



The Actuarial Profession

making financial sense of the future

Research Report

Resource constraints: sharing a finite world

Implications of Limits to Growth for the Actuarial Profession

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Resource constraints: sharing a finite world Implications of Limits to Growth for the Actuarial Profession

*Presented by the
The Institute and Faculty of Actuaries*

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Executive Summary

The evidence for resource constraints is strong but many actors in the global economy are not considering it in their decision making processes

This report, and an accompanying evidence report¹, demonstrate clear evidence for constraints across a range of resources over the short (years) and medium (decades) term. Some resource constraints will have local impacts (such as water) while others will have global impacts (such as oil). How resource constraints impact upon the economy is complex, uncertain and depends on a number of factors including how society responds. Political and market responses will have far reaching consequences which need to be better understood and better modelled by decision makers and their advisors. To some degree the impacts can be managed, or at the very least influenced – the outcomes very much depend on societal and government response to the problems caused.

Resource constraints might place a limit to future economic growth rates

Resource constraints will, at best, increase energy and commodity prices over the next century and, at worse, trigger a long term decline in the global economy and civil unrest. As resource constraints raise the possibility of a limit to economic growth over the medium term, actuaries should urgently seek to understand the implications of this for their advice, assumptions and models.

Resources (and their interrelationship) represent a hidden set of determining factors to financial and demographic variables

These factors are ignored in standard economic modelling although they have had a significant impact on the economy in the past. In this report we review the historical evidence to explore the implications for the main actuarial assumptions including:

- **Discount rates:** Historical evidence suggests that lack of access to resources, especially energy, can lead to low economic growth which could cause low real interest rates and asset returns. Nominal interest rates are not predictably affected by low growth and in times of duress, governments might suppress interest rates and investment returns.
- **Inflation:** Periods of low growth tend to correspond to periods of low real wage growth. Commodity price shocks can cause inflation, but, depending on the circumstances and the reaction of policymakers, shocks cause inflation but also lead to low or negative real wage growth. Wages can be suppressed in times of national crisis.
- **Demography:** Historical evidence suggests that while life expectancies have improved, periods of social and economic trauma can lead to declines in life expectancy. Beneficiaries of long term financial products such as pensions are a select group who may be insulated from the worsening mortality of the rest of the population.

The reaction of governments and other agents is crucial to the outcome for the global economy

If governments and economic agents anticipate resource constraints and act in a constructive manner, many of the worst affects can be avoided. Following shocks caused by resource constraints, the reaction of governments, for example in their decision over money supply and where to direct investment, will be the major determinant of the impact on the

¹ Jones, Allen, Silver, Cameron, Howarth & Caldecott, 2013, *Resource Constraints: The Evidence and scenarios for the future*, The Institute and Faculty of Actuaries

economy and the finance sector. Actuaries are well placed to advise governments and other economic agents because of their understanding of risk management and long term modelling.

This report modelled the impact of resource constraints on a pension fund

All of the scenarios modelled in this report showed lower returns on assets and higher costs for schemes compared to the “no constraints” model. Specifically the level of defined contribution pensions, compared to projected salary prior to retirement, for the worst scenarios is almost half of that of the “no constraints” scenario. A healthy defined benefit pension scheme could become insolvent within 35 years solely as a result of the limitations to growth as modelled, and in the absence of other detrimental influences (such as those experienced over the last 15 years in some western countries).

The impact of resource constraints on a long term savings vehicle such as a pension fund would be profound

If future economic growth is limited by resource constraints, or realistically by other factors such as debt overhang or reduced productivity, this puts into question the viability of current savings vehicles’ structure, regulation and even purpose.

Modelling resource constraints

In this report we explore 4 different scenarios associated with resource constraints:

Business as usual

Governments and financial markets have a low sensitivity to resource limitations. Prices for resources are set based on short term availability (supply and demand) and government regulation focuses on managing the flows of these resources rather than their stocks. Decision making for both the finance sector and government does not take into account limits to resources.

Price driven change

Governments have a low sensitivity to resource limitations, while markets have a long term outlook of the stock availability of resources. Price signals within the market are set based on the long term availability of resources. However, no regulation is put in place to manage the availability of resources.

Regulation driven change

Governments operate on a long term basis and regulate the stock of resources rather than the flows. The market responds to regulatory change in a short term way. The feedback from market change to policy development is not always effective.

Consensus driven change

Governments and the market operate on a long term basis by pricing and regulating the stock of resources rather than the flows.

Each of the 4 scenarios is developed on an “optimistic” and “pessimistic” basis resulting in 8 possible outcomes. These scenarios explore the implications of markets and/or government responding to the resource challenge. These scenario outcomes are then compared with a “no constraints” scenario to explore a worked example of an actuarial model for a pension scheme.

Questions for the Actuarial Profession

The findings of this report suggest actuaries need to become conversant in a number of issues which are not within their traditional range of expertise, such as the relationship between energy and other resources and the economy and the economic impacts of climate change.

The following are suggested questions which could help frame future work for the Actuarial Profession:

The role of the actuary

- Should the profession investigate a range of “future scenarios” and engage with the membership on these?
- How best should actuaries communicate emergent risks?
- Do actuarial standards need review in this context?
- If these risks are modelled how should actuaries present this information to help inform political decision making?
- What is the most useful measure (or set of measures) of these risks?

Actuarial methodology

- What sort of changes of circumstances might give rise to volatility and step-changes in financial and demographic variables?
- How key is continued economic growth to the institutions and financial products modelled by actuaries? What would actuarial models look like in a low growth world?
- What is rational savings behaviour, and hence how should savings and risk management vehicles be designed in a low growth world?
- How can future low probability, high impact events (extreme cases, contingent scenarios and catastrophic risk) be modelled?
- Are correlated risks associated with resource constraints and climate change being recognised in investment and business strategies?

The impact of resource constraints

- Which resources or combination of resources, if any, could give rise to systemic economic risks and under what time frame?
- What effect might systemic economic risks have?
- What are the implications of resource constraints and systemic risk for capital market regulators?
- How may investments be affected by future political responses to resource constraints and climate change?
- What are the implications for enterprise risk management (ERM) of the risks associated with resource constraints and climate change?

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1. Introduction

The Institute and Faculty of Actuaries have conducted a series of literature reviews² to explore the current evidence for resource constraints and climate change. To build on this work the Global Sustainability Institute at Anglia Ruskin University was commissioned to undertake further research and modelling of the possible impacts of resource constraints on actuarial advice.

This report, and the accompanying evidence report³, brings together the latest information and research on resource constraints. We examine the current situation and projections for a range of resources including oil, coal, natural gas, uranium, land, food, water and metals. We also consider the environmental loading of the planet in terms of climate change and planetary limits.

