

# money *is* energy

## an Exponential Economics primer

- **We have called for urgent research into “exponential economics” in general, and the critical energy returns (EROEI) equation in particular. Here’s why.**

In a major report published on 11<sup>th</sup> November<sup>1</sup>, we set out to demonstrate two things – first, that the global economic system has entered a period of unprecedented change, and, second, that **the challenges of this new chapter cannot be addressed effectively using current methods of economic analysis.**

We therefore called for the development of a new discipline of “**exponential economics**” (EE). This brief Note explains what EE is, and why it is so urgently needed.

Essentially, EE means two things. First, it means that we need to move away from the customary short-term assessment of economic issues, and instead adopt an ultra-long term perspective, if we are to understand the essentially *exponential* nature of economic and financial constructs. Second, it means that we need to understand that the economy is, ultimately, **an energy equation.**

From this perspective alone can it be appreciated that our energy-driven economy has turned exponential – an exponential expansion in population, and an exponentially-growing financial system, have been based upon an energy exponential **which is now becoming unsustainable.** Existing systems of economic interpretation – such as Keynesianism and free-market liberalism – do not even begin to tell us what the coming challenge is, let alone how to manage it.

Hence the need for Exponential Economics. Let’s start with the *real* nature of the economy.

### **The economy is *not* about money.....**

Though economists and policymakers customarily think in terms of money, that’s not what the economy is really about. Ultimately, **the economy is an energy equation**, not a monetary one. To be slightly more precise, it is a *surplus* energy dynamic.

*All* forms of energy – food, work and exogenous inputs like oil, gas and coal – are versions of the same thing. Back in pre-agricultural days, when every person was a hunter-gatherer, all of the energy consumed by each person as food was expended finding and catching that food, so there was no energy surplus. No energy surplus meant no specialisation, no society and no economy.

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<sup>1</sup> See Tullett Prebon Strategy Insights, issue six, *End-Game: The Denouement of Exponentials*

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*“If EROEI falls materially, our consumerist way of life is over. It is hardly too much to say that a declining EROEI could bomb societies back into the pre-industrial age”.*

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The first big step forward was the discovery of agriculture in about 9,500 BC. By harnessing economies of scale and by utilising the labour of animals, five individuals or families could be fed by the labour of four, freeing the fifth for non-subsistence activities. This very modest energy surplus enabled limited specialisation, making possible a rudimentary society and economy. But the narrowness of the energy surplus meant that specialisation didn't go far beyond unsophisticated trades and relatively primitive systems of government and law.

The game-changer for human society was the discovery of the heat-engine in the second half of the eighteenth century. From here on, very limited human capabilities could be leveraged massively using exogenous energy inputs such as coal, oil and natural gas. Over the course of the following two centuries, the human population expanded massively, increasing from 700 million at the dawn of the industrial age in the 1770s to almost 7,000 million today, a number that is expected to exceed 8.8 billion by 2040. At the same time, and particularly in the developed economies of the West, very few of these people are engaged in agriculture. The 'green revolution', which *alone* enables the world to feed the current massively-expanded population, is a function of enormous energy inputs.

Here are two examples of the massive leveraging effects of exogenous energy. First, put a gallon of gasoline in your car, drive it until the fuel runs out, then pay someone to push it back. It has been calculated<sup>2</sup> that this would take 500 hours of strenuous labour which, at \$15 per hour, would cost you \$7,500. Yet equivalent work is done by a gallon of fuel costing just \$3.

Second, fix a dynamo to an exercise bicycle, pedal hard and see how many light-bulbs or domestic appliances you can power. The electricity consumed in the typical Western home is roughly equivalent to having an army of 100 employees pedalling exercise bikes. Again, cost that effort at appropriate labour rates, and compare the resulting sum with your electricity bill.

Seen in these ways, **the economy is an energy equation**. Energy inputs do not just make it possible to feed a vast population, but they do so by leveraging the labour of a minority to feed everyone, thereby freeing the majority of the developed world's population to do other things, whether in manufacturing, distribution, technology, government, education, healthcare, the military or any of the thousands of other professions which are essential to society as we know it. And, because of its historic abundance, exogenous energy is extraordinarily cheap, relative to human labour, if we measure both in terms of the common denominator of energy, and then compare their prices.

