tullett prebon

dangerous exponentials

a radical take on the future

our core thesis

Dr Tim Morgan Global Head of Research

strategy insights | issue five

dangerous exponentials

a radical take on the future

contents

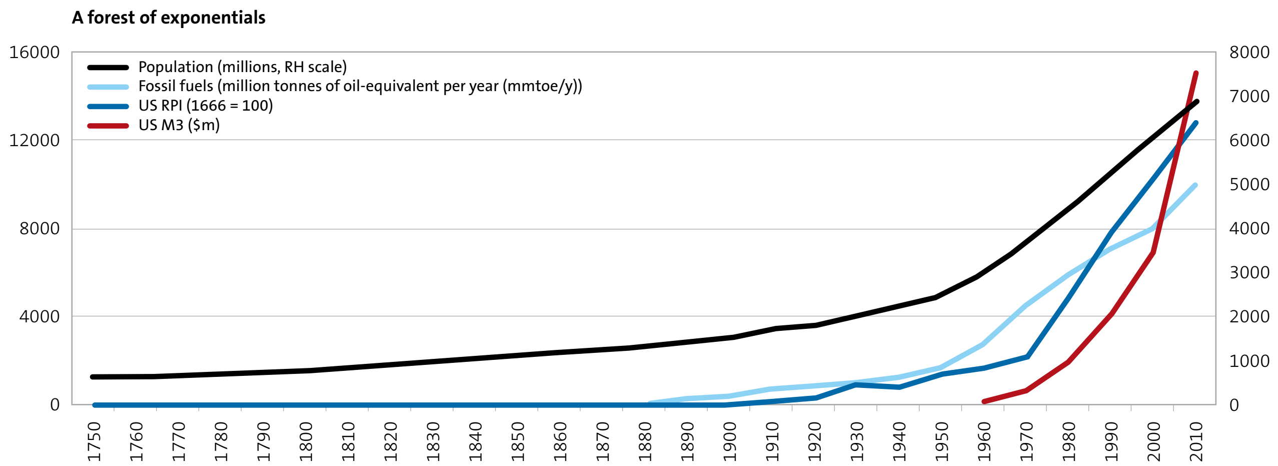
> "Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist".
>
> **Kenneth Boulding**

dangerous exponentials

a radical take on the future

- In this report, the fifth in the *Tullett Prebon Strategy Insights* series, we set out our core thesis, which is that **the global economy is in the grip of a forest of dangerous financial and non-financial exponentials**.
- As Fig. 1 illustrates, a series of key indicators – including population growth, energy consumption, cumulative inflation and the money supply – all appear to have turned into exponential 'hockey-stick' curves.
- Amongst the non-financial indicators, there are reasons to fear that exponential trends in population growth and energy consumption may not be sustainable, because both may be heading for practicality constraints. Meanwhile, the intrinsic values of the principal currencies (including the dollar, the euro and sterling) may be threatened by escalating debt, by dangerously rapid expansion in the money supply, and by continuing deteriorations in purchasing power.
- This report has been reinforced by the thinking of *Crash Course* author Chris Martenson, whose interpretation uncannily parallels our own. Amongst the many thought-provoking aspects of *Crash Course*, perhaps the most important is the identification of the parallel trajectories of the financial and resource exponentials discussed in this report.
- We conclude that **the 'forest of exponentials' is indeed highly dangerous, particularly because it is neither properly understood, effectively calibrated or coherently managed**.
- In particular, we identify an urgent need to foster an understanding of energy returns on energy invested (EROEI), and to develop a universal system of measurement and calibration.
- **Ultimately, the economy is an energy-driven construct**, yet the vital concept of energy *returns* is woefully misunderstood.

Fig. 1: Gathering exponentials?



about this report

Have you ever had the uncomfortable feeling that we are losing control of our financial system? If so, you may well be right. As the title of this report suggests, we strongly suspect that economic evolution is now in the grip of an exponentials process which can alone explain the expansion of the money supply, the deteriorating value of currencies, the recurrence of asset bubbles, and the unprecedented, seemingly out-of-control expansions in private and public debt.

Within our general remit of stimulating debate on important issues and thinking outside the box, Tullett Prebon's strategy research aims to identify and probe over-arching themes. Our *Insights* reports have already looked at the general lines of economic development which are to be anticipated over the coming decade, at the weakness of the Anglo-American economic orthodoxy, and at how to fix the potentially-lethal bubble-creating dynamic which has caused *sequential* banking, financial and economic crises over the last ten years. In future reports, we shall consider the reliability of reported data, and the likely emergence of "resource constraint" (a term which we prefer to "peak oil").

Similarly, our shorter *Notes* programme has addressed such diverse topics as "generational theft", and the possibility that western sovereign debt may now, to all intents and purposes, be out of control. We have an equally broad range of subjects lined up for future investigation.

But we believe that this report – the fifth in our *Insights* series – is **the most important research theme that Tullett Prebon has identified**. We urge everyone to read and consider it, and to discuss it with others.

Dangerous Exponentials is our core thesis about how the dynamics of society and the economy work. Clearly, if our claim about "dangerous exponentials" is a valid one – which is for the reader to judge – we need to understand it if we are to plan effectively.

We believe that an exponentials analysis can alone explain an impending collision between **an economic system which, by its nature, *must* grow, and a finite resource set which, ultimately, *cannot* grow**. When this collision eventuates, it is likely to be one of the most important changes in the lifetime of anyone reading this report.

This study is divided into three parts. In Part One, we explain the deceptively-simple exponentials process. The second section – *exponential money* – looks at disturbing trends that affect indebtedness, demographics and the value of money. In Part Three – *the governing dynamic* – we look at exponentials as they affect the interplay between money and resources.

the economy is an energy dynamic

Contained in the latter section is our explanation of the essential dynamic which drives society and the economy as we know them today. Essentially, *the economy is an energy equation*.

tullett prebon

To understand why this is so, we need to appreciate that a string of variables – food, labour, energy, money, debt, population, output – are all dimensions of the same equation. In the 'hunter-gatherer' society of ancient times, 'energy in' was in equilibrium with 'energy out', since the energy obtained from food was wholly absorbed in obtaining that food. There was no energy surplus, no specialisation, no society, and no economy.

Then came the first of the two discoveries that has transformed mankind – agriculture. The development of organised farming liberated an energy surplus, since five people could now be fed by the labour of four. Since the resulting energy surplus was modest, specialisation, society and the economy were pretty rudimentary.

The second (and vastly more important) big discovery was the heat engine, which harnessed the extraneous energy to be obtained from coal, oil and gas. This was, and remains, the basis of the complex economy that we know today. It is no coincidence at all that the rapid development of society – and the exponential increases in the global population and in the scale and complexity of the economy – have marched in step with a dramatic rise in the use of extraneous energy, the overwhelming majority of which remains of hydrocarbon origin.

Ultimately, then, **society and the economy are, essentially, energy constructs**.

A system at risk

Are these constructs now at risk? Whilst we believe that 'peak oil' theories are over-simplified, we accept the essential proposition that supplies of hydrocarbon energy are, by definition, finite. 'Resource constraint' seems, therefore, inevitable. Will the cessation of 'the energy exponential' put all of the linked societal and economic exponentials into reverse? This is both a disturbing thesis, and an all-too-plausible one.

This is an issue that surely requires intensive study. Yet the irony is that the essentially energy-based nature of our society is not effectively researched, not least because economic enquiry is almost universally calibrated in terms, not of energy (which is both real and finite), but rather of money, which is an artificial derivative of the energy-based economy, not its driving factor.

In the hope that this research project will help to promote a wider understanding of an essential dynamic which seems nowhere to be properly understood, we welcome you to our core thesis – *Dangerous Exponentials*.

Dr Tim Morgan
Global Head of Research
June 2010

"The greatest shortcoming of the human race is our inability to understand the exponential function".

Albert A. Bartlett

part one:

the logic of exponentials

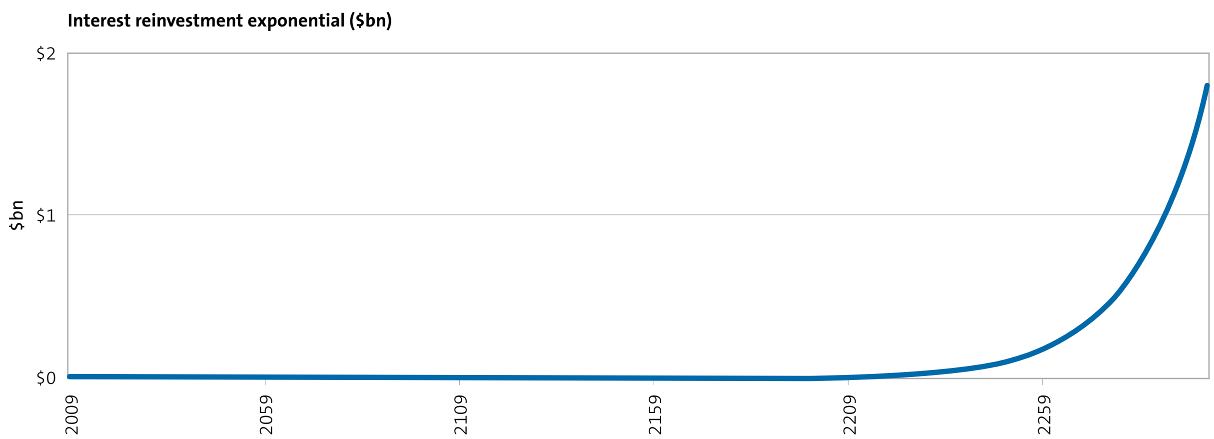
From time to time, most of us must have puzzled over a gift suitable for a friend or a relative who works in the financial markets. One obvious choice would be Niall Ferguson's magisterial history of finance[1].

But our top selection would not be a book, but, rather, a DVD produced by Chris Martenson[2]. Also available for viewing on-line – and intended for publication at a later date – *Crash Course* presents an outside-the-box take on what the future might look like. If Mr Martenson's slant on "the three Es" – the economy, energy and the environment – is on target, the world of the near future is going to bear very little resemblance to the world as we know it today. Mr Martenson's thinking is almost uncannily in line with our own core thesis, which is explained in this report as 'the theory of exponentials'.