Actuaries are ideally placed to play a key role in the identification, measurement and modelling of the systemic risks that these threats could represent. If resource constraints do provide a limit to economic growth then these impacts need to be modelled and understood.

The aim of this research is not to declare that we are all “doomed!” Rather the research questions the risks that resource constraints hold for policy makers and financial institutions when considering the future and what impact this has on the products, services and decisions that we make today. There is a particular emphasis on the questions that we should be raising now in order that we might divert the worst case scenarios in favour of better outcomes for all.

The current narratives around economics and limits to growth are discussed in this context within the report. The report explores the potential impact of resource constraints on the global economy and society by developing a number of scenarios, which reflect the range of possible outcomes. These scenarios are then developed into a case study illustrating how an actuary might incorporate resource constraints by developing assumptions and a model of a savings vehicle.

The evidence shows that resource constraints will, at best, increase energy and commodity prices over the next century and, at worse, create an uncertain and unstable economy. As resource constraints raise the possibility of a limit to economic growth over the medium term, actuaries should seek to understand the implications of this for their advice, assumptions and models.

The future could be very different from the past. If we were faced with a constraint on one resource, such as oil, the market would be able to respond through appropriate pricing and business would innovate to create an appropriate substitution. However, the global economy and financial sector are facing a systemic risk – one in which many resources are

² See for example *Climate change and resource depletion: the challenges for actuaries: Review of literature* 2011, I. Allen, N.G. Aspinall, S.D. Baxter, O.D. Bettis, S.J.R. Brimblecombe, F. M. Brofman-Epelbaum, C. Fitzgerald, S. Harrison, V.J. Hodge, C. C. Jones, B.P. Maher, E.H. McNeill, P.G. Meins, A. Mookerjee, G. Morrison, N. Niami, N.G. Silver, T. Zalk, The Institute and Faculty of Actuaries

³ Jones, Allen, Silver, Cameron, Howarth & Caldecott, 2013, *Resource Constraints: The Evidence and scenarios for the future*, The Institute and Faculty of Actuaries

becoming more expensive and increasing environmental pressures are creating additional costs. The implications for actuarial practice are urgent, complex and many.

In 1972 the Club of Rome⁴ produced a report called the Limits to Growth. This used systems dynamics theory and computer modelling to analyze the long term causes and consequences of growth in the world's population and material economy. Twelve scenarios from the World 3 computer model showed different possible patterns of world development over the two centuries from 1900 to 2100. These illustrated how world population and resource use interact with a variety of limits. In every realistic scenario the model found that these limits force an end to growth sometime in the 21st century. However, by specifying major changes in policies the model can generate scenarios with an orderly end to growth followed by a long period of relatively high human welfare.

The Limits to Growth report attracted significant controversy and rejection of its scenarios, however the data available to the present day agrees worryingly well with the projections, as figure 1 below illustrates.

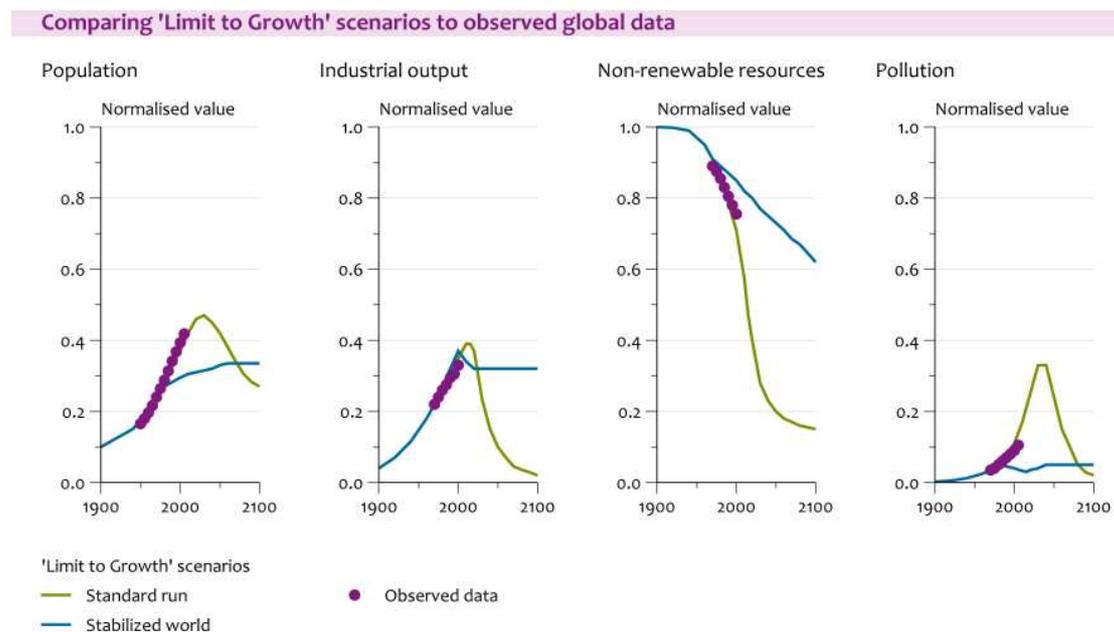


Figure 1: Comparison of World3 Limits to Growth scenarios (the standard run 'business as usual' projection and the stabilised world projection) to observed data.⁵

The impact of resource constraints on economies is complex and depends on a number of factors. Political and market responses to the challenges associated with resource constraints will have far reaching consequences which need to be better understood and better modelled. To a large extent the impacts could be managed, or at the very least influenced.

⁴ Donella Meadows, Jorgen Randers, Dennis Meadows & William W Behrens *The Limits to Growth*, 1972.

⁵ *Growing within Limits: A Report to the Global Assembly 2009 of the Club of Rome*, PBL Netherlands Environmental Assessment Agency, October 2009

2. Resource constraints

The evidence for resource constraints is compelling. Particular resources constraints will have direct local impacts (such as water), and could impact globally through supply chains and through second order effects such as increased food prices and instability, while others will have direct global impacts (such as oil).

Here we briefly highlight some of the constraints the global economy faces. The accompanying evidence report⁶ brings together a more detailed review of these resource constraints.

For every resource examined the overall trend is one of more expensive extraction and increasing prices. In addition the environmental damage caused by the use of these resources is becoming more expensive – in particular through the impact of increased extreme weather events driven by climate change.

Figure 2 is an example of a local resource constraint – namely soil degradation. While agricultural productivity has increased, competition over land is increasingly driven by growing populations, non food crop production, urbanisation, desertification, salination and soil erosion. Land availability and quality will have global consequences through food availability and prices. There is an increasing trend for large scale land purchases globally and average global soil quality is lowering due to a number of factors including over farming and changes in weather patterns.

