

September 2026

CURMUDGEON'S CORNER

VOLUME 3

curmudgeon (cur mud geon)

noun [ker-muj-uhn]

A bad tempered, difficult, contentious, querulous, grouchy, cantankerous person

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The Rise of the Machines: Part 2

Lessons from a whistlestop tour of 250 years of the New Economy

In the last issue of Curmudgeon's Corner I explored my personal skepticism when it comes to the intelligence and usefulness of AI. In this issue I will put that aside and instead offer some thoughts on how a value investor might go about dealing with technological revolutions. This may seem like a very tall order, since technological upheavals are inherently always about a structural shift, whilst value investing is often about mean reversion. A potential conundrum for sure. However, for those willing to learn from history, we have seen many technological waves before, thus many historically astute value investors can claim to have seen this movie before.

If Karl Marx was correct when he noted in 1852, "History repeats itself, first as tragedy, second as farce", we must be on slap stick by now! Or as George Santayana opined in 1905, "Those who cannot remember the past are condemned to repeat it". In an effort not to fall into that trap, this paper will explore what we can learn from the history of technological innovations.

A framework for thinking about Technological Revolutions

As I was thinking about this paper, I came across a book on my shelves that I had long since forgotten about, to my shame; Carlota Perez's *Technological Revolutions and Finance Capital*. This book was published in 2002, and I remember reading it at the time, but given my current interest it seemed particularly apposite.

Perez lays out a series of stylised phases that technological innovations tend to move through (Exhibit 1). However, she points out that the real world is often messier with cycles overlapping in the late and early stages, and the added complications of including the world of finance into the analysis. This gives rise to a second and more complicated version of the tech wave seen in exhibit 2.

Exhibit 1: A stylised technology wave

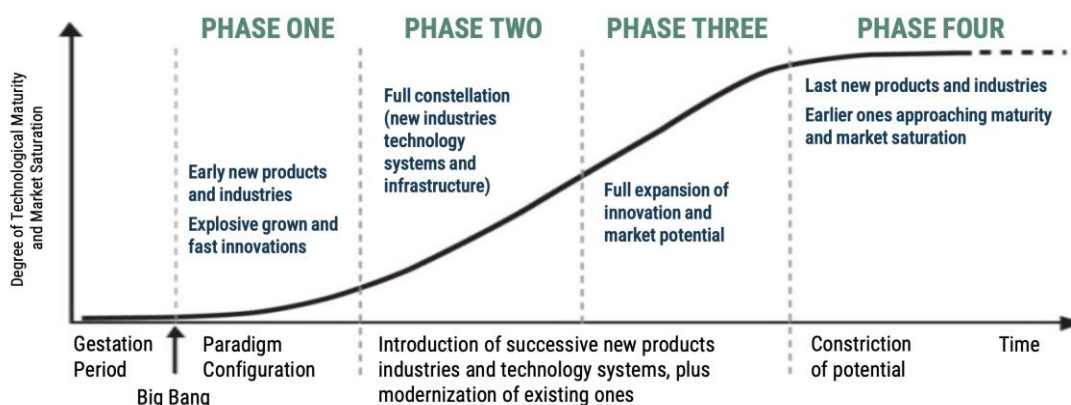
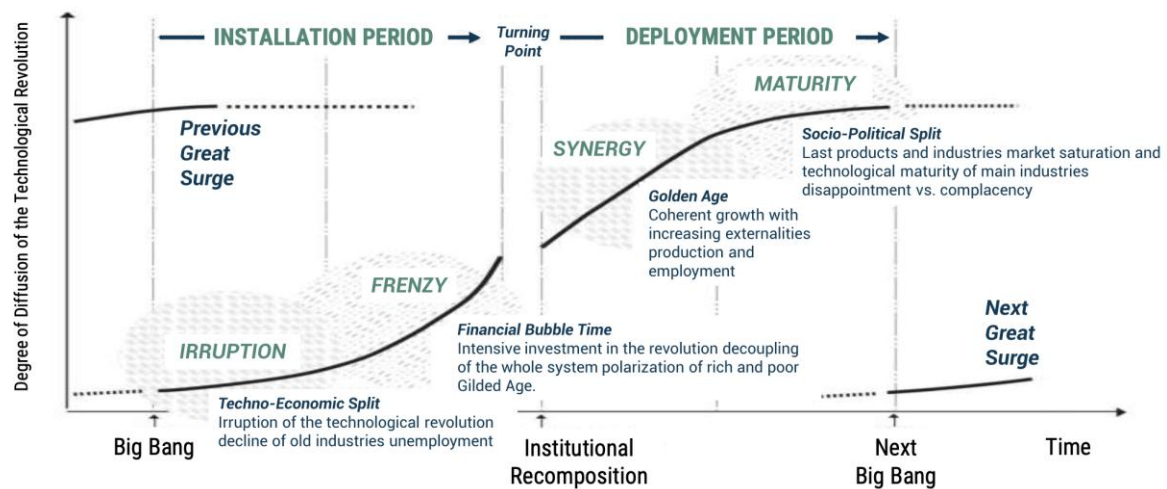


Exhibit 2: A more realistic wave incorporating finance's role

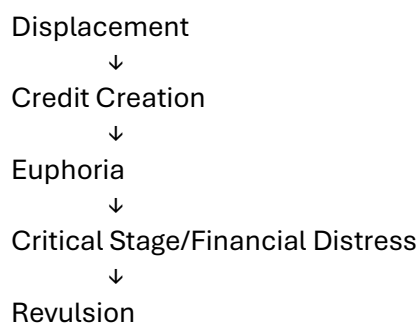


Here we have some elements that seem very familiar to students of history. Perez uses the term irruption (as opposed to eruption) since the early stages are all about the sucking in of capital (hence an analogy to implosion vs explosion), the creation of new profit opportunities and the decline of profits in older industries (accompanied by rising unemployment). This phase is overlapped with the frenzy (about which we will have more to say below). For now, we can think of this as the excitement expressed in financial markets for the profit opportunities related to the new technology. It should be noted that this phase often witnesses the decoupling of finance from being productive (i.e. the source of funding for innovation) to speculative (think greater fool markets, “this time is different” thinking, and the birth of belief in a new era). The irruption and frenzy phases can be combined to give us the installation period.

A brief aside on Frenzy

Of course, the frenzy stage is one we value investors are most familiar with. In the past I have often used the Kindleberger/Minsky model to explore the anatomy of a bubble.

This model breaks down the frenzy into five stages, shown below:



Displacement is very like the irruption process that Perez outlined above. Essentially it can be seen as an exogenous shock that triggers the creation of profit opportunities in some sectors, whilst shutting down profit availability in other sectors (disruption in the modern parlance perhaps). As long as the opportunities created are greater than those that get shut down, investment and production will pick up to exploit these new opportunities. Investment often occurs in both financial and investment assets. Essentially a boom is born.

The boom is then further exacerbated by credit creation. In this framework money/credit is held to be endogenous to the system such that, for any given banking system, monetary means of payments can be expanded not only within the existing system but also by the creation of new banks, the development of new credit instruments and the expansion of personal credit outside the banking system, (shadow banking, vendor financing etc).

Sooner or later the demand for the asset(s) will outstrip the supply, resulting in rising prices. These price increases give rise to yet more investment (both real and financial). A positive feedback loop ensues: new investment leads to increased income, which in turn further stimulates investment.

Euphoria is the term given when speculation of price increase is added to investment, production and sales. We might call this the perversion of capital from productive to speculative purposes. Momentum trading or the Greater Fool Theory becomes the prevailing wisdom (which Adam Smith termed overtrading) along with a widespread belief in a new era and those most fateful of words: "This time is different" become an everyday mantra. Kindleberger notes that overtrading is a nebulous term and covers what we might call pure speculation (greater fool), overestimation of prospective returns (often by reference to simply implausible growth estimates), or excessive gearing. To this list I would add a further category of errors namely to the underestimation of the risk involved.

The fourth stage of the bubble process is labelled as the critical stage or the financial distress stage. The critical stage is where the insiders decide to take their profits and cash out (think IPO boom - noted above - and insider selling). Financial distress usually follows straight on from the critical stage. It refers to situations where the projected cash flows (or expectations of those cash flows) receive a reality check, and they fall short of the level required to cover liabilities. In asset markets, the equivalent condition is an awareness on the part of the considerable segment of the speculating community that a rush for liquidity (out of assets into cash) may develop. Kindleberger opines "The specific signal that precipitates the crisis may be a failure of a bank, or a firm stretched too tight, the revelation of a swindle".

Revulsion is the final stage of the bubble cycle. It refers to the fact that people are so badly scarred by the events in which they were embroiled that they can no longer bring themselves to participate in the market at all. It is preceded by capitulation where the former bulls throw in the towel (described by Kindleberger as degenerate panic). The panic ends when one of three events occur:

- Prices fall so low that investors (of the value persuasion) are tempted to move back into the asset
- Trade is cut off by setting limits on price declines (although this generally only works in the short term)
- The Lender of last resort steps in

In the last few decades, it is the last option that has generally been the driving force in ending the panic - think the Greenspan/Bernanke/Yellen Put.

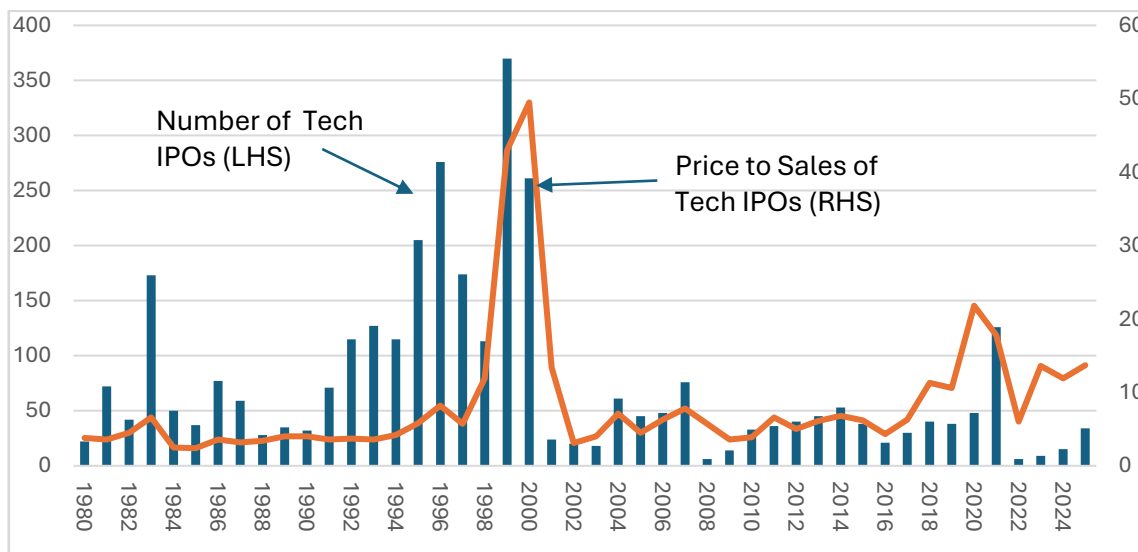
Back to the Perez framework

After the frenzy eventually ends (as they inevitably do) there is a reassessment of the technology, often accompanied by growing inequality, and political unrest. Regulation is often deployed as a public backlash after the madness and embarrassment of the frenzy has faded. However, the

technology becomes more widely adopted and new synergies appear which foster growth. Eventually we reach maturity where saturation occurs and we see widespread social adoption of the technology. These two phases are combined to give us the deployment period.

My own addition to this framework concerns who captures the economic surplus during this process. In general, I think the producers are the beneficiaries during the installation phase. Think of those who win during the frenzy, it is the guys selling the equities or receiving the funding (i.e. The corporates, not the investors - just recall the IPO boom that accompanied the TMT bubble, exhibit 3)

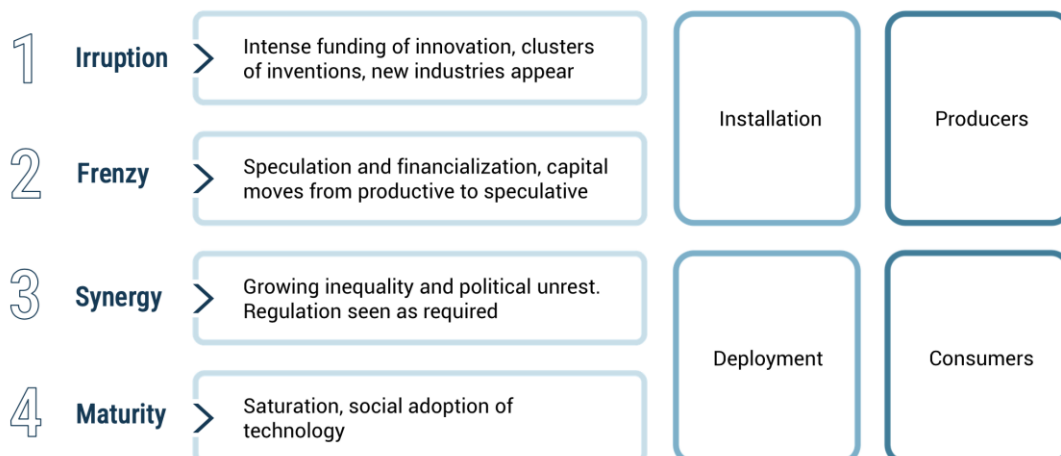
Exhibit 3: IPO Boom during the Tech Bubble



Source: Jay Ritter

However, as the technology matures the producers lose their ground, (sometimes aided by the imposition of regulation as noted above) and instead the surplus is captured by the consumers. Society is the ultimate winner in technological revolutions.

