Green Alliance policy insight
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Managing resources for a resilient economy

lessons from the financial sector

Summary

This policy insight is aimed at those whose role it is to help businesses manage resource risks better, including investors, portfolio managers and government.

Rising commodity prices since the turn of the century have given governments around the world a strong incentive to consider better resource stewardship as a way to build greater resilience into their economies. Significant policy effort has been devoted to promoting more resource efficiency and recycling. However with the recent falls in commodity prices, notably oil, some have questioned whether we need to recalibrate resources policy to an era of lower commodity prices.[1]

As we show here, this critique ignores the inherent volatility and unpredictability of commodity prices. There is evidence that, despite recent falls in some commodity prices, resource prices have risen substantially over the past 15 years and have become more volatile. Many previous confident predictions of low or stable commodity prices have been confounded by unforeseen events.[2]

The volatility and uncertainty surrounding commodity prices has wide ranging macroeconomic as well as specific business impacts. Energy and other widely used commodities, such as food, have major impacts on inflation, living standards and economic growth. Other critical resources, such as rare earths and precious metals can be vitally important for specific products or processes.

Financial analysts spend a lot of time considering volatility and risk. Because of the enormous sums of money that can ride on some investments, the financial sector has developed a variety of approaches to managing risk which seek to achieve a combination of good returns with acceptable levels of risk.

We consider the approaches taken by financial analysts and believe there are lessons that can be learnt for resource management.

Greater investment in resource efficiency and recycling, and the adoption of circular economy business models, have important benefits from a risk management perspective. From a societal perspective, an economy less reliant on imported commodities would naturally be more resilient to gyrations in international commodity markets.

Achieving greater resource efficiency will require investment. In some cases, resource efficient solutions may appear more costly than continuing dependence on raw commodities. Nevertheless, such investment can be justified on three grounds from a risk management perspective:

- Reduced volatility
  When comparing investments in either resource efficiency or the development of new resources, it is important to account for the inherent volatility in commodity prices. This means that a risk premium to reflect volatility should be required for alternatives based on the use of new resources.
- Diversification
  Increasing the share of resource efficient activities in the economy may be justified from a portfolio diversification perspective. An economy with a broad range of approaches should be more resilient to resource price shocks.
- Mitigation of 'fat tail' risk
  So called 'tail events' lead to large price spikes and, although rare, can have major economic impacts. Such events can be driven by geopolitical developments in resource producing countries, and resource efficiency can help to decrease reliance on foreign imports.

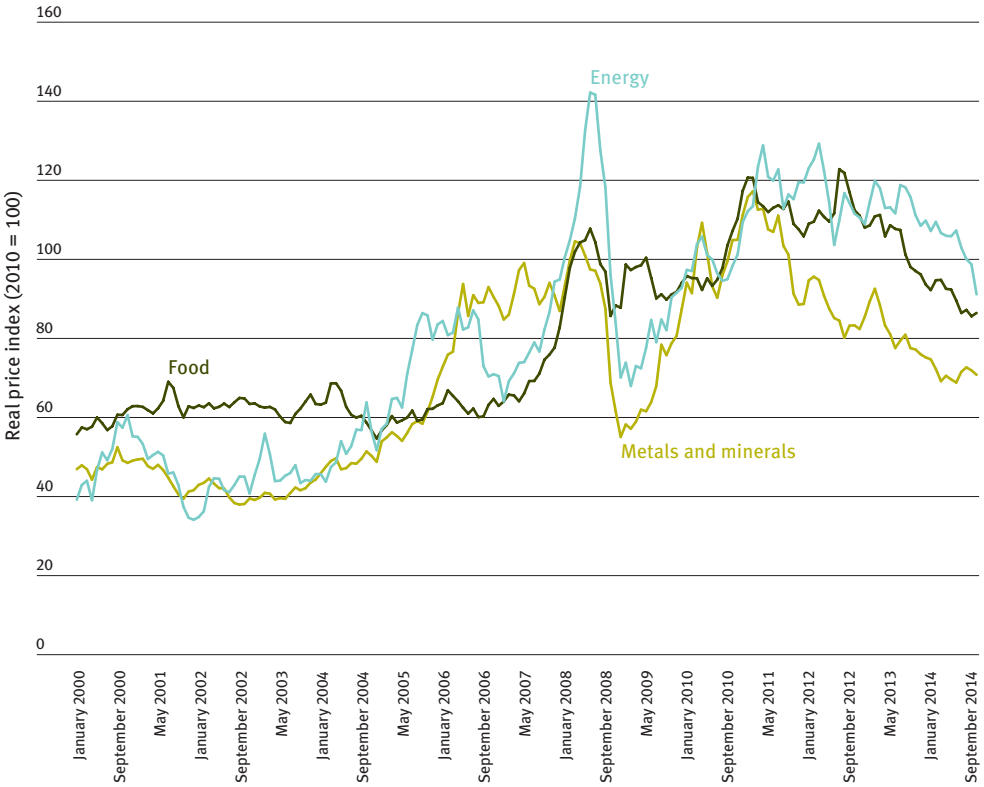
However, risk based approaches may not be enough to deliver greater resource efficiency without action from government. Market failures, particularly relating to externalities, public goods and imperfect information may discourage individual private investors from making the necessary investments. The government should take an active role by setting up a strategic risk assessment and using industrial policy to deliver the necessary conditions for resource efficient businesses to develop.

Trends in commodity prices

Global commodity prices are notoriously volatile. They surged in the first decade of this century as between January 2000 and December 2009 real food prices rose by 69 per cent, metals and minerals by 86 per cent and energy by 137 per cent.