Figure 3 highlights the approximate number of years left for globally traded resources including fossil fuels and metals based on current consumption. The overall trend for all of these resources is increasingly difficult extraction, lower quality ores and higher demand. Therefore, the increases in prices seen over the past decade for these resources is likely to remain and projections for the future would indicate further rises are likely⁷. If demand for these resources were to increase (as is projected for the majority) then there would be further stress placed on availability.

Figure 4 explores environmental loading as another resource constraint. The ability of the environment and the atmosphere to absorb and process society's waste (whether solid waste, pollution or carbon dioxide emissions) is reducing and key 'sinks' are already projected to cause significant impacts on human society over the next century including changes to the nitrogen cycle. While the analysis of planetary boundaries does not directly link to economic risks and includes both local and global issues there is already evidence of the increasing cost of environmental damage (in particular associated with climate change).

⁶ Jones, Allen, Silver, Cameron, Howarth & Caldecott, 2013, *Resource Constraints: The Evidence and scenarios for the future*, The Actuarial Profession

⁷ Gas fracking in the United States is the one exception where there is a medium term increase in the local supply available leading to a lower price.

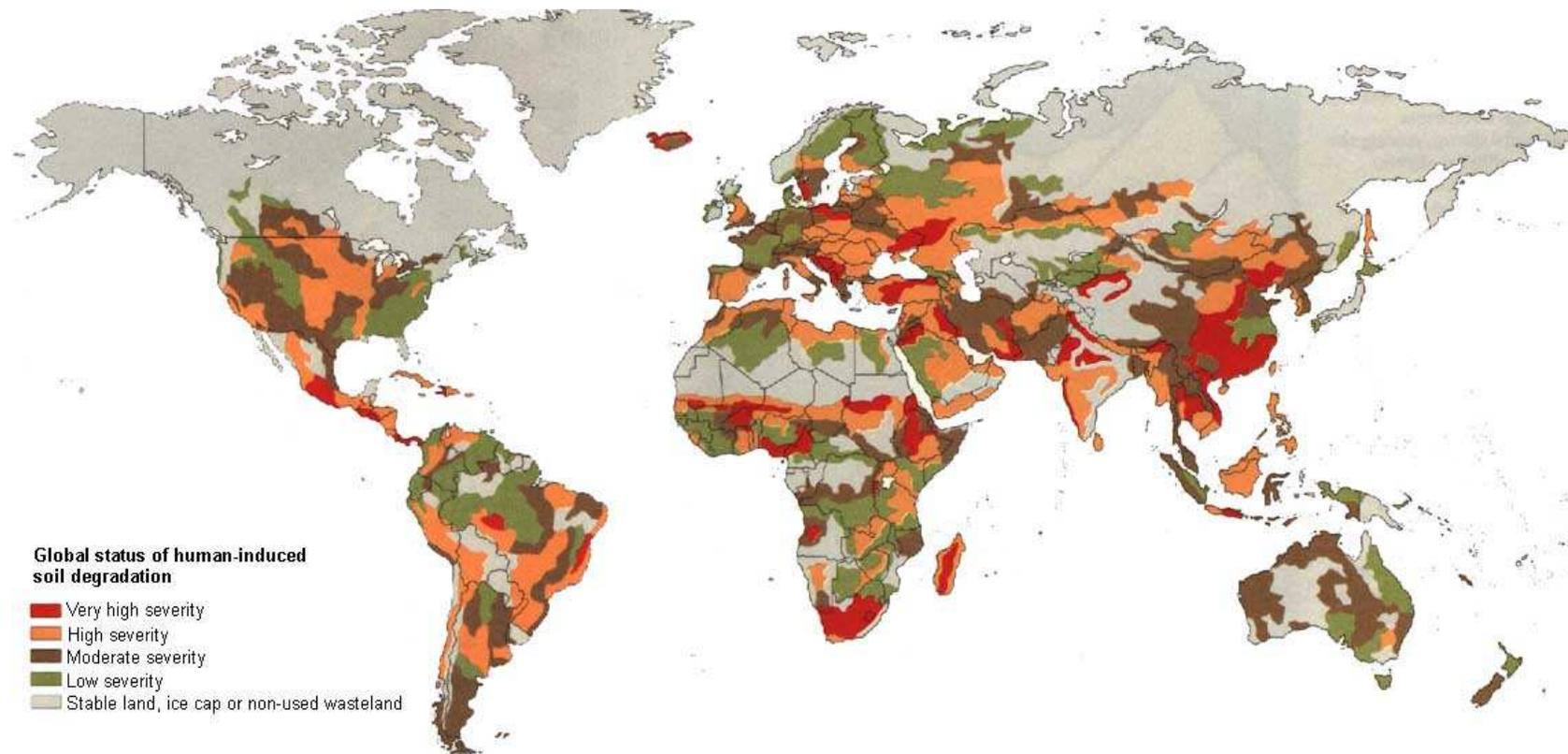


Figure 2: Global status of human induced soil degradation⁸

⁸ In Agriculture and Consumer Protection Department – Food and Agricultural Organization of the United Nations (FAO), 'Dimensions of need: An atlas of food and agriculture', *FAO Corporate Document Repository* <<http://www.fao.org/docrep/u8480e/U8480E0D.HTM>> [accessed March 2012]

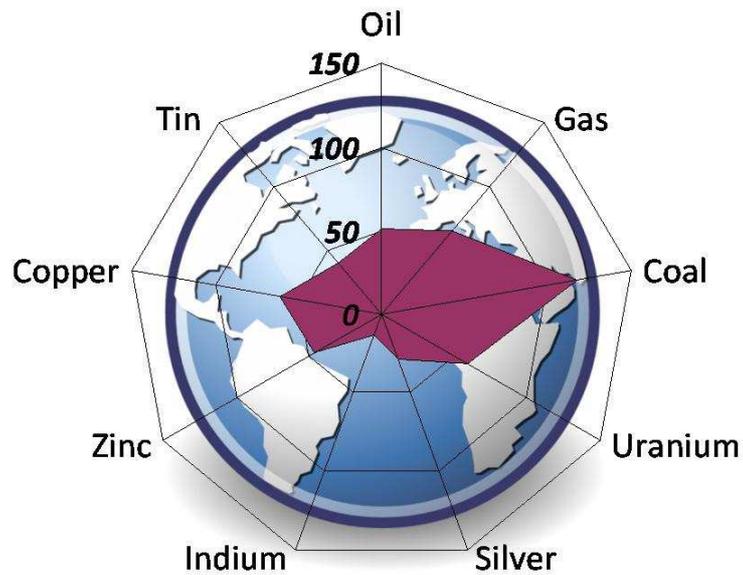


Figure 3: Approximate number of years left⁹ for a variety of commodities¹⁰.