CHARACTERISTICS OF TECHNOLOGICAL REVOLUTIONS



Source: Perez (2002)

Perez argues that we have witnessed 5 great waves of technological innovations over time. Starting, most obviously, with the industrial revolution in the late 1700s. This gave way to the age of steam and railways in the early 1800s. By the late 1800s we had transitioned into the age of electricity and heavy engineering. In the early 1900s, we started the age of oil, automobiles and mass production. In the late 1900s through to today we have been in the age of information and telecommunications. Each of these waves has contained multiple bubble episodes.

THE FIVE TECHNOLOGY WAVES

Technological Revolution	New Technologies and Industries	New Infrastructures	Country and Year of Onset
1 The industrial revolution	Mechanized cotton industry, wrought iron, machinery	Canals and waterways, water power, turnpike roads	Britain, 1771
2 Age of steam and railways	Steam engines and machinery, iron and coal mining, rolling stock production	Railways, ports, postal service, city gas	Britain 1829, spreading to Continent and USA
3 Age of steel, electricity and heavy engineering	Cheap steel, full development of steam engine, heavy chemistry, civil engineering, electrical equipment industry, canned and bottled food, paper and packaging	Worldwide shipping, transcontinental railways, worldwide telegraph, telephone, electrical networks	USA and Germany, 1875
4 Age of oil, automobiles, and mass production	Mass-produced automobiles, cheap oil and fuels, petrochemicals, internal combustion engine for automobiles, tractors, aeroplanes, war tanks, and electricity production, home electrical appliances, refrigerated and frozen foods	Worldwide analogue telecommunications	USA, spreading to Europe, 1908
5 Age of information and telecommunications	The information revolution, cheap microelectronics, computers, software, telecommunications, control instruments, computer-aided biotechnology, new materials	Worldwide digital telecommunications, the Internet, electronic mail and other e-services, multiple source electricity networks, high-speed multi-modal physical transport links by land, air and water	USA, spreading to Europe and Asia, 1971

Source: Perez (2002)

A blast from the past – 8 lessons from Technology Bubbles of yesteryear

Given this plethora of historical bubbles around technology, let's see what general lessons we can extract. I am incredibly grateful to my friend Sandy Nairn for writing his magnificent magnum opus, *Engines that Move Markets*. Sandy originally published this book in 2002, having been produced whilst Sandy was Head of Global Research at Templeton during the Dot Com era. If you don't own a copy of this wonderful guide to past tech manias, you should! Go and treat yourself immediately. I would also note that Sandy is currently writing a book on AI (and having had the privilege of reading a draft I can safely say it is excellent and highly recommended).

Much of what follows below is informed by Sandy's awesome work, although I should stress that these are my lessons and not necessarily shared by Sandy (although I suspect he would be sympathetic to most, but it isn't my place to put words in his mouth).

Lesson 1: Skeptics are often wrong

Given my skepticism over AI expressed at the previous paper in this series, it behoves me to pay heed to the fact that history is littered with the painful prognostications of technology doubters. One of my personal favourites is the utterance of Charles H Duell, Commissioner of the US Patents office, in 1889 proclaiming "Everything that can be invented has been invented". As the table below makes clear, he was far from unique in his misplaced view on technological progress. So the first lesson we can draw is that skepticism of new technologies is commonplace, and usually misplaced. So perhaps you should ignore all of my curmudgeonly thoughts contained in last missive.

Technology	Prognostication	
Railroads	What could be more palpably absurd than the prospect of locomotives travelling twice as fast as stagecoaches?	The Quarterly Review, March 1825
The Telephone	Well informed people know it is impossible to transmit the voice over wires and were that it were possible to do so, the thing would be of no practical value	Boston Post 1865
The Automobile	The ordinary 'horseless carriage' is at present a luxury for the wealthy; although its price will probably fall in the future, it will never, of course, come into as common use as the bicycle	Literary Digest October 1899
Television	For God's sake go down to reception and get rid of a lunatic who's down there. He says he got a machine for seeing by wireless! Watch him - he may have a razor with him	Editor of the Daily Express in response to a visit from John Logie Baird
Computers	I think there is a market for about five computers	Thomas Watson, Chair IBM 1943
PCs	There is no reason for the individual to have a computer in their home	Ken Olsen, President, DEC 1977
PCs	640k [of computer memory] ought to be enough for anybody	Bill Gates, 1981
The Internet	By 2005 or so, it will become clear that the internet's impact on the economy has been no greater than the fax machine's	Paul Krugman

Source: Nairn (2002)

Lesson 2: Tech revolutions and bubbles go hand in hand

As the frameworks set out by Perez and Kindleberger/Minsky presented earlier outline, tech revolutions seem to spur the imagination of the investing public like almost nothing else. New technologies with the promise of new profits, and the allure of growth entice speculation on a truly impressive scale and have done so since the industrial revolution onwards.

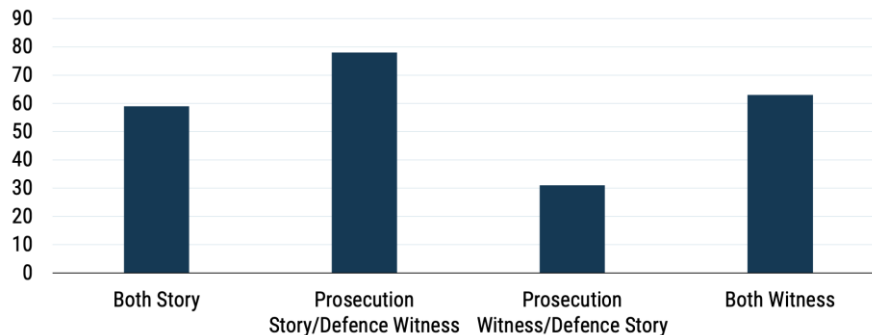
I suspect that this is largely due to the overwhelming power of the growth narrative that they inspire. Stories are incredibly powerful motivators of our behaviour, with the ability to bypass our logical minds and appeal directly to the emotional pathways for decision making. Stories are like Siren's songs to the mind, we are drawn to them, little realising that they may end up with us shipwrecked on rocks.

In the rational view of the world, we gather evidence, we weigh and evaluate this evidence and then after deliberation we reach a decision. When stories are involved, we tend to gather evidence (usually in a highly biased fashion, looking only for the information that suits our case), we then explain this evidence with a story, and then match the decision we make to the story we like.

To illustrate the framing power of stories, consider the following example of a mock trial conducted in Hastie and Pennington (1998). The crime under consideration is murder, so no mere trivial case. In the experiment, Hastie and Pennington followed one of four possible combinations of information disclosure. When both the defence and the prosecution were allowed to present the evidence using a story, the conviction rate was around 60%. When the prosecution were allowed to use a story, and the defence could only use witnesses who effectively randomly revealed information, the conviction rate soared to 80%. When the roles were reversed so the prosecution could only use witnesses, but the defence could tell a story,

the conviction rate collapsed to 30%. Finally, when both prosecution and defence were constrained to use witnesses, the conviction rate was back to around 60%.

% of Jurors returning a guilty verdict



Source: Hastie and Pennington (1998)

Bear in mind that in all cases, exactly the same information was revealed. It is simply the way in which the information was presented that was altered. As can be so easily observed, stories had a massive impact! So, we are often motivated by the presence of a story.

When this vulnerability to stories is coupled with that most human of traits – hope or allure of growth (more properly overoptimism) the stage is set for the birth of a tech bubble.

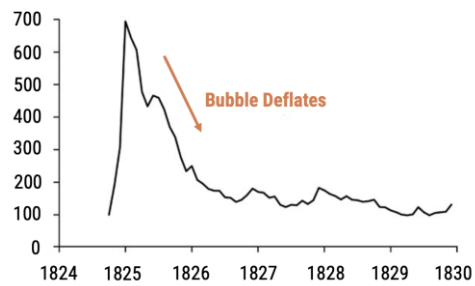
Cornell and Damodaran (2020) talk about the Big Market Delusion. They say, “It applies to many companies, particularly in the technology space, that enter what are seen as “big markets.” The peril of a big market, though, especially in its early stages, is that the entrepreneurs it attracts and the investors who provide funding are often so enthused about their prospects for dramatic growth, that they become overconfident, leading to the businesses that will serve the new market being overpriced, at least collectively. The divergence between price and value, reflecting a more realistic assessment of the earnings that the big market can deliver, eventually leads to a correction.”

Quite correctly, they highlight overconfidence as being a key driver in this delusion, “The more uncertainty there is about business models and the ability to convert them into revenues, the more overconfidence will skew the numbers, leading to greater overpricing in the market. For example, there should be more overpricing in artificial intelligence, a big market where there is greater uncertainty about not only what technologies will end up as winners, but also in the uses to which that technology can be put, than in online food delivery, a more established market with fewer technological twists. It also follows that overpricing should be greater, earlier in a market’s evolution, and should decrease over time, as evidence accumulates as to actual market size and business successes and failures.”

Over-optimism and over-confidence are a potent combination leading unwary investors to simultaneously over-estimate the returns and under-estimate the risks involved, a perfect recipe for a bubble to form. The historical record bears this out. Every major technological innovation since the Industrial Revolution seems to have resulted in a bubble.

Mining & Rails

UK MINING STOCKS



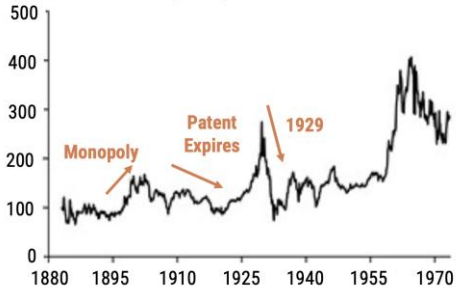
UK RAIL ROADS



Source: Naim (2002)

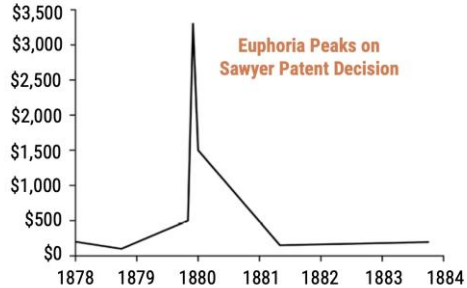
Telephones and Electric Light

AMERICAN BELL (AT&T)



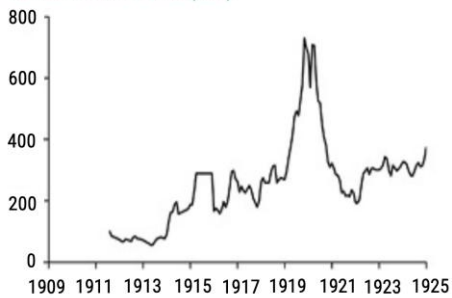
Source: Naim (2002)

EDISON ELECTRIC



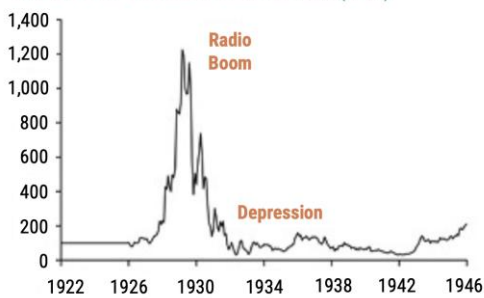
Autos and Radio

GENERAL MOTORS (GM)



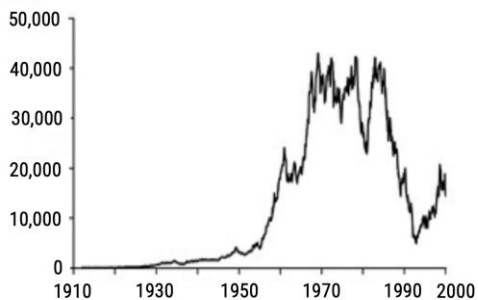
Source: Naim (2002)

RADIO CORPORATION OF AMERICA (RCA)



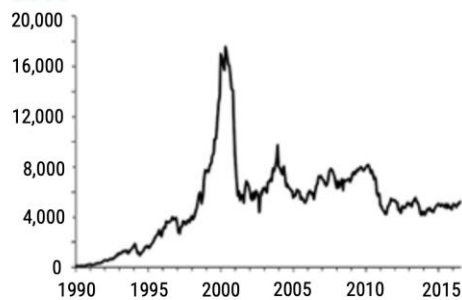
Big Computing and the Internet

IBM



Source: Naim (2002)

CISCO



There can be little doubt that AI has a powerful story behind it...indeed perhaps the most powerful story ever told. We are told that AI is going to:

- **Transform the Workforce:** AI is poised to automate "thinking" jobs, including writing, design, research, and coding. By 2030, while it may displace 92 million jobs, it is expected to create 170 million new roles, requiring a significant shift toward "human-plus" capabilities, such as AI ethics officers and human-AI collaboration designers.
- **Accelerate Scientific Discovery:** AI is becoming the operational backbone of research, with autonomous systems shortening R&D cycles, such as reducing prototype development for EV batteries by nearly 46%. It could speed up biological research tenfold, compressing 50-100 years of innovation into 5-10 years.
- **Reshape Daily Life and Industries:** Beyond chatbots, AI is integrating into manufacturing (robotic arms), healthcare (faster diagnostics), finance (fraud detection), and education (personalized learning).

At least that is what AI said AI is going to do!

The growth story can also be encapsulated as follows:

For nearly four decades, Moore's Law has been the governing dynamic of the computer industry, which in turn has impacted every industry. The exponential performance increase at constant cost and power has slowed. Yet, computing advance has gone to light speed. The warp drive engine is accelerated computing and the energy source is AI.

-Jensen Huang, CEO Nvidia (2023)

Now to be clear, I don't have the foggiest idea what any of the above means. It sounds like something out of Star Trek to me (I can almost hear Scotty screaming in the face of a bewildered Kirk). However, it does sound exciting.

Or perhaps you would prefer Satya Nadella of Microsoft's suggestion that the success of AI should be measured not against gameable benchmarks but rather "The real benchmark is the world growing at 10%". Or Demis Hassabis of DeepMind claiming AI "Is going to be 10 times bigger than the Industrial Revolution".