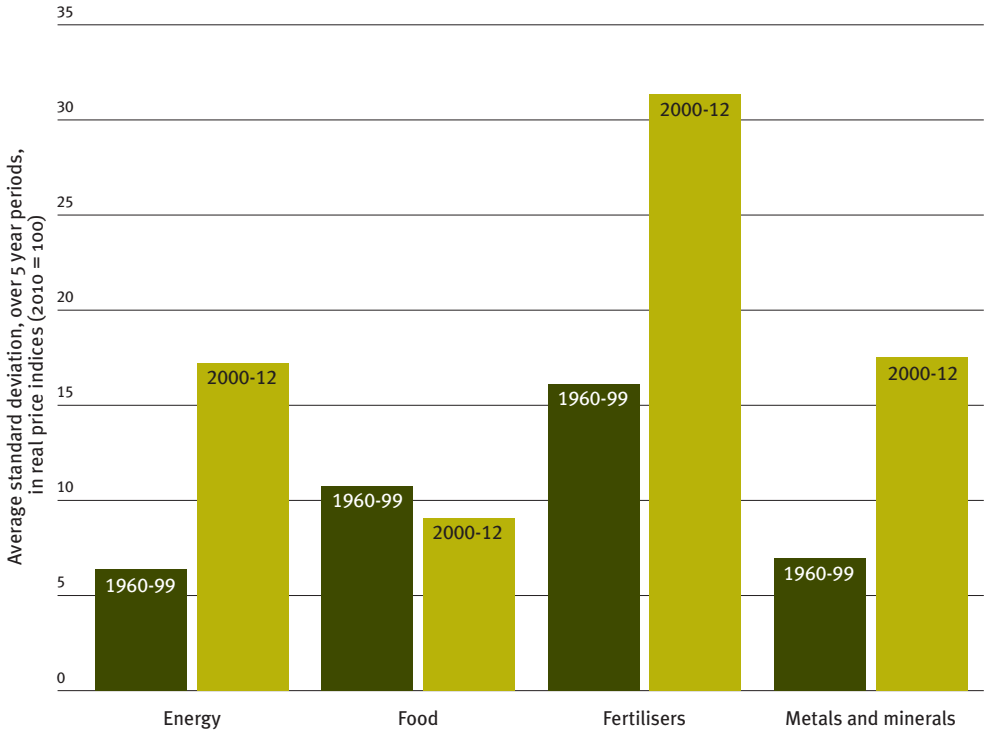
Major price spikes occurred in 2008, followed by sharp falls in 2009 as the financial crisis intensified and then there was a subsequent strong recovery. Recently prices have fallen back, but still remain substantially above the levels recorded in January 2000 (in October 2014, real food, metals and minerals and energy prices were still respectively 55 per cent, 51 per cent and 133 per cent above their January 2000 levels).[3]

Real global commodity price indices[4]



The volatility experienced since 2000 is also high by historical standards. As the chart below shows, for energy, metals and minerals, and fertiliser prices the average standard deviation has been much higher since 2000 than it was over the preceding 40 years. Only in the case of food prices has volatility remained at a similar level to that seen in the previous four decades.

Volatility in real global commodity prices[5]



The pitfalls of price prediction

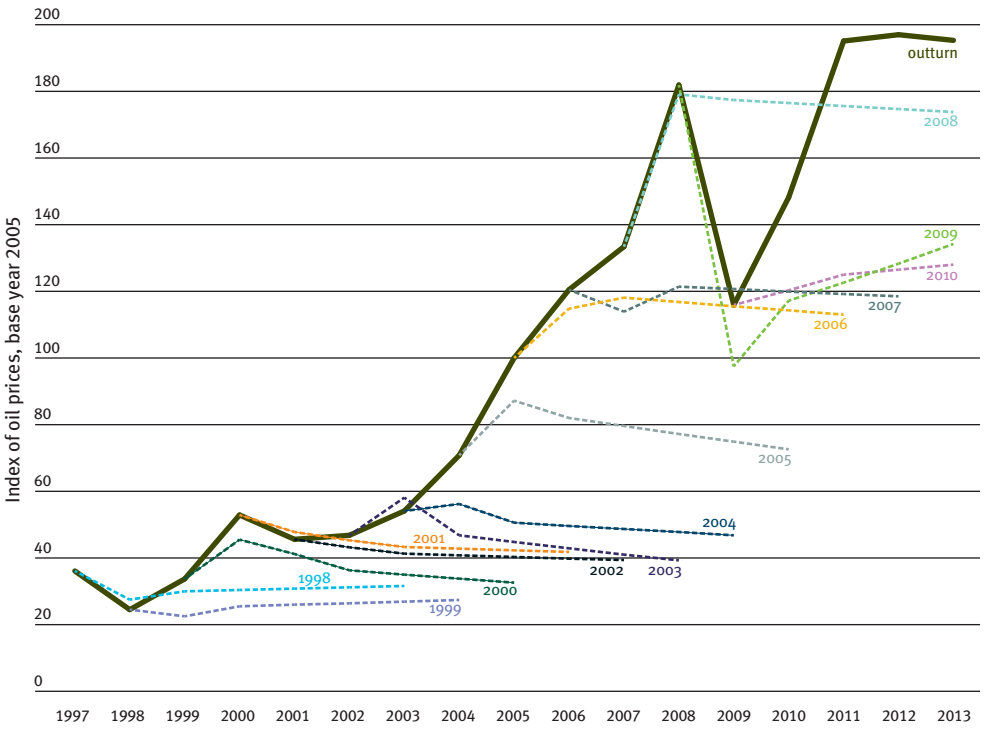
The high volatility of commodity prices points to the difficulty in trying to gauge what will happen in future. Given the importance of knowing what will happen to future commodity prices, many attempt predictions, ranging from newspaper columnists to international financial institutions. Sadly, the only thing that is predictable is the inevitable failure of such efforts.

Here are two examples. First, an article from *The Economist* in 1999 discussed the recent fall in the oil price to $10 a barrel and suggested that oil prices might fall further to $5 a barrel. It also stated that "Consumers everywhere will rejoice at the prospect of cheap, plentiful oil for the foreseeable future."[6] Instead, oil prices rose to nearly $150 a barrel just nine years later.