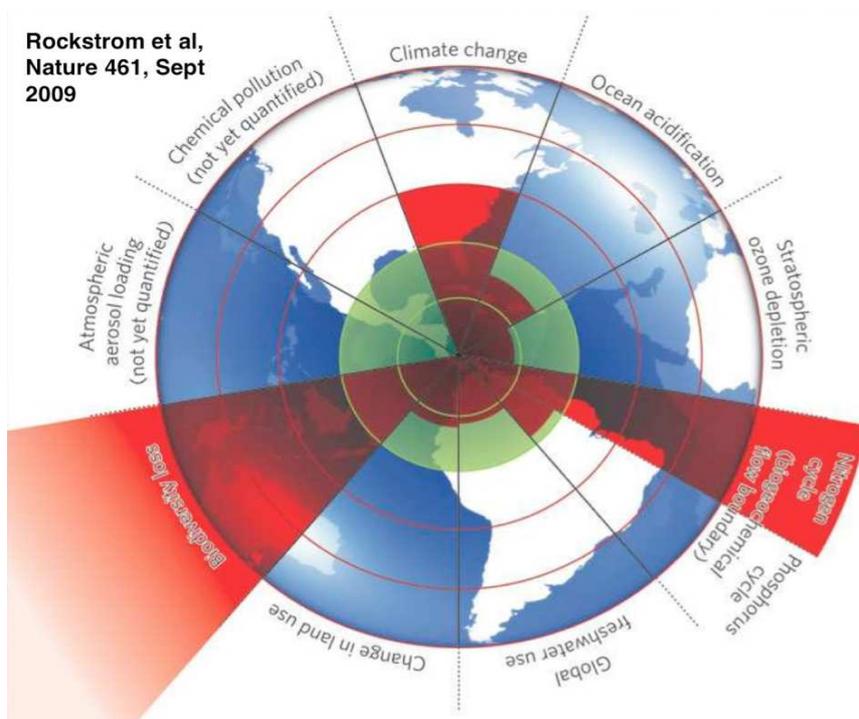


Figure 4: The 9 planetary boundaries of the Stockholm Resilience Centre.¹¹ The green circle signifies a planetary boundary and the red wedges signify the current global footprint.

⁹ Current global economically viable reserves divided by current annual consumption (assuming no growth in demand).

¹⁰ Data taken from BP Statistical Review 2012, <http://bp.com/statisticalreview> and David Cohen, 'Earth's natural wealth: an audit', *New Scientist*, Issue 2605 (23 May 2007) pp. 34-41

¹¹ Reprinted by permission from Macmillan Publishers Ltd: Rockstrom et al, *A safe operating space for humanity*, *Nature* 461, 472-475, 24 September 2009

3. The Economics of the Limits to Growth

*'You can have "growth" – for now – or you can have "sustainable" forever, but not both. This is a message brought to you by the laws of compound interest and the laws of nature.'*¹²

3.1 Growth definition

Economic growth is simply the increase in the amount of the goods and services produced by an economy over time. It is conventionally measured as the percentage rate of increase in *real gross domestic product, or real GDP*.

The shortcomings of the GDP measure

The risks of a heavy reliance on a simple measure of growth in GDP have been highlighted and understood since the measure was first adopted. Simon Kuznets, one of the principal architects of what became the standard way of creating national accounting systems, declared in 1933 that *"the welfare of a nation can scarcely be inferred from a measurement of the national income"* and went on to warn in 1962 *"Distinctions must be kept in mind between quantity and quality of growth, between its costs and return, and between the short and the long term. Goals for more growth should specify more growth of what and for what."* The raft of recent initiatives indicates a growing recognition that the simple GDP measure is not adequate, hence the rise in measures to supplement this, or in some instances provide an alternative. e.g. the OECD Better Life Index¹³, *Mismeasuring Our Lives*.¹⁴

In February 2012 the UK released the first analysis of the new well being measure developed by the Office for National Statistics.¹⁵ This report opens with the statement: *'It is increasingly understood that traditional economic measures are necessary, but not sufficient, to reflect a nation's overall progress or well-being. There has been increasing interest in the UK and around the world in using wider measures of well-being to monitor progress and evaluate policy in order to focus on quality of life and the environment, as well as economic growth in assessing progress.'* The first UK Annual Report on Measuring National Well Being was published on 20th November 2012. It has 10 domains: individual well being, our relationships, health, what we do, where we live, personal finance, education & skills, the economy, governance and the natural environment.¹⁶

The principle flaws to GDP are understood to be:

- i) It is neutral in its measurement of goods and services adding up 'goods' and 'bads' together. For example, nuclear waste, congestion, pollution. So it fails to capture the negative consequences of growth.

¹² Jeremy Grantham, *'Your Grandchildren have no value (and other deficiencies of capitalism)'*, February 2012 GMO Quarterly newsletter

¹³ <http://www.oecdbetterlifeindex.org>. This scores 11 elements: housing, incomes, jobs, community, education, environment, civic engagement, health, life satisfaction, safety, work-life balance.

¹⁴ The Report by the Commission on the *Measurement of Economic Performance and Social Progress*¹⁴, led by Amartya Sen and Joe Stiglitz, with Nick Stern and other luminaries, endorsed by the then President of France Nicholas Sarkozy in 2009 and in a subsequent book, *Mismeasuring Our Lives*, in 2010

¹⁵ www.ons.gov.uk/ons/rel/wellbeing/measuring-subjective-wellbeing-in-the-uk/analysis-of-experimental-subjective-well-being-data-from-the-annual-population-survey--april---september-2011/report-april-to-september-2011.html

¹⁶ http://www.ons.gov.uk/ons/dcp171766_287415.pdf

- ii) Not measuring positive aspects of our lives which are not monetised, such as caring for children, the sick or elderly, working in the community. As a result GDP can mask the breakdown of the social structures and natural habitats.
- iii) It does not capture other aspects that contribute to our well-being and quality of life such as education, health, infant and child mortality, life expectancy and leisure time.
- iv) Empirically, GDP growth can lead to widening inequality – and adverse impacts on social indicators and well-being.
- v) GDP does not take fully or consistently into account improvements in quality and new goods. e.g. in the ICT or health sectors.
- vi) Using a GDP per capita average ignores the distribution of incomes within a country.

3.2 Growth and Debt

Nobel Prize winning economist Robert Lucas famously said “*Once you start thinking about (growth), it's hard to think about anything else.*” This reflects a general belief in the necessity of economic growth. There are 3 main reasons for this.

Firstly, modern economies contain large amounts of debt. They therefore need to grow to pay back this debt¹⁷, as if economies decline the debt would increase in relation to the size of economy and would ultimately become unsustainable. This is the position we are in now where growth is required *in order* to at least service debt.

