Resource and Environmental Limits to Economic Growth

1. Key messages for pensions actuaries
2. A long term view of growth; we live in an exponential world
3. Resource and environmental limits to economic growth?
4. Making sense of the data: The “Limits to Growth”
5. What is the actuarial profession doing?
6. What could it mean for actuarial advice?
Key messages for pensions actuaries

The core issue

• The economy has grown exponentially since the industrial revolution.
• Most pension promises are pre-funded, on the assumption that exponential growth will continue.
• But are our assumptions about exponential investment returns realistic?
• Might we hit biophysical limits to growth within the next few decades?

Key messages for pensions actuaries

Implications for actuarial advice?

• Potential for fundamental changes to economic variables used to value pension liabilities:
  – gilt yields; inflation; equity returns; corporate bond yields
• Uncertain impact on investment returns and sponsor covenant strength
• How might this affect:
  – amount of funding required?
  – where to invest that funding?
• How can the associated risks be managed?
• How does this affect the advice pension actuaries give today?
Resource and Environmental Limits to Economic Growth

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2. A long term view; we live in an exponential world
A Long Term View of Growth

Source: Maddison 2008 [http://www.ggdc.net/MADDISON/maddisonbih.htm](http://www.ggdc.net/MADDISON/maddisonbih.htm)
2. A long term view; we live in an exponential world
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 the 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.


2. A long term view; we live in an exponential world
The importance of energy to our economy

Road transport
Aviation
Heating and lighting
Construction
Mining
Food production
2. A long term view; we live in an exponential world

World primary energy consumption

- Our industrial civilization uses about 13 Tera Watts for machinery.
- Estimated net primary productivity of Earth’s ecosystems ≈ 70TW on land.

Source: BP Statistical Review of World Energy 2011

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*
  (= 5.2kW per person)
- 1 person produces ~ 75 Watts sustained power
- UK citizens use ~ 70 “energy slaves”

* Refer: www.withouthotair.com - David MacKay, ‘Sustainable Energy Without Hot Air’
2. A long term view; we live in an exponential world

We are addicted to oil

We are addicted to fossil fuels, especially oil.

"Here we have a serious problem: America is addicted to oil, which is often imported from unstable parts of the world,“ George W. Bush, 2006 State of the Union address


2. A long term view; we live in an exponential world

Exponential Growth

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

– Professor Albert Bartlett, Colorado University

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

Source: http://www.albartlett.org

There is a great presentation about exponential growth at this web address.
2. A long term view; we live in an exponential world

Exponential Growth

Well known rule of thumb for doubling time

- Approx. doubling time = 70/(Growth Rate in %)
  Reason: $70 \approx 100*\ln(2)$
- E.g. 7% p.a. growth means doubling time of $70/7 = 10$ years

Not so well known rule of thumb for cumulative resource used during doubling period

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.

Cumulative Resource Use @7% p.a. growth

- 10\textsuperscript{th} doubling period.
- Same resource used as in previous 9 periods combined.
2. We live in an exponential world

Technology and knowledge

Moore's Law
The number of transistors that can be placed inexpensively on an integrated circuit doubles approximately every two years.

Intellectual Property
No. of patents granted illustrates the explosive growth in human knowledge.

Utility Patents Granted in United States 1800-2010

1. GDP
2. Population
3. Paper consumption
4. Motor vehicles
5. Foreign investment
6. CO₂ concentration
7. Loss of tropical woodland
8. Water use
9. Species extinction
10. Fisheries exploited

Source: New Scientist 16 October 2008
http://www.newscientist.com/article/mg20026786.000-special-report-how-our-economy-is-killing-the-earth.html
2. We live in an exponential world
World GDP Growth Trends

- World GDP has grown at average rate of c.3% per year in recent decades (in real terms).
- Doubling time at 3% p.a. is just over 23 years.
- From 2012 to 2100 is almost 4 doubling periods.
- World economy would grow 14 times as large in 2100 as it is now.

2. A long term view; we live in an exponential world
Is growth always good?

- Many things have an optimal size – further growth is bad
  - E.g. People!

Question: Is economic growth always good?
Resource and Environmental Limits to Economic Growth

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3. Resource limits to growth: Peak oil
Global Oil Production Since 1920

Was no accident that the original “Limits to Growth” study was published in 1972.