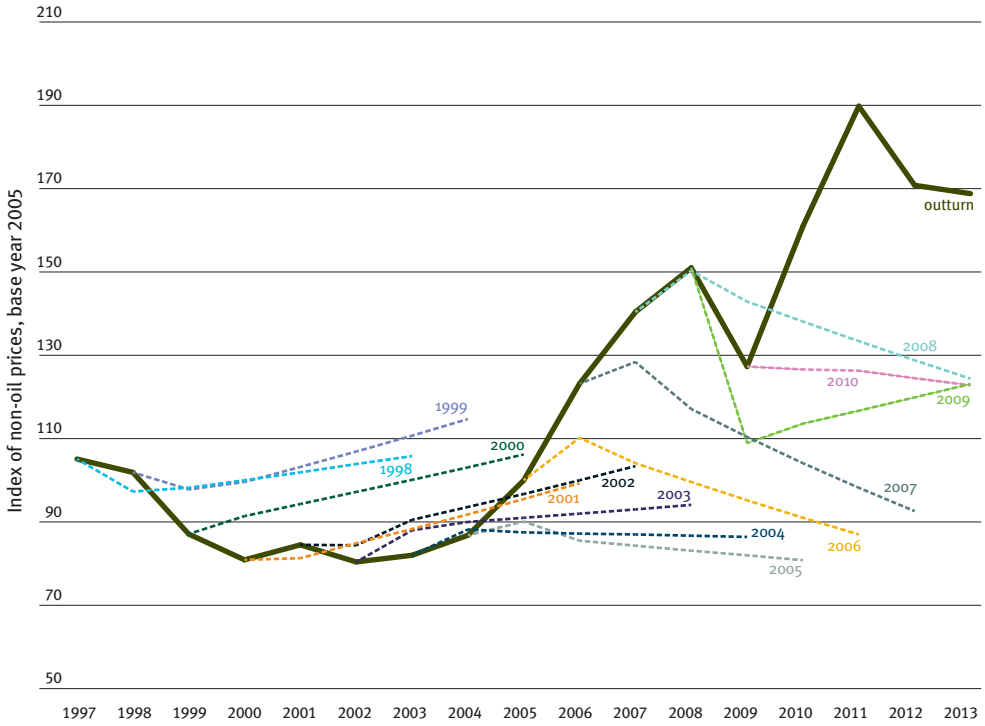
Second, it is worth looking at the International Monetary Fund (IMF)'s record in projecting future commodity prices as part of its World Economic Outlook (WEO).[7] The chart below reports the outturn and IMF's forecast for the oil price (using an implied index with a base year of 2005=100) based on the WEO released in April/May of each year for consistency. For instance, in April 2005 the IMF projections implied an oil price index of 87 in 2005 falling gradually to 73 in 2010 (the grey dotted line). In fact, oil prices were 100 in 2005 and then rose sharply to 182 in 2008 before falling back to 148 in 2010 (the black line). We repeated this comparison for every April/May WEO from 1999 to 2010, as shown in the chart. The chart opposite shows the same for all non-oil commodity prices.

The main message from these charts is that these projections have, for the most part, not been able to track subsequent commodity prices. This is even true for projections made for the current year, despite the fact that these projections are released in the second quarter of the year when around four months of developments in commodity prices are already known.

Actual and IMF forecast change in oil prices between 1997 and 2013[8]



Actual and IMF forecast change in non-oil prices between 1997 and 2013



We have chosen the IMF projections to illustrate the difficulty in predicting commodity prices, not to single them out for criticism, but to show that even large and well-resourced organisations make major projection errors. The IMF, like many others, bases its oil price projections on futures contracts. Many believe that this provides the best guide to future developments.[9] At the time of writing, five year futures for oil point to moderate recovery in oil prices to around $70-$80 a barrel over the next few years.[10] Yet there is huge uncertainty around these estimates. For instance, the IMF estimated that in December 2014 the 68 per cent confidence band for the price in 2019 ranged from $48-$85 per barrel and the 95 per cent confidence band was from $38-$115.[11] If this is the best guide there is for future oil price developments, then it seems hardly surprising that the errors seen in the charts above are being made.

A sense of the complexity of projecting the oil price can be gained by considering the current drivers of price changes. Calculations by IMF staff suggest that unexpected falls in the demand for oil due to a weaker global economy can account for only 20-35 per cent of its price decline[12.] However, this weakening in demand has been accompanied by increases in supply. There may be a number of factors behind this, including an unexpected recovery and maintenance of Iraqi production despite unrest and the announced intention of Saudi Arabia not to offset rises in production elsewhere.[13] Forecasting the oil price requires being able to predict the evolution of the world economy, the geopolitics of the Middle East and the oil production strategy of Saudi Arabia. On top of this, there are significant uncertainties regarding the response of supply and demand to the lower oil prices. It is not known how higher cost suppliers, such as unconventional oil in North America, will respond to lower prices; or by how much consumers, who have got used to higher prices, will raise their demand.