In China official government debt is low at some 30% of GDP but the debt of companies and households is some 130% of GDP, among the highest levels in emerging markets. This is partly because Beijing ordered banks to issue a huge expanse in credit in response to the 2008 crisis. If shadow banking¹⁸ is included the ratio of debt: GDP rises to 200% - *‘levels unseen before, fueling a consumption boom.’* In the UK public sector net debt more than doubled in 8 years, from 32.5% of GDP in 2003 to 42.8% in 2008 to 65.7% in 2011.¹⁹

Secondly with technological progress, the economy becomes more productive, so, employment would fall over time without growth.

Thirdly growth is one way of dealing with inequality, since if the economy did not grow some people would remain, or end up, worse off and this may lead to social problems. Thus growth avoids the need for redistribution, which would be strongly resisted by some.

The heavy reliance on debt has been highlighted by Coyle²⁰ who suggests that in mature (developed) economies, economic policy has “*borrowed from the future on a significant scale, both through the accumulation of debt in order to finance consumption now, or through the depletion of natural resources and social capital*”. The 2008 financial crash was *‘an indication of a system wide failure.’* She highlights that *‘market economies are unstable’* with *‘constant vulnerability to boom and bust’*.

¹⁷ Of course if debt is taken on due to an immediate crisis, such as war, and not an ongoing way to provide additional public finance, then it is possible to pay debt through subsequent budget surplus. However, we note that debt has increasingly been used to fund ‘normal’ government spending.

¹⁸ Non bank finance intermediaries such as hedge funds and structured investment vehicles.

¹⁹ Measuring National Well-being: Life in the UK , 2012, ONS, Self, Thomas and Randall

²⁰ Coyle D. The Economics of Enough, 2011

An additional instability is the super interconnectedness of the global system, with fragile highly leveraged economies having a concomitant vulnerability to market crises of confidence, as we are witnessing now in the Eurozone. Reinhart and Rogoff suggest that we are now in 'the Second Great Contraction.'²¹ In times of uncertainty, globalised highly efficient and standardised economic systems are vulnerable to shocks with high risk of contagion due to interconnectedness of systems.

3.3 Growth and Limits – a shift in the narrative

The current economic crisis has reinvigorated the debate on limits to growth. Opinions put forward by thought leaders, governments, academics, the private sector and NGOs can be grouped around four broad themes:

1) Growth is the solution

Commentators argue that economic growth brings with it technological innovation that would bring about the required changes to meet resource constraint and other challenges faced by the modern world such as poverty and inequality.

2) Green growth

By examining and changing indicators of growth to be more aligned with resource constraints (and climate change) global economic development would more naturally develop the required solutions to the global challenges, without harming people's standard of living.

3) End of growth

The finite size of the planet combined with the fact that the economy is now operating on a world-wide scale means that growth cannot continue and must stabilise to remain within global boundaries. Economies need to be restructured to accommodate a low growth future.

4) Beyond the limits.

Resource limits and/or climate change have been ignored for too long and the global economy and population is now too large to be supported at current rates of consumption. Since long-term decline is inevitable, the best course of action is to manage this decline.

There is significant attraction and traction to the green growth path, but there are limits to this approach. In particular ecological limits and tipping points, combined with the potential long term impact of inequality, may put a limit on any type of growth. Successfully achieving green growth would mean the total decoupling of economic growth from resource use, which has no historical precedent.

²¹ The Great Contraction was a term coined by Friedman & Schwartz in 1963 to depict the 1930s Great Depression. Contraction covers the wholesale collapse of credit markets and asset prices together with contracting employment and output (GDP).

4. Scenarios for the future

To understand how resource constraints may impact economic development in an uncertain future we need to explore how these issues drive global change. There are two key agents in enabling the flow of resources around the world - governments and markets (such as finance and commodity markets). Both offer some form of 'management' to this flow. Therefore, for this research we built scenarios based on their sensitivity to future resources constraints.

High sensitivity implies long term planning drives decision making and resource stocks are a key element in day-to-day policy development or market pricing. Low sensitivity implies short term impacts drive decision making with prices reflecting current flows and production of resources rather than long term stocks and political decisions driven mainly by resource availability within political cycles (2-5 years). The sectors (government and markets) are mapped onto two axes with a scale from low to high sensitivity for each (see below). Each quadrant of this plot then corresponds to a different scenario that we will explore further.

The scenarios are artificially constrained along the axes as outlined (we do not allow a future scenario to move between quadrants). Scenario techniques are a useful way to explore issues that may result in disruptive events over the long term that do not follow past behaviours.

The scenarios are used to set up a simple actuarial model outlined in the remainder of this report.

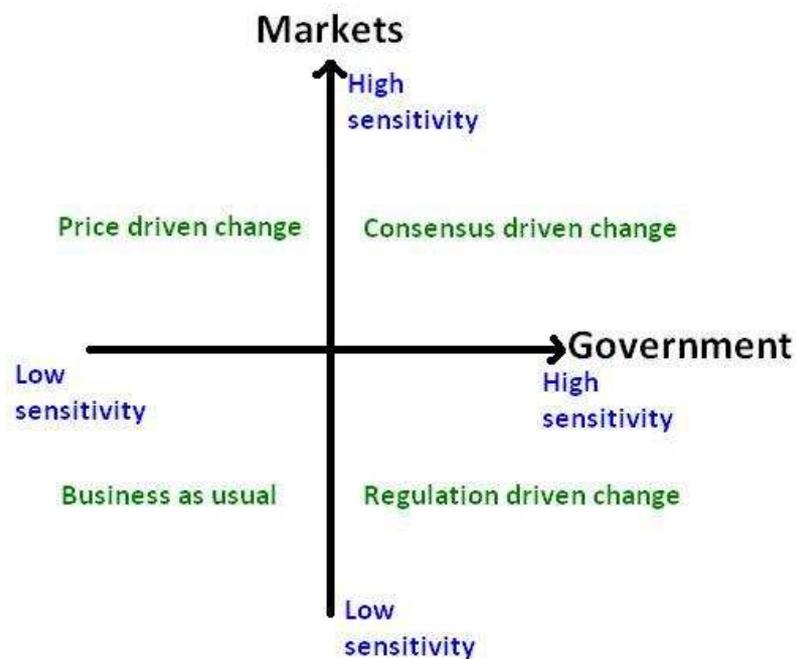


Figure 5: Scenario map showing sensitivity of the governments and financial markets. Each quadrant corresponds to one of the four scenarios.

The output of the four scenarios outlined above is expanded below. The four scenarios are developed on an optimistic and pessimistic basis leading to 8 possible sets of actuarial assumptions used in subsequent modelling. These assumptions are then compared with a 'no constraints' world – one in which there is no resource issue and the global economy can continue to grow as it has in the past.