Regardless of which messianic prophet you choose to listen to, the proclamations of the importance and impact of AI are ringing out like the sweetest of the Siren's songs.

Lesson 3: Clusters of innovation: tech begets tech

Once again, as Perez observed, technological revolutions usually involve clusters of innovation. These may be synergistic or antagonistic. That is to say, sometimes some members of the cluster are prerequisites for other members (think the telecommunication companies who built the infrastructure for the internet). Similarly, mining led to the development of the canal system (for transportation purposes). Steam power gave rise to the railroads. Digital networks gave rise to software, to robots, to AI. These technological advances are anything but independent of each other.

Other times, competing technologies occur, and duke it out for dominance. Although history teaches us that the 'best' technology doesn't always win! For instance the automobile market of

1900 was composed of three broad competing technologies - gasoline (22% of the market), electric (38% of the market) and steam (40% of the market). Even within the gasoline market there were several different engine designs some of which were considerably more efficient than the eventual winner, the internal combustion engine!

This, of course, makes it exceptionally hard to pick the winners in any technology cycle, which leads onto:

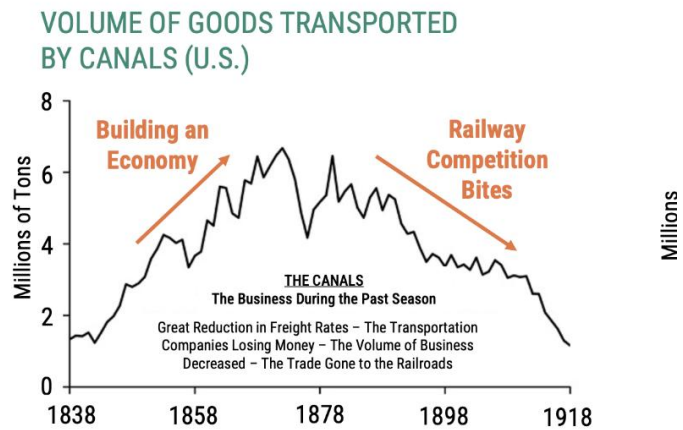
Lesson 4: Disrupters can be disrupted: Nothing lasts forever

Clusters of innovation often end up disrupting each other. For instance, the railroads originated as a means of moving ores from the mines to the canals. However, then someone raised the very inconvenient question (from the perspective of the canals) "Why don't we just use the railroads?"

The replacement of the telegram by the telephone is another cautionary tale of sequential disruption. In the US, Western Union (the leading telegraph company) even signed a deal stating that they would keep out of the telephone business (after turning down the right to buy Bell's telephone company).

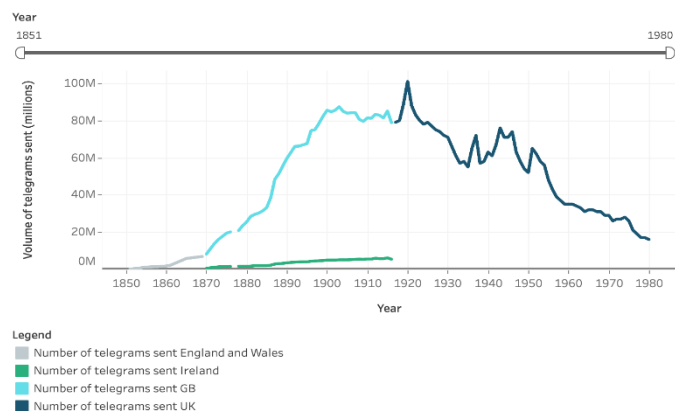
The exhibit shows the situation in the UK, where there was a Telegraphy monopoly until around 1900. But once the telephone arrived on the scene, telegrams went into terminal decline. This is a vital lesson for anyone investing in tech. Given the importance of growth to the very high valuations associated with many tech stocks, it is important to remember that the historical evidence isn't kind to the assumption of long lasting (let alone eternal) growth.

More recent evidence of this transient dominance can be found in the browser wars. For those with near pachydermia memory capacity, the originally dominant browser was Netscape, this was then almost entirely displaced by Microsoft's Explorer (largely due to its bundled nature). However, this was replaced with Google's Chrome and Apple's Safari. So once again, we see the one constant is change.



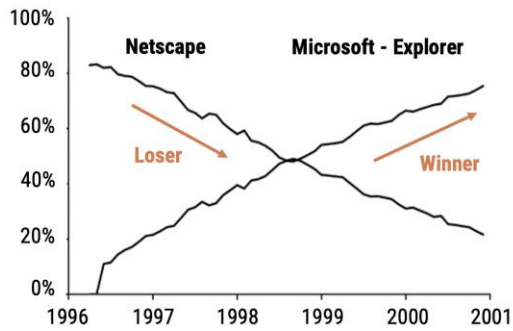
Source: Nairn (2002)

Telegram volumes



Source: Stata

Market Share (%)



Source: Naim (2002), Statcounter

STATCOUNTER GLOBAL STATS

Browser Market Share, United States of America from Jan 2009 – Sept 2023

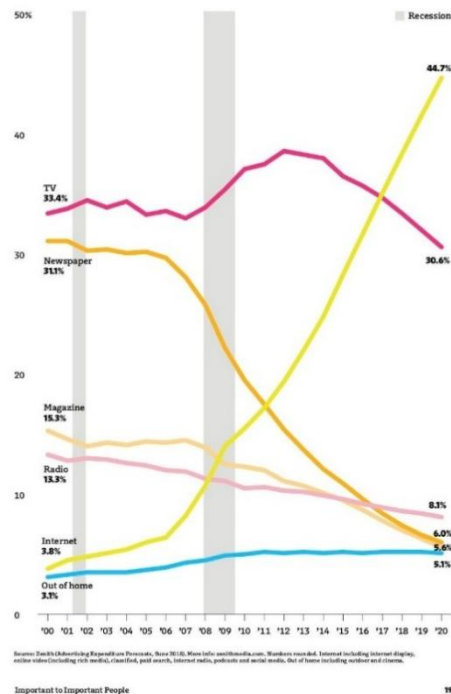


Similarly, principally a duopoly of Google (Alphabet) and Meta has succeeded in capturing a massive amount of ad spending at the expense of old media like print and even TV. Will they be able to hang onto this in the face of AI? Will AI providers seek to go down the 'advertising as payment' route? One of the potentially likely paths to profitability for providers of LLMs is to try and capture ad spending, something that Google will not take lying down for sure.

Even within the world of AI currently, we see shifting sands. According to Ramp, Anthropic has been gaining ground against Open AI in the last year in terms of usage. Who will win is anybody's guess....and that certainly is not a strategy when it comes to investing!

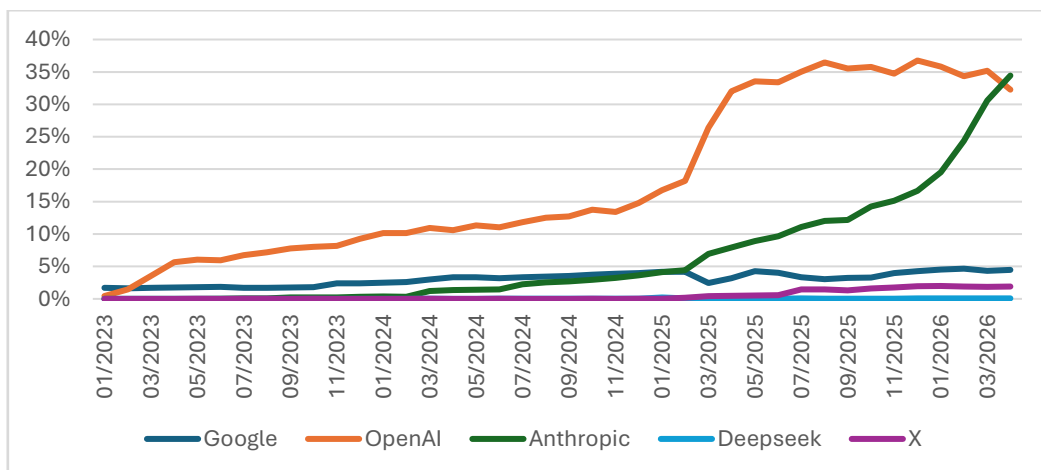
Share of U.S. ad spending by medium, 2000-2020

From Zenith. The media agency says the internet in 2017 passed TV to become the biggest U.S. ad medium.



Important to Important People

19

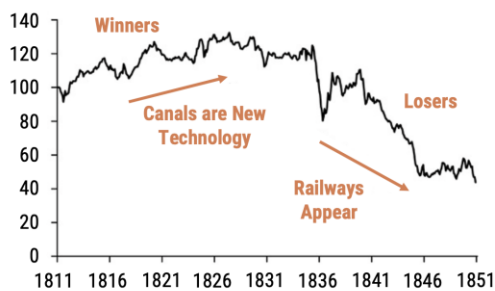


Source: Ramp

Lesson 5: It is near impossible to pick winners

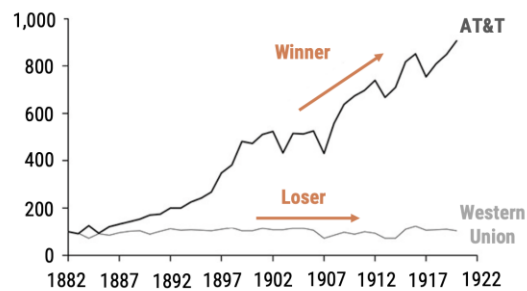
Once again following on from the previous two lessons, we can suggest that the winners are remarkably difficult to identify. However, if there is a lesson to be learnt beyond that; it is that the disrupted or incumbent technology or business rarely seems to respond well to the arrival of the new technological upstart. Thus whilst it may not be easy to divine the eventual winner for any new technology (see lessons 3 and 4 above), it is a pretty sure bet that the existing technology isn't going to fare well.

CANALS LOSE OUT TO RAILS IN THE UK



Source: Naim (2002)

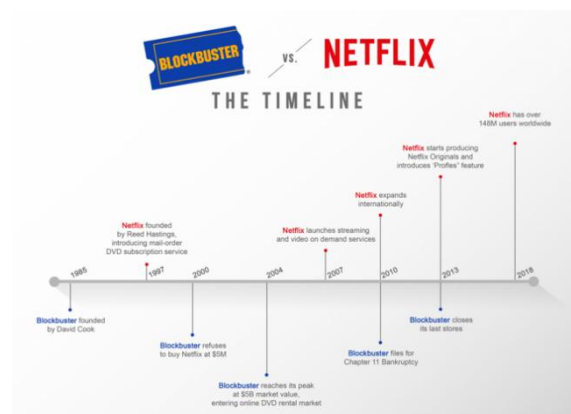
TELEGRAM LOSES OUT TO THE TELEPHONE



If you are of a certain vintage, you may recall the idea of video rental back in the mid-1980s, and the company Blockbuster that was synonymous with the concept. Ultimately it was disrupted by a company that is as much a household name as Blockbuster was in the 1980s, Netflix.

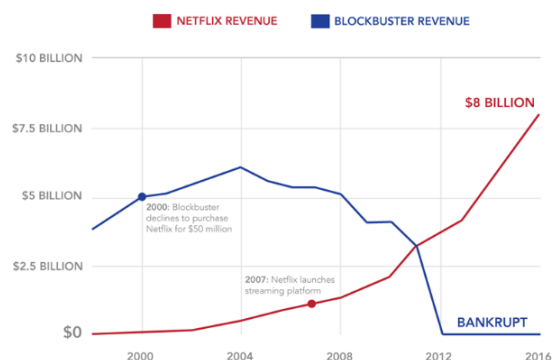
Originally Netflix started out as a mail order DVD subscription service, aimed at competing with Blockbuster by cutting out the need for in-store visits and without the late return fees. However, the sea change really occurred in 2007 when Netflix launched its streaming platform – no need to wait for the post, let alone visit a store, now videos were available from your home in a touch of a button. This was then followed in 2013 with a move into in-house production of content, the same year as Blockbuster closed its last store!

Of course, all of this is perfectly obviously with the benefit of 20/20 hindsight. However, at the time it was much harder to predict. As a further reminder of the difficulty of picking winners, and foreseeing the future, just remember:



Source: The Strategy Journey

NETFLIX VS. BLOCKBUSTER (1998 - 2016)



Source: Disrupted or Disrupter: Which One Will You Be? (Cloud Technology Partners, 2017)

To invest in the telephone, one had to presume greater foresight than Western Union, the leading communications experts at the time.

To invest in electric lights, one had to not invest in arc lighting (widely seen as the winner), and instead go with incandescent lighting, but wait until the various light companies had been rationalised.

To invest in autos, one had to find Henry Ford but wait for him to be bankrupt twice before investing in the Ford Motor Company, plus one would have needed to know that steam and electricity, not to mention the more efficient rotary engine would all fail.

To invest in computers, one would need to wait for Apple to appear, and exit before Microsoft attacked, own IBM until the arrival of Dell, and of course, remember to buy Apple again before the rise of the iPhone etc.

These are extremely absurd compound probabilities. You would need a truly amazing crystal ball to be able to forecast these particular paths and outcomes. Yet despite this, many will tell you they know exactly which technology and which firms will win out!

Lesson 6: Technology doesn't create mass unemployment

One of the perennial concerns shared by a lot of the technology waves seems to be that the adoption of the new technology will create mass unemployment. For instance, in 1921, the New York Times ran an article with the headline, Man Devoured by His Machines¹. In 1928, a piece appeared with "Unemployment is blamed on New machines" as the headline – reporting a speech by Senator Smoot, or the headline 'March of the Machine Makes Idle Hands'. Even great minds such as Einstein and Keynes concerned themselves over the prospect. The former opined "Great distress of current times as the result of man-made machines" and the latter noted "We are being afflicted with a new disease, technological unemployment". The New York Times printed "Does Machine Displace Men In The Long Run?" covering a debate between President Roosevelt and Karl Compton (the president of MIT) – more on his view in just a little bit. In the 1950s, the International Labor Organisation published a study on the "Promise and Peril Of Automation." One of my personal favourites (from the 1970s) is a headline "Copy Machines Poison to Writers" argues that the widespread use of photocopiers (which obviously don't pay royalties to authors) would result in the end of books being written! The economist Wassily Leontief argued in the 1980s that there was a limit to full employment because of growing technologies, and the New York Times published a headline "A Robot is After Your Job".