To grasp our thesis – which is that the world is in the grip of a plethora of unsustainable exponentials – the investor needs to understand the basic logic of exponential progressions. Essentially – and this is a point which is unlikely to be a new one to anyone working in financial markets – any chart of a linear percentage progression eventually turns into an exponential, 'hockey-stick' curve.

To illustrate this point, fig. 2 shows the effect of reinvested flat compound interest on a sum of $1,000 invested today. At an interest rate of 5%, the invested sum rises to $2,000 in 2025, meaning that the second $1,000 arrives after fifteen years. The third $1,000 comes up in eight years, the fourth in six years and the fifth after just four years. And so on. But the key point is the hockey-stick shape that any exponential chart eventually adopts.

Fig. 2: Compound interest – the principle of exponentials*



*The value of $1,000, invested at a compound interest rate of 5% per annum

[1] Niall Ferguson, *The Ascent of Money*, revised edition, 2009
[2] See http://www.chrismartenson.com/crashcourse

real world exponentials

'So far, so what?', might seem an apt observation at this point. But **the principle of exponential expansion takes on a wholly new meaning when it is applied to critical, real-world parameters**.

In fig. 3, we set out the population of the earth from 2000 BC through to projected numbers for 2050. At the beginning of this period, historians estimate the world population at 170 millions, and this number increased only gradually thereafter, reaching 254 millions by 1000AD. By the time of the American Revolution (1776), the global population was approaching 700 millions, but did not reach the first billion until the 1830s[3].

Thereafter, population growth accelerated markedly. Whilst it had taken thousands of years to reach the first billion, the second billion was achieved in the 1920s – that is, adding the second billion took about ninety years. The third billion was added much more quickly – taking about thirty years – whilst the fourth was added in less than twenty years. From the mid-nineteenth century, the population growth chart turns into a characteristic exponential 'hockey-stick' shape. The current population total is about 6.7bn, and this is expected to increase to 7.6bn by 2020, and 8.8bn by 2040.

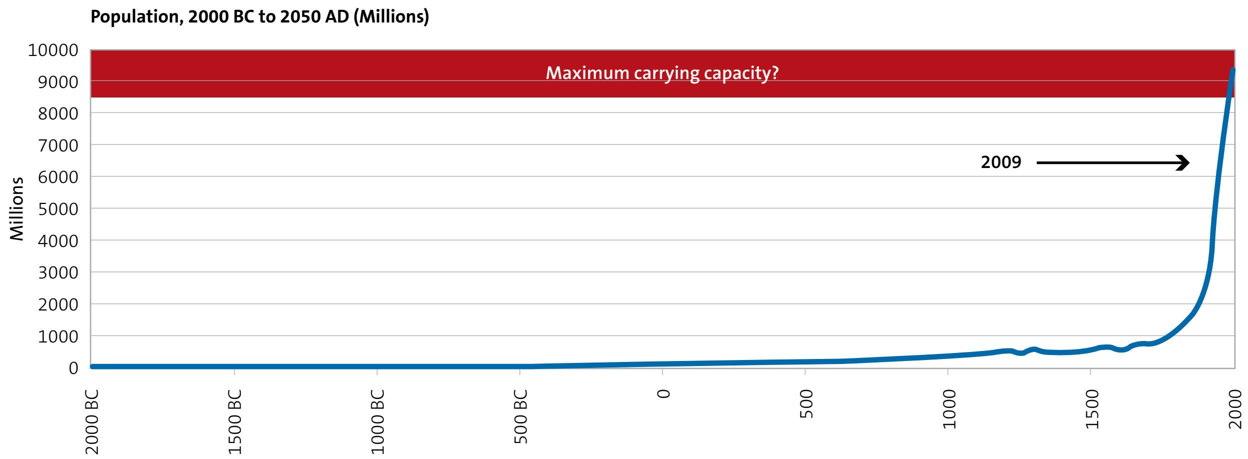
Anyone who is mathematically inclined might point out that any compound progression chart, if projected forward far enough, will take on a hockey-stick shape, and that this doesn't particularly matter unless the progression begins to hit physical parameters. Moreover, current calculations suggest that population could top out in the middle of the century at somewhere between nine and ten billions, since the global average fertility rate is declining rapidly with improvements in living conditions in the developing world.

But the earth's resources – such as land, food production capacity, energy and, perhaps most important of all, water – are **not** infinite, and some specialists believe that the earth's 'carrying capacity' may be limited, with estimates varying between perhaps 8.5bn and 11bn. This range is superimposed on the chart.

If a physical constraint is imposed in this way, the vertical axis becomes referenced, and the hockey-stick trajectory takes on far greater significance. And this observation is by no means confined to the population explosion.

[3] Source: US Census Bureau. Unit: millions

Fig. 3: An example of exponentials – world population*



*Source of population data: US Census Bureau

Fig. 4: Fossil fuel consumption

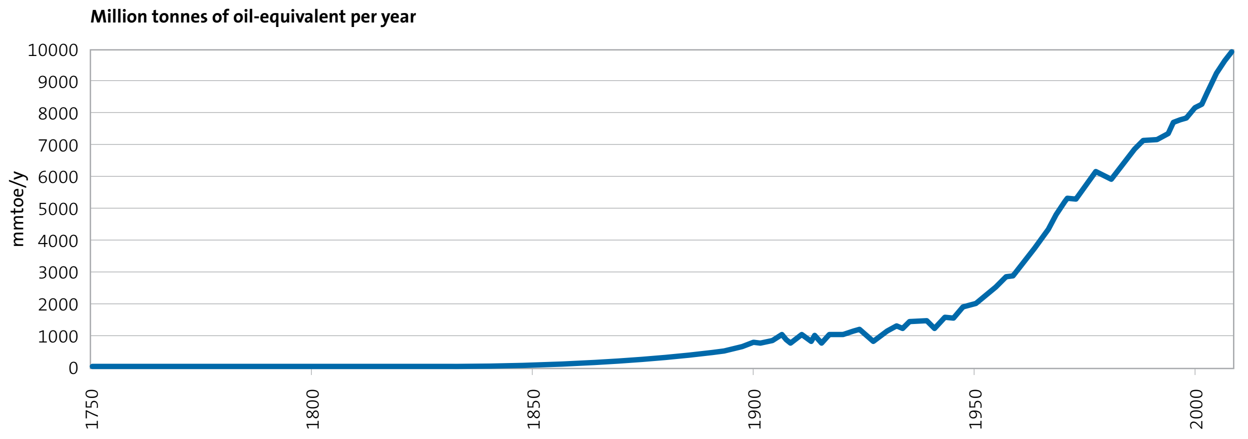


Fig. 5: Fossil fuel consumption by type

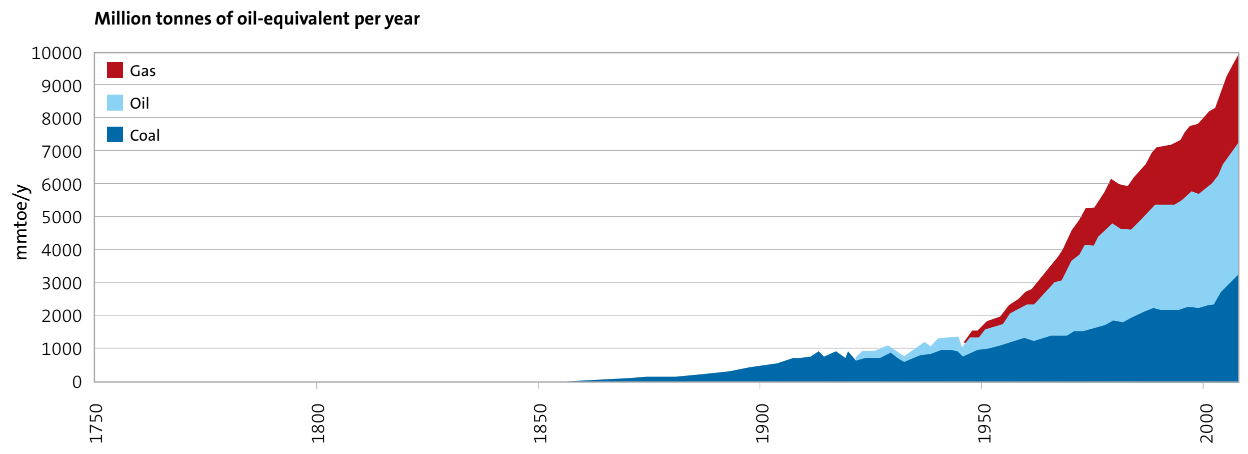
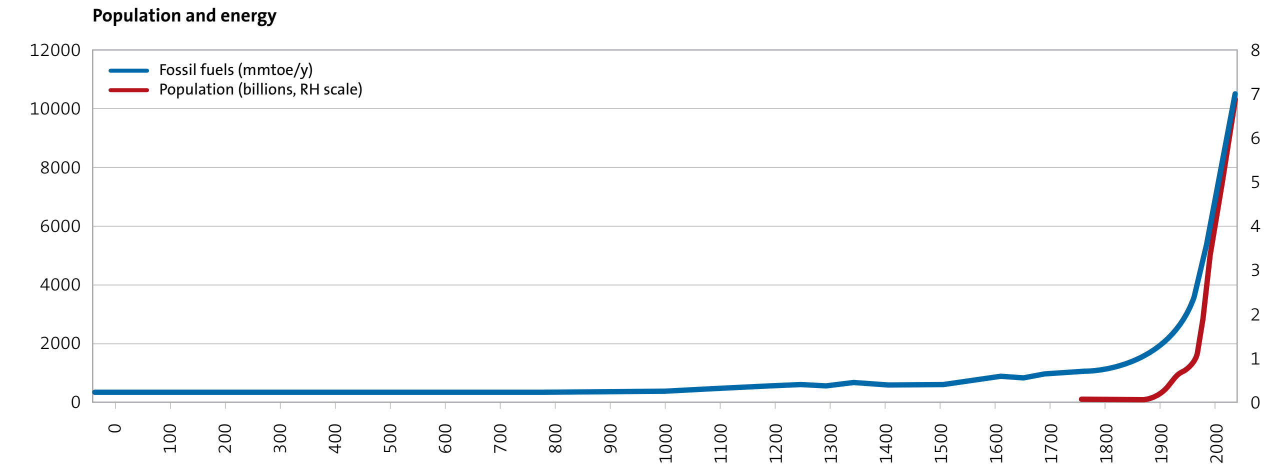


Fig. 6: Population and energy consumption*



*Sources: see earlier charts

From an economic perspective – and beyond intuitive questions about whether the world really can support the projected numbers of people – two things are striking about the population trend.