From “The Oil Crunch”; Second report of the UK Industry Taskforce on Peak Oil & Energy Security (ITPOES) , February 2010 http://peakoiltaskforce.net/
3. Resource limits to growth: Peak oil

IMF World Economic Outlook, April 2011

Baseline scenario 0.8% p.a. oil growth for 20 years.
- Minimal effect on economic growth (reduction of <0.25%)

Two alternative “peak oil” scenarios: Greater decline in oil (-2% p.a. instead of +0.8%); and greater dependence on oil.
- Result was much larger loss of GDP than baseline (3 to 4X in first scenario and double in second scenario).
- Oil price increases 800% over 20 years.
- Additional adverse effects possible from interdependencies.
- Oil-exporting nations may keep more oil for themselves.

Source: IMF World Economic Outlook – April 2011
3. Resource limits to growth: Peak oil
Oil Discoveries versus Oil Production

"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."

Source: Munich Re Foundation 2009 Report page 28

3. Resource limits to growth: Peak oil
Global Fossil Fuel Use – A Long Term View

"Hubbert’s pimple”

Total world fossil fuel consumption in 2008 estimated at 116.8 x 10^15 watts

3. Resource limits to growth: Peak oil
United States Oil Production 1900-1956

In 1956 the geologist M. King Hubbert predicted US oil production would peak by 1970.

The US Geological Survey said that this prediction was nonsense – the peak would be much further in the future.


3. Resource limits to growth: Peak oil
United States Oil Production 1900-2010

3. Resource limits to growth: Peak oil
International Energy Agency WEO 2010

World oil production by type in the New Policies Scenario

- Unconventional oil
- Natural gas liquids
- Crude oil - fields yet to be developed or found
- Crude oil - currently producing fields
- Total crude oil

Source: Lecture Fatih Birol, Chief Economist of the IEA, at Imperial College, 18 January 2011
http://www3.imperial.ac.uk/newsandevents/pggrp/imperialcollege/naturalsciences/climatechange/newssummary/news_2011-13-4-51

3. Resource limits to growth: Peak oil
IEA: WEO forecasts in years 2004-2010

In the 2004 WEO forecast of oil price until 2030:
- Baseline forecast was $25 a barrel.
- “High” scenario was $35 a barrel.

Source: Chris Martenson summary of IEA WEO's http://www.chrismartenson.com/
3. Resource limits to growth: Peak oil

Some reports on resource constraints

- Feb 2010 – UK Industry Task Force on Peak Oil, 2nd Report
  “The next five years will see us face … the oil crunch.”
- June 2010 – Lloyd’s 360 Report, Sustainable Energy Security
  “We are in a period akin to a phoney war”, Lloyd’s CEO R.Ward
- June 2010 – Tullett Prebon research “Dangerous Exponentials”
  “… 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”

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3. Resource limits to growth: Peak oil

The Energy Crunch: Another Credit Crunch?

Two excellent books telling stories about people that saw the credit crunch coming.

- Not many people predicted the severity of the credit crunch.
- But some people did predict it - it was predictable.
- Why did so few people predict the credit crunch?
- What can we predict today?
3. Environmental limits to growth
Hard-wired environmental limits?

From Rockstrom et al "A safe operating space for humanity", Nature 2009
http://www.nature.com/nature/journal/v461/n7263/full/461472a.html

3. Environmental limits to growth: Climate change
Cumulative CO₂ emissions from fossil fuels

Carbon dioxide Emissions from fossil fuel burning 1750-2004

- Total CO₂ emissions from fossil-fuels (million metric tons of C)
- CO₂ emissions from gas fuel consumption
- CO₂ emissions from liquid fuel consumption
- CO₂ emissions from solid fuel consumption
3. Environmental limits to growth: Climate change

Temperature versus CO₂ concentration

Carbon Dioxide and Temperature Records

3. Environmental limits to growth: Climate change
Updated “Reasons for Concern”

From: Smith et al PNAS
3. Environmental limits to growth: Climate change
NAS - Climate Stabilization Targets 2011

- Fossil fuel CO$_2$ emissions have created new epoch.
- Human activities will largely determine the evolution of Earth’s climate.
- Man-made CO$_2$ stays in the atmosphere a long time.
- Future generations may be locked into a range of impacts, some of which could become very severe.
- E.g. For 4°C temperature increase, c.9 out of 10 summers warmer than warmest ever experienced in late 20$^{th}$ century.