One reason why exogenous (fossil) fuels are so cheap, of course, is that we have cherry-picked the easiest-to-produce resources first. These are usually thought of as 'cheap' to extract, which indeed they are, but 'cheapness' should be expressed not in terms of dollars, but rather of the energy that has to be consumed in the extraction process. This will be addressed shortly, when we look at the truly critical equation of EROEI (energy return on energy invested).

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<sup>2</sup> See Chris Martenson's *Crash Course*

### ....because money *is* energy

If the economy is an energy equation, it follows that **money is a tokenisation of energy**.

In pre-industrial societies, anything that could be bought with money was the product of human labour, past, present or future. If you bought a house, you were purchasing a product of *past* labour. Paying someone to plant a field was obviously a *current* labour transaction, whilst engaging a carpenter to build a table for you was a payment for *future* labour.

And this equation – money as a tokenisation of labour – remains true, but with the vital difference that the human labour for which money is exchanged is now leveraged massively by exogenous energy inputs. The principle, then, is that **money is energy**, or, rather, is the tokenisation of energy into a convenient form.

Because money is energy, and debt represents a monetary transaction – in which the borrower gives the lender a claim on future money, plus interest – then **debt is a claim on future energy**. In terms of the ability of today's massively-indebted Western economies to repay their obligations, what matters is not whether they will, in the future, have sufficient money – which can always be printed – but whether they will have access to the energy necessary to deliver on what amount to future energy claims.

The alternative, which is simply to 'repay' debts by printing money, does **not** amount to repayment,, but is actually 'soft default'. If someone owes you \$2m, and repays this in money which has since lost half of its value through inflation, he has really only paid you 'value' of \$1m. And, whilst that might seem fine to him, you would think long and hard before lending that person (*or that government*) any further sums in the future.

### The exponential function

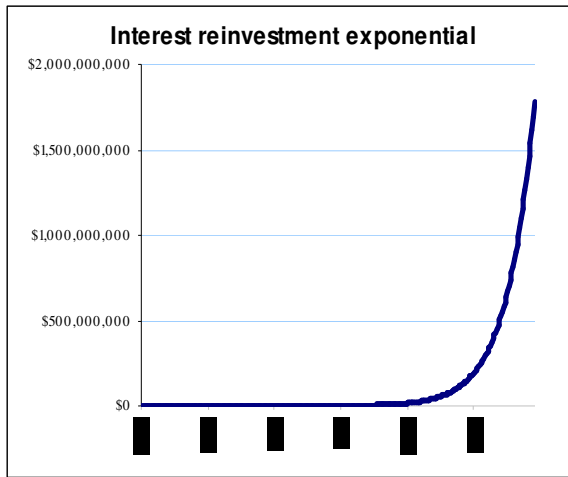
The first key point to note, then, is that the economy is an energy equation. Money is a quantification of energy, so debt, as a claim on future money, is ultimately a claim on future energy.

Since the late eighteenth century, our use of energy has escalated, just as, courtesy of rising energy inputs, the population has escalated as well. A growing population, supported by growing energy inputs, has necessarily resulted in escalating economic output. Unfortunately, it has also resulted in massive forward energy claims, which is what unprecedented indebtedness really amounts to. The big worries here must be, first, that the 'prop' of ever-greater energy usage might weaken and, second, that *the financial system might implode* because the energy claims that it embodies may not be capable of being met in a shrinking economy.

To understand this issue, we need to appreciate the nature of exponential progressions. "The greatest shortcoming of the human race", in the opinion of Prof. Albert Bartlett, "is our inability to understand the exponential function". Though true, this widespread incomprehension is an oddity, and probably results from the customary application of analytical timescales that are simply too short.

