out tomorrow, in blue) are;

- What is productivity?
- How could productivity be slowing with all these new inventions?
- Is there a good analogy to help understand productivity & the capital stock?
- What type of innovation makes a difference?
- Do oil production constraints hurt productivity?
- How about all the free stuff?
- What impact does the end of computer productivity growth have?
- Is productivity falling in healthcare?
- Does a rising level of debt or QE affect productivity?
- Isn't the capital-light model more efficient?
- Aren't robots driving productivity higher?
- What are the implications of your views?



Sources; BEA, Conference board, BLS, The MacroStrategy Partnership.

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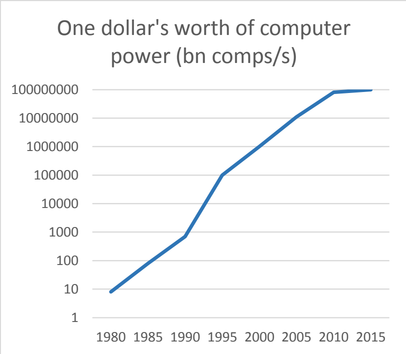
Recommendations

- **Short US equity indices.**
- **Long gold & gold stocks.**
- **Short silver/gold ratio.**
- **Long the US$.**
- **Long volatility.**
- **Short US non-bank lenders**
- **Short US auto sector.**
- **Short UK Miners.**

Key chart



Source; William Nordhaus; Two centuries of productivity growth in computers

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Notice and Disclaimer - Refer to Appendix 1

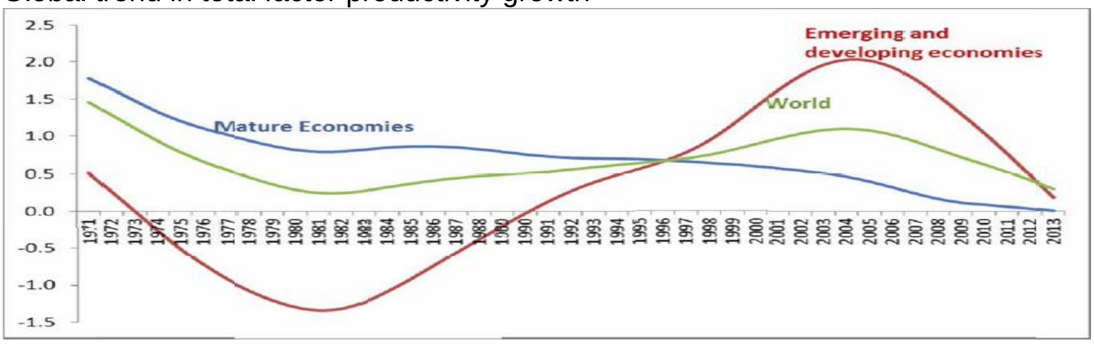
First, what is productivity?

The simple answer is that it is the efficiency with which the economy combines labour and the capital stock to create GDP, the sum of all activity that makes a return over the cost of capital.

But that's not quite good enough. Because, as Knut Wicksell explained, you have to measure returns over an entire credit cycle, during which credit grows at the same average pace as GDP. The problem is that the US has not had a credit cycle for 45 years – we have had a secular credit expansion in excess of GDP growth.

For Wicksell, the danger of the credit expansion phase of the cycle is that it fosters investment in businesses and the growth of jobs that only make a return while credit is expanding (stockbrokers & real estate agents?). So an important problem with productivity analysis today is that returns are being pushed higher by excess credit formation. But despite that, productivity growth around the world has collapsed.

Global trend in total factor productivity growth



Source; Conference board

That means that the downtrend in productivity that we are seeing is likely a generous interpretation of developments. When credit conditions deteriorate, we would expect to see a sharp cyclical downturn in addition to the declining trend.

Andy highlights there is a second, parallel, way of looking at productivity. It is the ease of extracting energy from the earth's resources, and the effectiveness with which that energy is converted into productive work (exergy). More on that insight later.

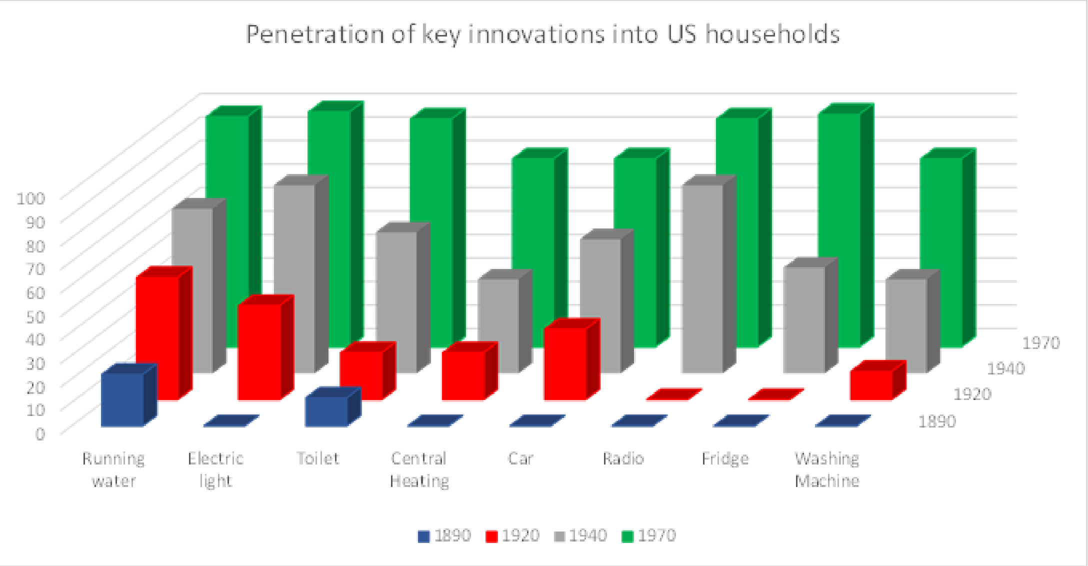
How could productivity be slowing; what about 3-d printing, electric cars, energy efficient lightbulbs, etc.?

We agree with one thing that the tech evangelists say, there is constant innovation. The issue we have is the context; is new innovation as profound as in the past? How widely is new innovation applied? And are there other areas where productivity is going backwards?