The aforementioned Karl Compton wrote a very insightful article in 1938, entitled "New Demands on Technology" published in The Technology Review. In this article Compton essentially distinguished between what I would call the micro and macro reality of technological unemployment. As he explains:

In recent years much discussion has centred around technological unemployment – the loss of work due to obsolescence of an industry or use of machine to replace

¹ A book review of Freeman's Social Decay and Regeneration

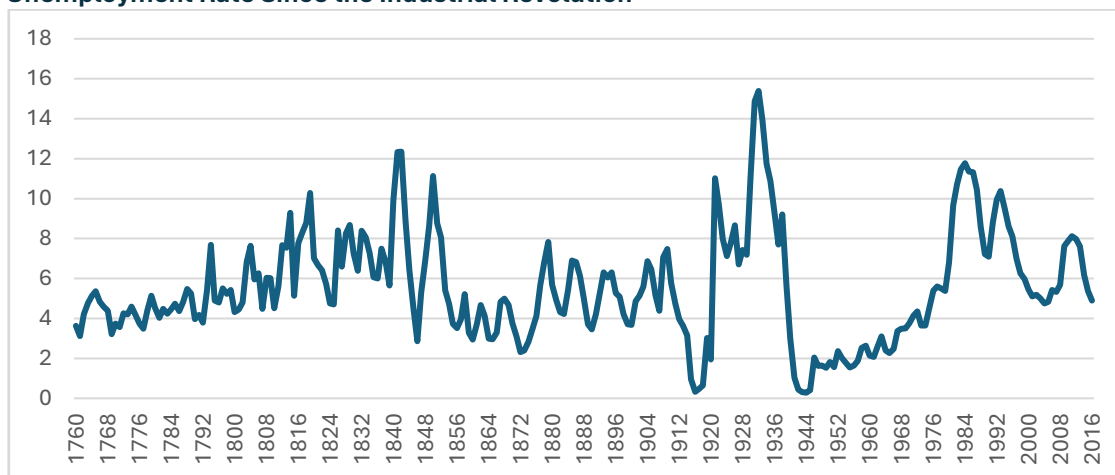
workmen or increase their per capita production. Are machines the genii which spring from Aladdin's Lamp of Science to supply every need and desire of man, or are they Frankenstein monsters which will destroy man who created them? Startling examples of both viewpoints can be given. I shall only try to summarize the situation as I see it.

If we look at industry as a whole, without inquiring into particular cases, we would conclude that technological unemployment is a myth, because statistics show no decrease in the fraction of our population gainfully employed during the last few generations in which machine production has become important. This is because technology has created so many new industries and has so greatly increased the market for many commodities by lowering the cost of production to make a price within reach of large masses of purchasers.

In individual instances, however, technological unemployment may be a very serious social problem, as in a town whose mill has had to shut down, or in a craft which has been superseded by a new art. For example, the photoflash lamp has been a very useful development in the art of taking flashlight pictures and has largely increased activity and employment in this art, but it did suddenly take away the job of those who made the old-fashioned magnesium flashlight powder. Here the fact that technological unemployment does not exist as measured by over-all statistics is of small comfort to the families whose wage earners have lost their job.

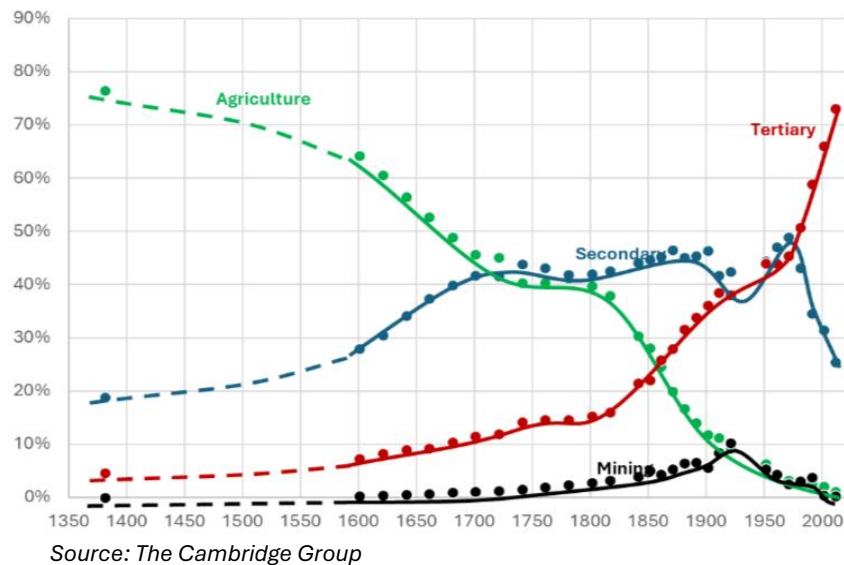
The distinction between micro and macro consequences of technological unemployment are clearly visible in the data. On the macro front, for instance, if we examine the long run unemployment for the UK going back to Industrial Revolution, we can see no discernible trend despite the many waves of technological innovation.

UK Unemployment Rate Since the Industrial Revolution



Source: The Bank of England

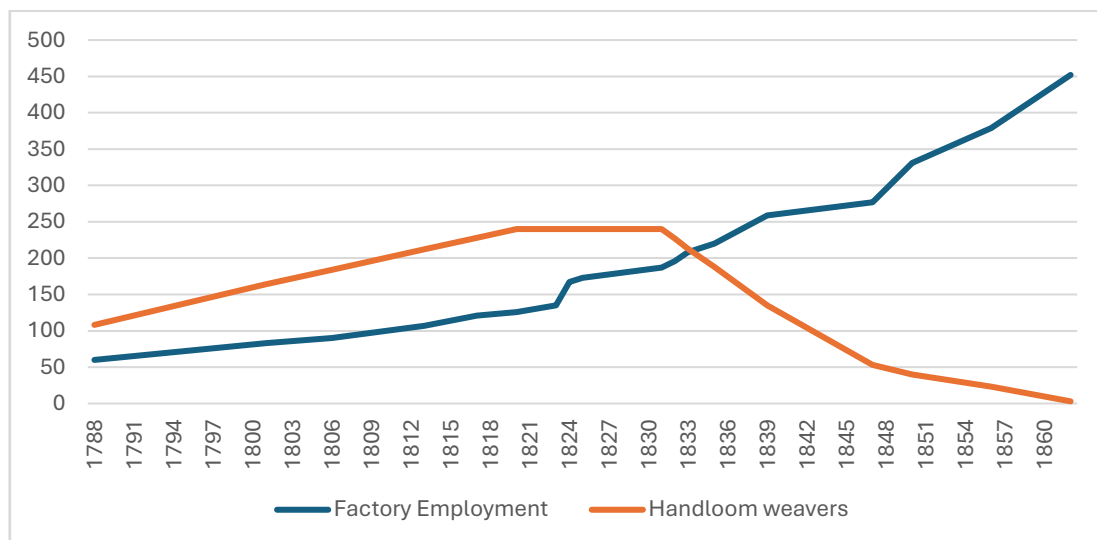
Similarly, we can examine the long run employment shares for the UK, and see that shifts across broadly defined sectors (agriculture, manufacturing (secondary) and services (tertiary)) have occurred over time, yet unemployment rates remain stable in aggregate, despite a growing workforce.



However, scratch beneath the surface, and the micro story of technological unemployment becomes very real.

For instance, we can explore the employment of handloom weavers and their factory based counterparts during the Industrial Revolution in the UK. The impact of the rise of the power loom is clear for all to see. It spelt the death knell for the Handloom weavers – despite the best efforts of the Luddite movement².

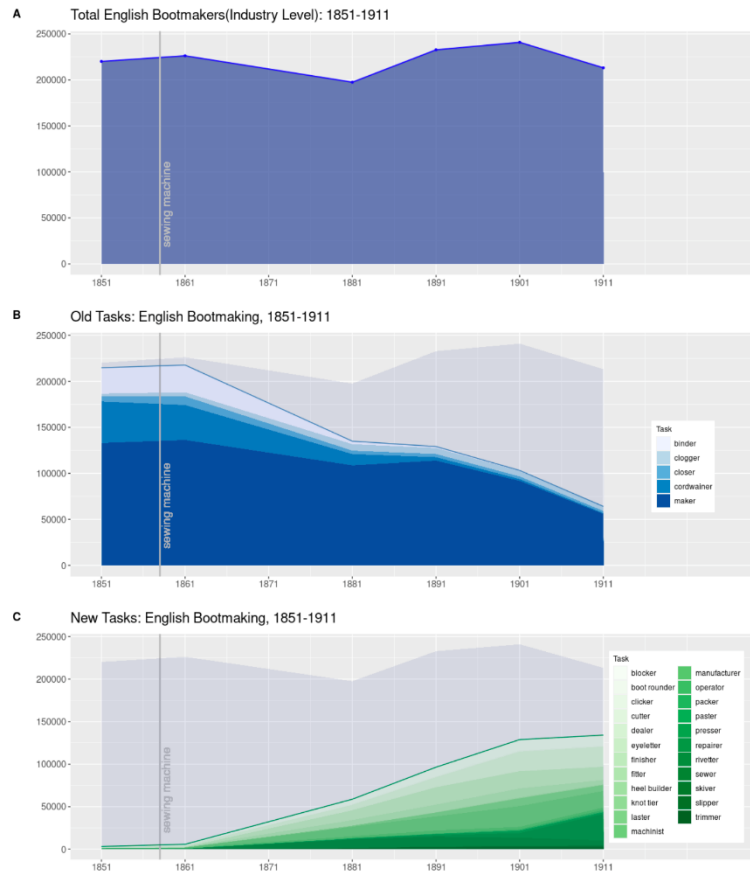
Employment of Weavers and Spinners – UK, Thousands



Source: G.H. Wood

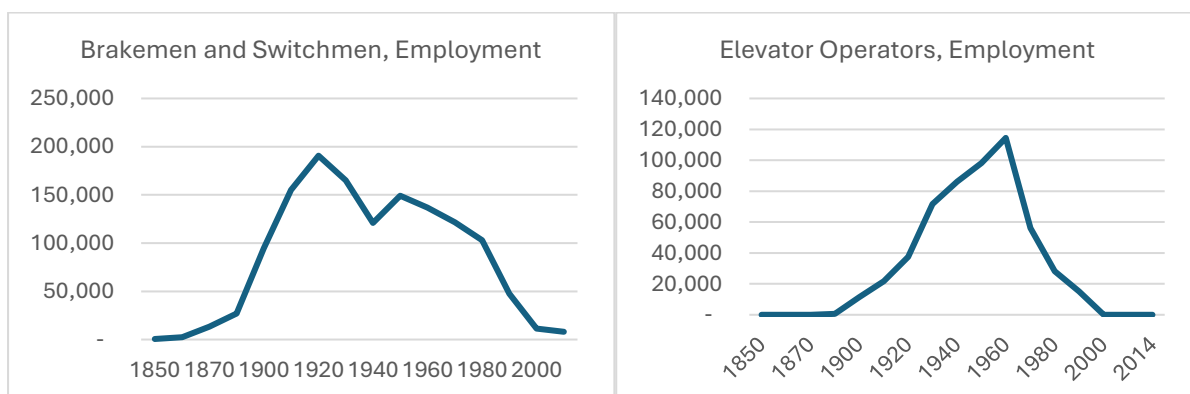
² For a wonderful read on the Luddite Movement not as an anti- technology movement but rather an attempt to defend labour in the face of capitalistic pressure see Brian Merchants Blood in the Machine (2023)

Similarly, Vipond (2024)³ explores the fate of Bootmakers in Victorian Britain. In keeping with the “myth of macro level technological unemployment” the labour displacement is “almost entirely masked at the industry level” (see panel A). However, as the industry mechanized, “the number of people employed in “old” boot making tasks declined by about 152,000, while 144,000 new jobs were generated in emerging work.” In the census data prior to the adoption of new machines “97% of bootmakers were employed as “Shoemakers”, “Cordwainers”, “Cloggers”, “Binders” and Closers”. After mechanization, swing machinists, riveters, operators and foremen became the source of employment. This isn’t just a change of nomenclature, but a fundamental shift in the nature of the work (and its location).



Source: Vipond (2024)

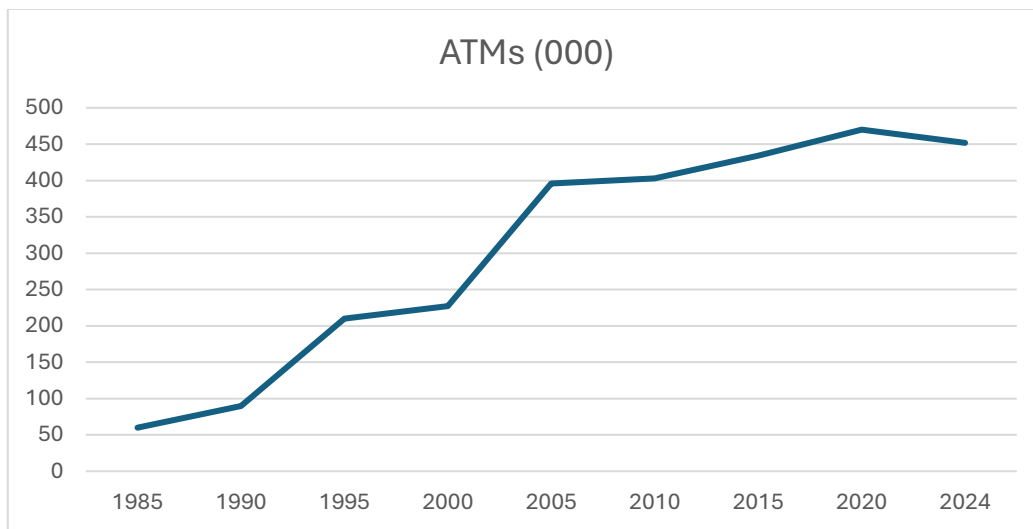
Obviously if a technology becomes completely outdated then we may observe the death of an occupation. For instance, railroad brakemen and switchmen or elevator operators illustrate the ways in which technological advances can undermine a specific job. Although, it should be noted that the diffusion of technology takes time (as the Perez framework suggest and we will return to in lesson 9), the self-service elevator was introduced in the 1920s, but the peak in elevator operators wasn’t seen until the 1950s!