The first, to which we shall return later, is that the rapid up-tick in the curve began in the mid-nineteenth century. And this, coincidentally – or, in our view, *not coincidentally at all* – was also when the use of hydrocarbon energy began to expand rapidly.

Chris Martenson contends – and we wholly concur in this belief – that **the current population of the earth is sustainable only because of an abundant supply of hydrocarbons, and principally of oil**. This is surely obvious enough when we bear in mind the vast scale of hydrocarbon energy inputs employed in modern intensive agriculture.

The close correlation between population and energy usage can be gauged by comparing population growth (fig. 3) with fossil fuels consumption (figs. 4 and 5). Though shown on a very much shorter timescale than the population chart, fig. 4 nevertheless reveals a distinctive hockey-stick curve. The comparison between population growth and energy consumption is set out in fig. 6.

The second striking feature about the population exponential chart is that its shape is echoed in a number of charts of other key determinants. Those identified by Chris Martenson include deforestation, species extinction and water consumption. Similar exponential progressions are evident in financial indicators such as aggregate (government and private) debt, inflation and the money supply.

As we shall see, there is a close correlation between these financial indicators and the exponential progressions of population and of energy usage. This, in turn, will lead to some highly significant conclusions.

part two:

exponential money

Economic and financial indicators provide ample support for the exponentials thesis. This is strikingly evident, for example, in the chart of US inflation which, dating back as it does to the seventeenth century, is one of the longest-running financial data series available to the analyst (fig. 7).

The characteristic exponential 'hockey-stick' shape is starkly evident in the deterioration of the purchasing power of the American currency. But – when allowance is made for the shorter duration of the time-series data – much the same can be said for the shapes of the US money supply (fig. 10) and the federal debt (fig.12) curves, shown later in this report.

In *Crash Course*, Chris Martenson is particularly scathing about the way in which the public accepts the normality or necessity of inflation without demur. As Mr Martenson puts it, we have "been living on the steeply rising portion of the graph for so long that [we] think it's level ground"[4]. We concur with Mr Martenson's belief that inflation – which in reality is the theft of value from the public – is far too readily taken for granted. More pertinently, **the devaluation of money** – aptly described by Keynes as the debauching of the currency – **is rapidly forming into yet another exponential hockey-stick**, as fig. 7 strikingly illustrates.

The history of American money and inflation is a fascinating subject, one key point being that devaluation through inflation has only really accelerated over the last forty years. Prior to that – as Chris Martenson convincingly demonstrates – inflation was almost always a function of war. The war-inflation axis is well worth reviewing.

In 1766, the cost of living, as measured by American RPI, was actually *lower* (by 9%) than it had been a century earlier. It is a remarkable fact – and one almost outside the comprehension of the modern observer – that somebody could have buried some money in the yard in 1666 and that, had it been dug up by that person's great great grandson a century later, it would have had undiminished value. In that era, American money was based on a gold or silver standard (and was, indeed, to remain gold-backed until 1971).

The first challenge to the integrity of the currency occurred in 1776, with the War of Independence. The government was unable to meet the costs of the war from its reserves, so introduced America's first paper currency in the form of notes known colloquially as "continentals". The government printed too many of these notes, and the British – aware of the corrosive effects of inflation – added to the problem through counterfeiting on a massive scale.

As a result, in the space of just five years between 1775 and 1780, the cost of living as measured by RPI increased by 78% (or, to put it another way, the dollar lost four-fifths of its value). After the war, as Americans speedily abandoned "continentals" and reverted to gold and silver, the devaluation of the currency reversed, such that, by 1789, the cost of living had fallen almost all of the way back to the 1666 level.

> "I am a rich man, as long as I do not pay my creditors".
>
> Titus Maccius Plautus

[4] Martenson, *Crash Course*, op cit

Fig. 7: US inflation since 1666

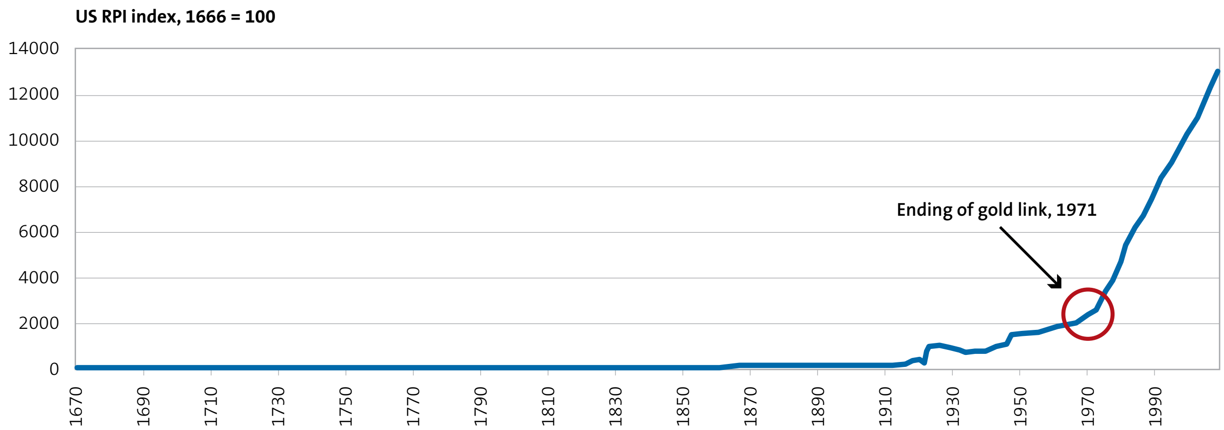
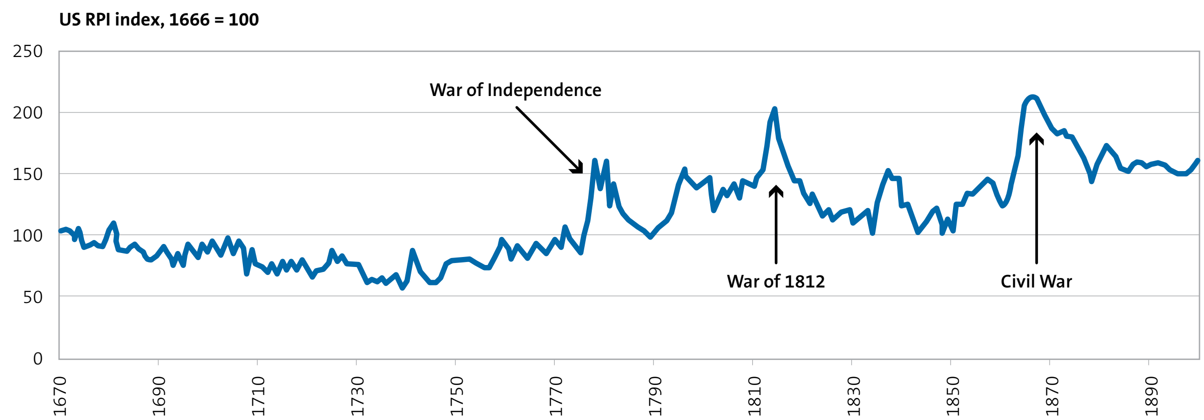


Fig. 8: US inflation, 1666-1900



The next big slide in the value of the currency was again occasioned by conflict, in this instance the War of 1812. Again, once the war was over, the value of the currency recovered, and was to remain little changed until the next big conflict – the Civil War. These war-related bouts of inflation are annotated on fig. 8, which charts American RPI between 1666 and 1900.

Much the same thing happened after 1917, when America entered World War I, and after 1941, when US participation in World War II decisively ended the deflationary pressures of the 1930s. Fig. 9 ends in 1985 because, as a glance at fig. 7 will reveal, the calibration of the vertical axis would otherwise be overwhelmed by **the post-1985 collapse in the purchasing power of the dollar**.

By far the most significant single event in the post-war debauching of the dollar was the removal of the gold standard by Richard Nixon in 1971, but other noteworthy milestones had occurred before that. In 1933, President Roosevelt expropriated – or, to put it in unequivocal language, *stole* – all privately-owned gold in the United States. To be sure, Americans could buy their gold back, but at a price of $35/oz, significantly higher than the $21/oz paid to them in compensation.

As well as being outright confiscation, this represented a huge devaluation of the dollar. For good measure – and with the approval of the Supreme Court – Mr Roosevelt also unilaterally cancelled all government obligations payable in gold. As Chris Martenson puts it, “this goes to show how governments, in a period of emergency, can change rules and break their own laws”[5].

Needless to say – though the data for this series only goes back to 1959 – the deterioration in the value of the dollar has been matched by a corresponding increase in the money supply as measured by M3 (fig. 10). Despite its very much shorter time axis, this chart displays the characteristic exponential hockey-stick shape discussed elsewhere in this report. The US authorities ceased the disclosure of M3 data during 2006, but all available evidence points to dramatic further expansion since then, not least because of ‘quantitative easing’ (QE). Unofficial sources indicate that US M3 has increased from $10 trillion in 2006 to at least $15 tn today, a rise of about 50% in the space of just four years.