In my view, the main reason why the market is struggling to get to grips with the collapse in productivity (and its profound implications) is that we hear a lot about new tech. Danny Kahneman, the Nobel prize winning behavioural psychologist describes the subsequent thought process as the king of all cognitive biases; recency bias. He sums up recency bias as 'whatever you are thinking about isn't as important as you think'. We overweight the importance of stuff we've just heard about.

There are two problems with recency bias when we apply it to productivity. First, while we hear about new tech and assume productivity is rising, we don't tend to hear about all the things that make productivity reverse like the collapse of Dennard scaling, peak oil, government waste etc. They don't make good soundbite TV, and as part I & II of this note attest, it is hard to summarise them in 140 characters. So in general, people are not weighting these issues properly.

Second, Robert Gordon's book 'The welfare of the American people' describes eloquently how small the innovations of today are relative to those in the past.



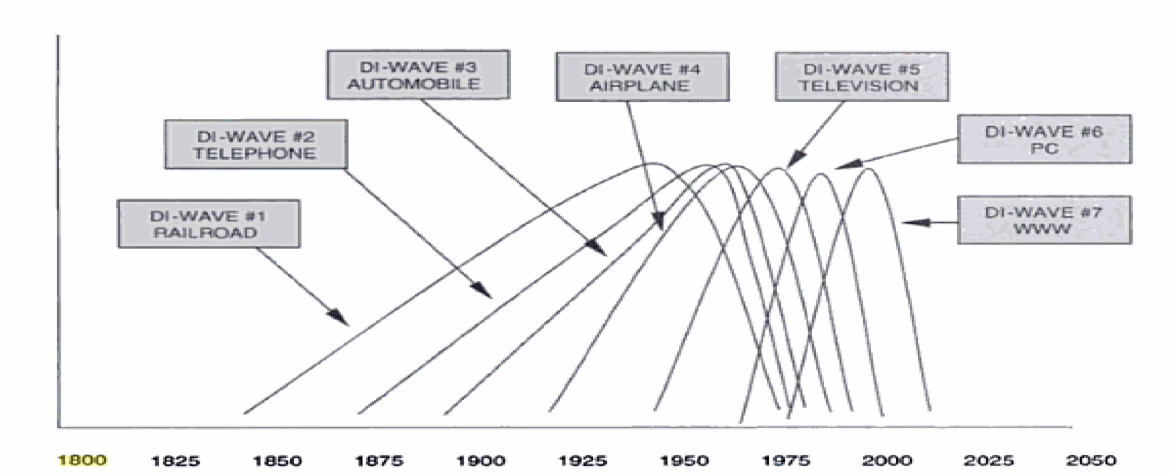
Source; Robert Gordon

The only innovation over the last 25 years that stands up to the innovations above is the personal computer. But that was ubiquitous in offices in 1992, a quarter of a century ago. The net and email was widely available five years later. As Robert Gordon is fond of saying, when you sit at your computer in your office today, you realise that nothing much has changed in the last 10 years.

Andy highlights that innovations are classified as continuous or discontinuous. Discontinuous innovations create whole new industries, so the computer was discontinuous. Most of the innovations since have just been part of the continuous development of the computer. A discontinuous innovation follows a normal shaped curve / S-curve as the marginal return from using the product increases until it eventually reaches innovation saturation, when the marginal return from using it more starts to decline. That is where we are at today, so all the "innovation" that we hear about such as mobile phones etc. are all part of the continuous development of that discontinuous computer technology, and the declining marginal return from each of these sub-innovations is exactly what you would expect.

The really big thing is that the sum of these discontinuous waves also follows a normal curve/s-curve, and you can work out from that that we are towards the bottom right hand tail of the Industrial Revolution, about 90% through the Industrial Revolution. Whilst that still means 10% potential, because we are at the bottom right hand tail, and each innovation is that much more marginal, it will take that much more time to achieve, so even slower growth.

Innovation curves



Source; The death of demand, Tom Osenton

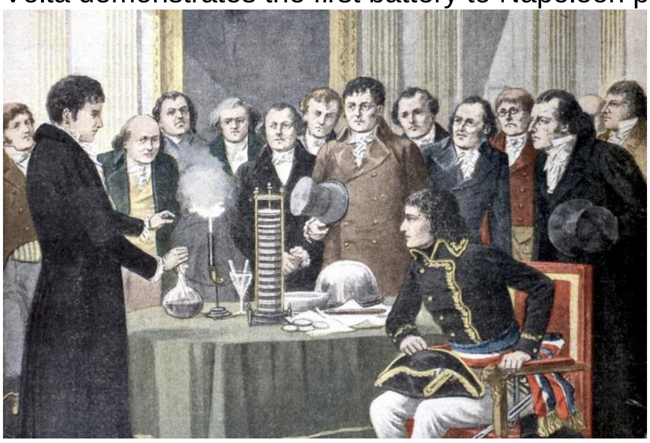
Is there a good analogy to help understand productivity & the capital stock?

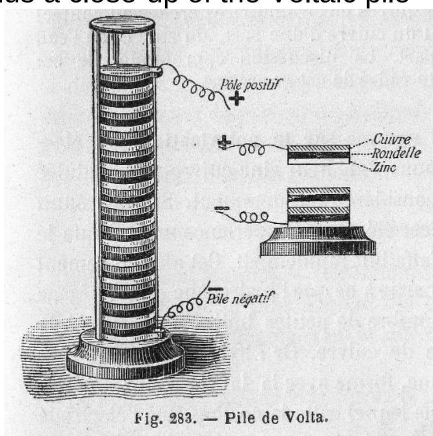
Our capital stock comes in three forms; natural, physical & human. It stores the energy from our previous investment in innovations (and natural resources) in a wide range of materials from the oil embedded in rock strata, the copper of a telephone wire, and in the synapses & ganglions of the brain.

So we can see the entire capital stock, and the entirety of human capital and of natural resources as a giant battery. Natural, physical & human capital is all stored energy.

Andreas Volta invented the first battery in 1799, in part to prove his argument that frogs didn't generate electricity (yes, really). The Voltaic pile was made up of zinc & copper plates, separated by cloth soaked in brine, and connected at each end by copper wire.

