Risks to the economy arising from constrained global energy supply
Risks to the economy arising from constrained global energy supply

Exponential Growth
• “The greatest shortcoming of the human race…”

Energy
• The importance of energy to the economy
• History of oil production
• Future prospects for oil

The Economy
• The IMF World Economic Outlook
• The level of indebtedness in Western economies
• We live in interesting times…

Risks and Opportunities for the Actuarial Profession
Exponential Growth

“The greatest shortcoming of the human race is our inability to understand the exponential function” – Professor Albert Bartlett

\[ x(t) = x_0 e^{ti} \]

• The exponential function arises whenever a quantity grows or decays at a rate proportional to its current value.
• For example; compound interest.

Refer: [http://www.albartlett.org](http://www.albartlett.org)
Exponential Growth - Doubling Time

• Doubling time
  Approx. doubling time = 70/(Growth Rate in %)
  Reason: $70 \approx 100 \times \ln(2)$

• Every time you hear a growth rate, think doubling time:
  – “Crime Doubled in a Decade!”
  – “Growth in GDP”
Exponential Growth – Resource Use

For a resource which is used up at a constantly increasing rate:

• In the time it takes to double the rate of use, the amount of resource used will be the same as the resource used in all prior doubling periods combined.

• This is not an intuitive result!
Risks to the economy arising from constrained global energy supply

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Risks and Opportunities for the Actuarial Profession
Why did the industrial revolution start in England?

“Energy and the English Industrial Revolution”

By Sir Edward Anthony Wrigley:
– Professor of Economic History at Cambridge University

• Answers question, “Why didn’t growth stop?”
• Fossil fuel allowed us to escape the limits of land.
• England had easily accessible coal deposits
• Adam Smith and David Ricardo would have considered as absurd the notion that economy could grow by fixed % per year.
The importance of energy to our economy

- Road transport
- Aviation
- Heating and lighting
- Construction
- Mining
- Food production
Our industrial civilization uses about 13 Tera Watts for machinery.

Estimated net primary productivity of Earth’s ecosystems ≈70TW on land*².
Why are Fossil Fuels so Useful?

- Fossil fuel is very energy dense
- Oil is particularly useful as it is liquid – easy to transport
- Energy content of 1 barrel of oil = manual labour of 30 people for 1 month.

“Energy Slaves”

- UK energy consumption per person = 125kWh per day*1 (= 5.2kW per person)
- 1 person produces ~ 75 Watts sustained power
- UK citizens have ~ 70 “energy slaves”

*1 Refer: www.withouthotair.com - David MacKay, ‘Sustainable Energy Without Hot Air’
The Deepwater Horizon Oil Spill
Questions Raised by Deepwater Horizon

- Proximate cause of the oil spill was a blowout, with lax safety standards possibly a contributory factor.
- Why was the blowout so hard to plug?
- Deepwater Horizon rig was drilling through 1 mile of sea and 2 miles of rock.

Question:
- Why drill in such extreme conditions?
Discoveries of new deposits peaked as far back as the 1960s and 1970s. Now a number of countries in addition to the UK and the USA, for instance, have reached their production limits. The quantity of oil being pumped out of the earth exceeds new discoveries.
Global Oil Production Since 1920

From “The Oil Crunch”; Second report of the UK Industry Taskforce on Peak Oil & Energy Security (ITPOES), February 2010 http://peakoiltaskforce.net/
Oil Price and Global Oil Production 2004-
Supply has not yet responded to price signal

Sources: Oil Price – United States EIA http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=rbrte&f=m

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The history of one oil producing region
United States Oil Production 1900-1956

U.S. Crude Oil Production 1900-1956 (Million Barrels per Day)

Source: United States Energy Information Agency
United States Oil Production 1990-2010

U.S. Crude Oil Production 1900-2010 (Million Barrels per Day)

Source: United States Energy Information Agency

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International Energy Agency World Energy Outlook (WEO) 2010

World oil production by type in the New Policies Scenario

Source: Lecture Fatih Birol, Chief Economist of the IEA, at Imperial College, 18 January 2011
http://www3.imperial.ac.uk/newsandeventspggrp/imperialcollege/naturalsciences/climatechange/newssummary/news_20-1-2011-13-4-51
In the 2004 WEO, forecast oil price until 2030:

- Baseline forecast was $25 a barrel.
- “High” scenario was $35 a barrel.

Peak net energy is more important than peak oil energy.

Energy Return On Energy Invested (EROEI)

Energy Return On Energy Investment for an activity:

\[
\text{EROEI} = \frac{\text{Energy delivered to society}}{\text{Energy put into that activity}}
\]

Usually consider energy invested *from society*.

The oil business uses its own product e.g. drilling, exploration – but what matters is the net oil available to society.

From: Charles A.S. Hall
What about alternative energy sources?