Source: IPUMA

³ Vipond (2024) Technological Unemployment in Victorian Britain: A Tasks Based Approach, PhD Thesis, LSE

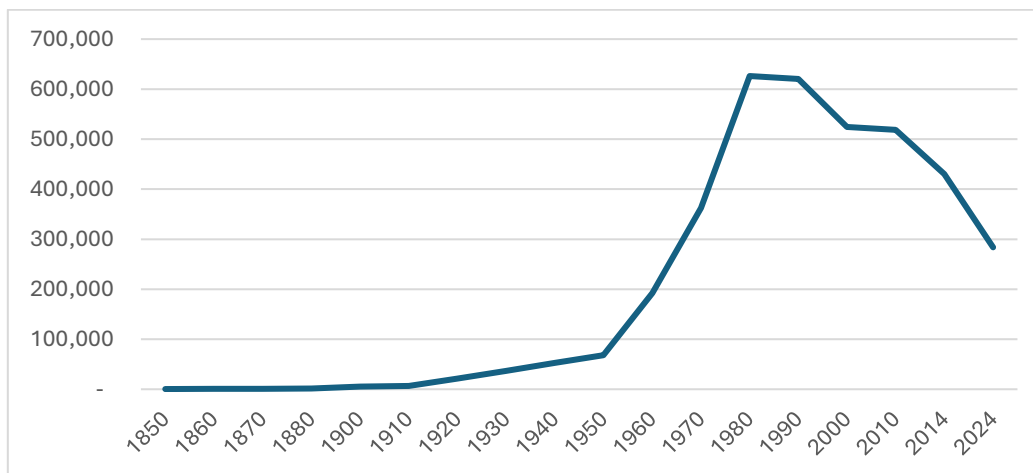
To provide a more modern example we can explore the fate of bank tellers. The Automatic Teller Machine was first installed in the US in 1979 and witnessed rapid growth between 1985 and the early 2000s.



Source: Various Industry Publications

Perfectly reasonably you might have assumed that this would herald the demise of the bank teller – after all, the ATM literally has their job replacement in its name. However, the number of bank tellers held up remarkably well in most of the deployment phase of the ATMs. This was largely due to banks expanding their physical presence (as the number of tellers per branch was actually declining).

Bank tellers, Employment



Source: IPUMA

However, the number of bank branches peaked in 2009 according to FDIC data and has been falling steadily ever since. The sharp decline in the number of bank tellers employed since 2010 reflects this closure trend. The reason for this closure trend is not the rise of the ATM, but rather the rise of another technology – mobile banking (all hail the iPhone).

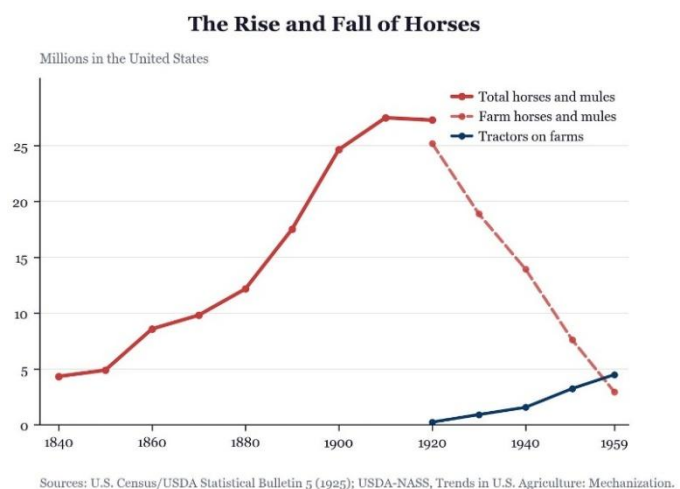
Fast forward to the current situation, the godfather of AI, Geoffrey Hinton (co-winner of the Nobel Prize in Physics in 2024) opined in 2016, “People should stop training radiologists now”, saying it

was “completely obvious” that within five years (or ten at the most) AI would do a better job. He continued, “you work as a radiologist, you’re like the coyote that’s already over the edge of the cliff but hasn’t looked down yet”.

Yet the number of radiologists has actually risen since 2016. Perhaps most concerning of all is a recent paper by Asadi et al ⁴ which showed that frontier models “readily generate detailed image descriptions and elaborate reasoning traces, including pathology-biased clinical findings, for images never provided”. That is to say without ever seeing any X-ray input these models didn’t hesitate to describe non-existent images and even offer up clinical diagnosis based on thin air!

But Hinton looks like a master of the understatement compared to other AI luminaries. The job apocalypse is constantly prophesied by AI leaders. Dario Amodei of Anthropic has talked of a white-collar bloodbath with AI eliminating 50% of entry-level white collar jobs within the next five years, and potentially pushing the unemployment rate to 10-20%. He has described AI as “A general labour substitute for humans”.

Not to be outdone, Mustafa Suleyman, head of AI for Microsoft has said that AI could replace most white-collar work in the next 12-18 months! (This is the same person who claimed that LLM hallucinations would be largely eradicated by 2025....so make of his predictions what you will!). Effectively these guys see human employment and labour as suffering the same fate as horses did when the electric motor was introduced!



In contrast, Amodei’s own sister, the co-founder of Anthropic, has a very different view. She has stated “The number of jobs that AI could do without help from people is vanishingly small”.

If the high prophets of employment doom are correct, then it will create what Karl Marx called a realization problem. Who will be buying all the things that this incredible AI is going to produce? It certainly won’t be the 20% of the population that is unemployed.

The bottom line is that we have never yet seen a macro level technological unemployment, but we have seen plenty of examples of micro technological unemployment – Compton was right way back in 1938! Of course, this time could be different but...

⁴ Asadi et al (2026) Mirage: The Illusion of Visual Understanding available at <https://arxiv.org/abs/2603.21687>

Lesson 7: Beware the capital cycle

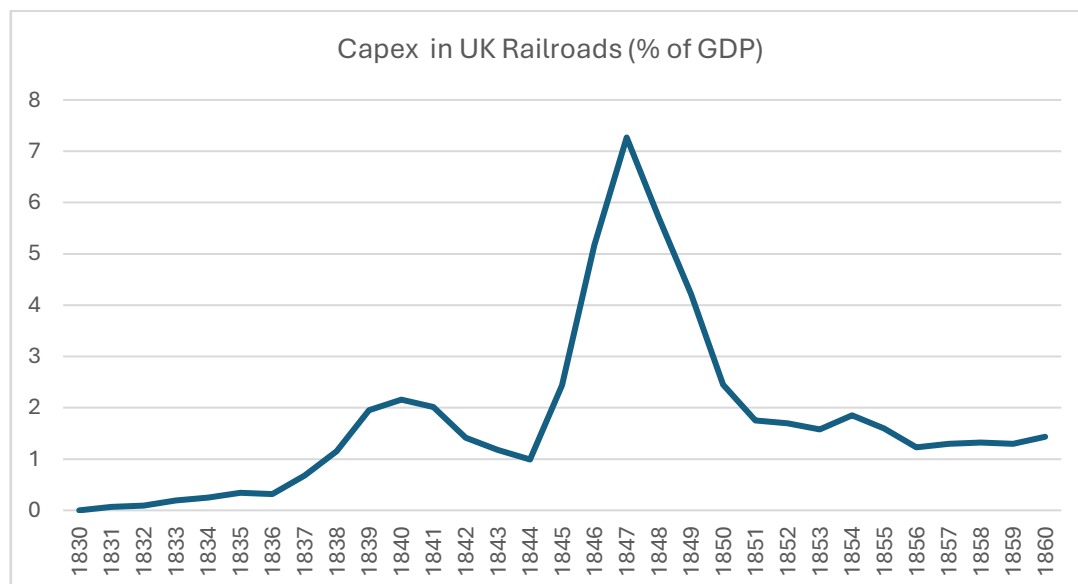
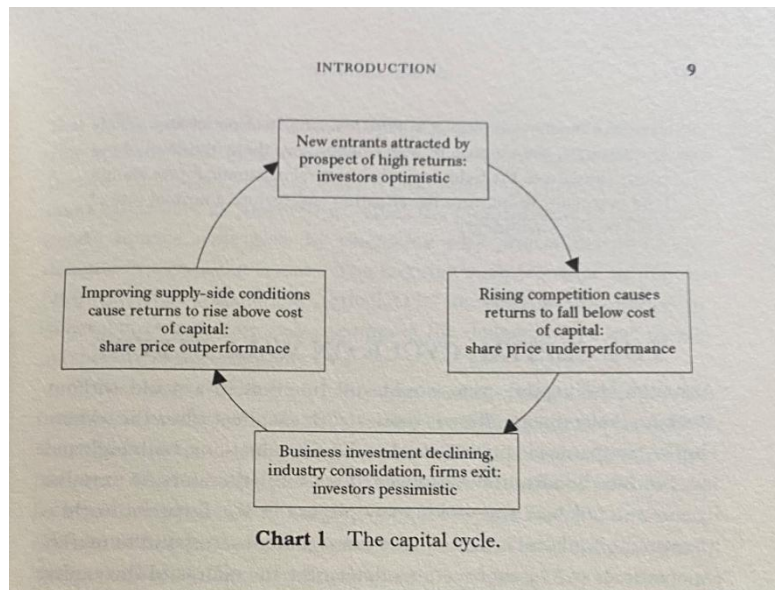
My friend and erstwhile colleague, Edward Chancellor, is the acknowledged expert on the role of the capital cycle. His stylised capital cycle is shown to the right. Again, we can see links with the Technology wars framework of Perez and the Kindleberger/Minsky model of bubbles outlined earlier.

When it comes to technology waves, it pays to be mindful of the capital cycle and its stages. The capital cycle can be seen as part of the engine of mean reversion (not the only source to be sure, but a component at least).

Firms get attracted to high (potential) rates of return and invest, leading to a capital deluge, that carries the seeds of its own destruction, helping to ensure lower rates of return.

Classic examples of the capital cycle can be found in tech waves such as the railroads in the UK in the mid 1840s⁵. The next four charts tell the story of the UK Railroad mania. The first shows the scale of the capex boom engendered by the enthusiasm for the growth story

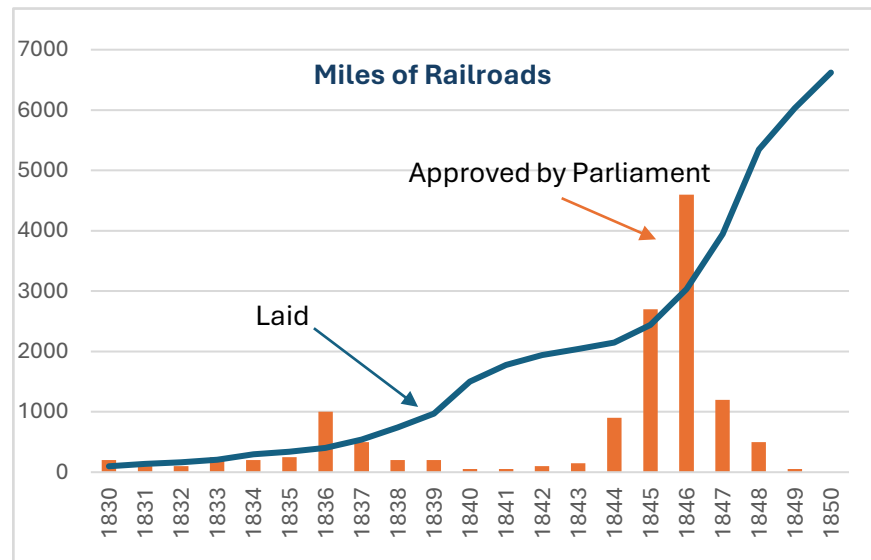
At the height of the mania, £4.4 million of private investor capital was being poured into the railroads, equivalent to around 7% of GDP! The sheer scale of this investment is just breathtaking.



Source: Based on Odlyzko (2010)

⁵ For those who are interested in this particular episode of insanity I refer you to the amazing work of Andrew Odlyzko (2010) *Collective Hallucinations and Inefficient markets: The British Railway Mania of the 1840s* available from <https://www-users.cse.umn.edu/~odlyzko/doc/hallucinations.pdf>

The next chart shows the extent of the rail network in the UK, and the amount of increase that was approved by parliament each year. Between 1843-1846, approval was granted for an incredible 9400 extra miles of railroad, this compared with the 3000 existing miles of railroad. The classic growth story writ large, a more than 3x increase. By 1850, of the 8200 miles approved only 3600 miles had been laid.