Volta demonstrates the first battery to Napoleon plus a close-up of the Voltaic pile





Sources; Google, Sparkfun.com

Now, to extend the analogy, think about every element of our natural resource base as a separate metal disk in the pile. Fresh air, underground aquifers, wood forest, dark soil, plants, animals and fish, coal, oil & gas reserves etc.

Then there is the physical capital; all our houses, offices and warehouses, car factories, food processing equipment, transport and communications infrastructure, oil rigs and refineries, Windows office, Google's servers, company models etc. All add more disks to the pile, and raise its power.

And finally, there is human or cultural capital; skills we've learnt through education or on the job, the rule of law, property rights, our cultural willingness to get along at work or behave civilly in public etc.

Each of these is an additional metal disk. And each contributes to the annual power that the battery can release. And that annual power generated is GDP.

When you put today's innovations in the context of the accumulated store of historical innovation embedded in the capital stock and the labour force, we would suggest that most innovations that hit the media might be the equivalent of putting a 2c coin on top of a pre-existing six foot Voltaic pile. They are having a barely discernible impact on GDP. Andy adds that the battery can only be used for one of two things. If the energy is not being used to add back to the Voltaic pile, it is depleting it, which is of course what we've been doing.

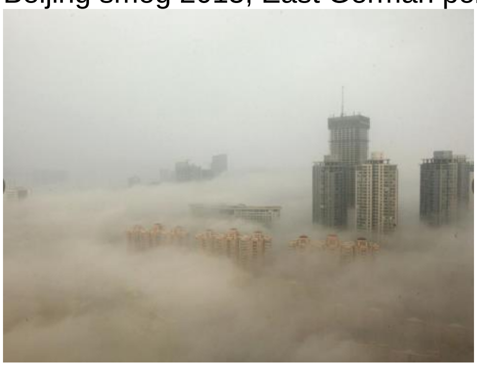
The next point is that modern economists don't try to measure the stock of natural resources, even though they are a critical element in the creation of GDP. That is a huge oversight, and one that could be quite easily corrected. Because it is not measured, the implications are generally ignored. But the analysis of natural resources is critical to the outlook for growth.

We argue in the sections below that the depletion of cheap natural energy resources has forced a substantial increase in measured drilling capital stock - for no net gain and an increased cost of output or lower productivity. For every metal disk the oil industry adds with new technology and measured physical capital, it takes away two from the unmeasured natural resource base. Andy and I estimate that it now takes 34x the value of physical capital stock to drill a unit of oil & gas as it did in 1977. See p11.

Andy highlights that the efficiency of turning energy into work is measured as the temperature differential between power and exhaust (Carnot efficiency). A formula one car is far less powerful in the Middle East grand prix than in a cool environment like Canada. If the atmosphere is warming, this will naturally reduce global efficiency, or at least be working against the innovations we are making.

The mispricing and degradation of aquifer water (Saudi Arabia, US) and fresh air (China) are having substantial but less easily quantifiable impacts.

Beijing smog 2015, East German pollution in 1985.




Sources; DDR museum, Flickr.

It is worth remembering that East German pollution spurred a green movement that was ultimately pivotal in bringing down the republic.

The fact that US healthcare spending is accelerating at the same time as health is deteriorating means that, for every metal disk added to the physical healthcare capital stock, two are taken away from the (unmeasured) human capital stock. Our calculations suggest that this is taking 27 basis points off potential GDP growth per year (see part II for details).

And then there is the misallocation of capital under the excess credit regimes of the 2000s and under QE. The most obvious destruction of capital has been in China (30% of GDP) and in the shales (3% of the US capital stock). Then there is the destruction through the ageing of the capital stock, as QE (and previous excess fixed capital formation in China) induced corporates to gear up for buybacks, rather than invest in productive technology. Our analysis suggests that the ageing of the capital stock alone is removing 2.9% from potential growth. (We write this up in part II).

What type of innovation makes a difference?

It is very hard to weigh up historical innovation properly, as once technology is embedded in the infrastructure around us, it tends to become invisible – we tend to ignore it.

One of the best insights into this that I've heard came from James Lovelock, who was contributing to a programme 'Seven wonders of the modern world', that I saw when I was 19. The programme was part of a series of seven, featuring theologians, scientists, philosophers, artists & architects. Lovelock said that the greatest wonder in the modern world was walking into a room, flicking the switch & seeing the light go on.

Why was this extraordinary? Because the light required a company to build a power plant and an electric grid, it needed someone to prospect for oil or natural gas, a business to drill in the north sea, someone to build the oil derrick, it needed a culture that established property rights, the rule of law and a functioning electricity market, it needed everyone to get educated to perform those roles, it needed someone to pay for the education, someone else had to invent the lightbulb, mine the copper for the wires, and blow the glass for the bulb etc. etc. ad infinitum.

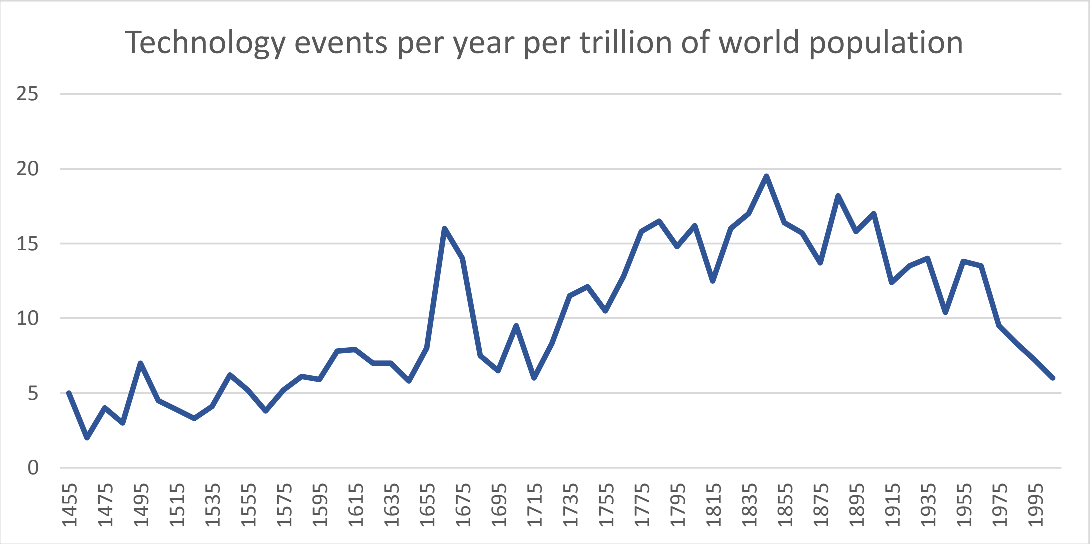
Lovelock's point was that the number of agents involved in the process, and their interactions both past and present, exceeded the number of synapses in the brain. And so, by definition, it is more complex than our ability to understand. So if you turn on a light, Lovelock said, 'it is as if we are seeing the mind of god'. Now I'm not religious, I'm more of a market guy, but I think it is worth thinking about these complex processes that almost everyone else ignores. Because, if there is structure there, then there's an opportunity to profit from it.