There are plenty of alternative hydrocarbons:

- Tar sands
- Oil shale
- Shale gas
- Coal (can convert to synthetic oil – “coal to liquid”)

However:

- Transport needs liquid fuel. There are no easy substitutes*
- The alternatives emit more carbon – this is highly dangerous

*Refer: Hirsch Report, 2005 for the US Department of Energy
Why we can’t burn all the unconventional hydrocarbons

Climate Change

Carbon Dioxide and Temperature Records

Present CO₂ level

δ²H (permille)

Atmospheric CO₂ (ppm)

Thousands of Years Ago
Renewable Energy Sources

- There is a huge amount of renewable energy available: wind, wave, tidal and solar.
- However, these energy sources are diffuse.
- Problem is in capturing, concentrating and storing the energy.
- This requires huge investment.
- Can the investment be ramped up quickly enough to avoid “energy descent”? (i.e. decrease in per capita energy availability).

Refer: David Mackay “Renewable Energy Without the Hot Air”
Risks to the economy arising from constrained global energy supply

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Risks and Opportunities for the Actuarial Profession
Modelling

• IMF estimated energy and oil elasticities in OECD and non-OECD regions (regression on c.50 nations).

• With global growth at 4.6% in 2011-15, oil price rises 75% assuming no supply response.

• China’s energy demand doubles by 2017 vs 2008

Baseline scenario – oil growth reduces from 1.8% to 0.8% p.a.

• 0.8% growth is broadly consistent with the 2010 IEA WEO

• Reduction in global economic growth rate of <0.25%

• Oil price increase of 200% over 20 years
Scenario 2: Faster oil decline (-2% per year)
- 3 to 4x reduction in GDP growth vs baseline scenario
- Oil price increase of 800% over 20 years
- Likely non-linear outcomes of such an increase

Scenario 3: Greater economic role for oil
- Contribution of oil to output 20-25% instead of the 2-5% cost share in the benchmark scenario
- Deterioration in GDP is about 2x larger than in the baseline
IMF World Economic Outlook, April 2011
Chapter 3: Oil Scarcity, Growth and Global Imbalances

Additional Considerations

• Model used by the IMF assumes smooth transitions
• Real economies have highly interdependent industries. Adverse effects could spread to rest of the economy
• Modelling does not consider the possibility that oil exporters may reserve an increasing share of oil output for themselves

Not modelled in the IMF chapter
• What if premises of both scenarios 2 and 3 are true?
The Energy Crunch: A Parallel with the Credit Crunch?

• Not many people predicted the severity of the credit crunch before it happened.

• But some people did predict it - it was predictable.

• Why did so few people predict the credit crunch?

• What can we predict today?
Some recent reports

- Feb 2010 – UK Industry Task Force on Peak Oil, 2\textsuperscript{nd} Report
  “The next five years will see us face another crunch - the oil crunch. ... the era of cheap oil is behind us.”
- June 2010 – Lloyd’s 360 Report, Sustainable Energy Security
  “We are in a period akin to a phoney war”, Lloyd’s CEO Richard Ward
- June 2010 – Tullett Prebon research “Dangerous Exponentialts”
  “there is an impending collision between economic system that must grow and finite resources which cannot grow.”
- April 2011 - GMO letter to investors “Time to wake up: Days of abundant resources and falling prices are over”

GMO are an asset management firm controlling >$100 billion of assets.

Time to Wake Up: Days of Abundant Resources and Falling Prices Are Over Forever

Jeremy Grantham

Summary of the Summary
The world is using up its natural resources at an alarming rate, and this has caused a permanent shift in their value. We all need to adjust our behavior to this new environment. It would help if we did it quickly.
Iron Ore Price
100 year low – then 110 year high within 8 years

Source: GMO Quarterly Letter, April 2011
Oil and Food Prices

UN FAO Food Price Index and Oil Price

Social unrest. Many countries banned grain exports

“Arab Spring”

## Debt to GDP Ratios in Western economies

### Debt remains high in the world's largest mature economies

**Domestic private and public sector debt**

<table>
<thead>
<tr>
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<tr>
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<td>4.7</td>
<td>182</td>
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<tr>
<td>Japan</td>
<td>1.2</td>
<td>1.1</td>
<td>52</td>
</tr>
<tr>
<td>Spain</td>
<td>4.1</td>
<td>6.7</td>
<td>177</td>
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<tr>
<td>France</td>
<td>1.3</td>
<td>4.5</td>
<td>123</td>
</tr>
<tr>
<td>Italy</td>
<td>3.0</td>
<td>3.0</td>
<td>82</td>
</tr>
<tr>
<td>United States</td>
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<tr>
<td>Germany</td>
<td>5.6</td>
<td>0.5</td>
<td>15</td>
</tr>
<tr>
<td>Canada</td>
<td>0.3</td>
<td>1.9</td>
<td>44</td>
</tr>
</tbody>
</table>

1. "Debt" defined as all credit market borrowing, including loans and fixed-income securities.
2. Or longest time period available.