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4. Making sense of the data: The Limits to Growth

The human economy is a subset of the Earth

- Climate change
- Other environmental problems e.g. biodiversity
- Oil depletion
- Other resource depletion e.g. phosphorus

All driven by increasing consumption by humans – caused by exponential growth of population and the global economy.

Growth drives our problems!
4. Making sense of the data: The Limits to Growth

The human economy is a subset of the Earth

*Space to grow*  
*At the limits*

(adapted from Clapp and Dauvergne 2005: p.101)

4. Making sense of the data: The Limits to Growth

Human impact on the Earth – a simple approach

\[ I = P \times A \times T \]

* I = Impact  
* P = Population  
* A = Affluence (consumption per capita)  
* T = Technology (environmental impact per unit of consumption)
4. Making sense of the data: The Limits to Growth
What about technology?

\[ I = P \times A \times T \]

- If affluence and population grow, for impact to stabilize or shrink, technology must improve.
- But, since 2000, global carbon intensity of GDP has been increasing. Probably driven by increased coal use*.
- We are betting the house on technology. But it isn’t working yet!

*Reference: “Reframing the climate change challenge”, Anderson & Bows 2008
http://rsta.royalsocietypublishing.org/content/366/1882/3863.short
4. Making sense of the data: The Limits to Growth
The myth of decoupling GDP from physical inputs

From The Economist magazine, May 2011

- Humans are reshaping the planet on a geological scale
- e.g. Athabasca tar sands, 30 bn tonnes of earth moved per year = 2x sediment flowing down all rivers in the world
- Moment of realisation, like Copernicus grasping that the Earth revolves around the sun.
- “It would be odd not to be worried.”

4. Making sense of the data: The Limits to Growth
The “End of the World Syndrome”

- Joseph Tainter “The Collapse of Complex Societies”*
- Every age has its doomsayers. They’ve all been wrong.
- Need a scientific approach not value judgments.
- Is there data which shows that our age is objectively different?
  Yes!
  - Wealth
  - Fossil fuel use
  - Atmospheric CO\textsubscript{2} concentration c.390ppm
  - Population c.7 billion


State of the Planet Declaration:
- “1. Research now demonstrates that the continued functioning of the Earth system as it has supported the well-being of human civilization in recent centuries is at risk…”

See: http://www.planetunderpressure2012.net/
4. Making sense of the data: The Limits to Growth

1. Tullett Prebon (£0.5bn revenue), 2010
   • Impending collision between economic system and finite resources.
   • “one of the most important changes in the lifetime of anyone reading this report”

   “A forest of exponentials”*  
   Dr. Tim Morgan, head of research

2. GMO Asset Managers (> $100bn assets under management)
   Jeremy Grantham, Quarterly Letter, April 2011: “Time to Wake Up”
   • Days of abundant resources and falling prices are over forever.
   • The world is using up its natural resources at an alarming rate.
   • This has caused a permanent shift in their value.

   *Chart from: Morgan T. “Dangerous exponentials: A radical take on the future”  
   Tullett Prebon Strategy Insights issue 5, June 2010

4. Making sense of the data: The Limits to Growth

Why didn’t anyone see this coming?

• Exponential growth has a simple mathematical formula.

• Why didn’t anyone predict these problems decades ago?

• Answer: Someone did, but the message was forgotten.
4. Making sense of the data: The Limits to Growth

The “Limits to Growth” Study

The original 1972 study was updated in 2004

Example below of one of the indicative modelled scenarios (not a prediction)

4. Making sense of the data: The Limits to Growth

The story of the “Limits to Growth”

- A group of systems scientists in MIT* were commissioned by the Club of Rome.
- The book “Limits to Growth” was published in 1972. Sold over 20 million copies.
- Was controversial, attacked by “cornucopians”.
- 1970s oil shocks and “stagflation” appeared to confirm predictions.
- But in 1980s, cheaper oil let economies grow again. The “Limits to Growth” was forgotten.

Time to rediscover the Limits to Growth?