My view is that the cumulative stored innovations of the past are two orders of magnitude larger or more important than the innovation of the past decade.

Bryan Bunch & Alexander Hellemans' book 'The timetables of technology' lists 8,583 significant technological innovations, from the Middle Ages up to the modern era.

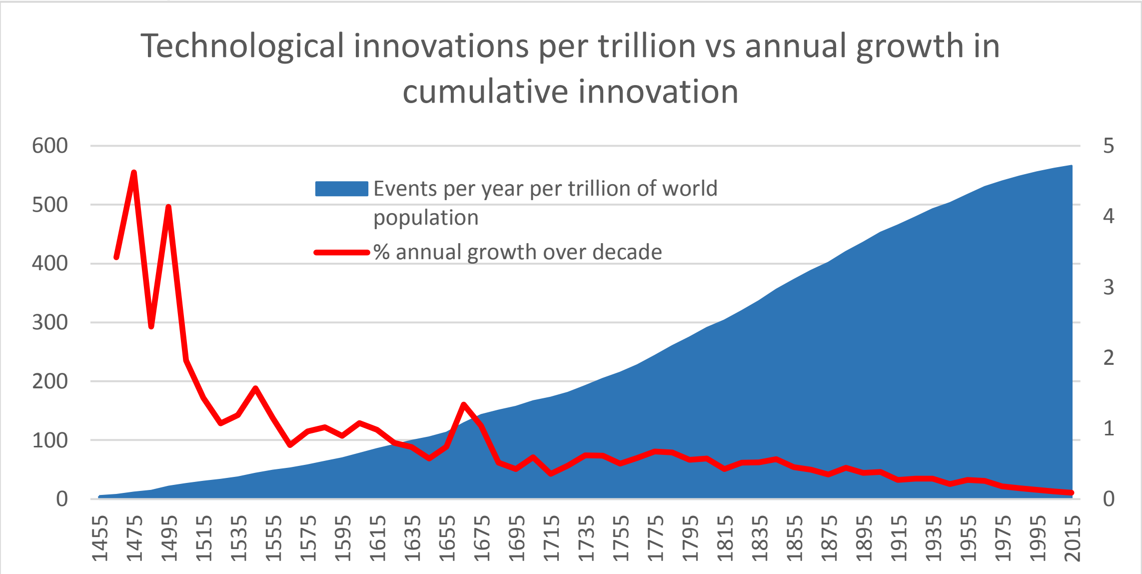
Jonathan Heubner used their database of technological innovations to show that the speed of innovations is now declining relative to the world's population. (See

Link for details; [link to Huebner](#)).



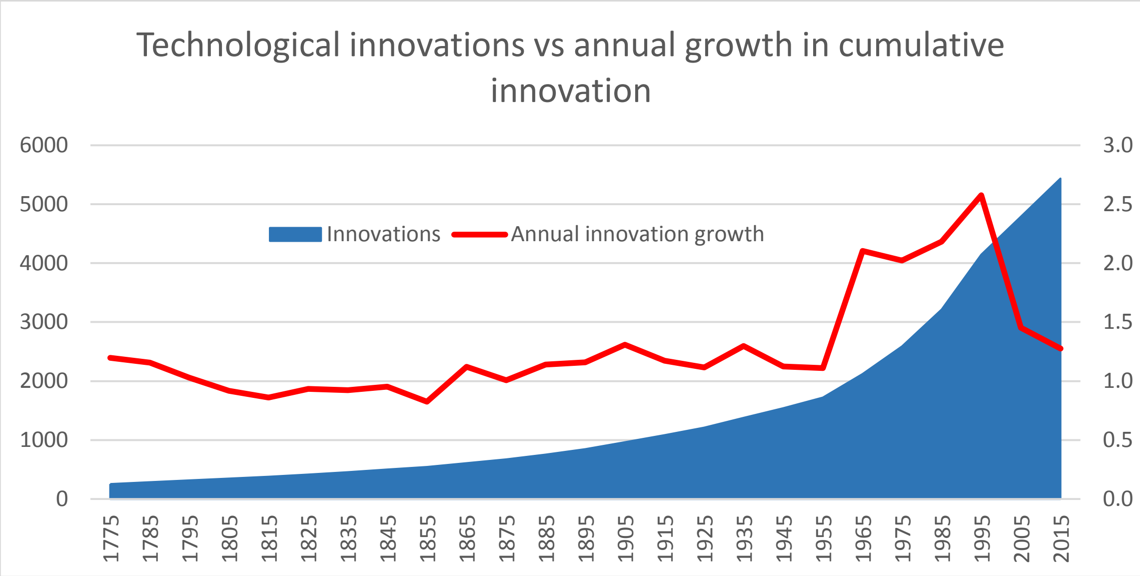
Source; Bunch & Hellemans & Jonathan Heubner; 'A possible declining trend for worldwide innovation'.

But this slowdown in innovation is not an accurate depiction of how technology works. Once it is embedded in the capital stock it is like a battery – that continues to generate power, and then acts as a base upon which further innovation can build. So the chart that better represents innovation is cumulative.



Source; Bunch & Hellemans & Jonathan Heubner.

Even if we argue that innovations are immediately global (i.e. we don't adjust for the population size, and that's a very generous assumption), it is clear that the pace of innovation has slowed over the past two decades, despite the continued growth of the world population.