“… deleveraging has followed nearly every major financial crisis in the post-World War II period.”

The four archetypes of deleveraging:

1) Austerity (or “belt-tightening) in which credit growth lags behind GDP growth for many years

2) Massive defaults

3) High inflation

4) Growing out of debt through very rapid GDP growth

My guess: High inflation is most likely. Inflation will be >10% within the next few years – although deflation is also possible.

We live in interesting times…
Bank of England Base Rates since 1694

Source: Bank of England http://www.bankofengland.co.uk/monetarypolicy/decisions/decisions11.htm
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We live in interesting times… United States total debt – fundamental shift

Source: United States Federal Reserve data download program
http://www.federalreserve.gov/datadownload/
We live in interesting times…
The price of gold has nearly doubled since 2009

Source: www.bullionvault.com
Summary of the Argument:

1. Economy relies on fossil energy – oil is the most important part.
2. Oil supply constraints will constrain global GDP growth.
3. Western economies are likely to deleverage, this has hardly started yet.
4. Deleveraging is unlikely to occur through rapid GDP growth.
5. Therefore austerity, default or inflation are most likely.
Risks:

- Actuaries seek to “make financial sense of the future”
- What if we miss the big trends?
- What if our economic assumptions are inaccurate?
Resource and Environmental Issues
Risks and Opportunities for the Actuarial Profession

Opportunities:

• Research on the limits to growth, closing date 31\textsuperscript{st} July 2011.
• New governance structure for the Profession: Resource and environmental issues to be addressed with urgency.
• IAA have organised an environmental committee, we will contribute. IAA meeting in Zagreb, 29\textsuperscript{th} September 2011.
• Networking event on 13\textsuperscript{th} September for actuaries working in this field
• The Resource & Environment Member Interest Group are producing the 2\textsuperscript{nd} Edition Literature Review on Resource & Environment, launch date 17\textsuperscript{th} October 2011
Resource and Environmental Issues
Risks and Opportunities for the Actuarial Profession

• The world needs unbiased forecasting – not optimistic or pessimistic. Actuaries are ideally suited for this role:*
  – Long term thinking
  – Base decisions on data; scientific approach
  – Experts in risk and modelling
  – Exponential growth is bread and butter
  – Used to giving bad news!
• We are coming to this field relatively late. In many ways this is an advantage.
• This is potentially a huge area of work for actuaries; we can be leaders in this field.

Questions or comments?

Expressions of individual views by members of The Actuarial Profession and its staff are encouraged. The views expressed in this presentation are those of the presenter.
Additional slides after here
Exponential Growth – Resource Use

Example: 7% p.a. growth
Exponential Growth – Resource Use

Cumulative Resource Use

- Exponential Growth
- Resource Use

Cumulative Resource Used

- Cumulative Resource Use

- 0

- 2,000

- 4,000

- 6,000

- 8,000

- 10,000

- 12,000

- 14,000

- 16,000

- 0.0

- 20.0

- 40.0

- 60.0

- 80.0

- 100.0

Cumulative Resource Used

- Cumulative Resource Used

- Exponential Growth

- Resource Use

- Cumulative Resource Used

- Exponential Growth

- Resource Use
Where does our energy come from? How much do we use?

Whether directly, or from energy trapped in fossil fuel, the great majority of our energy comes from the sun.

Our industrial civilization uses about 13 Tera Watts (=13 million million Watts) for machinery. In comparison, heat flow from centre of Earth powering all earthquakes ≈40TW. Estimated net primary productivity of Earth’s ecosystems ≈70TW on land.

Source: “Eating the Sun”, by Oliver Morton
Global Fossil Fuel Use – A Long Term View
(after Hubbert, 1969)

Trillion kwh per year

-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5

“Hubbert’s pimple”

Source: Professor Charles A.S. Hall, State University of New York http://www.esf.edu/efb/hall/
Energy Return On Energy Invested (EROEI)

“An assessment of the future outlook for energy inputs needs to be calibrated in terms of an energy rather than a monetary equation.”

Chart from: Morgan T. “Dangerous exponentials: A radical take on the future” Tullett Prebon Strategy Insights issue 5, June 2010
The argument for increased importance of energy to the economy

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The argument for increased importance of energy to the economy
What if we can’t grow the economy?

Economist and Nobel Laureat Robert Solow
From Harper’s Magazine, March 2008

“It is possible,” says Solow, “that the United States and Europe will find that, as the decades go by, either continued growth will be too destructive to the environment and they are too dependent on scarce natural resources, or that they would rather use increasing productivity in the form of leisure. . . . There is nothing intrinsic in the system that says it cannot exist happily in a stationary state.”
Fractional Reserve Banking

“… of all the many ways of organising banking, the worst is the one we have today.” Possible remedies included not just breaking up banks, but also “eliminating fractional reserve banking”

Mervyn King, reported in the Economist, 28\textsuperscript{th} October 2010