[5] Martenson, *Crash Course*, op cit

Fig. 9: US inflation, 1910-2009

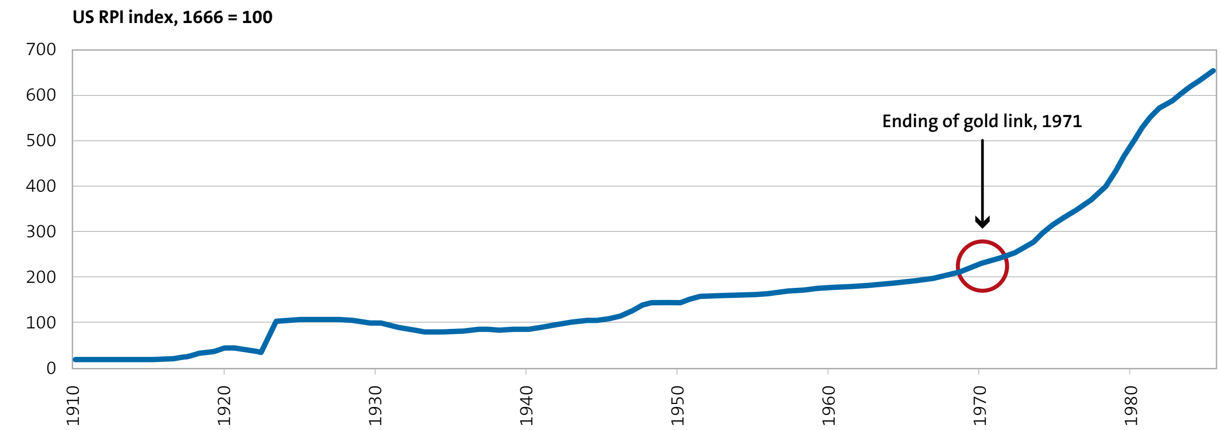
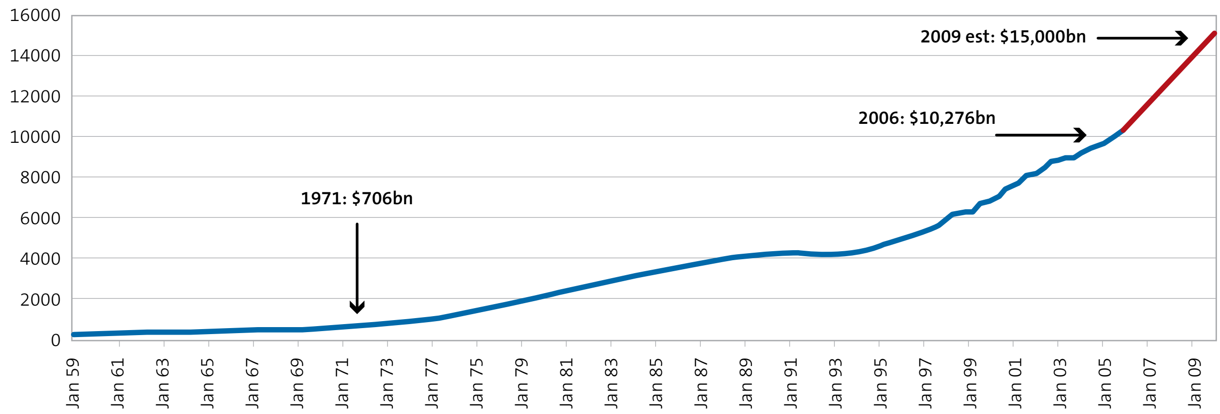


Fig. 10: US M3 money supply*



*Sources: 1959-2006 – Federal Reserve of St Louis. Since 2006 – Tullett Prebon estimates

quantitative euphemisms

QE is something of a euphemism, and we should be clear that, in layman's terms, **QE amounts to the printing of money**. Since QE has been a characteristic of the post-crisis economic response in the worst-hit economies, it is worth looking at what it amounts to, not just in the US but in the UK as well. In the US, QE has boosted the money supply by some $1.2 trillion, whilst the Bank of England has injected £200bn through QE.

According to classical monetarist theory, an increase in the money supply, since it occurs without a corresponding increase in goods and services, necessarily creates inflation. This monetarist interpretation appears, at first sight, to have solid historical backing. The most obvious examples are Weimar Germany and present-day Zimbabwe, where massive expansions in the money supply led directly to hyperinflation.

Though famous, these are by no means the only examples of the creation of hyperinflation through the irresponsible use of the printing press. Of the 3,800 or so paper currencies that have been confined to the dustbin of history, the overwhelming majority were victims of hyperinflation created by a reckless expansion of the money supply. Hyperinflation destroys currencies, and printing money has, historically, been the near-universal route to hyperinflation. On this basis, should investors feel misgivings about QE?

Fortunately, conventional monetarist theories are somewhat oversimplified, because they leave an important item out of the equation. This omitted item is the velocity of money – in other words, the rapidity with which money is spent. Where inflationary pressures are concerned, the 'effective money supply' can be defined not simply as the stock of money but, rather, as the combination of the quantity of money and the velocity with which it circulates.

In the immediate aftermath of the crisis of 2008, the velocity of money dropped dramatically. Not surprisingly, fear and uncertainty prompted banks, businesses and individuals to hoard their cash holdings. At the same time, the usual process of credit creation reversed, and became a process of credit destruction (which should also help allay the somewhat exaggerated fears sometimes expressed about fractional reserve banking).

Optimistically, therefore, QE can be regarded as an appropriate expansion of the *quantity* of money in order to offset a rapid deterioration in its *velocity*.

However, the quantity-velocity interpretation of the money supply can provide only short-term reassurance where QE is concerned. **As soon as the economy begins to recover, it will become imperative that the earlier process of QE is reversed**. Otherwise, a recovery in velocity will combine with an expanded stock of money to boost the 'effective money supply', and this truly *would* lead to inflation. Given that inflation really amounts to a devaluation of money, an inflationary process prompted by a failure to reverse QE would raise legitimate investor concerns about the future value of sterling and the dollar, the currencies most affected by QE.

Investors are entitled to be particularly sceptical about the willingness of governments actually to reverse QE when the time comes, not least because of the understandable fear that governments are printing money to pay bills that they could otherwise not afford. This fear is a well founded one. In the UK, for example, the scale of QE (£200bn) correlates remarkably closely with the government's money-raising requirement (CGNCR[6]) in 2009-10 (£201bn) (fig 11). Moreover, of the QE deployed thus far, 99% has taken the form of the purchase of gilts[7].

In its defence, the Bank of England argues that it is acquiring existing gilts held by others, not purchasing newly-issued gilts from the DMO[8]. Indeed, using newly-created money to buy gilts from the DMO would be illegal, since it would contravene Article 101 of the Maastricht Treaty, which prohibits the monetizing of debt. But critics are entitled to regard this defence as being specious at best, in that the money paid for existing gilts tends to be channelled back into new gilts by institutions whose investment profiles require a consistent level of gilts exposure. Moreover, the presence of a huge purchaser of gilts has the effect of raising their price, thereby depressing yields and artificially lowering the interest rate at which government can borrow.

Without going into the truly parlous state of the UK (or the US) fiscal situation – the near-catastrophic state of British public finances has been explained in Issue Four, and we anticipate looking at the US in a future report – we conclude that governments are indeed using QE, not just for its legitimate purpose of boosting the 'effective money supply' by offsetting impaired velocity, but also to pay for the deficit consequences of fiscal profligacy.

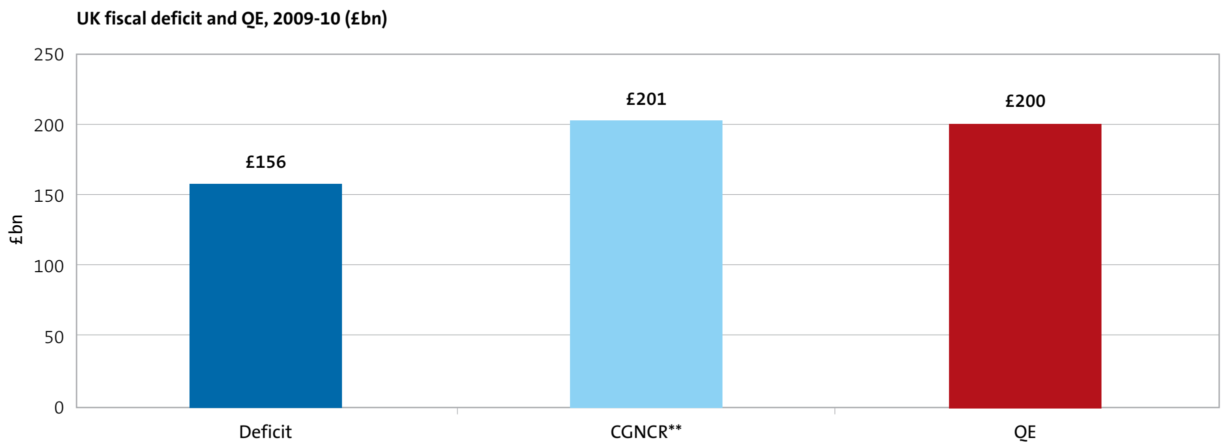
Of course, QE only represents a threat to the future value of the USD and the GBP if it is not reversed. Again using the UK as an example – though this is just as true of the US – government will, in the not too distant future, need to make a set of very painful decisions. First, public spending (at 48% of British GDP last year) is vastly higher than revenue (36%). Obviously, this means either that spending must be reduced, that taxes must be increased, or that there will be a combination of the two.

The need to reverse QE adds a further significant complication to this issue, since reversing QE will markedly increase interest rates attaching to government borrowing. If this issue is ducked – as seems probable, because of the short-term pressures on the policymaking process that we have outlined elsewhere[9] – then **the likelihood is that both inflation and interest rates will trend sharply upwards**, simultaneously depressing economic activity and adding to the stretch on government finances.

These pressures could further depress sterling and the dollar, boosting import prices and thus further stoking-up inflation. Lenin once remarked that, whilst America would spend her way to oblivion, Britain would achieve the same result through taxation. Unless tough decisions are taken on both sides of the Atlantic, **he could yet be proved right**.