Scenario	Pessimistic predictions	Optimistic predictions
Business as usual (market & government short term focussed)	<i>Long term global economic decline (based on energy availability) and local economic decline (based on food and water availability)</i> Actuary case study scenario: Severe Decline (B1)	<i>Slightly delayed long term global economic decline</i> Actuary case study scenario: Islands of stability (B2)
Price driven change (market long term, government short term)	<i>Some local long term declines in developing & emerging countries (water and food availability and penetration of new technologies into certain markets pushing back development gains) but major global economic decline averted</i> Actuary case study scenario: Wage stagnation (P1)	<i>Major global economic decline averted and fewer regions impacted by local declines</i> Actuary case study scenario: Labour shortage (P2)
Regulation driven change (government long term, market short term)	<i>Some local long term declines in all countries (technology fails to change fast enough) and long term global economic decline follows as market failures are widely seen and cannot be managed</i> Actuary case study scenario: Financial repression (R1)	<i>Fewer local declines but global economic decline follows as market failures are seen and cannot be managed (possibly delayed from the pessimistic prediction)</i> Actuary case study scenario: Partial decline (R2)
Consensus driven change (market & government long term)	<i>Some local declines (water and food) however global growth stabilises based on new technologies</i> Actuary case study scenario: Partial adaptation (C1)	<i>Fewer local declines and global economy stabilises</i> Actuary case study scenario: Green growth (C2)

5. Key variables: impact of resources on actuarial assumptions

The overall factors that may affect actuarial assumptions include:

1. Reduced economic growth caused by resource constraints and reduced confidence.
2. Reduced access to many commodities, and hence increased prices or lack of availability.
3. A series of price shocks caused by 2).
4. Reduced international security and coordination as countries compete for scarce resources.
5. Repression of investment returns as governments seek to direct investment into sectors that are required to make the economy more resilient.
6. Increased differential of investment returns in different countries that are starting from different allocations of resources, efficiency and debt levels.
7. Lower growth could lead to increased bankruptcies as heavily indebted countries, companies and individuals are unable to pay their debts, due to the lack of growth.
8. Warmer temperatures and more climate disruption e.g. sea level rise, cyclones, droughts and flooding.
9. Increased domestic and international social tension brought about by inequality and hardships exacerbated by resource constraints, climate disruption and lower economic growth.
10. Possible changes to life expectancy and morbidity caused by climate change, lack of access to resources, or changing ability to afford medical care.

The assumptions are grouped into 3 broad categories, namely discount rates (this includes interest rates and investment returns), inflation (including salary and prices), and demographic factors (mortality and morbidity). How society reacts will be a major determinant of outcomes. This can be in a number of ways, but some of the most important are:

1. The reaction of monetary authorities to increases in commodity prices – this will determine whether increases in commodities result in general inflation.
2. Society will need to invest more and consume less²² – the way this is achieved will determine investment returns both absolute and relative to wage growth.
3. Financial repression – in certain circumstances governments could pro-actively or re-actively intervene in allocating investment, to react to a perceived or actual threat. This could constrain investment returns and wage growth.
4. Social upheaval - increased resource prices will cause income re-distribution, possibly leading to increased social tensions and resource constraints will be unequally distributed between countries, with some countries lacking access to key resources. This could lead to international tension, with potentially reduced trade, economic activity or possible breakdown in security. How governments react will be crucial - a financial consequence could be increased inflation as governments are tempted to inflate away debt to reduce social inequality, and also increased interest rates due to increased uncertainty. Increased military spending is another possibility.
5. International investment – many institutions rely on returns generated internationally both directly or indirectly (via domestically listed entities operating internationally). Some regions' economies will fare better than others.²³ However,

²² J. Randers, 2052: A global forecast for the next 40 years, 2012

²³ *ibid.*

the extent to which domestic entities can benefit relies on continued international cooperation and willingness of investee countries to attract foreign investment.

5.1 Discount Rates

There are 3 separate discount rates investigated, which will be affected differently:

Matched calculation: is effectively the market rate of bond yields for a given duration. The “risk free rate” is usually taken as a government bond yield, for discounting pension liabilities corporate bond yields are used. The latter is therefore determined by government bond yields plus the spread. Long dated government bond yields in theory are influenced by expectations of future inflation, general levels of uncertainty and, latterly, government’s creditworthiness (both actual and perceived). All of these are likely to change in a resource constrained world. The credit spread is likely to increase, although in the long term it is not necessary that corporate bond yields will always be used to discount liabilities. However, as we tend towards increasingly extreme scenarios, there are no risk free investments to match cashflows. This means that there is a risk of the cash-flows from assets not being paid, and hence the assumed returns should be lower.

Budgeting calculation: this is given by expected investment returns, which are determined by the “risk free” yield as described above and a combination of equity risk premia and credit spreads. All of these are predicted to increase, however this does not mean that returns can be expected to increase; in the past where conditions have been relatively benign and stable, the risk has ended up with positive outcomes. In a more unstable world with declining economies, this risk might inevitably give rise to negative outcomes. Therefore the actual returns could be expected to reduce. An actuary or other modeler with perfect foresight would therefore predict this, however, in the past backward looking models have been used and therefore discount rates used might be expected to overstate future returns.

Social time preference: this is made up of how individuals discount the future and an assumption that consumption now is more valuable, as we will be wealthier in the future. The latter assumption breaks down in a resource constrained world, so this part of the formulae would reduce, possibly becoming negative. The impact of resource constraints of the former may also change but less predictably. If we are going into a world of greater uncertainty, people might be more inclined to spend today rather than save (tomorrow they may be dead!). This happens in unstable poor countries where interest rates tend to be high. The long term inter-generational calculations may also change. If the future is increasingly uncertain and society and the economy might go into long term decline, then it is rational to spend more today, as there may be nothing to spend in the future: this could happen as a result of a break down in trust.

Historical evidence from the 1970s oil crisis, the Japanese “lost decade”, the second world war and pre-industrialised Britain suggests that lack of access to resources, especially energy, can lead to low economic growth, low growth can cause low real interest rates and asset returns, nominal interest rates are not predictably affected by low growth and in times of duress, governments might suppress interest rates and investment returns.

5.2 Inflation – prices and wages

A series of economic price shocks from lack of availability of resources would lead to short-term inflation. As we have identified, oil is one of the crucial depleting resources, and hence is the most likely candidate to cause price shocks. Oil is, at the moment, the only credible

transport fuel, so if the price of oil increases so does the price of everything else. This would cause long term inflation only if the rate of the increase in money supply was speeded up, which is in the hands of the government. However, governments would be tempted to increase the money supply as the rise in commodity prices would suppress growth, make debts harder to pay off and change the distribution of wealth within the economy. Also a series of price shocks would lead to a change in rational expectations.