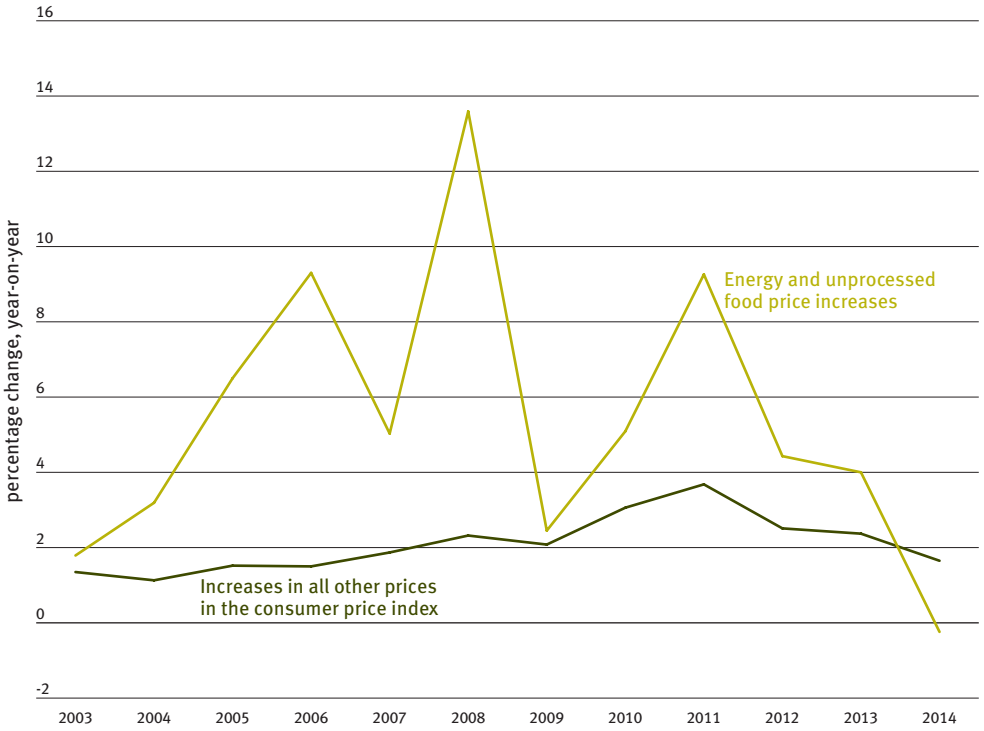
Why commodity prices matter to the UK

This volatility and unpredictability might not matter, were it not for the importance of commodity prices for our economy. The UK is a net importer of food and energy and this import dependence has been increasing over time. Between 2000 and 2012 the UK went from being a net exporter of energy (an import dependency of -17 per cent in 2000) to a substantial net importer (import dependency of 43 per cent in 2012), and our net import dependency for imported food also increased from 33 per cent to 38 per cent over this period.[14] This means that our economy is becoming more vulnerable to commodity price developments, with significant implications for inflation, living standards and GDP.

Against this background it is being increasingly recognised that the UK needs to become more resilient to price shocks affecting global resources.[15] Resilience does not require the economy to be completely insulated from changes in resource markets; this would be neither possible nor desirable, as price changes may be sending important economic signals. Our notion of resilience is an economy that can adjust to commodity price fluctuations relatively smoothly, without generating major dislocations in output, employment and inflation.

In *The great resource price shock* (Green Alliance, 2014) we showed the effects of rising energy and food prices on UK inflation, household bills and real wages.[16] We found that they have had a significant impact on UK consumer prices. As shown below, energy and food prices increased faster than other prices in the decade 2003-13. Indeed, excluding food and energy, inflation would have been on average around 0.5 percentage points lower than overall inflation. Only in the past year have these items increased more slowly, reflecting the recent weakening in global commodity prices.

UK energy and food price inflation compared to general inflation[17]



Our analysis has shown that without the excess inflation stemming from food and energy prices increasing more quickly than other prices, UK consumers could have saved over £1,000 on average food and household energy bills in 2012; and real incomes could have risen, rather than fallen, between 2003-13.[18]

The most recent evidence of the impact on GDP comes from estimates of the effect of the near 50 per cent fall in oil prices which occurred between June and December 2014. The IMF, which had actually pencilled a 0.1 per cent rise in oil prices into its April 2014 WEO, has now analysed the possible impacts of the fall in oil prices on the world economy.[19] Its analysis suggests that there may be an increase in global GDP between 0.3 and 0.7 percent in 2015, compared to a scenario in which there was no drop in oil prices.[20]

Although such a stimulus to the world economy may appear welcome, it is not certain how long the lower oil price will last. Given past volatility it seems highly likely that prices will recover at some stage, reversing the temporary boost to GDP provided by the recent falls. Moreover, the economic impacts of these fluctuations in commodity prices may not neatly cancel out when commodity prices return to their previous levels.

Volatility in itself can carry significant economic consequences, and is likely to have adverse impacts on GDP growth.[21] Risk averse consumers and investors are more likely to delay major purchases or investments during a period of elevated volatility and uncertainty. Additionally, volatility in resource prices can also lead to volatility in relative prices which can damage the efficiency with which the price signal allocates resources. As *The great resource price shock* highlighted, this is likely to lead to volatility in living standards, particularly for the poorest in society. Finally, volatility may not just affect prices but may also reduce the security of supply for inputs to production, potentially causing costly shut downs for UK producers.

In 2014, the World Economic Forum asked over 13,000 executives in 144 economies about the global risks of highest concern for business. The risk of an oil price shock was seen as the third highest risk, and other resource issues including food, water and resource nationalism also featured on the list.[22]

Critical resources for industry

In addition to energy and food there are many other resources which play a vital role in UK industry. Critical raw materials, such as metals and minerals are important to many supply chains. The need to secure reliable, sustainable and open access to these resources is an increasing priority for many nations. The following are some examples of critical materials on the EU and British Geological Society's *Risk List*:[23]

- **Antimony** Used as a hardener in semiconductors, and in the production of lead acid batteries and flame retardants.
- **Dysprosium** A rare earth element used in permanent magnets for electric cars and wind turbines.
- **Indium** Used in coating LCD touchscreens and for the production of low melting point alloys and solders. It is also found in photovoltaic films for solar panels.
- **Phosphate rock** Primarily used in the chemical industry, to produce fertilisers and animal feed supplements.

As the table opposite shows, the EU is highly dependent on imports of these materials and some have seen spectacular price increases this century. Between 2000 and 2012, prices increased by nearly 200 per cent for phosphate rock, over 500 per cent for antimony and nearly 1,000 per cent for dysprosium.

Prices have not only risen but have been subject to high levels of volatility, especially due to sharp price increases caused by demand and supply concerns. Strong demand growth is anticipated for the current decade, averaging nine per cent for dysprosium and 5.5 per cent for indium.[24]

Supply concentration in a few large nations (including China and Russia) is an important risk for these resources, and there are other significant supply risks described below. China, the United States and Russia dominate the global production of many of these materials. Key risks also include the use of export restrictions from some resource rich nations, the effects of which can be felt across many industries.