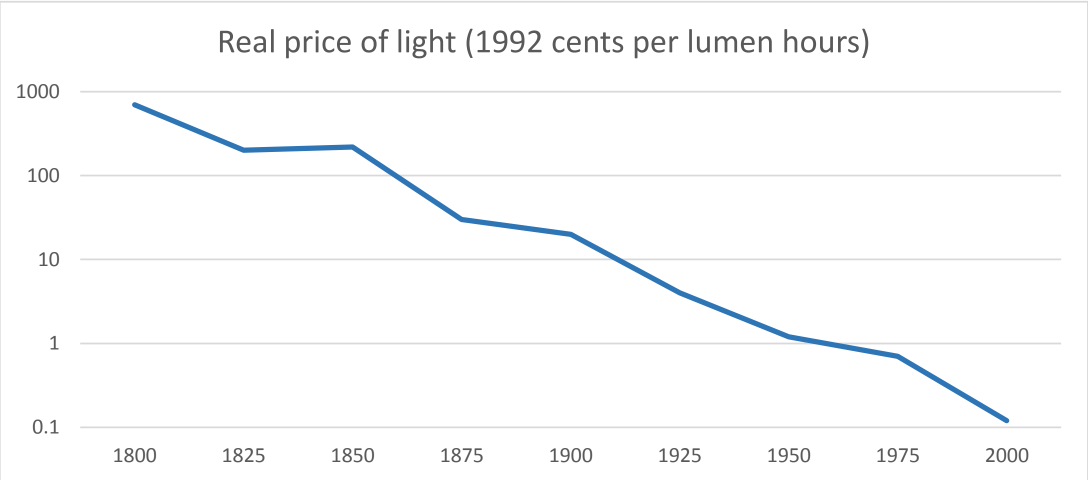


Source; Bunch & Hellemans & Jonathan Heubner.

To see why this is important it is worth using a broad rule of thumb; unless a new innovation can create a significant new industry (greater than 1% of GDP) or it can reduce the costs in a major existing industry (accounting for 5%+ of GDP) by around an order of magnitude (90%) then it won't make a mark compared to the aggregated innovations of the past. It won't raise GDP by more than 1%. And that means that the productive benefit of those innovations will likely get swamped by activities where productivity is declining. That is an extremely high hurdle rate.

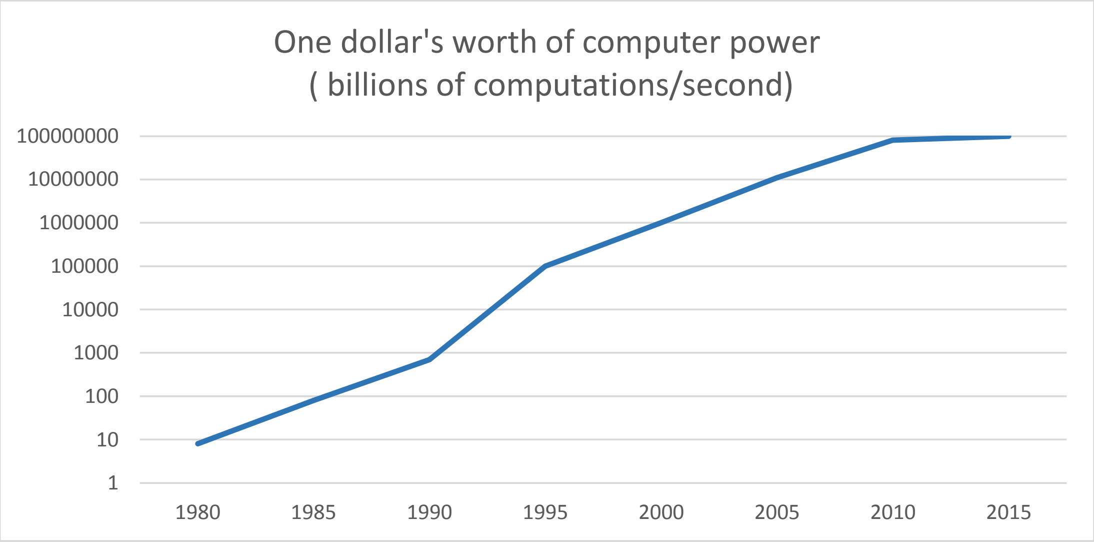
Two of the best examples of the power of historical innovations come from the work of William Nordhaus.

- Electricity and the electric lightbulb. William Nordhaus (The cost of light, 1992, link to cost of light) estimates that the cost of light, in cents per lumen hours, has fallen to 1/5000th of its price 200 years ago.



Source; William Nordhaus – The cost of light.

- Computers – Nordhaus estimates that a dollar's worth of computing now does 10,000,000 more computations per second than it did in 1980.



Source; William Nordhaus; Two centuries of productivity growth in computers. Note; Nordhaus's definition of computer power is the rate of executing a set of standard mathematical tasks. Data is 2006 real US$s.

Neither Andy nor I can think of any innovations over the past 10 years that, if you'll forgive the pun, can even hold a candle up to these two innovations.

- For all the hype around the iPhone, it has made the mobile phone larger (because the batteries would run out too quickly on a smaller phone), it has increased the cost of making mobile phone calls, and lowered the quality of the call. Of course, it looks nice & it has apps, and you can use it to take selfies. Unfortunately, selfies have no value, otherwise the economy might be in much better shape.

- Amazon has reduced the cost of a book by around 20-30%. But I'd argue the quality is lower, as I can't lend my kindle titles, and, apparently, I can't bequeath them. So I don't own them. They are a lifetime lease. And you have to recharge when you want to read.

- 3D printing has so far only proved viable in specialist aerospace applications.

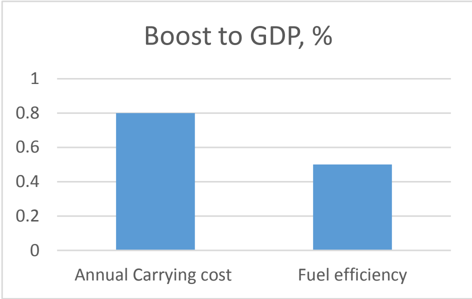
- Google maps is free (bar the data usage). And it is rapidly eroding Satnav sales. Satnav was 10x cheaper than the military hardware that preceded it. But, at 0.1% of US GDP at peak, it was not a big enough business to make a difference. But isn't it productive if something that used to cost money is now available for free? See p13 for our discussion 'what about the free stuff?'