The impact of resource constraints cannot be predicted with any certainty on real wage increases. As the economy as a whole has to dedicate more (financial) resources to (non-renewable) resources, you would expect this means that there would be less resources paid to labour. However, on the other hand, because resources are more expensive, that might make returns to certain forms of labour greater. Workers who have a company pension are a select, relatively elite group who might (financially) benefit from the scarcity of resources as their skills become more valuable. Hence wage inflation could also increase under certain circumstances, depending on how events play out.

Historical evidence suggests that periods of low growth tend to correspond to periods of low real wage growth, commodity price shocks can cause inflation, but this is not necessarily a given, it depends on the circumstances that prevail before the shock and the reaction of policymakers to the shock, shocks (e.g. oil price or war) cause inflation but also lead to low or negative real wage growth and wages can be suppressed in times of national crisis (e.g. war).

5.3 Demographic assumptions

Life expectancies have been steadily increasing in developed countries since the industrial revolution, and more recently in developing countries. This report is looking at the life expectancy of a specific group of people; namely beneficiaries of a UK long-term financial product such as a pension scheme. This group is by definition select, i.e. they live in the UK which has a temperate climate and they are likely to be relatively affluent within the UK, and possibly have other benefits such as health insurance. The mortality and morbidity trends of this group will diverge significantly from that of the population as a whole (both global and UK specific).

Resource constraints could impact mortality trends in a number of ways which could be categorised as follows:

1. Impact of climate change: Climate change is predicted to increase the incidence of certain diseases (especially vector borne ones), cause increased pollution levels and increase the incidence of premature deaths from heat-waves. This is particularly relevant to pension schemes, as it is often vulnerable people such as the elderly who are killed by heat waves. Conversely a warmer UK will mean less cold winters and diseases such as influenza, which are big killers of the elderly²⁴.
2. Reduced economic growth caused by resource constraints: if a country's growth rates decline, then it will have to deploy a higher proportion of wealth to servicing debt and on a social safety net, so it will have less resources to devote to health care. There will

²⁴ Confalonieri, U., B. Menne, R. Akhtar, K.L. Ebi, M. Hauengue, R.S. Kovats, B. Revich and A. Woodward (2007) *Human health. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 391-431.

be fewer jobs and hence higher social deprivation, and possibly higher inequality, which all contribute to lower life expectancy.

3. Lack of access to resources: It is possible that certain crucial elements, such as rare earth metals, may become unavailable and worsening international security situation could lead to disruption in medical supply chains. In extremis food supplies could be disrupted.²⁵
4. Change in societies' priorities: Faced with physical resource limits, climate change and international security issues, the economy as a whole will have to devote more (economic) resources to securing (physical) resources, adaptation to climate change and defence, which could lead to less investment in healthcare.

Historical evidence suggest that developed country life expectancies have improved with time, periods of social and economic trauma could lead to declines in life expectancy and beneficiaries of long term financial products such as pensions are a select group who may be insulated from the worsening mortality of the rest of the population

5.4 Developing an actuarial model incorporating resource constraints

An actuarial model is developed to demonstrate the effects of resource constraints which limit economic growth on a savings vehicle. Two different versions of the model have been run in order to examine a simplified defined contribution and benefit scheme with a contribution rate increasing at a fixed rate, and a defined benefit scheme.

These models were run on 9 different scenarios. No probabilities are attached to the likelihood of any of these scenarios, and no view is taken as to which is the most likely; they are "what-if" scenarios which attempt to translate the scenarios built up in the rest of this report into an actuarial basis. One of the scenarios chosen is a "No constraints" scenario – this assumes the future is broadly in line with the past. The other scenarios are compared to this baseline.

As illustrations of the model, figure 6 shows a comparison of replacement ratios for the different scenarios (the replacement rate being the initial pension paid on average divided by the salary prior to retirement) for a defined contribution scheme. This shows that the replacement rate for the worst scenarios is almost half of that of the "no constraints scenarios", although in 1 scenario the replacement ratio is actually higher.

Figure 7 shows the assets of a defined benefit scheme under the different scenarios run in the model. In the "no constraints" scenario, the Fund is healthy increasing in size, whereas in some scenarios the assets are exhausted. Figure 8 shows the impact of severe economic decline on a defined benefit pension scheme, which represents the worst case scenario that is modelled. This shows the assets of the Scheme exhausted by constant economic shocks within 35 years and the Scheme becoming insolvent solely as a result of the limitations to growth as modelled, and in the absence of other detrimental influences (such as those experienced over the last 15 years in some western countries).

²⁵ An example of this can be seen in the disruption to global supply chains after the Fukushima earthquake and tsunami in March 2011.