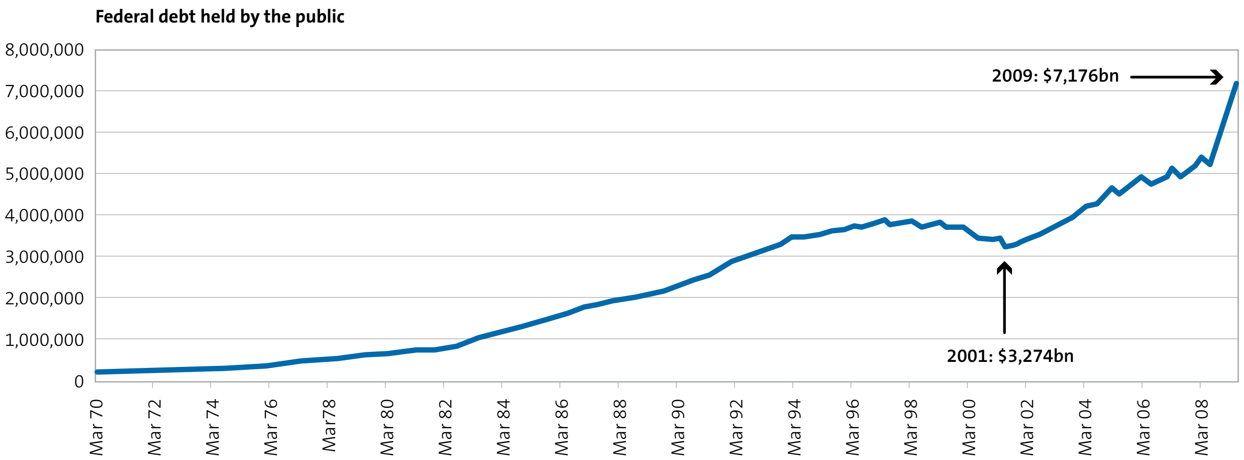
[6] Central Government Net Cash Requirement
[7] Source: Bank of England, http://www.bankofengland.co.uk/markets/apf/results.htm
[8] Debt Management Office
[9] See Issue Three, *Forever Blowing Bubbles*, March 2010

Fig. 11: Coincidence? – QE and the UK deficit, 2009-10*



*Sources: H.M. Treasury, Bank of England **Central Government Net Cash Requirement

Fig. 12: US federal debt



exponential debt, systematic generational theft

In a recent *Strategy Note*[10] , we explained that the sovereign debt crisis of 2010 is the logical consequence of the banking crisis of 2008, not least (though by no means only) because financial interventions effectively transitioned unsustainable bank indebtedness to the public balance sheet. Drawing upon a ground-breaking report by the Bank for International Settlements (BIS)[11], we showed that sovereign debt in most OECD countries has now taken on an upwards trajectory that is essentially irreversible. Various BIS test-studies revealed that any fiscal rebalancing plan aimed at restoring government debt to its 2007 levels is effectively unworkable, involving, as it would, the reversal of current structural deficits into enormous surpluses.

A glance at three of the BIS charts – reproduced here as figs. 13, 14 and 15 – will reveal the relevance of this situation within the context of "dangerous exponentials". Essentially, the projected debt curves of each of the OECD countries reveals that **sovereign debt has become exponential**. The various forward risks identified by the BIS – including much higher debt service costs, and the inflationary risk implicit in any attempt to monetise debts through expansions of the money supply – are remarkably consistent with other characteristics of exponential money.

Drawing upon the BIS report, our Note identified two primary reasons why sovereign debt has turned exponential. The first of these, of course, is the general exponential tendency now evident in most monetary indicators, a tendency which is the subject of this report.

The second factor driving sovereign debt along an exponential curve is a process that we have explained in earlier research as "generational theft"[12]. By "generational theft", we mean a tendency whereby the present generation plunders future generations by loading them with potentially unsustainable debt, both private and public.

Fig. 13: Public debt outlook, United States*

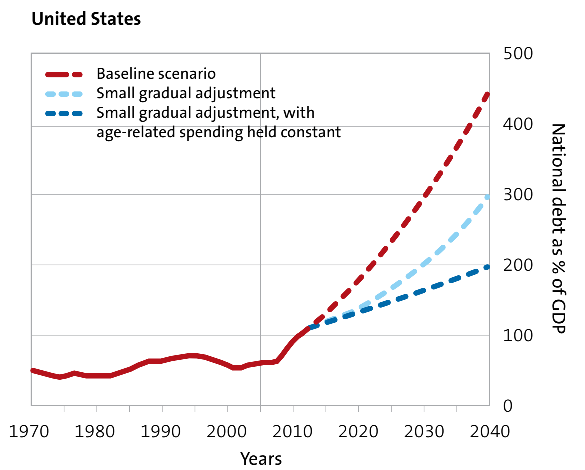
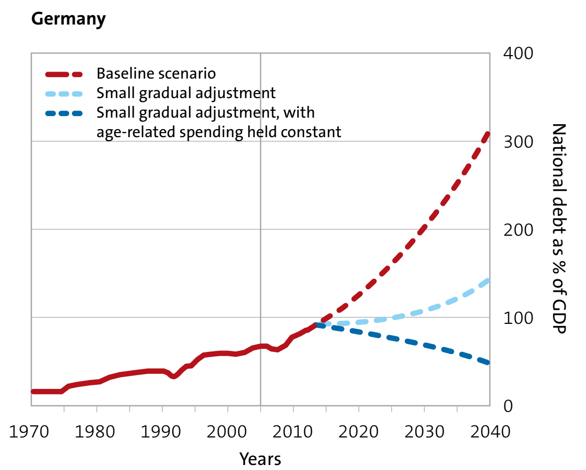


Fig. 14: Public debt outlook, Germany*



*Source for figs. 13, 14 and 15: *The future of public debt: prospects and implications*, BIS Working Papers No. 300, March 2010

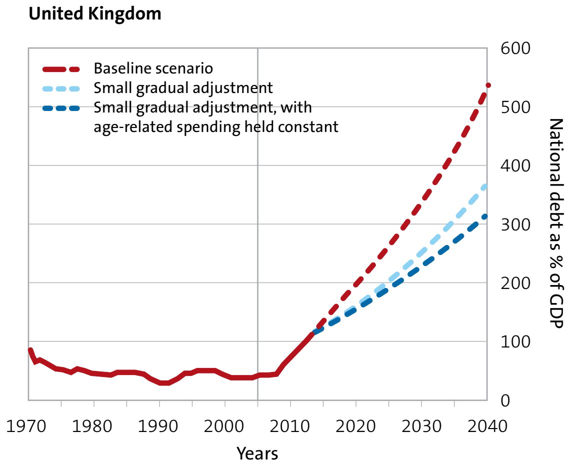
[10] See *Tullett Prebon Strategy Notes*, issue six, *Out of Control*, 12th May 2010
[11] *The future of public debt: prospects and implications*, BIS Working Papers No. 300, March 2010
[12] See *Tullett Prebon Strategy Notes*, issue one, *The Dick Turpin Generation*, 18th March 2010

Demographic pressures are adding to the sovereign debt trajectory, in two respects. First, the ratio between working-age and retired people is worsening rapidly, in part as a result of greater life expectancy.

Second, as the 'baby boom' generation reaches retirement age, there is a need for their assets to be monetised, which really means 'sold to upcoming generations'[13]. Since the upcoming generations are not only poorer than the boomers but fewer in number, this poses a clear threat to asset values. But, of course, **whilst asset values are variable, debt is immutable**.

Obviously, there are only two ways in which debt can be extinguished. The first is via repayment, which is implausible given the sheer scale of the economic surplus which this process would require. The second is through inflation, whereby the real value of obligations is eroded through a devaluation of the currency. But **inflation itself is another of the core exponentials identified in this report**. Moreover, as Malcolm Offord has explained, "inflation is the "hard drug" of the capitalist system"[14]. In other words, **the debt and inflation components of the picture are characteristic of how the whole economic system has become exponential**.

Fig. 15: Public debt outlook, United Kingdom*



[13] See *Tullett Prebon Strategy Insights*, issue two, *Brave New World?*, March 2010
[14] Malcolm Offord, *Bankrupt Britain*, February 2009

inflation – a matter of policy?

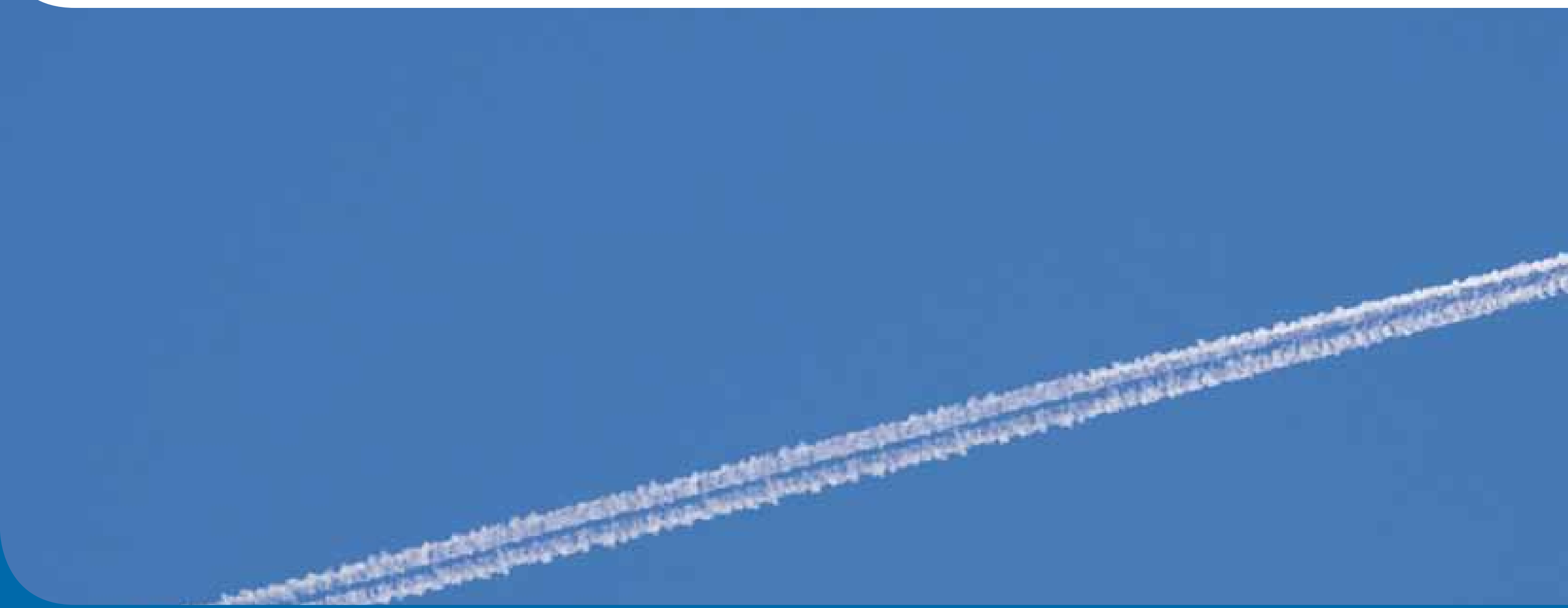
According to the consensus view, the likelihood of a general inflationary spiral taking off looks pretty remote, at least in the short term. One reason often cited for this is that overcapacity remains substantial. Another is that unemployment remains high.