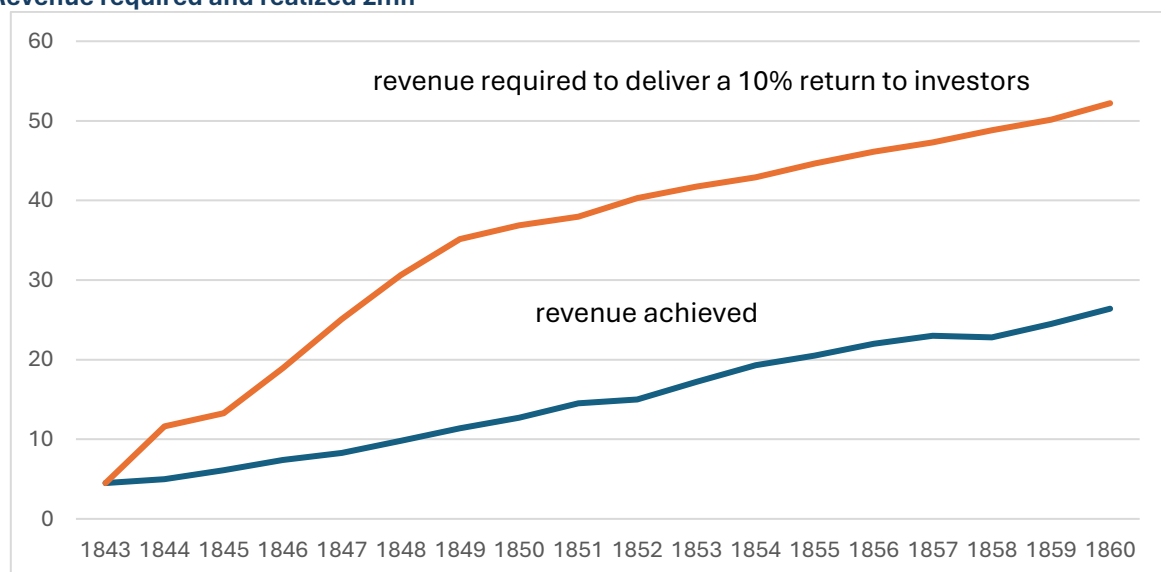


Source: Based on Odlyzko (2010)

Of course, what really matters is what return investors were expecting, and what did they actually witness? In 1844 the UK railroads produced revenue of around £5mn. Contemporary estimates suggest that expenses were around 40 per cent of revenues. But let's be generous and say they were only 30 per cent of revenues. So, in 1845, the railroads were probably earning around £3.5mn. The capital invested up to 1845 stood at just over £126mn, so a return on capital of around 4%.

Investors poured in some £163mn between 1844-1850. To receive a 10% return on the increased capital base of £289mn, the railroads would need to see profits of approximately £29mn, equivalent to a revenue of around £43mn – a nearly 9x expansion from the levels in 1844. In fact, in 1850 the UK railroads produced revenue of just £13mn! A truly massive profits disappointment that resulted in the horrific performance of railroad shares shown below.

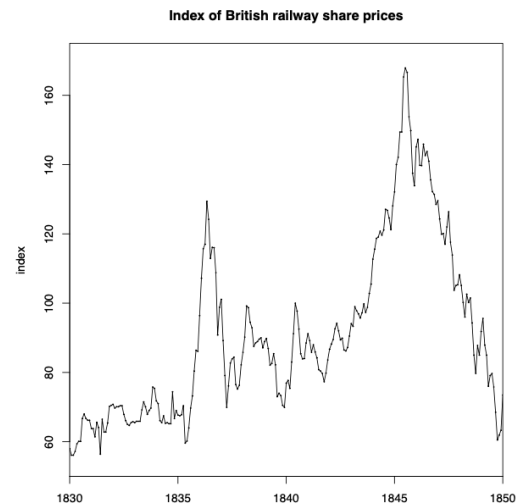
Revenue required and realized £mn



Source: Based on Odlyzko (2010)

A more modern example is provided by the Telecommunication companies who built the infrastructure for the internet in the late 1990s. Whilst much of the attention during the TMT bubble was grabbed by the dot coms (such as webvan and eToys), it was the behaviour of the Telecomms firms that was of far more interest from a capital cycle perspective.

During the mania it was common to hear one particular “factoid” repeated almost ad nauseum – “Internet traffic is doubling every 90 days” or occasionally every 100 days. No less than the US Department of Commerce cited that “fact” in their 1998 publication, *The Merging Digital Economy*. James Crowe, the head of Level 3 Communications, cited the “doubling of internet traffic every three or four months” as proof that the supply of fiber in the US couldn’t possibly meet demand in the next few years.

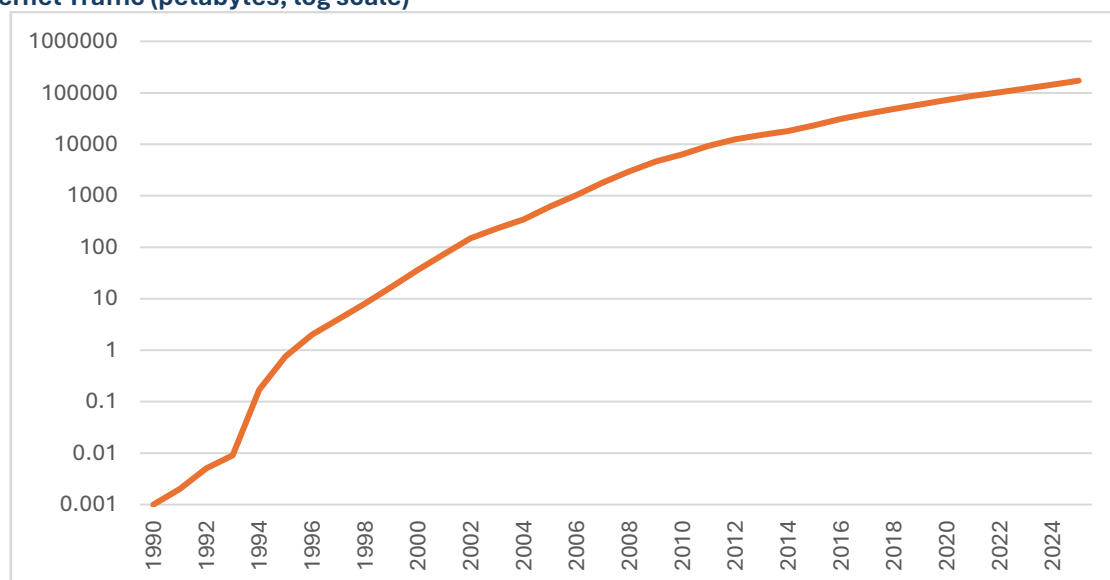


Source: Odlyzko (2010)

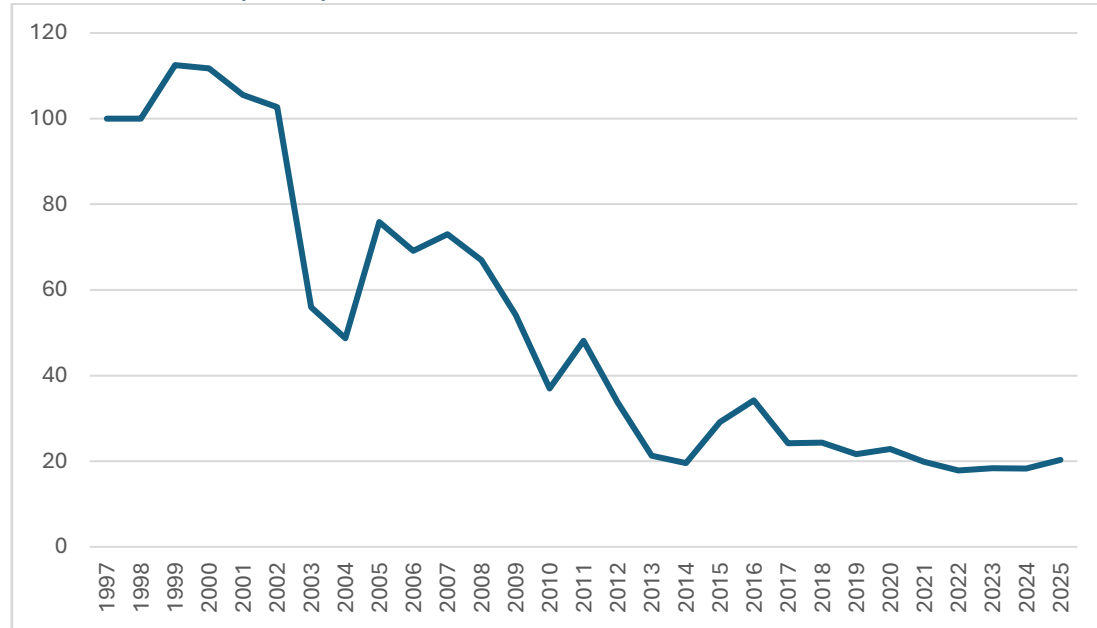
The origins of this particular myth seem to have been the UUNet division of WorldCom! John Sidgmore (head of UUNet) and Michael O’Dell (Chief Scientist) often referred to growth rates of over 1000% per year. Even at the very height of the bubble in March 2000, the chief NASDAQ trader at Lehman Brothers was quoted in the New York Times as saying “I’m a believer in the new paradigm. Traffic on the Internet is doubling every 100 days; If you think about that, you begin to understand the magnitude of this technology revolution”.

In fact, Odlyzko (yes, the very same expert on the 1840s railroads) was working at AT&T Labs during this time period, and wrote on the impossibility of such staggeringly high growth rates. It transpires that such incredible growth rates were actually seen in 1994/1995, but by 1997 internet traffic was growing at 100% every year! Still breathtaking, but an order of magnitude less than the commonly cited statistic. Odlyzko was pointing this out in real time, but, as is usual during the madness of crowds, no one was willing to listen.

Internet Traffic (petabytes, log scale)

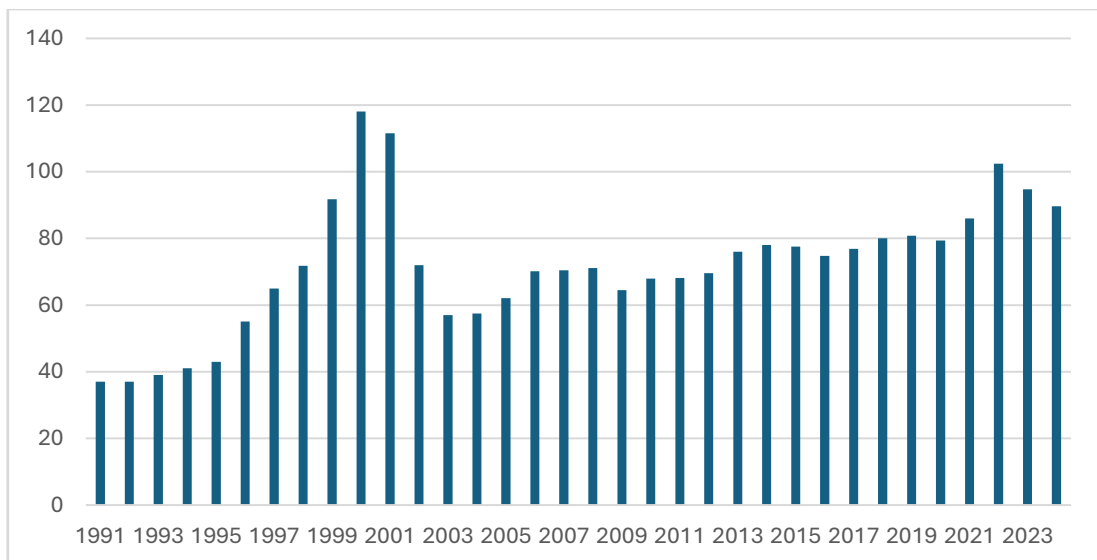


Source: Cisco

Internet Traffic Growth (YoY %)

Source: Cisco

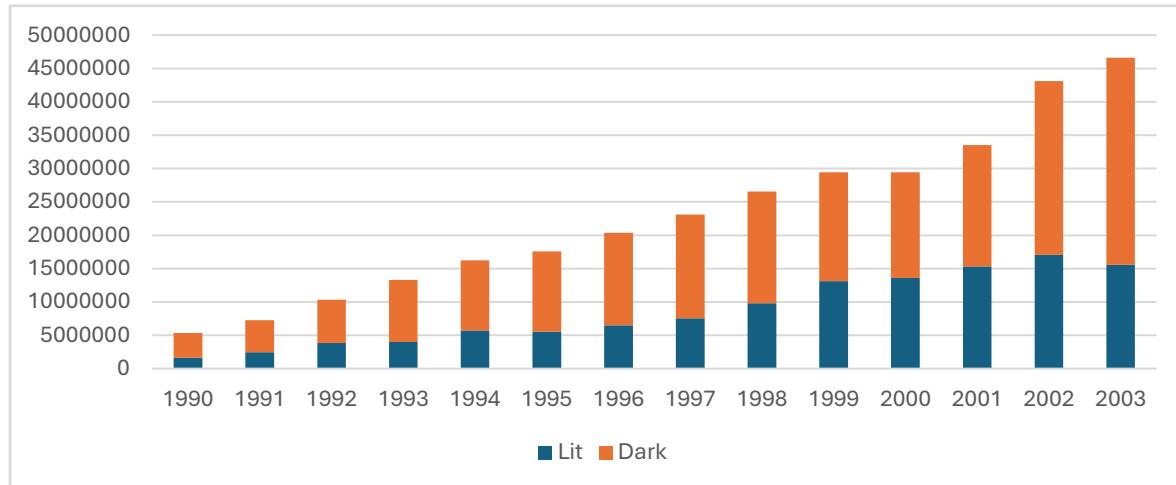
Never ones to let the facts stand in the way of good story, the Telecom companies used this statistically fiction to justify an enormous surge of capex. At its peak in 2000, this represented just over 1% of GDP!

US Telecom Capex (\$bn)

Source: USTelecom

This capex built on the belief that demand was outpacing supply of transport capacity, creating virtually bottomless ways to make profits. It transpired that this capex explosion resulted in massive amounts of fiber being laid, but only a small fraction of it was actually used (lit). By 2003, some 46.6 million kilometers of fibre laid in the US, but 66% of it remained dark (unused)!