*Donella H. Meadows, Dennis L. Meadows, Jørgen Randers, and William W. Behrens
4. Making sense of the data: The Limits to Growth

The “Limits to Growth” argument

- Endless physical growth in a finite world is not possible.
- If growth in consumption is not contained, humanity will exceed the carrying capacity of the Earth.
- Exceeding the carrying capacity of the Earth carries risk.

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5. What are actuaries doing?

**UK Profession**

- Resource & Environment MIG has >400 members
- Resource & Environment Panel set up to guide profession. Peter Tompkins chairs. Philip Scott has joined.
- Networking event held in September 2011. To be repeated this September.
- Research into the limits to growth has been commissioned. Led by Dr Aled Jones at Anglia Ruskin University.
- Launch event for Limits to Growth research in January 2013.

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5. What are actuaries doing?

**UK Profession – Literature Reviews**

1\textsuperscript{st} Review – November 2010
Broad range of climate change, environmental and resource issues covered

2\textsuperscript{nd} Review – November 2011
17 actuaries reviewed 21 papers and reports
Continued coverage of broad environmental and resource issues, with particular focus on energy

3\textsuperscript{rd} Review – estimated March 2013
Focus will be on the sustainability of the financial system

Search for “Climate change and resource depletion” on [www.actuaries.org.uk](http://www.actuaries.org.uk) for easy access to the reviews
5. What are actuaries doing?

**Capital Markets Climate Initiative**

“CMCI is a public-private initiative designed to support the scale up of private finance flows for low carbon technologies, solutions and infrastructure in developing economies…”

**Climate Bonds Initiative**

*Co-founded by Nick Silver*

- “We are looking for investment-grade returns that also address climate change. The Climate Bond Standard will allow us to know that investment opportunities put before us will be the right ones to build a Low Carbon Economy.”

  — Jack Ehnes, CEO of California Teachers Retirement System

http://climatebonds.net/

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5. What are actuaries doing?

**International Profession**

- United States: Society of Actuaries group to investigate resources, assisted by Professor Molly Jahn
- Casualty Actuarial Society Climate Change Committee
- IAA Environment Working Group
- Environment session at IAA meeting Los Angeles 25th May 2012

5. What are actuaries doing?
Tick the REG box if you want to keep up to date

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6. What could it mean for pensions actuaries?

• Resource and environmental limits to growth could fundamentally change the pensions landscape:
  – The past may be a poor guide to the future
  – Current market prices may not fully reflect the risks
  – Risk assessments may underestimate the potential impacts
• How might this affect actuarial advice?
  – Have your clients considered the risks of limits to growth?
  – How do these risks affect the pension funding scenarios?
  – Does this strengthen the case for “green” investment?

6. What could it mean for pensions actuaries?

• What does this mean for pensions more generally?
  – People will still need pensions
  – Actuaries are ideally placed to develop solutions
  – The Profession’s “Limits to Growth” project will provide a useful platform
• And what about wider fields?
  – Some actuaries are already thinking hard about these issues
  – This is about long-term (financial) risks and fits well with actuaries’ core skills
  – It is potentially a huge area of work for us; we can be leaders in this field.
Final Thought and Further Reading

Every time you see growth mentioned, question the assumptions that lie behind…

Further reading:
- [www.theoildrum.com](http://www.theoildrum.com) (energy)
- [http://www.energybulletin.net/](http://www.energybulletin.net/) (energy)

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.

Feel free to contact me at: oliver@oliverbettis.com

Also Twitter at @OliverBettis
Limits to Growth: Additional Slides

Red Pill or Blue Pill?
Red Pill or Blue Pill?
Why take the red pill?

- Solvency II
- We actuaries have the skill-set to understand what’s going on.
- We are actuaries – we look at data and try to strip away bias every day of the week.

Red Pill or Blue Pill?
Shift from financial assets to real assets

Source: www.bullionvault.com
Red Pill or Blue Pill?
Shift from financial to real assets: Iron Ore

Red Pill or Blue Pill?

USA total debt outstanding, private and government 1952-2010

Source: United States Federal Reserve data download program
http://www.federalreserve.gov/datadownload/
Red Pill or Blue Pill?
Opportunities for Actuaries

• 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  
  – Experts in the financial system  

• This is potentially a huge area of work for actuaries; we can be leaders in this field.