We believe that **false comfort tends to be drawn from these indicators**. Surplus capacity is not necessarily a dampener of inflation if that surplus capacity is in non-relevant sectors. The auto industry is a case in point. Fearful both of direct unemployment and of the knock-on effects on the supply chain, governments around the world have propped up loss-making auto makers. In other countries, industries such as house-building are on direct or indirect life-support.

But the continued existence of an essentially-redundant capacity to build homes or cars is no guarantor of low inflation – looked at realistically, **artificially-maintained capacity is no guarantee of anything other than inefficiency**. High unemployment does damp-down wage inflation, but it offers little defence against the real causes of inflation, since these causes are essentially monetary. As Chris Martenson puts it, "inflation is a deliberate act of policy"[15].

Sometimes, political exigencies – such as wars or, more recently, a need to prop up the banking system – force policymakers into running the printing presses, but **the result is always the same**, in that excessive expansion of the money supply inevitably leads to inflation. There is, moreover, a compounding effect which kicks in if international markets become spooked by a country's excessive printing of money. If this happens, the value of the currency declines, resulting in escalating import costs.

For very good reasons, any possibility of deflation tends to give economists bouts of the fits. If an economist is also happens to be a devotee of Bram Stoker, he or she is likely to call for a cross and some garlic at the very mention of the word 'deflation'. If deflation kicks in, the real value of debt rises, as does the real cost of servicing it. At the same time, consumers tend to turn cautious, knowing that their money will increase in purchasing power if it is left in the bank. Whilst a deflationary spiral brings wages downwards, it is effectively impossible



[15] Martenson, *Crash Course*, op cit

for interest rates to turn negative. There are, then, very good reasons for fearing deflation.

Yet the corollary of this is that, supposedly in the interest of 'erring on the safe side', governments tend to aim for a 'low' (but not a zero) rate of inflation. Chris Martenson is pretty scathing about this, and with good reason. Inflation, even at seemingly modest levels, is a theft of value from the public. If someone borrowed $1000 from you today, and repaid you only $980 a year later, you would, quite properly, feel short-changed, yet this is exactly what inflation of 'just' 2% amounts to.

Governments compound this theft of value in several ways. First, and most obviously, they do this by taxing interest income, choosing to regard such income as a 'profit' rather than, as is usually the case, simply the maintenance of value in a context of inflation (if interest achieves even that). Second, governments exploit 'fiscal drag', profiting from the time-lag within the process of raising tax bands and allowances in line with inflation. Third, and most insidiously, governments choose measures which understate the true rate of inflation. CPI is a particularly pernicious method of understatement, but neither RPI nor the GDP deflator is immune from criticism.

Where governments are concerned, one great benefit of understated inflation is that it flatters reported economic growth. We suspect that the flattery of 'real' growth through the understatement of inflation is an extremely widespread practice, most notably in the US and the UK[16].

The clear implication of Chris Martenson's scathing assessment of inflation is that this theft of value from the public could be countered by anchoring the value of the currency to an external benchmark. This is precisely what the gold standard amounted to. We are **not** advocates of a return to the gold standard which, in our judgement, is too restrictive, since the money supply does need to grow over time as the economy expands. But Mr Martenson is surely right to warn about the over-rapid expansion of the money supply, and to add the money supply – and, for that matter, government debt – to the forest of dangerous exponentials that may well be running out of control.

[16] The unreliability of official data for GDP, debt, inflation and growth is a very important issue, and will be addressed in a future Issue of *Tullett Prebon Strategy Insights*

part three:

the governing dynamic

Chris Martenson's *Crash Course* is, in very many ways, an invaluable contribution to the economic debate. But if there is one single area in which *Crash Course* excels, it is in the identification which Mr Martenson establishes between the issues of energy and the economy. Moreover, he correctly widens the energy focus from the simple matter of the availability of fossil fuels to the broader and far more significant issues surrounding the role played within society and the economy by energy in its every sense.

As Mr Martenson explains, money is, by definition, debt (since money represents not just a store of value but, intrinsically, a debt created by the issuer of the currency). Furthermore, both money and debt are, at the most fundamental level, a claim on human labour, be it past or future labour. Labour relates directly to energy when the latter concept is broadened to include not just exogenous fuels but human activity as well. Essentially, then, **money is a token of energy**.

Thus seen, **the pricing of fuel has been massively distorted by its abundance**. At one level, the price of gasoline is, in the US, about $2.90/gal. But does this represent its real value in terms of its energy content when a link is made between the way in which gasoline (or any other exogenous fuel) displaces human labour? To find out, Mr Martenson recommends that one puts a gallon of gasoline in his or her car, drives the vehicle until the fuel runs out, and then pays someone to push the vehicle back to the start point.

This, Mr Martenson says, would equate to 500 hours of hard human labour, costing $7500 even if we paid someone only $15 per hour for this arduous work[17]. This rather startling calculation puts the true *value* of energy into its broader context.

[17] Martenson, *Crash Course*, op cit

"For those who want some proof that physicists are human, the proof is in the idiocy of all the different units which they use for measuring energy".

Richard Feynman[18]

[18] Richard Feynman, *The Character of Physical Law*, 1964

the economy – an energy equation

The energy story really begins with the most primitive form of human existence, which was the hunter-gatherer system prior to the invention of agriculture. All of the energy that humans derived from their food was used up catching and finding that food. There was no energy surplus at an individual level and, since every single individual (or family unit) was fully engaged in the obtaining of food, there was no specialisation, and no society.

The development of agriculture can be regarded as one of the two greatest steps forward in human existence. Agriculture probably began in the 'fertile crescent' (in the present-day countries of Iraq, Syria, Lebanon, Israel, Kuwait, Jordan, Turkey and Iran) in about 9500 BC. In addition to allowing population densities to increase from the maximum of about one person per km^2 under the hunter-gatherer system, agriculture liberated surplus energy. Agriculture was almost as energy-intensive as hunting-gathering, but it had two very great advantages in terms of energy efficiency – it utilised the energy of animals, and it harnessed economies of scale.

Put very simply, the labour of four individuals or families could now support five individuals or families. The ability of five persons to be fed by the labour of four was the first instance of an 'energy surplus', and it enabled some very modest forms of specialisation to occur. In Europe, this specialisation took the form of very rudimentary structures of government and law, and led to the creation of a limited number of specialist trades such as miller, smith and shoemaker.

Over time, the development of increasingly efficient agriculture led to the most sophisticated social constructs of the pre-industrial period, which were the monastic establishments and the ship-building and seafaring trades. Enclosure of common land, despite its very retrograde social implications[19], furthered the efficiency of agriculture but, by the late eighteenth century, society was still overwhelmingly agrarian, and specialisation was extremely modest by later standards.

And then came the second great form of social progression – the discovery of the 'heat engine', initially in the form of steam-power derived from coal. The crucial point to note about the harnessing of coal – and latterly of other fossil fuels such as oil and natural gas – was that **the energy equation altered drastically from the agricultural model**.

Agriculture itself was made vastly more efficient, initially through the use of motive power and latterly through the introduction of hydrocarbon-based fertilisers and pesticides. Within a hundred years of the first use of steam-power, the proportion of the populations of most developed countries engaged in farming had fallen to less than ten percent. Specialisation had arrived, courtesy of the harnessing of the energy contained in fossil fuels.

The purpose of this digression into history (and, indeed, into pre-history) has been both straightforward and vital – to establish the essential connection between *all* forms of energy, a connection which embraces food, human labour and exogenous forms of energy such as fossil fuels. And if we accept – as we surely must – that money is the tokenisation of

[19] Their traditional share of common lands gave labourers an alternative method of survival, but enclosure of the commons turned the peasantry into wage-labourers wholly dependent upon landowner employers.

work, then we should also accept that the bulk of that 'work' is provided not by human labour but by the vast input of fuel energy (which replaces, and therefore equates to, work). In other words, **all of the economic 'exponentials' – including both population numbers and financial aggregates – are energy-dependent**.

As Chris Martenson points out, the role played by energy in the modern household corresponds to the energy (labour) of at least a hundred people in pre-fuel times – one person's continuous physical effort on a dynamo-driving exercise bicycle would be barely sufficient to power one light-bulb. In comparison to pre-industrial times, we are all, as Mr Martenson puts it, "living like kings", and both the lifestyles of individuals and the specialisations of societies are made possible only by exogenous energy, derived overwhelmingly from fossil fuels.

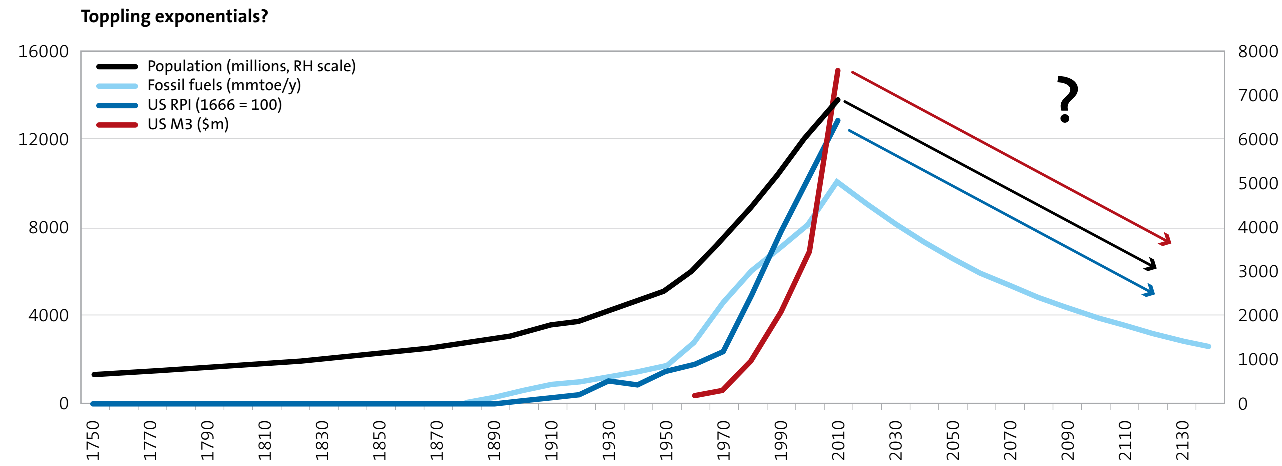
a 'collapse of exponentials'?