KMs of Fiber Laid in the US

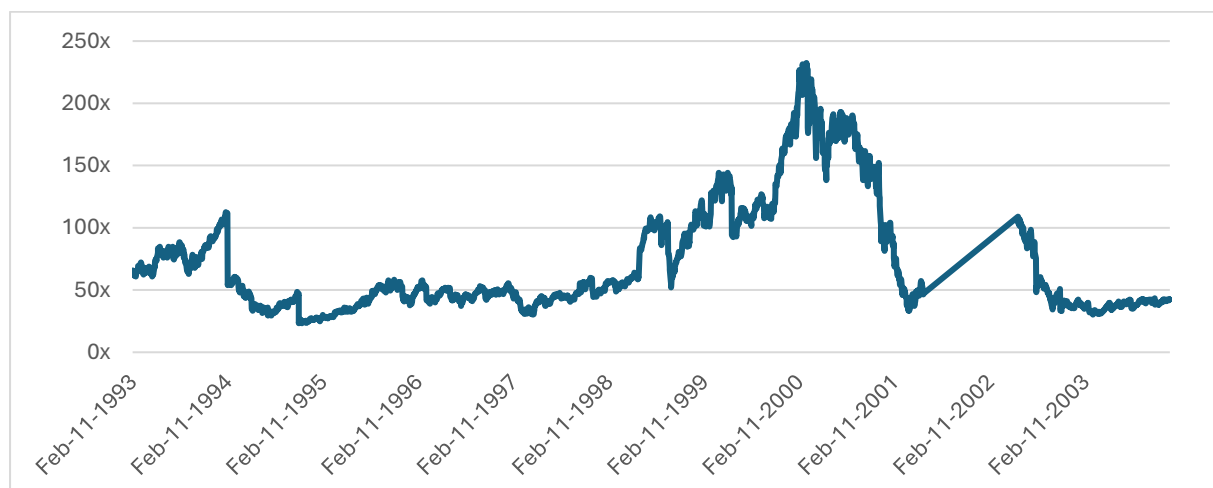


Source: FCC

Just as with the Railroad mania, you didn't need complex and in-depth models to spot the insanity. Cliff Asness published a real time analysis of Cisco Systems in his Bubble Logic piece⁶. He showed that at 140x trailing earnings (as of June 2000, already down from a peak valuation of 221x), even with accepting a 30% five year growth rate that analysts were forecasting with a further five years of above market growth, the likely return was 7.5%! That 30% growth was above what CISCO had actually managed to generate in recent years, so already represented a very optimistic outlook.

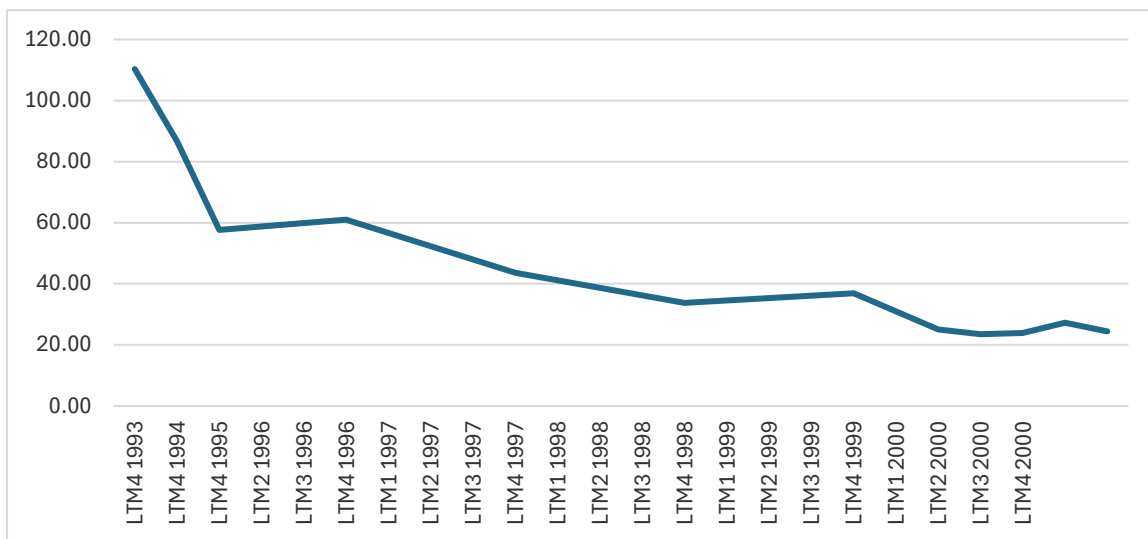
To get to 10% return you had to make some truly heroic assumptions such as five year growth of 54% and then a five year adjustment period to normal market levels of growth. As Asness notes "Many Cisco investors would laugh at you if you told them they were only to make 10% a year going forward". In the event, by 2005, net income had grown by just 9% p.a.

Cisco PE



Source: S&P CapIQ

⁶ <https://www.aqr.com/Insights/Research/Working-Paper/Bubble-Logic-Or-How-to-Learn-to-Stop-Worrying-and-Love-the-Bull>

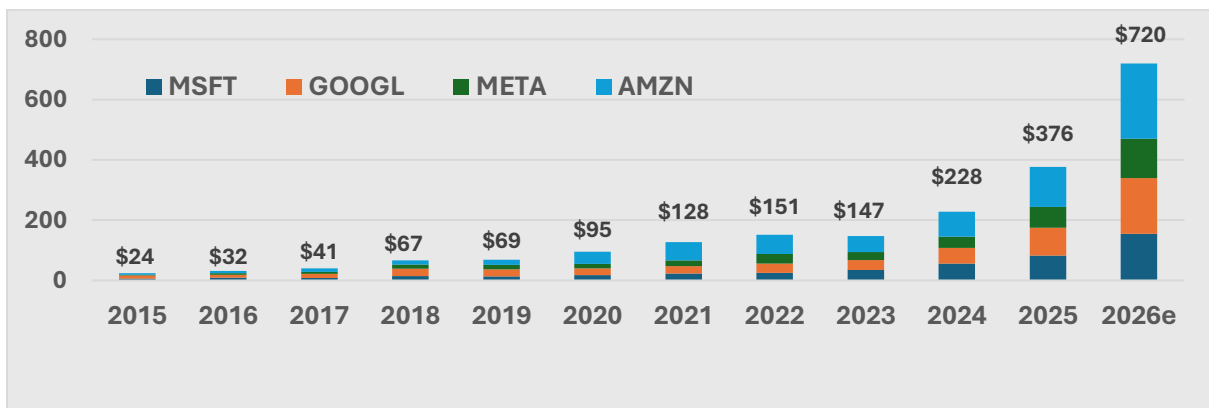
Cisco Net Income Growth (1993-2000, % pa over five years)

Source: S&P CapIQ

In both cases the promise of exceptional returns on capital tempted real investment (as opposed to financial speculation) to enter the fray, and beautifully paradoxically undermined the very essence of the returns they were trying to achieve.

It is not hard to draw parallels with the capital expenditure being carried by the hyperscalers. I will have a lot more to say about this in Part III of this series, but for now I will just note the sheer scale of the capex explosion and that the estimated 2026 investment is equivalent to over 2% of GDP.....twice the size of the Telecomm capex boom at the peak of the TMT mania.

It seems that the hyperscalers are all driven by FOMO (fear of missing out), effectively the possible road to nowhere they are all chasing down is a dangerous game of prisoner's dilemma. For instance, Mark Zuckerberg of Meta has said "We are going to spend aggressively. Even if we lose a couple of hundred billion. It would suck, but it's better than being behind the race of super intelligence", Sundar Pichai of Alphabet "The biggest risk could be missing out", or Sam Altman of OpenAI "Whether we burn 500 million a year, or 5 billion or 50 billion I don't care. I genuinely don't...we're making AGI, it's going to be expensive, it's totally worth it"!

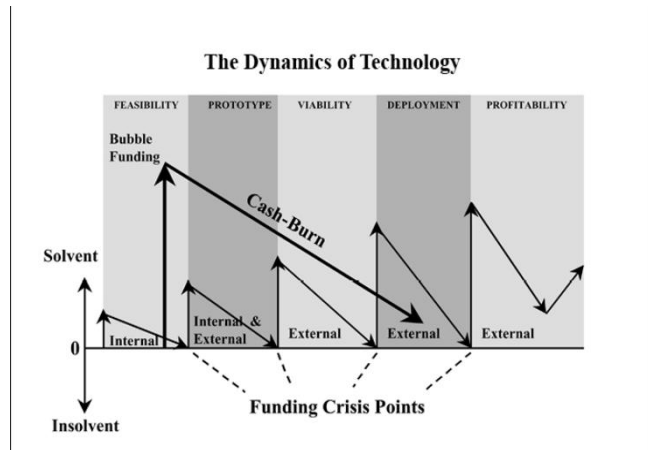
Hyperscalers Capex (US\$ bn)

Source: S&P CapIQ

This incredible surge in Capex is a true sign of the capital cycle at work...investors should ignore this at their own peril.

Lesson 8: Corporate malfeasance and Ponzi financing

Our eighth lesson is that during Technology bubbles we often see corporate malfeasance and Ponzi financing. Sandy Nairn created the model shown on the right to highlight the stages that are typical of a technology cycle. At the end of each stage, he highlights the funding crisis that occurs. Of course, in order to avoid this, occasionally firms are tempted to engage in what is sometimes euphemistically referred to as creative accounting (lying to the rest of us).



Source: *The Nairn, Engines that Move Markets*

In a related vein, in his work on the financial instability hypothesis, Minsky outlined three different sorts of financing arrangement:

Hedge financing: Borrowers can meet all debt obligations (both interest and principal) from cash flows

Speculative financing: Borrowers can meet interest payments but roll over the debt (refinance) in order to repay principal

Ponzi financing: Borrowers are unable to meet debt payments from cash flows and must borrow further or sell assets to pay interest.

The sort of financing crisis that Nairn alludes to are inherently Ponzi financing, the combination of early stage businesses and negative cash flows (often driven by high Capex see above) means that many technology innovators have no choice but to operate as Ponzi units.

We can find evidence of ethically challenged behaviour in the 1840s UK railroads case. One of the leading exponents of the Railroad boom was George “the Railway king” Hudson, a member of Parliament and business owner. At the peak of his reign, Hudson’s companies controlled a quarter of the UK’s railroads! In 1848, it was uncovered that Hudson had been paying dividends out of capital rather than out of profits, capitalizing expenses and misappropriating funds.

Thanks to my friend George Noble, I am the proud owner of a collection of Enron memorabilia ranging from a Enron baseball cap and post-it notes to a copy of the History of Arthur Andersen. These sit on my shelves as wonderful reminders of one of the greatest corporate malfeasances of all time. Revenue recognition, loans marked as sales, off-balance sheet entities (Special Purposes Vehicles) all featured in this remarkable incidence of corporate wrong doing.

Yet Enron was far from alone. Worldcom (yes the same guys from the internet is doubling every 100 days) was found to have capitalized \$10 billion in expenses as assets, and the founder had received \$400 million in the off the books loans!

Tyco's CEO and CFO secretly awarded themselves options and used their companies treasury to fund their living expenses. Famously, the CEO once spent \$6,000 on a shower curtain, and had the company split a \$2million bill for his wife's birthday party.

Adelphia Communications became the 6th largest cable system in the US. In a wonderful example of circular financing, the company guaranteed many of the loans made to the founding family, and the family guaranteed many of the companies loans!

Global Crossing, Lucent, Nortel Networks and Cisco were all engaged in other misdeeds including vendor financing. For instance Lucent provided some \$8bn to customers to allow them to purchase Lucent equipment!

Bad accounting, ponzi finance and corporate malfeasance seem to follow Keynes' Law – Demand creates its own supply! When investors want good "results", corporates will bend over backwards to deliver them.

The situation in AI today could be described as a financial equivalent of the Ouroboros, a web of intertangled threads that create the AI eco-system. Such complexity is rarely a good sign. In this setting we have one company's expenditure being another companies income (sometimes with that expenditure financed by the vendor). When that expenditure is treated as cap ex then a mismatch occurs, as the supplier (Nvidia for example) recognizes that revenue straight away, as they should since they have sold goods (GPUs). However, the purchasers will depreciate the asset (most of the hyper scalers are using 5-6 years... which is likely far too long, more on this on the Rise of the Machines Part III). Thus only twenty percent of the cost is taken in the first year. This is perfectly normal, of course, but the sheer scale of the undertaking with respect to AI makes the situation unusual. This arrangement obviously leads to profits being boosted by the mismatch.

From the perspective of the listed sector there is further profits inflation. The Hyperscalers put these GPUs to work (although data center construction is way behind the targeted level). The cloud companies (Open AI, Anthropic etc) are not listed, obviously, which means that their losses (which are very significant) are outside of the scope of the S&P500, so we only see one side of the situation in listed earnings.