- Video Streaming. This is better than schlepping to the video store but it isn't that cheap, as they still charge for quality content, and quality content costs money.

Of course, there is always a lot of talk about potential new technologies that haven't made it to market.

Intuitively, you'd think that switching to driverless electric cars all connected by an Uber network would be dramatic and ground breaking. But it isn't. My analysis shows it would only add 1.3% to US GDP (See Destructive destruction, November 2015). And that estimate makes the very generous assumption that you could build the infrastructure for no more than the cost of maintaining the old infrastructure.

Mercedes concept car & the potential benefit from driverless, electric cars



Source; Mercedes, MacroStrategy Partnership calculations

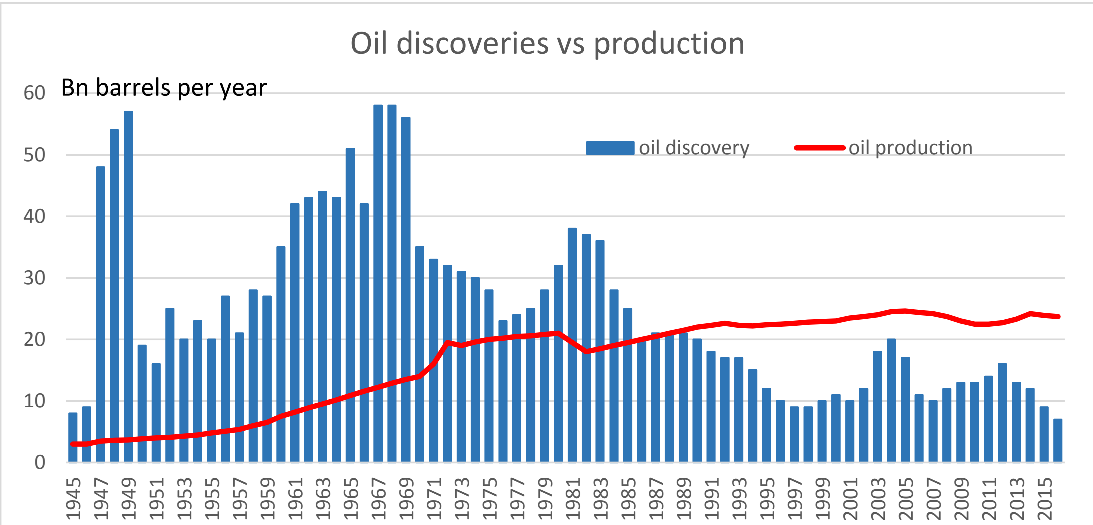
What impact do geological constraints on oil have on productivity?

A central thesis in Andy's book from earlier this year; 'The Productivity Engine' (please drop us a line if you would like a copy), is that you can look at the economy as a thermodynamic system. It is about the amount of energy extracted, and then the efficiency of its transformation into productive work.

Andy goes on to highlight the Jevons Paradox, which proves that you must increase the consumption of energy in order to increase the efficiency of it use. As nothing is 100% efficient, exergy (the ability of energy to do useful work) is lost at every single transformation. At every stage of a food or production chain, there is less exergy available, so additional energy is required to add a new level of technology.

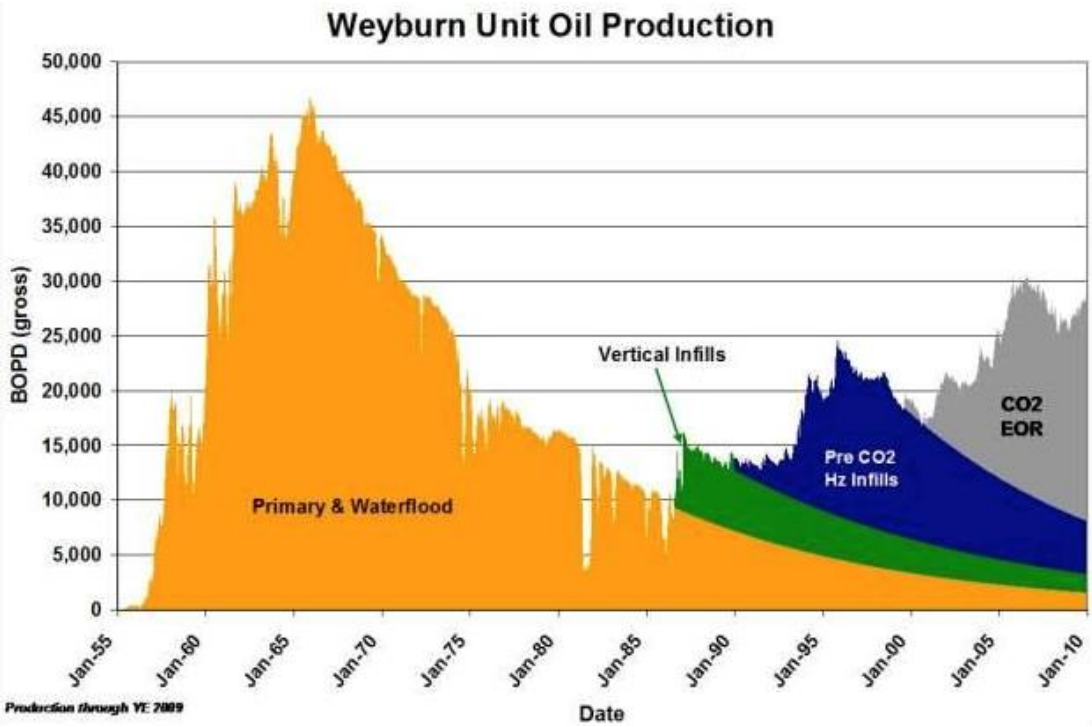
So the basis of any discussion must be how efficiently we can generate energy. And that starts with extracting fuel.

The geological imperative in oil & gas production means that more energy, more technology and more resources are needed to discover and produce less oil. My colleague James Ferguson showed the deterioration in his report last month 'From peak oil to zero oil'.



Sources; Colin Campbell, Association for the study of peak oil, BP statistical review

James also showed that the combined impact of deteriorating reserves and technological enhancement process from waterflood (which is a double edge sword), & infilling. The chart shows the extent of the new technology and new capital stock required to prevent a more rapid decline in well productivity.