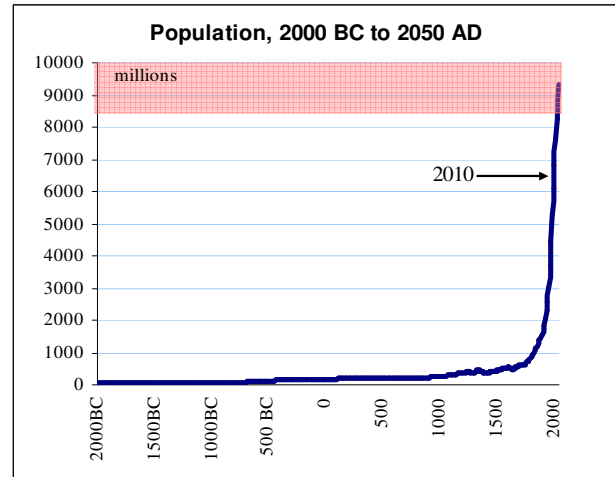
For the exponential function is actually a simple concept. It states that any linear progression of constant percentage changes eventually turns into an exponential dynamic. This is illustrated in fig. 1, which shows the growth in a capital sum of \$1,000 on which annual interest of 5% is reinvested. The result is an accelerating take-off which, when charted, eventually describes a characteristic 'j-curve' or 'hockey-stick' shape.

Fig. 1: Interest exponential



\*Source: Tullett Prebon calculations

Fig. 2: An exponential population



\*Source: US Census Bureau

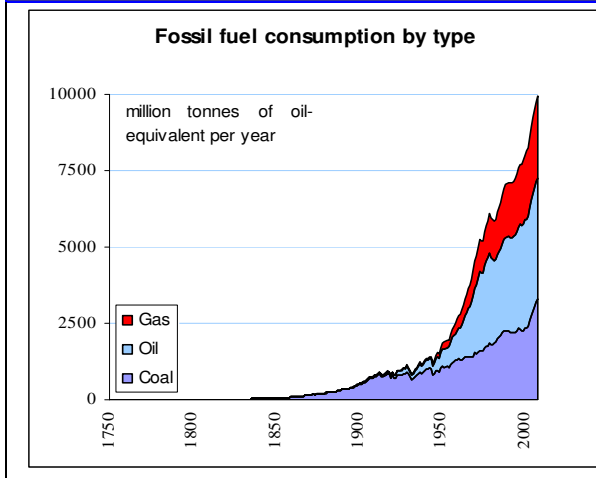
This may seem of no more than passing interest until it is appreciated that *exactly the same thing* has been happening to ‘real world’ issues, typified by population growth, as set out in fig. 2. A glance at this chart will reveal not just that the population has increased massively, but also that it has, to put it colloquially, “turned exponential”. Moreover, the sharp up-trend in population numbers coincides pretty exactly with similarly exponential expansion in the use of hydrocarbons.

That the exponential explosion in hydrocarbon use (fig. 3) should be in sync with the similarly exponential expansion in the global population is no coincidence at all, of course, because, as we have seen, it was the harnessing of exogenous energy which alone made the rapid expansion in the population possible. In fig. 4, we make this relationship explicit. Before about 1770, use of fossil fuels was negligible, and the population was just 700 million. Now, vast amounts of energy are used to sustain a population which has increased roughly ten-fold since then.

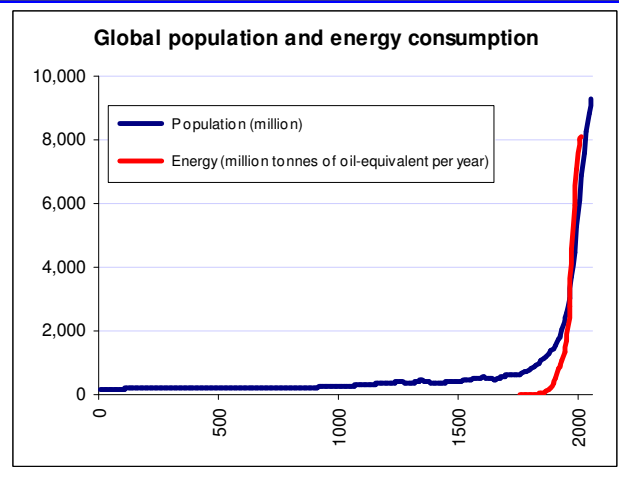
At this point, we might well wonder what might happen if population were to continue to grow – as is generally expected – but the supply of exogenous energy were unable to continue to expand at the same rapid pace.