Shocks to the markets for these materials can drastically disturb national and global supply chains, so there is a strong policy interest in building more resilience to them.

Economic impacts and geopolitical risks of critical raw materials[25]

	EU import dependency rate	Price increase 2000-12	Price volatility 2000-12	Annual growth in global demand	Main global producers	Key risks
Antimony	45%	553%	67%	3%	China (86%), Tajikistan, Russia, Bolivia, South Africa	Supply is concentrated in China. China wants to close some antimony mines to meet environmental targets.
Dysprosium	≥100%	981%	98%	9%	China (99.1%), United States, Russia and Australia	Past export restrictions from China. Essential for supply chains and continued development in low carbon energy and automobile industries.
Indium	≥100%	160%	55%	5.5%	Excluding China (uncertain data), Peru (50%), Bolivia (24%), Canada (12%), Australia (8%)	Mined as a by-product of zinc and copper, production depends on refineries capacity to expand their metal extraction from the primary metal ores. Recycling is difficult due to the extreme thinness and low concentration of indium in solar PVs
Phosphate rock	≥100%	196%	55%	2%	China (38%), USA (17%), Morocco (15%), Tunisia, Jordan, Brazil (all 4%)	Supply is concentrated in China and Morocco. Not recyclable. Essential for the production of food.

How financial analysts view volatility and uncertainty

Analysts in the financial markets spend a lot of time considering volatility and risk. They frequently have to make choices between alternative investments, each offering different returns and risk profiles. They also aim to build portfolios of investments with differing characteristics. With the enormous sums of money that can ride on these investments, the financial sector has developed a variety of approaches to risk, which the analysts hope will achieve a combination of good returns with acceptable levels of risk.

Below, we outline the approach taken by financial analysts before considering if there are any lessons that can be applied to resource stewardship. It is important to acknowledge that some of the ways in which risk management was applied by parts of the financial sector was at the root of the recent financial crisis. So although the basic tool box used by financial analysts is powerful, it needs to be enhanced along a number of dimensions which we discuss below.

The following are the three main approaches to risk used by analysts:

Lower weight for volatile investments

In the finance industry, risk is most commonly seen as the volatility of investment returns, but can also be extended to include the consequences of volatility. A decision to invest in a stock typically considers the expected return on the investment and its variability, ie uncertainty. There is usually a trade off between risk and return. Analysts evaluate different investments using the Sharpe ratio, which is the expected return on an asset minus the risk free return (usually the yield on a government bond) divided by the volatility of the asset.[26] This effectively means that more risky investments require a higher expected return, or a risk premium, to make them equivalent to safer ones.

Portfolio diversification

Financial analysts typically do not only consider investments in isolation, but as part of a wider portfolio. The expected performance of a portfolio is not necessarily equal to the sum of its parts, as it will also depend on the correlation between individual investments.[27] As a consequence, analysts may combine assets with returns that are not highly correlated to create portfolios that offer higher returns for a given level of risk.

Minimising large losses and 'fat tail' risk

Reflecting the human tendency to react asymmetrically to losses and gains, another approach is to think of risk in terms of how much we are willing to lose.[28] There is an approach called Value at Risk (VAR) which measures the maximum likely loss that could occur at a particular confidence level over a set time period. The financial crisis of 2008 exposed the limitations of such approaches to risk, which are based on assumptions about normal, or Gaussian, probability distributions.[29] In reality, probability distributions are often skewed and have 'fat tails' and outcomes, thought of as unlikely to occur when using a normal distribution, may in fact be a lot more likely in the real world. Another problem exposed by the crisis is that estimates of expected future returns, volatilities and correlations made, using relationships implied by historical data, can also break down. For instance, during the financial crisis, some asset returns that were previously uncorrelated, began to move strongly together. Therefore, it can also be worthwhile to consider a range of scenarios to see how a portfolio would perform if adverse situations occurred and estimate their consequences.

Taking a risk management approach to resource stewardship

How could the risk management techniques employed by financial analysts be used to make resource policy more effective?

A range of policy responses are available, including developing new supplies or alternatives to existing resources, stockpiling, developing exclusive trading arrangements with resource suppliers or adopting resource stewardship approaches. Many of these options may have a role to play in building resilience but, here, we focus on the particular contribution that resource stewardship measures can make to risk management. Investment in these measures may offer tangible benefits in terms of reducing volatility, diversifying portfolio risk or protection against fat tail risk.

We consider measures in three areas: efficiency, recycling and those that support and enable circular economy business models. Our primary focus is on whether such measures offer risk management benefits from a national perspective, ie does reducing the nation's dependence on virgin resources increase economic resilience to commodity shocks? This resilience could manifest itself in a reduced sensitivity to changes in commodity availability or prices, ie improving output, employment or inflation. As we discuss, this does not imply that all businesses within the economy will necessarily see such a benefit.

Efficiency

This is concerned with producing the same good or service with fewer resources. In the case of energy, this could be insulation, or in the case of metals it could be a new product design, for instance, to produce a car of the same standard with less metal. As the UK represents only a small share of the global economy, increased efficiency in the UK is unlikely to moderate the fluctuations in world commodity prices, but it would reduce the overall exposure of our own economy to world price volatility. As an economy lowers its consumption of a resource, the extent to which it is affected by volatility in its price decreases. By limiting dependence on commodity imports, the impact of any fat tail risk is reduced.

To the extent that efficiency does not broaden the choice of resources used in production or consumption, it may not be seen as offering a benefit in terms of portfolio diversification of the source of resources. However, because investment in resource efficiency involves an upfront capital cost to lower the dependence on variable resource costs, it can be seen as offering some diversification in the cost base. The cost of financing the investments in resource efficiency is likely to be linked to the economy wide costs of financing, eg LIBOR, which is unlikely to be closely correlated with resource prices.[30] Hence, by broadening the cost base, the economy can gain from diversification.