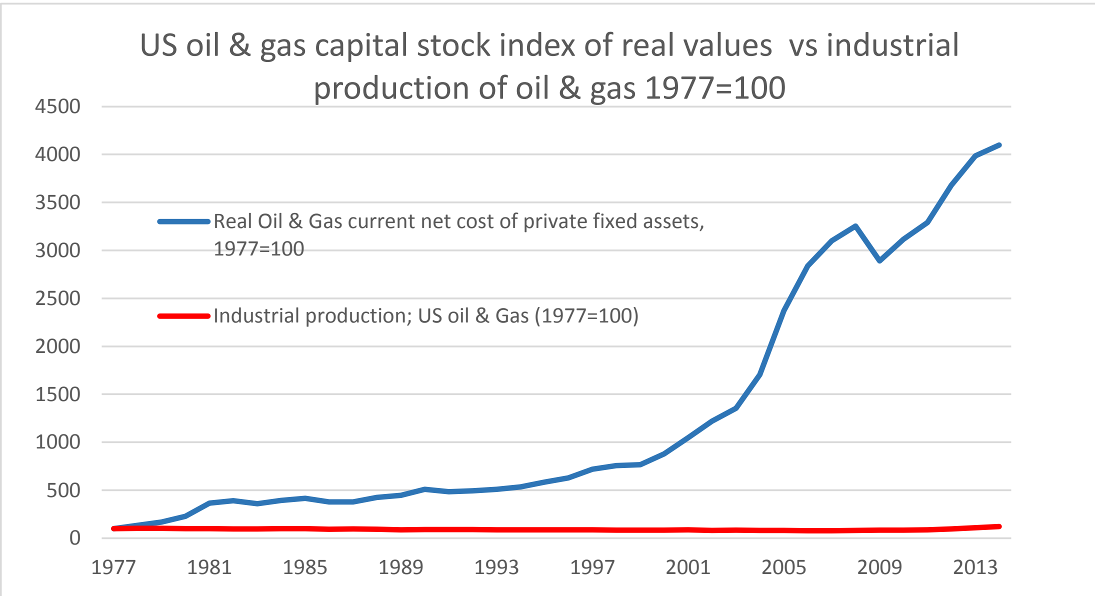


Source; Weybern

So how much more is being spent on the energy capital stock, per unit of energy production today than 30 years ago?

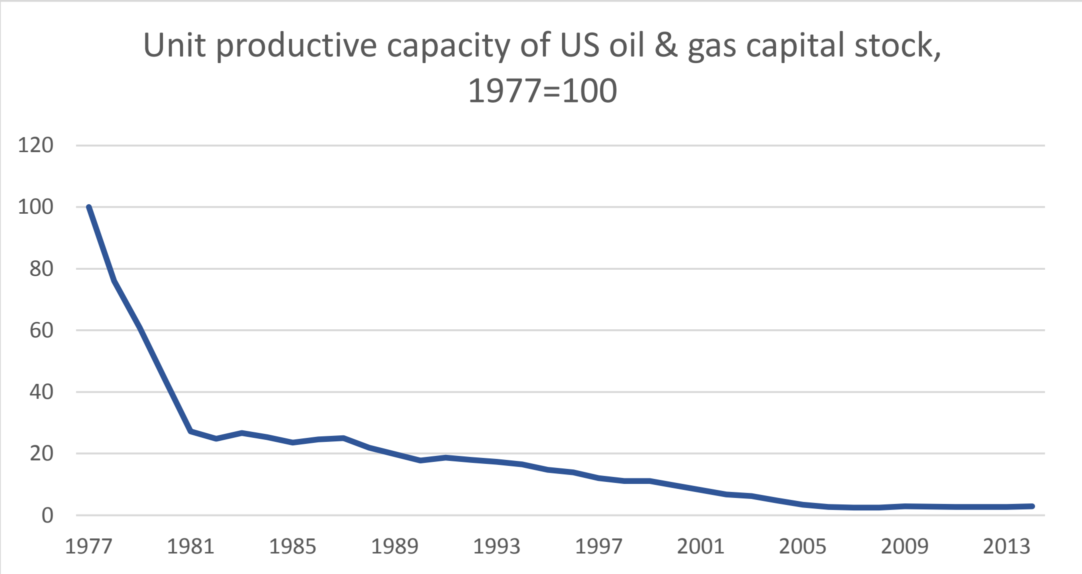
One way to calculate this is to look at the BEA's estimates of the US capital stock involved in energy extraction relative to the US production of oil & gas.

Here is the real value of the US oil & gas capital stock vs the US industrial production figure for oil & gas, which is a weighted volume measure. Both are indexed at 100 in 1977.



Sources; BEA & FRED.

From this we can create an index for the unit productive capacity of the physical capital stock in oil & gas.



Sources; BEA & FRED.

I think this chart is extraordinary – in 2014 US corporations needed 34x more capital stock in place in real value terms per unit of oil & gas production vs 1977.

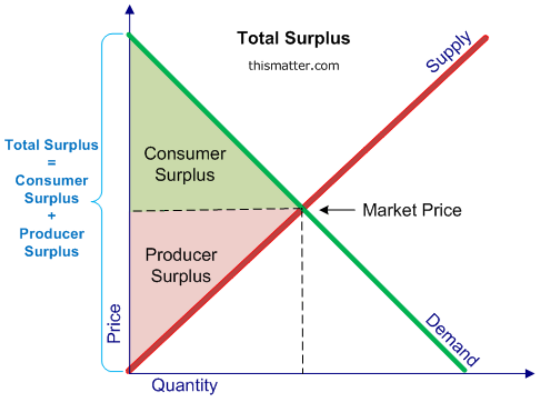
But that was 2014. It has now started to deteriorate again because the acceleration in shale production in the high price environment from 2010-2014 turned out to be a massive misallocation of resources into high cost oil production. As companies shutter production and natural decline rates drive output down faster than for conventional fields, the productive capacity of the use oil & gas capital stock will lurch lower again. If US oil production falls 10% from peak, we can expect this factor to lower total US total factor productivity by around 0.6%. If that happens over three years, it is a huge 0.2% a year drag on productivity growth on its own.