As fig. 4 shows, energy consumption has actually *out-grown* the population, as, of course, it has to if per capita incomes are to expand in an economy that, as we have seen, is ultimately an energy equation. If energy expansion merely matched population growth, real per-capita output would be stagnant. Of course, any failure of the energy supply to keep up with growth in the population would result in per-capita impoverishment. Were the absolute volume of available energy to decline, as many observers think it will, then this impoverishment would obviously be even worse.

**Fig. 3: Exponential energy consumption**



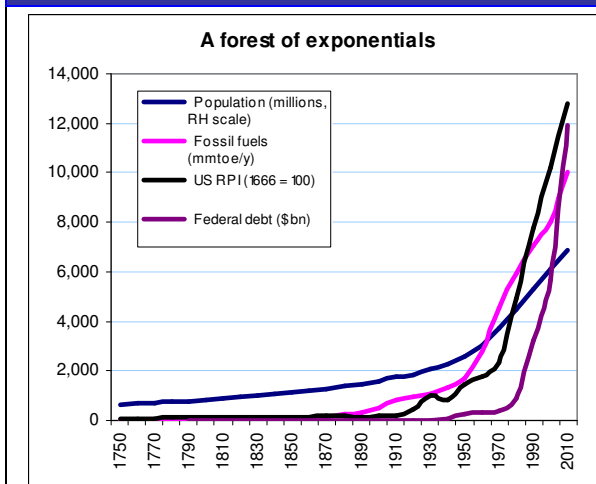
**Fig. 4: Energy and the population**



An absolute decline in available energy volumes, disastrous though it could be, is *not* the immediate issue. The problem is that we have built an exponential, anticipatory financial system on to the foundation of an exponential population and an exponential 'real' economy of goods and services, made possible, of course, by exponential use of comparatively abundant supplies of energy.

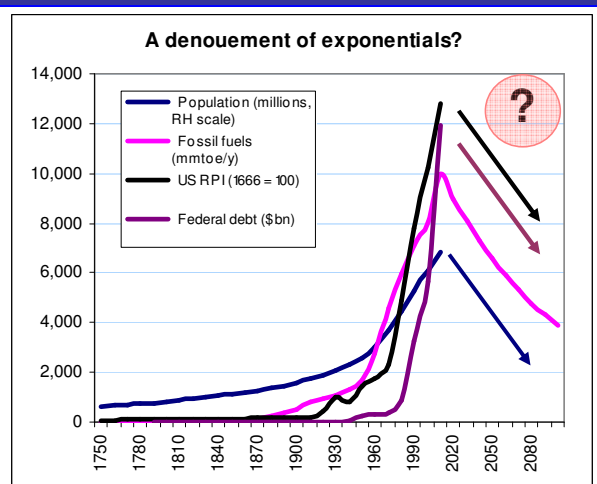
These relationships are made explicit in fig. 5, which shows the remarkably close correlation between trends in population, energy, inflation and debt. Two American examples are used here, but a host of other financial indicators from across the Western economies conform similarly to this exponential pattern. The danger, of course, as highlighted in fig. 6, is that **a decline in the driving energy dynamic could bring all of the other exponentials (including population numbers) down with it.**

**Fig. 5: A forest of exponentials**



\*Source: Tullett Prebon calculations

**Fig. 6: A denouement of exponentials?**



\*Source: Tullett Prebon calculations

### Three critical questions

From the foregoing, it is clear that there are three things which we need to know:

1. **Will** the energy exponential unwind?
2. If so, **when**?
3. **What** can we do about it?

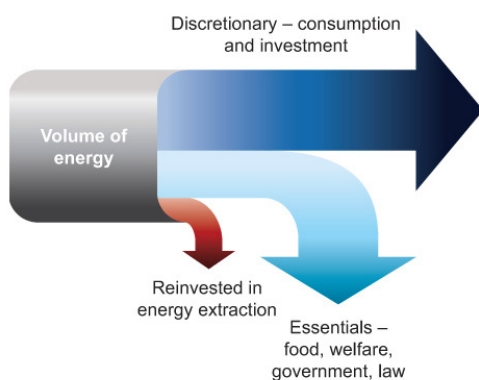
The answer to the first two questions is that *the energy exponential is unwinding already*. We do not subscribe to the Peak Oil belief that petroleum production is about to go into decline because half of all originally recoverable oil reserves have already been consumed, because the reserves argument isn't true if we include harder-to-recover unconventional oils.