Recycling

This entails keeping materials in use for as long as possible. Businesses involved are still likely to experience volatility in the prices of feedstock and recycled materials but, from a national perspective, the sensitivity of the economy to commodity fluctuations should be moderated. As recycling effectively provides a new domestic source of supply of the materials, import dependence can be reduced and the overall economic impact of price volatility dampened.

In addition, limiting commodity imports should reduce the impact of fat tail risk affecting these commodities. The benefits go beyond moderating the effects of rising prices as the resource cost elements of complex products may be comparatively small and include the risk of supply chain disruptions.[31] Consider the following hypothetical example of a hybrid car, which costs £25,000 to produce and uses £400 worth of dysprosium in its production. The fat tail supply risk may not involve dysprosium doubling or trebling in price as this would not have major impacts on the overall production costs (adding only two or three per cent). But the really damaging impacts would occur in the event of a complete hiatus in dysprosium supply, even for a limited period, which might prevent the manufacturer from selling a £25,000 product. Japan has invested in rare earth metal recycling, to avoid the disruption to hybrid car manufacture caused by the loss of just a few tonnes of raw material.[32]

Finally, as long as the prices of recycled and virgin materials are not perfectly correlated, there should be some portfolio management benefits in diversifying sources of supply away from purely virgin materials. When commodity prices are low, many resource efficient activities may struggle to compete with those using virgin resources. However, retaining such activities, particularly those that have required investment in infrastructure, represents a form of portfolio insurance for when prices rise again.

Supporting the circular economy

The circular economy involves keeping products in use for as long as possible, for instance through greater use of repair, reuse, remanufacture and servitisation (selling services in lieu of products). As products can be made from a wide variety of resources, and effectively embody substantial amounts of energy, they potentially offer significant risk management benefits. For instance, according to a report from a group at the University of Cambridge, production of recycled steel requires a third of the energy needed for primary production, but "up to 75 per cent of steel and 50 per cent of aluminium could be reused without melting, with negligible emissions," due to the very low energy input required for reuse.[33]

As with recycling, such business models should reduce our exposure to commodity price volatility, and increase protection against fat tail risk pushing up prices of raw materials. Developing supply chains and infrastructure for repair, reuse, remanufacturing and servitisation could be a readily scalable form of diversification. Take the example of a manufacturer like Rolls Royce that sells jet engines and provides a servitised 'power by the hour' offer, in which companies pay for thrust generated by the jet engines rather than the engine itself. If the price of rhenium, a critical material for high performance jet engines, spikes, this could dampen engine sales, but so long as demand for thrust continues, 'power by the hour' sales might be able to continue and even expand. The company could alter the balance of its sales from product to service. Another jet engine company that hadn't developed the logistics, sales, supply chain and back office functions for 'power by the hour' would not be able to easily shift to a servitised model, leaving it exposed to adverse risks.

Circular economy business models are likely to offer the broadest range of benefits in terms of portfolio diversification. In contrast to recycling, these models have the advantage of managing the wide range of resource risks embodied in products, including risks for energy resources, which would still be required for recycling, and all other materials embedded in the product. Most recycling processes are designed to extract only some materials; for example, electronic waste recycling tends to recover platinum group metals: gold, silver, and copper, but loses the other 30 or so elements used. By contrast, circular economy business models can keep all the resources embodied in products in use. This is particularly beneficial as, over the past 15 years, we have seen an increase in the cross-correlation of many resource prices. When resource prices rise together, keeping all the materials in products in use for longer is more resilient than recycling.

The risk management advantages of resource stewardship measures

	Resource efficiency Using fewer resources	**Recycling** Keeping resources in use for longer	**Circular economy business models** Keeping products in use for longer
Exposure to volatility	Reduces exposure to commodity price fluctuations	Reduces exposure to commodity price fluctuations	Reduces exposure to commodity price fluctuations
Diversified risk portfolio	Diversification away from variable resource costs towards fixed capital costs of efficiency investments	If recycled and virgin materials prices are not perfectly correlated, then there is a diversification benefit	Most substantial benefits stem from keeping the widest range of resources in use
Fat tail risk	Less resource use moderates the impact of fat tail events	Reduced use of imported resources moderates the impact of fat tail events, which may be extremely important for some critical materials	Reduced use of imported resources moderates the impact of fat tail events and offers the potential to increase scale in response to shocks

The impact on investment decisions

We have shown that different resource stewardship measures can have important risk management benefits. We now consider how this might affect the decision making process for investment in resource stewardship .

In practice there are a number of steps that could be taken under the broad heading of 'resource stewardship' to reduce risk. According to the UK's *Resource and security action plan*:

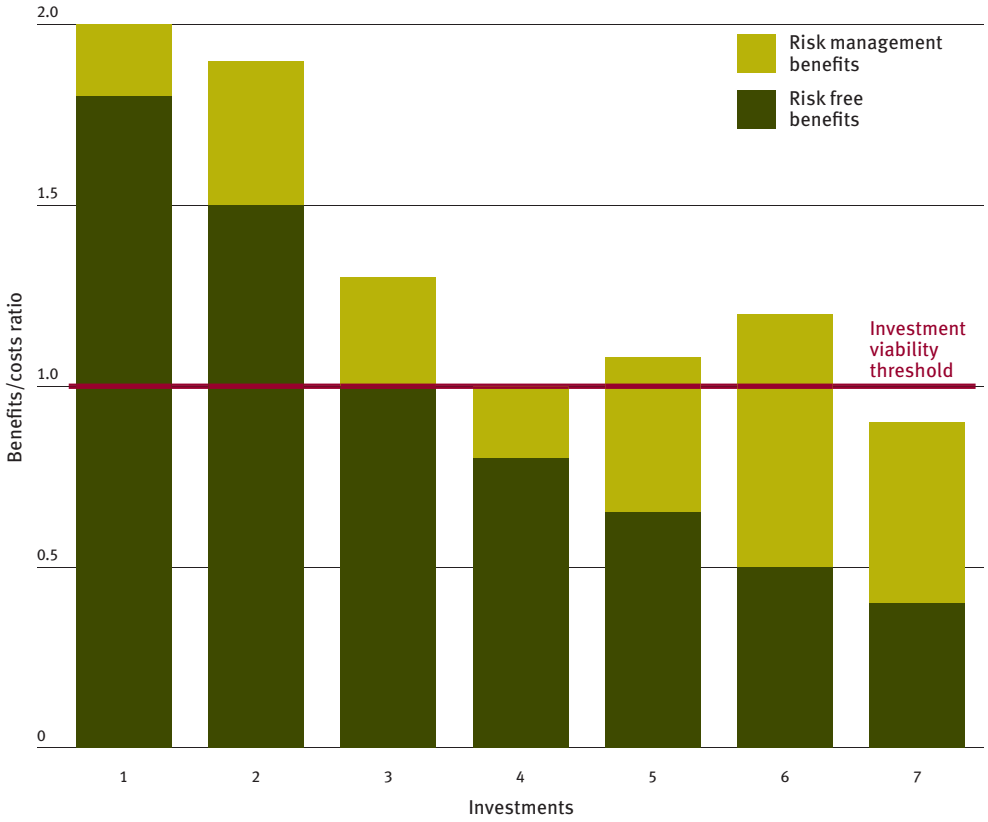
"There is a range of actions that can be taken now to reduce exposure to pricing and supply risks through improved resource efficiency and the development of 'secondary' supplies, or development of alternative materials. This means using less, wasting less, and reusing and recycling more. Risk can be reduced through a range of innovative approaches such as ecodesign, adoption of alternative business models to provide products and services in less resource-intensive ways and, in some cases, material substitution. At the same time there are business opportunities in taking advantage of new markets and maintaining 'whole lifetime' control over material resources."[34]

Inevitably when considering such a diverse range of potential steps to improve resource efficiency, each approach will offer different costs and benefits. The range of actions has been analysed in a number of studies by McKinsey which has estimated the cost effectiveness of possible investments in resource efficiency across the domains of energy, land, water and steel.[35] When deciding which investments in resource efficiency are cost effective, the expected price of commodities is a key factor as it determines the value of resource savings.

If commodity risks are ignored, the amount invested in resource efficiency is likely to rise and fall in line with expected commodity prices. However, if a risk management approach is adopted, investments that reduce the impact of volatility and fat tail risk, or offer portfolio diversification, can play an important role.

Given the wide range of potential measures, we will not attempt to be comprehensive about how a risk management approach may be used. Instead, the chart opposite provides an illustration of how it might be applied. The bars refer to a range of possible investments in resource efficiency, with different costs and benefits to society. The height of each bar shows the ratio of resource saving benefits to costs for each of each investment. The lower, dark green, part of each bar shows the ratio at today's commodity prices, taking no account of commodity price risks. Investments where the benefit versus cost ratio is above one will clearly pay off, and should take place at the current commodity price. But, if each investment is assessed in terms of its contribution to reducing the impact of commodity price volatility, and some value is placed on this, then more of the investments will return benefits greater than their costs. The contribution to reducing risk is likely to vary across projects, with some yielding much larger benefits than others. As can be seen, in this hypothetical example, taking a risk management approach means that the investments at bars four, five and six become viable, offering returns versus cost ratios above one.

The influence of a risk management approach on investment in resource efficiency



To quantify the potential risk management benefits of an investment in resource stewardship, it is necessary to turn to the financial analysts' toolkit discussed on page 14. The benefits of a reduced impact of volatility could be calculated using the increase in the Sharpe Ratio stemming from the investment in resource stewardship. The benefits of a reduced fat tail risk could be calculated by estimating how large an insurance premium one would be prepared to pay to achieve a similar reduction in the impact of a tail event, possibly through the use of Contingent Valuation techniques. Finally, the portfolio benefits could be obtained by estimating the expected improvement in returns from a more diverse portfolio.

A role for government

Governmental assessment of resource risk has tended to be insufficiently broad or strategic as it appears to take place mainly at the departmental level or even on a policy by policy basis. Arguably, governments have also tended to be reactive rather than proactive in their approaches to resources. For instance, many innovations, like increased energy efficiency and the development of nuclear power in France, followed the resource price shocks of the 1970s.

Identifying market failures which hamper the development of resource efficiency is a useful starting point for considering government policy measures for the UK. The Circular Economy Task Force has studied a range of market barriers which prevent companies from realising the benefits and identified mispriced risk as the first such problem: the assumption being that, because material availability and costs have been unproblematic in the past, they will not be so in the future.[36] It also pointed to other public benefits of circular economy systems, which may require financial incentives for companies to invest, and highlighted the inadequacy of current recovery infrastructure which requires substantial investment.

A major challenge is that, although risk management is a good reason for the UK business sector to adopt greater resource stewardship, the incentives for individual companies are not always obvious.[37] Risk management may even lead a business to be cautious about improving its resource stewardship, fearing that the investment will not pay off if commodity prices fall.

In formulating a policy for resources, the government should see itself as a portfolio manager, supporting the development of an economy with a broad range of activities to ensure greater resilience to a range of risks. Although, in a free market, it is not the responsibility of government to decide the exact structure of the economy, it can still take a strategic view and seek to shape development. It can do this through effective industrial policy, support for R&D, innovation and skills development in resource efficiency, and by overcoming barriers to the development of circular systems and infrastructure.

Endnotes

[1] See for instance: John Gapper, 27 November 2014, 'Cheap energy is the new cheap labour', *Financial Times*; Nicole Friedman, 2 January 2015, 'Low oil prices are the new normal, say analysts', *The Australian*; 1 March 2015, 'Oil prices at $60 is 'new normal', says Colombian finance minister', *The Daily Telegraph*; Anatole Kaletsky, 15 January 2015, 'A new ceiling for oil prices', Project Syndicate.