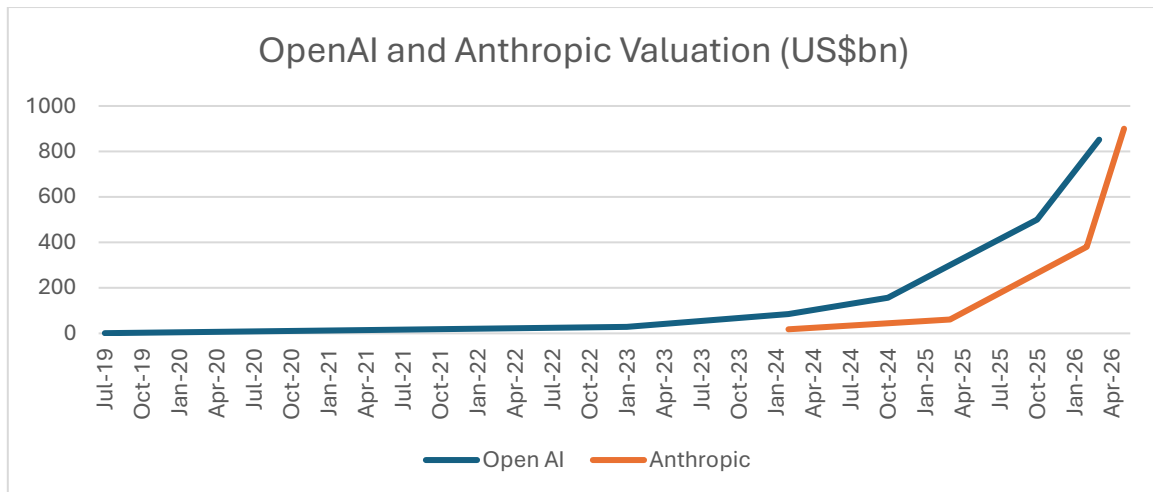
As is also evidenced by the chart below, cross share holding (a topic from days of old in Japan) and vendor financing are characteristics of the current AI landscape. Nvidia is investing in AI labs, which in turn buy Nvidia chips. The hyperscalers are also investing in the AI labs, who in turn buy cloud services. Given the boom, the shareholdings have likely increased significantly in value, leading to a recognition of unrealized gains which has boosted the earnings of the investing companies (i.e. the ones in the listed sector).

For instance, Microsoft maintains a massive equity stake in OpenAI, and has a lucrative revenue sharing agreement with OpenAI as well. However, OpenAI has simultaneously committed to purchasing \$250 billion worth of cloud computing services from Microsoft's Azure platform over

the next six years. Microsoft gives OpenAI cash, and OpenAI hands it right back to Microsoft to rent server space. Similarly, Google has been investing in Anthropic, in a very similar way.

Nvidia has been investing in just about every AI lab or Neo Cloud operator creating book gains due to appreciating assets and revenue since the AI Labs and Neo Clouds all buy guess which chips?!

It is telling that “other income” has been increasing as percentage of total income for the hyperscalers. Alphabet’s CFO explicitly stated “Other income and expenses were \$37.7bn... primarily due to unrealized gains in our nonmarketable equity securities portfolio”. Amazon noted that its \$15.6bn (net of expenses) was the result of “our investments in Anthropic”.



Source: Various Media Sources

As if this wasn't bad enough the hyperscalers also have around \$662bn in off-balance sheet liabilities representing signed contracts for data centers that are currently not yet constructed! Since they haven't commenced the liability doesn't show up on the balance sheet...but it is all too real!

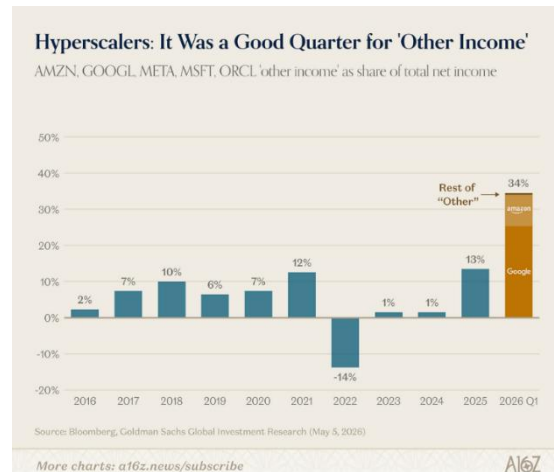
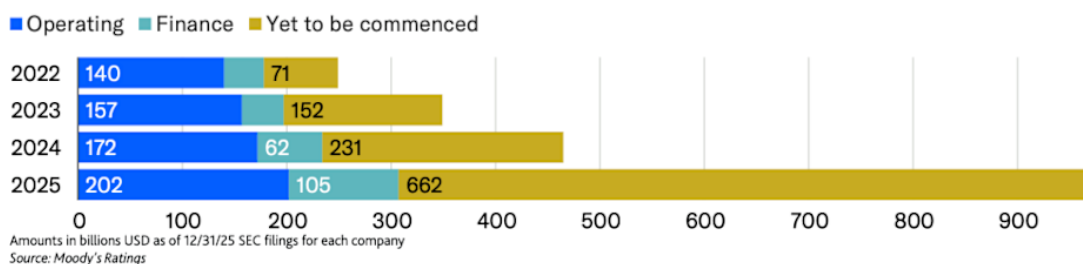
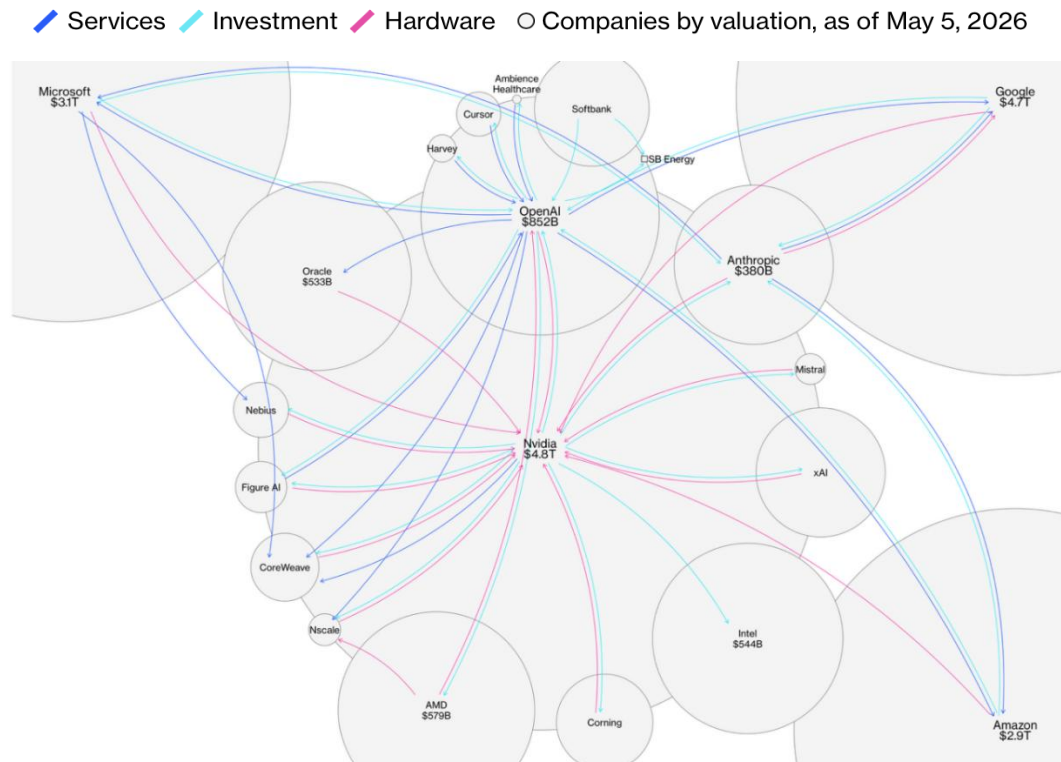


Exhibit 1
Hyperscalers' data center commitments soar, with most for leases that have yet to start
Undiscounted future lease payments



To be clear I am not suggesting that anything illegal has been going on. Rather I am just highlighting that self-reinforcing complex situations such as we see today are rarely the sign of a healthy system, and given the historical evidence, are entirely consistent with the creation of a bubble.



Source: Bloomberg Technology

Lesson 9: The long-term benefits of technology go to the consumer

The final lesson from our whistle-stop tour of 250 years of the New Economy is to return to a point I made when discussing Perez's framework presented above, and follows on from the capital cycle discussion above. At its most basic we could simply state it as "nothing lasts forever". More formally, the surplus value created by technology is captured by the consumers, not the producers, in the long run. Obviously this transfer can be postponed by patents or monopoly rights, but it has never yet been avoided.

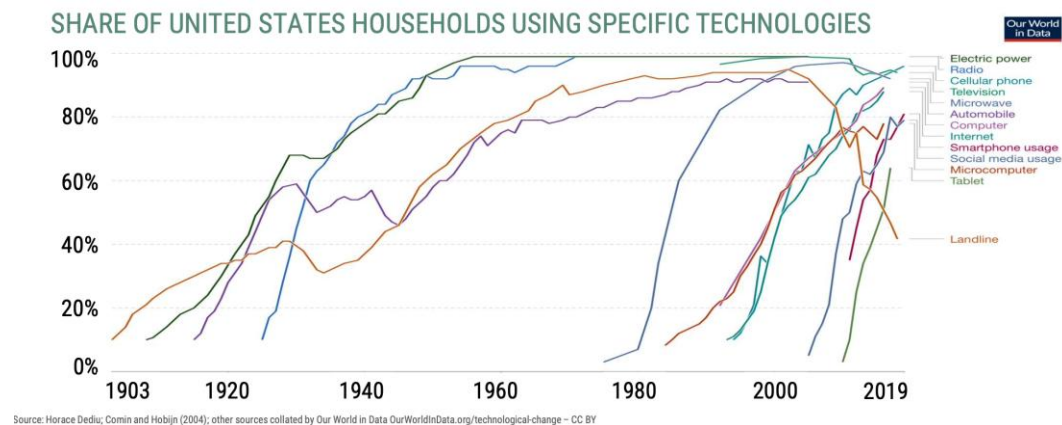
In a 2004 paper, William Nordhaus explores the importance of "Schumpeterian profits" (defined as those profits that arise when firms are able to appropriate the returns from innovative activity) for the US economy. He estimates that they account for only a surprisingly small amount of total corporate profitability (the average was just under 4% between 1948-2001)!

However, of more interest to us, is the estimate of how much of the "total present value of social returns to innovation" is captured by innovators. Nordhaus estimates this to be around 1-3%! That is to say 97% -99% of the gains of technology are captured by the consumers not the producers.

In a similar vein, Richard Hornbeck (2019)⁷ estimates the total social return on the \$8 billion capital invested in US railroads in the 1890s was 43%. Of that total social rate of return only 8% was captured by the railroads.

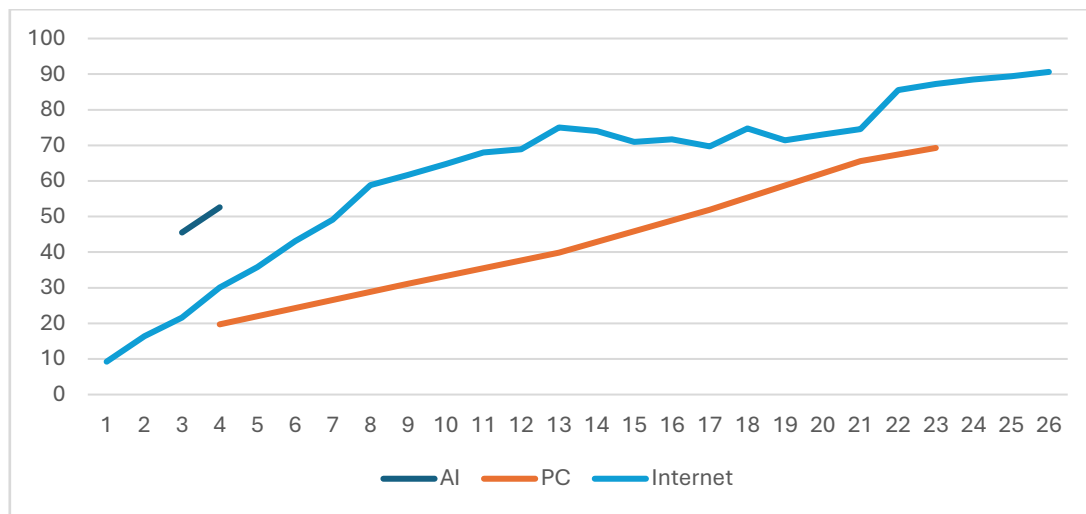
In every technology wave we have examined, the benefits always eventually seem to accrue to the consumer. This has dramatic implications for stocks where so much of the value is tied up in the terminal growth rate assumptions. Investors would be well advised to recognise that very few corporations are capable of sustaining their growth rate or indeed their profitability into the long run - even (or maybe especially) those at the cutting edge of technology.

In fact, one could argue that the adoption of technologies is speeding up. That is to say, we as a society, are faster at integrating new technologies into our existence than our predecessors were. This may suggest that the ability to sustain growth and profitability is even more limited than the historical evidence suggests. For instance, it took over almost 30 years to go from 10% of US Household using electricity to almost 70% using electricity. Fast forward to the mobile phone, it took just 14 years to reach the same level of adoption. The rise of the tablet has been even more impressive, taking just 7 years! Alongside this increase in the speed of technology adoption, we also see declines in the prices of these technologies.



⁷ Hornbeck (2019) Railroads, Reallocation and the Rise of American Manufacturing, available here <https://bfi.uchicago.edu/insight/research-summary/railroads-reallocation-and-the-rise-of-american-manufacturing/>

This appears to be true if we look at the AI vs the PC or the internet. In the exhibit below the horizontal axis represents years since the introduction of the first mass-market product for each technology. As is clear, AI is being adopted faster than either of the other two technologies.



Source: Generative AI Adoption Tracker

If the lifecycle of adoption is speeding up, it is likely (although not certain, of course) that the transfer of gains to the consumer will also be speeding up.

Final Words

This essay has attempted to provide a framework for thinking about technological waves and the role of structural change by harnessing history to provide us with a guide. It seems only fitting to leave the last words to the founder of value investing. As Ben Graham wrote, “Let me conclude with one of my favourite clichés – the French saying: ‘The more it changes the more it’s the same thing.’ I have always thought this motto applied to the stock market better than anywhere else. Now the really important part of this proverb is the phrase ‘the more it changes.’ The economic world has changed radically and it will change even more. Most people think now that the essential nature of the stock market has been undergoing a corresponding change. But if my cliché is sound – and a cliché’s only excuse, I suppose, is that it is sound – then the stock market will continue to be essentially what it always was in the past – a place where a big bull market is inevitably followed by a big bear market. In other words, a place where today’s free lunches are paid for doubly tomorrow. In the light of experience, I think the present level of the stock market is an extremely dangerous one.”

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