Another way of looking at this is to observe that, because GDP is a measure of work or exergy, this rising capital intensity of oil and gas production wouldn't be a problem if the rest of the economy was more efficient at turning the energy into useful work. Unfortunately, the fact that GDP growth has slowed suggests otherwise.

Andy adds that the rising cost of energy extraction is exactly as you would expect. Because no system can ever be more than 100% efficient, then it will again follow this normal curve s-curve towards the limits of the resources. If the Earth was significantly bigger and offered far more resources, then the S-curve would perhaps eventually take us to 100% efficient under the laws of thermodynamics, but as it is, the S-curve will be to the limits of the Earth's resources. You could draw a similar normal curve on energy production growth and derive from that we have largely exhausted our fossil fuel supplies etc. Using renewables is taking from natural capital, which would negatively affect the natural economy. This is not to say that we are talking Malthus, but that we need to shift from a revolution based on exploiting the laws of thermodynamics to one based on quantum mechanics, which means a fusion energy source.

How about the free stuff & are we counting GDP correctly?

The great side effect of capitalism is consumer surplus. The incentive for entrepreneurs to reduce costs, raise quality, cut prices and ramp-up sales means that many consumers can buy things, from Mars Bars to comfortable & reliable cars, that they would have been prepared to buy for a much higher price. That extra you'd have paid, but didn't have to, is your consumer surplus.



Source; Thismatters.com

It is worth noting that consumer surplus is almost entirely absent under socialism. The best example of the failed incentives under socialism that I read about was a nail factory in Moscow in the 1950s that, when given the order to produce one tonne of nails for the year, built a cast and produced one 1T nail, and then took the rest of the year off. That created a consumer deficit.

So when companies produce goods cheaper that increases consumer surplus. When companies produce better goods for the same price that increases consumer surplus. And when companies give you stuff for free, from morning newspapers on the tube to the Encyclopaedia Britannica online – it increases consumer surplus even more.

But none of that is included in GDP. And therefore it is not included in productivity data. Well, should it be? Aren't we underestimating GDP?

No it shouldn't and no we aren't.

We shouldn't because GDP, while it is not a full measure of welfare, it has a very important purpose.

It is there to measure the income, expenditure and value added in the monetary economy. That is quite useful, but it becomes really useful when you look at whether GDP growth is supported by an increase in productive work (through rising productivity, a growing quality adjusted workforce or an expanding productive capital stock), or whether it is supported through rising debt and the consumption of the capital stock.

Clearly, it is rising debt and capital stock consumption that has driven US GDP for the last six years. And that fact is central to our view that, in the absence of substantial fresh liquidity, the US economy will fall into a deflationary bust. It would be impossible to make that call if someone added some subjective measures of consumer surplus to GDP.

Andy also argues that the consumer surplus actually contributes to measured GDP, so adding it back in would be double counting. That extra time you off to enjoy the sun or read a book makes you more productive and therefore is included in the data. If we worked 24 hours a day, then our productivity and output would collapse. The consumer surplus is just a necessary part of the system allocating capital in the best way to maximise productivity. It's the same as if you used a field to grow the same crop year after year without rotating it (or using pesticides / fertilizers) - the productivity of that field would collapse. The system optimises human capital by giving consumers a surplus.

It is worth using the examples above to judge whether we should boost GDP to account for 'free stuff'.

So what happens when the Encyclopaedia Britannica decides to change its business model from selling books door to door, to selling advertising on the net?

Clearly they swap profits on bookselling, for profits from ads. These profits are measured in GDP – so it would be double counting to add in an 'extra benefit' from their service from the producer income point of view.

If an individual uses it to increase their knowledge, and therefore gets more productive at work, then corporate profits rise & his income rises. That's measured in GDP, and it is measured in the productivity data. So it would be double counting to include an estimate of the benefit of the 'free Britannica' to the production process.

If the person just read it for entertainment, then it has no impact on GDP. But that is fine, because it is not part of the monetary economy, and so shouldn't be included in GDP. So just like having a conversation with a friend as you're walking down the street – you may enjoy it, it may improve your life, but it is impossible to quantify and you shouldn't include it in GDP anyway – as that would distort what you are using GDP to measure the monetary economy.

How about quality improvements – like the massive improvement in computer power in the 90s and early 2000s that took place while computers got cheaper?

Well, it is the same argument. If a company buys a computer for US$1000 that is twice as powerful as the one they bought for US$1000 three years earlier, the company may be able to generate more profit. In which case, it shows up in GDP and productivity data.

And if the consumer has a bigger surplus, well that's nice, but it doesn't add to GDP.

So in our view it is fine say that 'free stuff' on the net, falling computer prices and the improved quality of certain goods has increased welfare. To claim, as tech evangelist Brynjolfsson does – that it should be included in GDP dubious for the reasons described above.

But to claim that the failure to include it means we are underestimating the trend in productivity is ridiculous. Because you would have to include the consumer surplus from all historic innovations - the consumer surplus of not having to carry water, heat it and use a mangle for the weekly wash to the use of a cheap PC etc. And if you could in some way measure that accurately, which you can't, you would then find that the increase in consumer surplus today is much less than it was in the past for precisely the reason that today's innovations are tiny relative to history. As Robert Gordon says 'what would you rather; running water or Twitter?' So productivity growth would be collapsing under Brynjolfsson's method as well.

A quick aside. Do you know what I hate about TED talks? There are no questions. As Karl Popper, the philosopher, would say; if you can't disprove something, it isn't science. Popper started thinking about this when he kept coming up against highly intelligent people espousing the Marxist theory of history, Freudianism etc. His flash of inspiration was that all these theories were impossible to disprove. And if you can't disprove something, if you can't interrogate the work, then it is not science, it is pseudo-science. Richard Feynman's lectures on physics start with the statement 'The test of all knowledge is experiment'. And that, by the way, is why economics is so far behind genuine scientific disciplines – it is hard to devise experiments that can disprove the consensus view. Hopefully the arguments in this note will get us part of the way there.

Look out for 'The Productivity Paradox part II', out tomorrow, where we will give our views on the following questions;

- What impact does the end of computer productivity growth have?
- Is productivity falling in healthcare?
- Does a rising level of debt or QE affect productivity?
- Isn't the capital-light model more efficient?
- Aren't robots driving productivity higher?
- What are the implications of your views?

APPENDIX 1 - NOTICE AND DISCLAIMER

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