Society as we know it, then, **is a direct function of exogenous energy** derived overwhelmingly from oil, gas and coal. The supply of money is simply the tokenisation of energy, the vast majority of which comes not from human labour but from exogenous energy inputs. This raises the obvious question of what would happen if access to abundant exogenous energy were to diminish, or even cease to grow. **Might such an event cause the entire structure of financial, economic and social exponentials to collapse?** (fig. 16). After all, the financial system looks increasingly unstable anyway.

In *Crash Course*, Chris Martenson draws heavily on the theory of Peak Oil. This concept – pioneered by M. King Hubbert and accordingly known as 'Hubbert's Peak' – contends that, at some time in the relatively near future, we will have consumed half of all originally-available reserves of oil.

At that point, Hubbertians argue, the supply of oil will decline, in pretty much a mirror-image of the increase in consumption which has taken place since the 1850s. Much the same, they argue, will eventually happen to supplies of natural gas and of coal, with depletion of these resources accelerating as a result of substitution from oil.

Fig. 16: Could energy decline cause a general collapse of exponentials?



The Peak Oil process can already be discerned in the context of individual provinces such as the UK North Sea, or of multi-province plays such as the Lower Forty-Eight (L48) States of the US. Annual rates of petroleum discovery in America peaked in 1930, and peak production occurred forty years later, in 1970, since when output has declined relentlessly. Since the global peak discovery rate occurred in the mid-1960s, it is argued, a similar time-lag implies that global Peak Oil is now imminent. Advocates of the Peak Oil interpretation argue that, seen on a timescale of social evolution, **the petroleum-based society is not so much a manageable trend** (fig. 17) **as a one-off event** (fig. 18).

In the context of *Crash Course*, the reversal of the energy exponential is depicted as the inevitable trigger for the equivalent reversals of other exponentials, including population and, critically, monetary and debt measures (see fig. 16).

A debt-based monetary system is founded on the intrinsic assumption that the economy of the future will *always* be bigger than that of the present – **if it is not bigger, how can both capital *and interest* be repaid?**

Reversing any exponential will be painful – indeed, society has absolutely **no** prior guide to how to manage successive (and perhaps rapid) decreases in population and in economic output. **A mass collapse of exponentials could be catastrophic**.

Fig. 17: Resource constraint – a gradual trend...

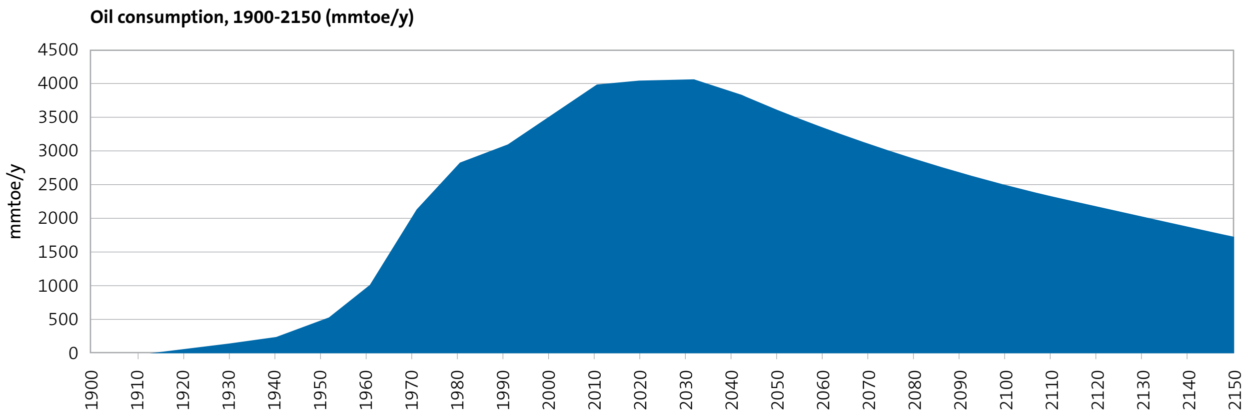
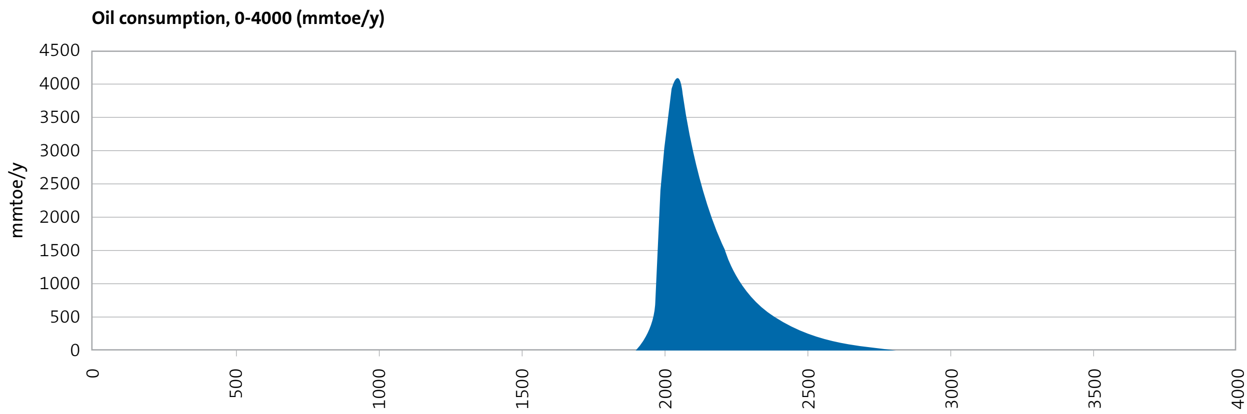


Fig. 18: ...or a one-off event?



towards resource constraint

It is not our intention to set out here, in full, our views on the Peak Oil issue, because this vitally-important subject is likely to be addressed in a future report. But the role of hydrocarbons within the exponentials thesis demands that we set out a summary of how we believe that the future of hydrocarbon supply is likely to pan out.

Hubbertians – who are also sometimes known as 'Peakniks' – tend to argue that oil production must soon enter an inexorable decline, because half of the world's originally-recoverable petroleum has already been extracted.

The first flaw in this argument is that it is simply not true. The application of the Hubbert thesis at this point implies that the original reserves base was of the order of 2.2 tn bbls (trillion barrels). Ample evidence exists to suggest that the originally-recoverable reserves base was of the order of 3.0 to 3.5 tn bbls, and possibly much larger. The Hubbertian case has considerable merit if it is applied to conventional oil, by which is meant light, sweet crudes which can be extracted relatively easily. But there is seemingly incontrovertible evidence that huge quantities of *unconventional* oils remain to be extracted.

In North America alone, tar sands reserves in Canada are estimated at no less than 170bn bbls (billion barrels), whilst shales in the US may hold as much as 800bn bbls of oil, though the extraction of much of that oil may be, to put it mildly, problematical. In South America, reserves of very heavy crudes in Venezuela are thought to be well in excess of 350bn bbls. To be sure, there seem to be many cases of overstatement where conventional reserves are concerned, most notably in OPEC countries, where, for many years, the quota allocation process incentivised over-statement of reserves. But the overall picture is one of relative abundance of reserves of oil *of all types*.

The second error within the Hubbert's Peak theory is that it tends to ignore economics. A scarcity of oil would cause prices to rise massively. As we have seen, a gallon of gasoline costs about $3 but, in energy terms, displaces human labour worth about $7,500. Scarcity-induced price escalation could be expected to change the equation in at least two material respects.

First, an escalation in prices would reduce demand by causing greater frugality in the use of oil. As Robert Hirsch cogently argued – in a thesis that essentially leant towards the concept of an oil production peak – there is a great deal that can be done to mitigate the economic impact of oil shortages, *always presupposing that action is taken at least ten years ahead of the event*[20].

A society threatened by oil scarcity would be required to change fundamentally. Suburbs – the quintessential characteristic of a car-based society – would be replaced by denser forms of habitation in a move that might yet be rendered necessary anyway by environmental considerations. The thirstiest vehicles (such as SUVs[21]) would rapidly be consigned to the scrap-heap, and private car ownership would be displaced by enhanced public transport. The second effect of very high oil prices would be to incentivise exploration for, and development of, resources currently rendered uneconomic by their geological nature or their inaccessible location.

These arguments – and the apparent scale of remaining recoverable reserves – have generally enabled opponents of Peak Oil (sometimes known as 'cornucopians') to counter the Hubbertians and thereby, in general,

[20] See Robert Hirsch et al, *Peaking of World Oil Production: Impacts, Mitigation, and Risk Management*. This groundbreaking report was written for, but then largely rejected by, the US Department of Energy.

[21] Sports-Utility Vehicles

to win the public debate. In so doing, they are providing the right answers to the *wrong question*. The critical issue with Peak Oil does *not* hinge around remaining reserves. Rather, **the key issues are energy returns on energy invested** (EROEI) – we'll look at this subject later in this report – **and *deliverability***.

The best way to illustrate the deliverability issue is to compare oil sands reserves in Canada (about 170bn bbls) with conventional reserves in Saudi Arabia (about 270bn bbls). Given that Saudi production capacity is about 12 mmb/d (million barrels per day), one might, on a simple pro-rata basis, expect Canadian oil sands output to reach perhaps 7 mmb/d. But the reality is that output is most unlikely to reach even 3.5 mmb/d. Deliverability from the Canadian resource, will, then, be less than half of that attained from conventional reserves in Saudi Arabia.

Not surprisingly, and for perfectly logical economic reasons, oil reserves have been cherry-picked – the cheapest, highest-quality and most accessible reserves have been exploited first. What this in turn means is that, even if reserves remain substantial, production levels might hit a ceiling in the relatively near future. It also needs to be remembered that net changes in output represent a two-piece equation – substantial new sources are needed each year simply to replace natural declines from already-producing fields. **As the industry moves from higher- to lower-deliverability fields, maintenance of existing production levels, let alone growth, becomes ever more difficult**.