Red Pill or Blue Pill?
One possible area – Reform of financial system?

This was a conference on 29th September 2011 organised by Prof. Richard Werner

Keynote speakers: Lord Adair Turner and Professor Charles Goodhart
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=pets&s=rbrte&f=m
Oil Production: BP Statistical Review of World Energy 2011
http://www.bp.com/sectionbodycopy.do?categoryId=7500&contentId=7068481

Oil and Food Prices

http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pets&s=rbrte&f=m
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

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”
Bank of England Base Rates since 1694

Interest Rate, %

Source: Bank of England [http://www.bankofengland.co.uk/monetarypolicy/decisions/decisions11.htm]

McKinsey Global Institute
Debt to GDP Ratios in Western economies

Debt remains high in the world’s largest mature economies
Domestic private and public sector debt by country, 1990–2010
% of GDP, quarterly data

Compound annual growth rate (%)

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</tbody>
</table>

1. Debt defined as all credit market borrowing, including loans and fixed-income securities.
2. Oldest 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.


The credit crunch
A risk management failure

• “Yes, I found a flaw,” Greenspan said in response to grilling from the House Committee on Oversight and Government Reform.

``We cannot expect perfection in any area where forecasting is required,” he said. “We have to do our best but not expect infallibility or omniscience.”

Worldview

- “Worldview” = beliefs, attitudes and values that make up our mental model of the world.
- Our worldview is our window on the world.
- It is also a filter. We tend to see only information that confirms our existing worldview.
- Psychologists call this assimilation bias.

Refer to: “Making Actuaries Less Human – lessons from behavioural finance”

Cognitive Dissonance

Inconsistent cognitions produce dissonance (a state of unpleasant arousal) when:
- You have freedom to decide
- You are committed to your behaviour
- The behaviour leads to foreseeable adverse consequences

The easiest way to reduce dissonance is to change beliefs.

Refer: “Mistakes were made (but not by me)” by C.Tavris and E.Aronson
Prosperity Without Growth
Happiness versus GDP per capita

When material needs are met, further wealth doesn't have much effect on happiness.

Summary of the argument

- Poor nations need growth for basic needs.
- For rich nations, much consumption is competitive. Competition induces anxiety.
- Trying to grow carries great risks and might not be possible much longer.
- For rich nations, it’s in our self-interest not to grow any more.
- Trade wealth for leisure.
- Alternative steady state economics exists, we can change if we want to.

Prosperity Without Growth
Economist and Nobel Laureat Robert Solow

“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.”

From Harper’s Magazine, March 2008

Prosperity Without Growth?
JS Mill on the stationary state

John Stuart Mill, Principles of Political Economy, 1848

“I cannot, therefore, regard the stationary state of capital and wealth with the unaffected aversion so generally manifested towards it by political economists of the old school. . . . I confess I am not charmed with the ideal of life held out by those who think that the normal state of human beings is that of struggling to get on; that the trampling, crushing, elbowing, and treading on each other’s heels, which form the existing type of social life, are the most desirable lot of human kind, or anything but the disagreeable symptoms of one of the phases of industrial progress.” [my emphasis]
Prosperity Without Growth?
JM Keynes

John Maynard Keynes, 1945
“The day is not far off when the economic problem will take the back seat where it belongs, and the arena of the heart and the head will be occupied or reoccupied, by our real problems — the problems of life and of human relations, of creation and behaviour and religion.”

Prosperity Without Growth
Why are politicians so afraid of growth stopping?

Our economic system depends on growth because:

• Improving technology drives increasing productivity.
• Productivity growth means the same number of people can generate more goods and services.
• People need to consume those additional goods & services or unemployment rises.
• Therefore the economic system we have needs rising consumption to function.
• Fractional reserve banking system adds to instability.
Prosperity Without Growth
We have a Culture of Exponential Growth

• Some things we “know” without learning. We “know” that economic growth is always good at all times, for everyone.
• These things that we “know” are cultural rules, not absolutes.

• The ancient Egyptians knew they should build pyramids.
• They were not built by slaves but by workers.


Prosperity Without Growth
Maybe the time has come?

In Ed Miliband’s holiday reading – August 2011

“Prosperity Without Growth” by Prof. Tim Jackson