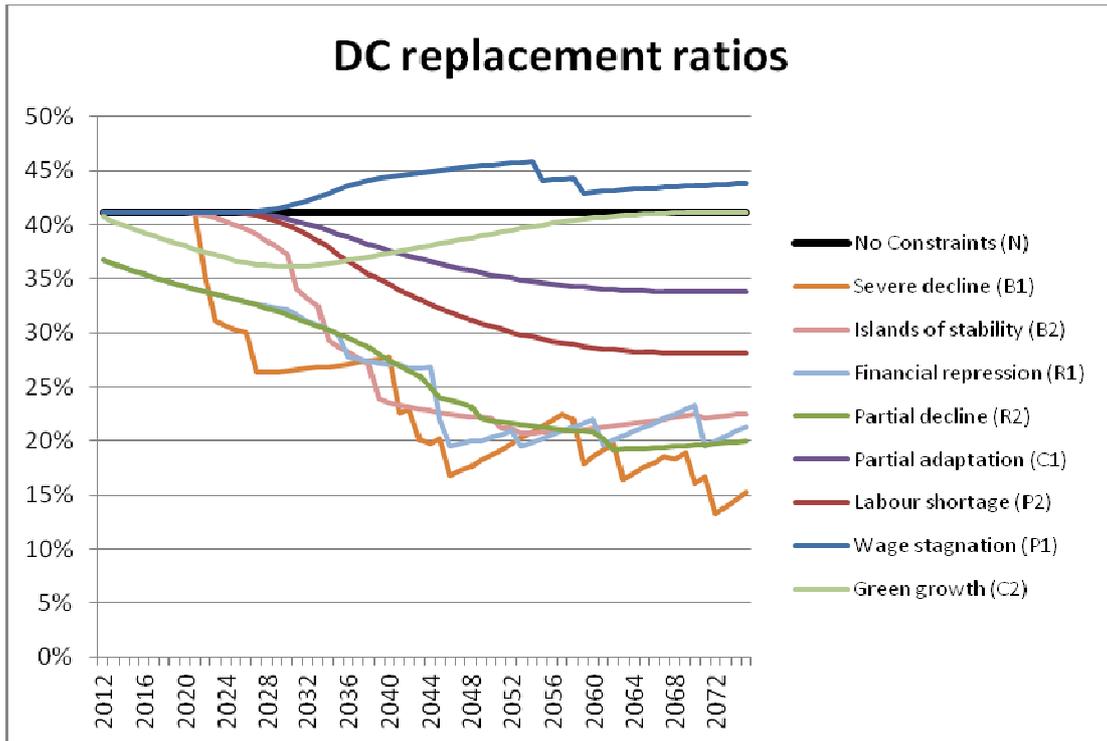


Figure 6: Replacement ratios: all scenarios

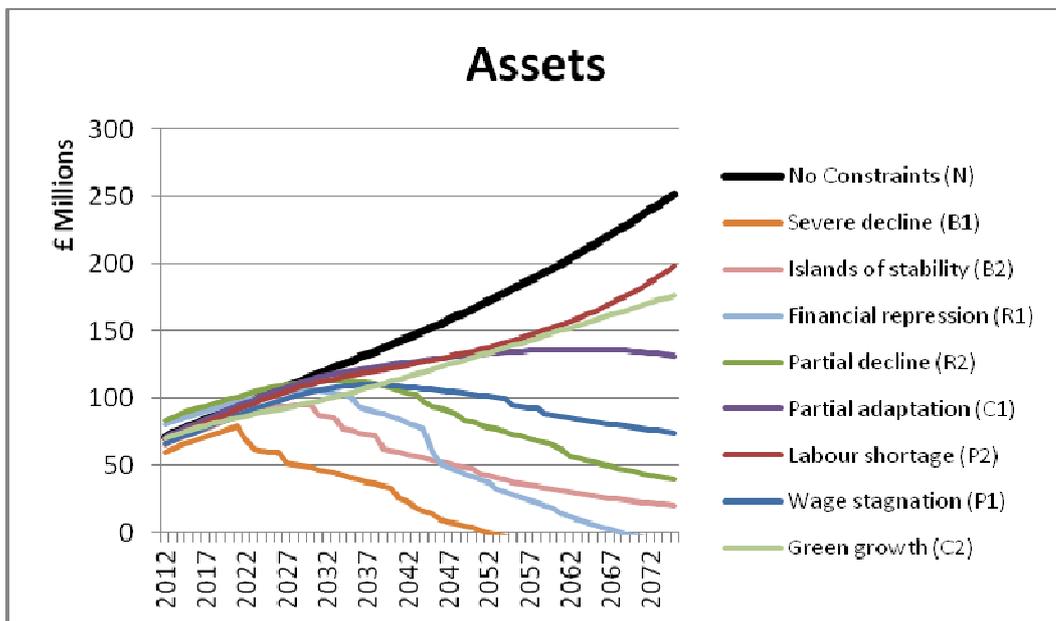


Figure 7: Defined benefit scheme asset projections: all scenarios

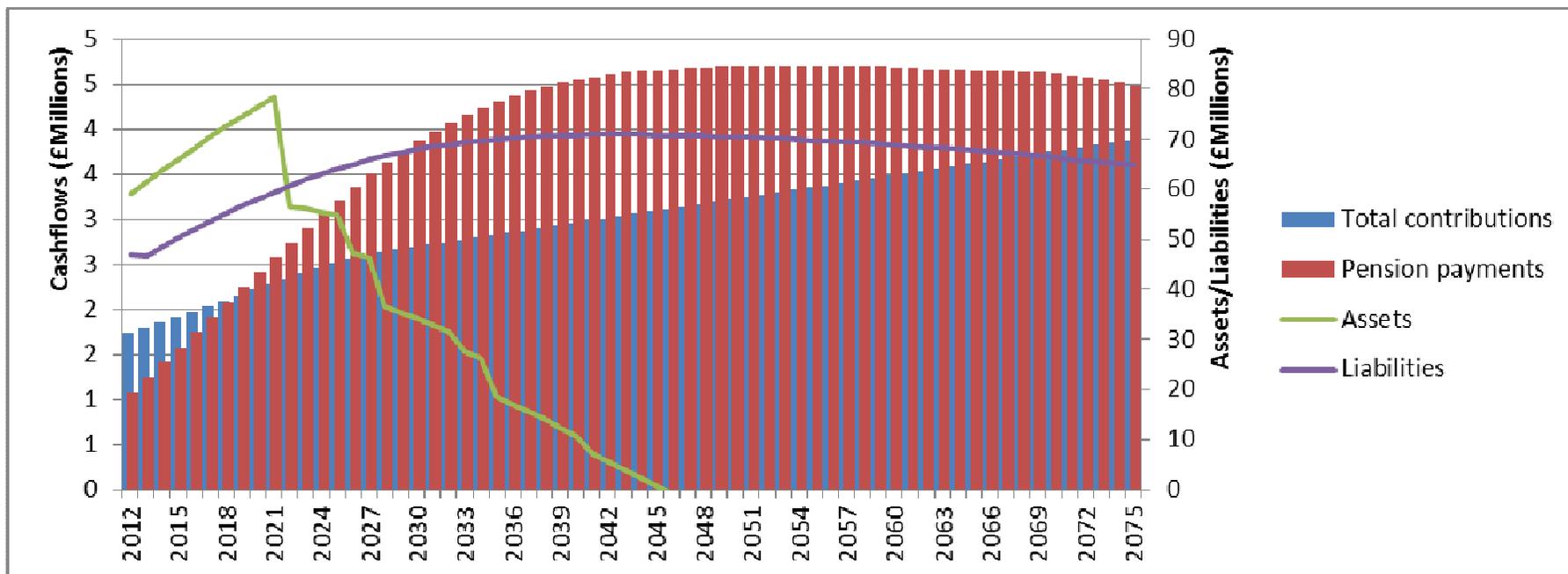


Figure 8: Defined benefit scheme: Severe economic decline

These scenarios do not reflect a worst case scenario. Were the global economy to go into long term decline the legal basis on which financial products sit could conceivably be undermined, and the sponsor employer may no longer exist to pay contributions, the financial markets may also cease to exist, at least in their current form, and hence the projection would become meaningless. Initial conclusions from the model outputs are:

1. The more extreme scenarios modelled represent financial disaster; the assets of pension schemes will effectively be wiped out and pensions will be reduced to negligible levels.
2. If resource constraints impact but not to such a severe extent, there still could be considerable impact on a financial vehicle. The different reaction of governments, regulators and financial agents can produce a spectrum of impacts the outcome of which will have an effect on savings vehicles.
3. Currently actuarial models are effectively discounting to zero the probability of economic growth being limited by resource constraints. If resource constraints are significant, this means that current models will persistently understate the value of liabilities.

If economic growth is limited by resource constraints, this could be reasonably expected to significantly affect future financial and demographic outcomes. If these future outcomes are indeed affected, then the assumptions that actuaries use should take into account these future developments.

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