In the 2009 edition of the *World Oil Outlook*, OPEC predicted that global consumption of oil will rise to 108 mmb/d by 2030. Though appreciably lower than the cartel's estimate two years previously (121 mmb/d), this 2030 target nevertheless represents a big (27%) increase from the outturn in 2009 (84 mmb/d)[22]. Is it achievable? Our research inclines us to agree with M. Christophe de Margerie, CEO of Total, who has questioned the ability of the industry to exceed 100 mmb/d[23].

Moreover, future supply projections assume that three-quarters (16.9 mmb/d) of all 2009-2030 net gains in production (22 mmb/d) will have to come from OPEC countries. This might be difficult to achieve, particularly given that Saudi Aramco now admits that it is injecting 13 mmb/d of treated seawater, most of it to sustain production at its giant (but ageing) Al Ghawar field, historically the source of about half of the kingdom's production[24].

Another way to look at the deliverability issue is that reserves need to be quality-weighted. We may have used up much less than half of the world's originally-recoverable reserves of oil, but we have, necessarily, resorted first to those reserves which are most readily and cheaply recovered. The reserves that remain are certain to be more difficult and costlier to extract.

Production may not 'peak' just yet, but a new concept – which we term 'resource constraint' – may soon kick in, implying that **an economic model based on abundant and ever-increasing hydrocarbon inputs might be running out of road**.

Neither should investors be fooled by the cornucopians' argument that technology will necessarily ride to the rescue. This argument is essentially equivalent to the statement that, if you locked a boffin up in a bank vault with enough cash and a sufficiently powerful computer, he would eventually materialise a ham sandwich. **Technology is not the Seventh Cavalry, poised to ride to the rescue**.

[22] http://www.opec.org/home/. All figures used here exclude processing effects

[23] As reported in the Financial Times, http://www.ft.com/cms/s/0/1d725e64-c8d2-11de-8f9d-00144feabdc0.html

[24] See http://www.saudiaramco.com/irj/portal/anonymous?favlnk=%2FSaudiAramcoPublic%2Fdocs%2FOur+Business%2FOil+Operations%2FProduction+Facilities%2FWater+Injection&ln=en
Until quite recently, the figure cited was only 7 mmb/d

urgently needed – a measure of energy *returns*

Where the future of energy supplies is concerned, most projections postulate increases in dollar oil prices if supply scarcity kicks in. Though true within its own confines, price-based analysis is inadequate in this context – we can always print dollars (indeed, they have already been printed at a rather alarming rate), but the real issues here are hard physical constraints. The same is true of supposed substitutes for oil, such as biofuels.

An assessment of the future outlook for energy inputs needs to be calibrated in terms of an energy rather than a monetary equation. It is evident that we need a new paradigm if we are to interpret energy constraint in an economy of exponentials.

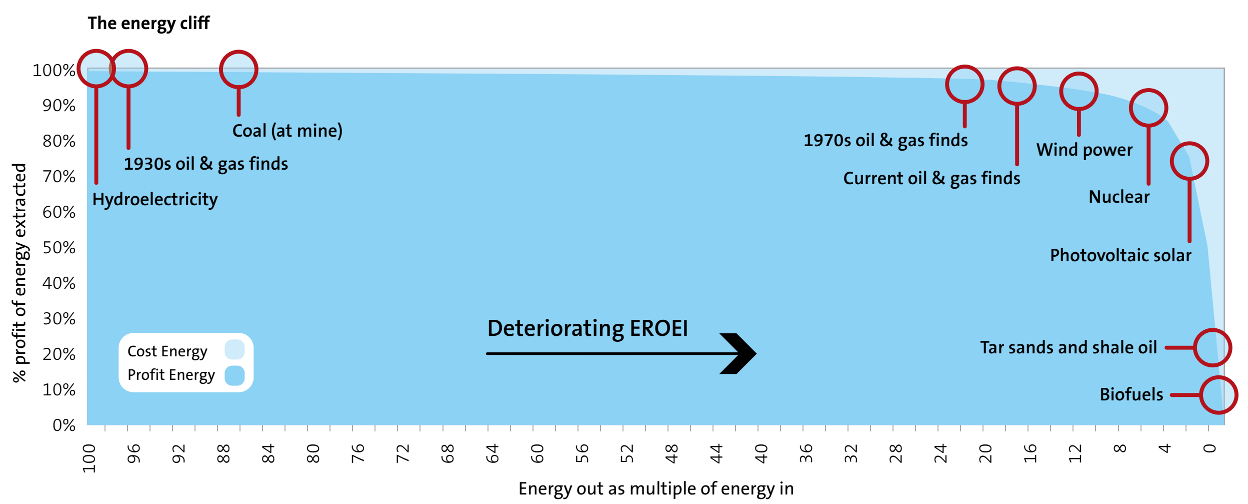
The appropriate energy-based equation is known as EROEI – energy return on energy invested. The theory of EROEI is extremely simple, but its application is complicated. The basic requirement is that the amount of energy extracted should be divided by the amount of energy involved in extracting it. The problem here is how far the calculation should be carried back up the supply chain.

For example, if calculating the EROEI of an oil field, it is obvious that inputs should include the energy component of the steel and other materials used to develop the field. But should it include the energy used to build the steelworks in the first place? The input calculation should include the cost of transporting materials to the site, but should it include labour and materials employed earlier in the supply chain?

Chris Martenson believes – and he is surely right – that the lack of a consistent basis of EROEI calculation is a huge flaw in our understanding of economics, and that a national effort is required to rectify this deficiency.

Given our belief that **economics is ultimately an energy equation**, we would go even further than this. We think that the lack of a definitive and standardised EROEI methodology is *the greatest single black hole in the toolkit that economists use to understand the dynamics of the society in which we live*.

Fig. 19: Going off a cliff? Energy return on energy invested



Though the lack of accurate calibration is a handicap, it does not prevent us from discerning an approximation of the EROEI landscape, and this landscape can best be depicted in the form of a 'cliff chart' (fig. 19). The horizontal and vertical axes are linked – the horizontal axis is calibrated to EROEI as a multiple, whilst the vertical axis expresses the same calculation by dividing energy output into percentages of 'cost' (energy in) and 'profit' (the surplus of energy out minus energy in). This tool is, we believe, highly instructive.

For example, oil discovered in the 1970s equated to about 30 BTU[25] of energy output for each BTU of input. This equates to a 'profit' and 'cost' percentage split of 97/3. This is a very healthy outturn (though it is noticeably less healthy than oil discovered in the 1930s).

The key point to note from fig. 19 is that newer sources of energy – some of which are seen as substitutes for oil, whilst others are regarded as environmentally advantageous – offer far lower EROEIs than traditional sources.

At EROEIs of less than about 15, **the energy returns equation drops off a cliff**. Biofuels, for instance, are likely to have an EROEI of barely 3x (and Chris Martenson is by no means alone in arguing that the EROEI of corn ethanol is so low that its production is simply not worth undertaking).

Likewise, tar sands and shale oils offer a very low EROEI (less than 5x), because huge amounts of energy have to be expended in extraction processes such as mining and SAGD[26]. Both biofuels and bitumens have EROEIs well down the adverse incline of the cliff. A society in which these displaced conventional, high-EROEI sources of energy would be a vastly weaker generator of value, **and its ability to sustain current social complexity would be, at best, debatable**.

The EROEI calculation set out in fig. 19 is a mathematical equation, not a time-linear one. But it will be obvious that recent and projected trends in energy supply are moving society along the chart from left to right, and moving the overall energy average ever closer to the cliff-edge. If the average EROEI does indeed move over the cliff, energy available to society will diminish rapidly, *irrespective of the absolute scale at which low-EROEI sources are developed*.

Slippage along the EROEI curve – and *not* the simple issue of 'running out of oil', as some fear – **is the clear and present threat to an economy based on dangerously energy-dependent exponentials**.

[25] British Thermal Unit, a traditional unit of energy
[26] Steam-Assisted Gravity Drainage, a method of extracting bitumen

conclusions – where do we go from here?

A principal aim of Tullett Prebon's strategy research is to identify issues and stimulate discussion. The subject of dangerous exponentials surely provides ample scope for thought for investors, policymakers and the general public alike. Indeed, we believe that **the implications of exponentials should outrank all other issues**.

In compiling this report, we have come to the view that there are two major deficiencies in our current understanding of the world. First, **the whole issue of financial exponentials is nowhere near as widely understood**, even at the policymaking level, **as it surely should be**. We suspect that both policymakers and the public may sense the exponential pattern subjectively, but that the overall picture has not been grasped, articulated, calibrated or discussed. This lack of awareness of the exponentials dynamic results, in part, from a short-term focus which, whilst implicit both in human nature and in the political process, can blind us to the real trends which are unfolding, and which are discernable only from a longer-term perspective.

Second, **there is a *huge* deficiency in the economists' and policymakers' toolkit where EROEI is concerned**.

Our strategy research does not make investment recommendations (though many will no doubt suggest themselves once the exponentials process is appreciated). But our first policy recommendation is that standardised calibration and propagation of EROEI methodology is imperative – without this, our assessment of energy and economic strategy may lead us into major, perhaps disastrous, mistakes.

A seemingly unavoidable implication of this study is that the energy pricing deficiency – the mismatch between, for example, the price of a gallon of gasoline ($2.90) and the value of the work that it displaces (in the example used here, $7,500) – will begin to narrow as the overall EROEI diminishes.

Another is that investors should keep a keen eye on expansions of the money supply because, if this necessary correction to the monetary quantity-velocity equation is not contained, there is a risk of very serious inflation.

A final consideration here is the relative pricing of labour and natural resources within the developed economies. For decades, this pricing equation has moved in favour of labour, yet the workforce has expanded relentlessly whilst the resource base of the earth has not. This is a subject to which we shall doubtless return in future strategy research.

Ultimately, and for all that economists and policymakers concentrate on it, money is not a finite commodity, and new monetary systems can always be devised if others fail. Resources, on the other hand, are as finite as they are critical and irreplaceable. One would indeed, as Kenneth Boulding put it, need to be either a madman or an extremely impractical economist to believe that exponential growth and a finite world are indefinitely compatible.

Dr Tim Morgan
Global Head of Research
June 2010

TPSI 005 | June 2010

Tullett Prebon Group Ltd

155 Bishopsgate
London EC2M 3TQ

Tel: +44 (0)20 7200 7000
Fax: +44 (0)20 7200 7176
www.tullettprebon.com