However, 'harder to recover' has two nasty implications. The first is that deliverability – that is, the amount produced per year for a given quantity of reserves – is already falling, potentially putting a ceiling over production even if reserves (of all types) remain comparatively plentiful. The second (and worse) implication is that the cost of extracting the remaining reserves of oil (and gas and coal) may escalate.

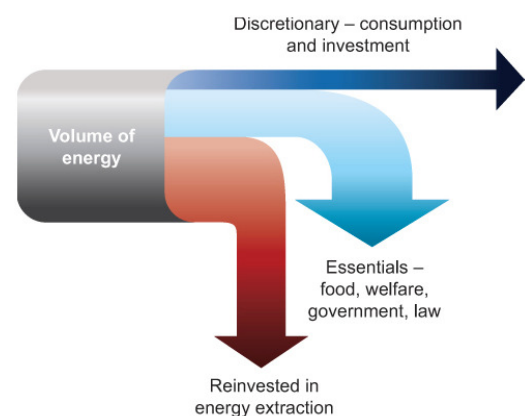
The point here, though, is not cost as expressed in dollars, euros or renminbi, but as expressed in energy. As we have explained, the economy is essentially a *surplus* energy equation. Not all of the energy that is extracted is available for us to use, because some of it has to be reinvested in getting the energy out in the first place. The relationship between energy outputs and inputs can be expressed as 'net energy', but our preferred measure is the Energy Return On Energy Invested (EROEI). It is extremely clear that EROEI is declining as we move from cheaper to costlier energy sources.

Figs. 7 and 8 show what happens if EROI declines. Each chart subdivides the totality of produced energy into three streams. The red component is the proportion of the extracted energy which has to be reinvested into the extraction process, whether as infrastructure (capital) or in extraction (operating) expense.

**Fig. 7: High EROEI**



**Fig. 8: Low EROEI**



With a high-EROEI (fig. 7), the reinvestment amount is small, leaving most of the produced energy to be used to power the economy. Of this, some – shown in light blue – is used for essential purposes, such as food production and the provision of healthcare, law and government. The remainder, shown in dark blue and substantial in fig. 7, powers *all* discretionary activities, including all other forms of consumption and investment.

If EROEI falls, as in fig. 8, much more of the extracted energy is consumed in the extraction process, resulting in a corresponding squeeze on the energy available to the economy. The essentials may still be affordable, but the leverage in the equation is such that energy available for discretionary uses diminishes very rapidly indeed. There, through the EROEI squeeze, goes the car, the holiday, the bigger home, the MP3, the meal out, toys for the children, the afternoon at the golf club or the football match. **If EROEI falls materially, our consumerist way of life is over.**

There are two *really* nasty stings in the tail of a declining EROEI. First, net energy availability may fall **below** the amount required for essential purposes including healthcare, government and law. It is hardly too much to say that a declining EROEI could bomb societies back into the pre-industrial age. Second, of course, a decline in net energy availability could result in conflict driven by competition for access to diminishing surplus energy resources.

What knowledge do we have that can enable us to manage this threat? Not, for sure, deregulated free-market economics (which has helped create the exponential debt mountain), or a reversion to Keynesianism (which proposes that we spend and borrow our way out of excessive indebtedness). Quite apart from their intrinsic impracticalities, both free-market liberalism and Keynesian demand management look at the economy in terms of money, **when the real dynamic isn't money at all, but energy.**

Therefore, *and as a matter of urgency*, we need to develop the technique, which we have dubbed “Exponential Economics”, of understanding the economy as an energy dynamic. And this should start with an effort to calibrate EROEI. A leading academic in this field has assured us that there has been never been *any* material government or corporate funding for EROEI research.

This situation needs to be resolved – and soon.



Dr Tim Morgan

**GLOBAL HEAD OF RESEARCH**

Tullett Prebon Group Ltd | 155 Bishopsgate, London EC2M 3TQ | Tel: +44 (0)20 7200 7000 | Fax: +44 (0)20 7200 7176 | [www.tullettprebon.com](http://www.tullettprebon.com)

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TPSN017 | Tuesday, November 16, 2010 | tpsn0017 - money is energy