[2] *The Economist*. 1999, 'The next shock?', www.economist.com/node/188181

[3] These World Bank indices are only available to October 2014. Other sources indicate that oil prices fell further in the next three months, but partly rebounded in February 2015.

[4] World Bank nominal commodity price indices (2010=100), converted from a dollar to a sterling based index and divided by the UK consumer price index. Sources: World Bank, Bank of England, ONS and Green Alliance calculations.

[5] Standard deviation of World Bank real commodity price indices over a moving five year window averaged for the period 1960-99 and 2000-12 respectively (dollar based). We take a five year standard deviation to dampen the effect of short term spikes that may be misleading. Sources: World Bank and Green Alliance calculations.

[6] *The Economist*, 1999, op cit

[7] IMF, World Economic Outlook Reports List, retrieved 26 March 2015 from www.imf.org/external/ns/cs.aspx?id=29

[8] IMF commodity price indices (2005=100), projected forward using the percentage change projection in each WEO (April/May for each year). Projections at horizons three to six years ahead are usually at a constant average growth rate. Sources: IMF WEO and Green Alliance calculations.

[9] Jim O'Neill, 7 January 2015, 'The Price of Oil in 2015', Project Syndicate.

[10] Ibid

[11] Rabah Arezki and Olivier Blanchard, 22 December 2014, 'Seven questions about the recent oil price slump', IMF Direct blog.

[12] Ibid

[13] Ibid

[14] J Morgan, 2014, *The great resource price shock*, Green Alliance

[15] 2020 Conservatives, 2014, *Sweating our assets: productivity and efficiency across the UK economy*

[16] J Morgan, 2014 , op cit

[17] Source: ONS, March 2015

[18] J Morgan, 2014, op cit

[19] IMF. 2014, 'World economic outlook: recovery strengthens, remains uneven', IMF

[20] Rabah Arezki and Olivier Blanchard, 22 December 2014, op cit

[21] For a useful review of these issues see: Z Ebrahim, O R Inderwildi and D A King, January 2014, 'Macroeconomic impacts of oil price volatility: mitigation and resilience', in *Frontiers in Energy*, Springer

[22] World Economic Forum, *Global Risks* 2015, 10th edition, figure C2, p 62

[23] European Commission, 2014, 'Critical raw materials profiles', *Report on critical raw materials for the EU*, ec.europa.eu/enterprise/policies/raw-materials/files/docs/crm-critical-material-profiles_en.pdf, (last accessed 16 February 2015); BGS, 2012, *Risk List 2012*, www.bgs.ac.uk/mineralsuk/statistics/risklist.html, (last accessed 16 February 2015).

[24] European Commission, 2014, op cit

[25] Sources: EU import dependency rates are calculated as the ratio of EU imports over consumption in 2012. Values are taken from the European Commission's report on raw materials profiles, part of the EU critical raw materials publications (see endnote 23). For antimony, imports represent both imports of antimony ores and concentrates, and unwrought and powered antimony. For dysprosium, an import dependency rate of 100 per cent is assumed, despite the lack of data, as the EU does not produce any dysprosium and China produces 99per cent of the world supply. Annual demand growth is an average growth rate for world demand over 2010-20, calculated by the European Commission in 2014. Price volatility is taken as the ratio of the standard deviation of the resource price 2000-12, over the

average price in the same period. For antimony, indium and phosphate rock, prices are taken from USGS 2014 *Historical statistics for mineral and material commodities in the United States* and figures have been calculated with $98 per tonne prices. For dysprosium, prices have been taken from the USGS *Metal prices in the United States through 2010* publication, and have been calculated with $/t prices. Furthermore, for dysprosium, the rate is calculated over the 2000-10 period. Data on the main producers has been taken from the European Commission's 2014 *Report on critical raw materials for the EU.*

[26] Named after the Nobel Laureate William Sharpe. W F Sharpe, 1966, 'Mutual fund performance', *Journal of Business*.

[27] Harry Markowitz showed in a ground breaking paper in 1952 that the performance depended on the correlation between a portfolio's constituent parts as well the performance of the individual parts themselves. H Markowitz, 1952, 'Portfolio selection', vol 7, *Journal of Finance*.

[28] For example, the joy of winning £100,000 pounds is far less than the pain of losing £100,000 D Kahneman and A Tversky, 1979, *Prospect theory: an analysis of decision under risk*, vol 47, Econometrica.

[29] See for instance the Wikipedia description of a normal distribution at en.wikipedia.org/wiki/Normal_distribution

[30] London inter-bank offer rate, seen as a benchmark bank interest rate.

[31] D Benton and J Hazell, 2013, *Resource Resilient UK*, Green Alliance, page 19.

[32] See D Benton. and J Hazell, March 2015, 'The circular economy in Japan', *Environmental Scientist*, Journal of the Institution of Environmental Sciences.

[33] J M Allwood, J M Cullen, D R Cooper, R L Milford, A C H Patel, M A Carruth and M McBrien, September 2010, 'Conserving our metal energy: avoiding melting steel and aluminium scrap to save energy and carbon', www.lcmp.eng.cam.ac.uk/wp-content/uploads/WellMet2050-Conserving-our-metal-energy-Sept-2010-Web.pdf

[34] BIS and Defra, 2012, *Resource security action plan: making the most of valuable materials*

[35] McKinsey, 2011, *Resource revolution: meeting the world's energy, materials, food, and water needs.* According to McKinsey many of these already make sense for investors and further investments could be justified from a societal perspective (taking into account externalities and a lower discount rate); McKinsey for the UK Government, 2012, *Capturing the full electricity efficiency potential of the UK*

[36] D Benton and J Hazell, 2013, *Resource resilient UK*, Green Alliance

[37] See, for instance, the analogy to the co-operative/non co-operative theoretical problem of hunting rabbits or stags made in *Resource resilient UK*

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