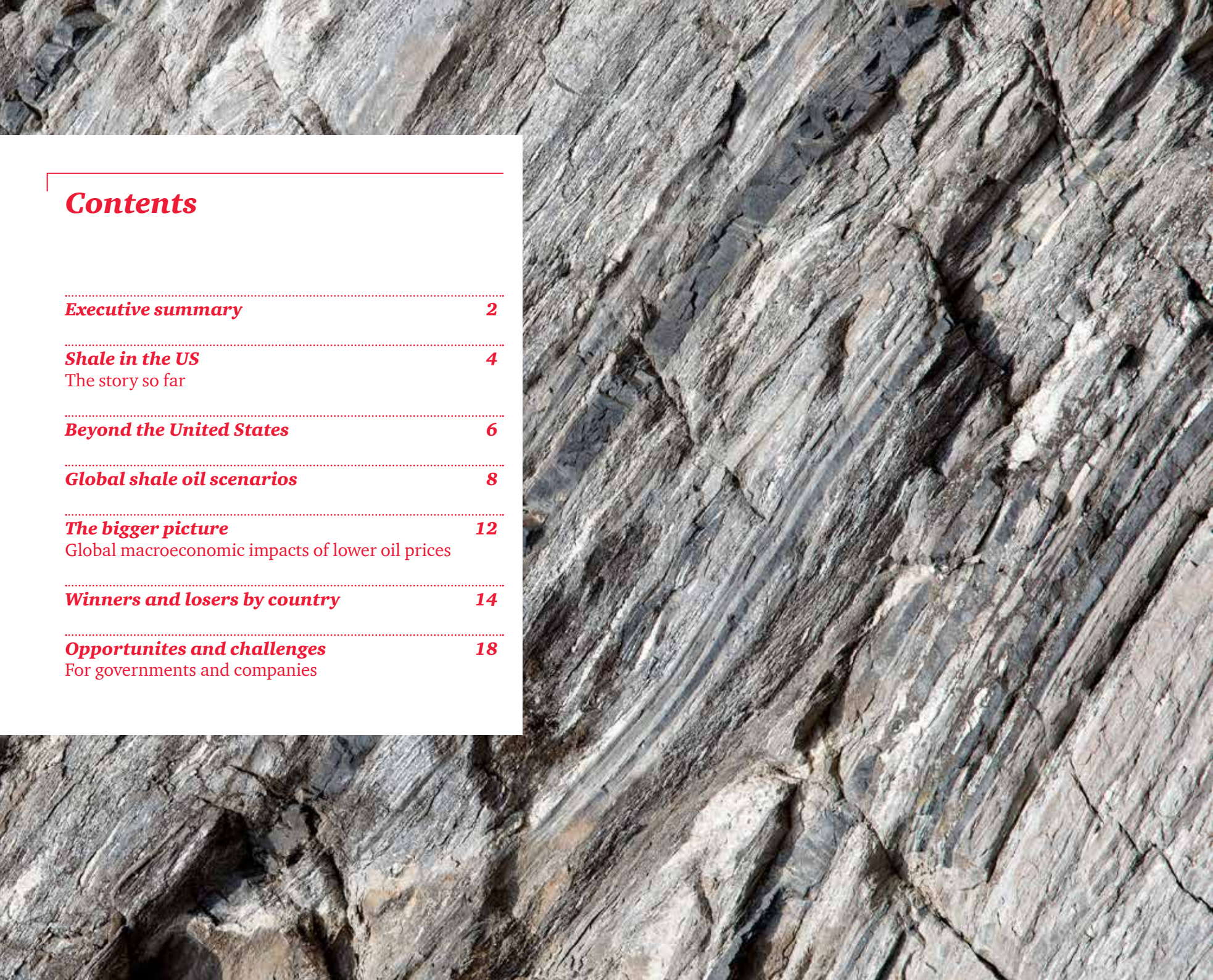
www.pwc.co.uk

Shale oil: the next energy revolution

The long term impact of shale oil on the global energy sector and the economy

February 2013

pwc



Contents

Executive summary

- Shale oil (light tight oil) is rapidly emerging as a significant and relatively low cost new unconventional resource in the US. There is potential for shale oil production to spread globally over the next couple of decades. If it does, it would revolutionise global energy markets, providing greater long term energy security at lower cost for many countries.

- Our analysis suggests that global shale oil production has the potential to reach up to 14 million barrels of oil per day by 2035; this amounts to 12% of the world's total oil supply.

- We estimate that this increase could reduce oil prices in 2035 by around 25%-40% ($83-$100/barrel in real terms) relative to the current baseline EIA projection of $133/barrel in 2035, which assumes low levels of shale oil production.

- In turn, we estimate this could increase the level of global GDP in 2035 by around 2.3%-3.7% (which equates to around $1.7-$2.7 trillion at today's global GDP values).

- However, the benefits of such oil price reductions will vary significantly by country. Large net oil importers such as India and Japan might see their GDP boosted by around 4%-7% by 2035, while the US, China, the Eurozone and the UK might gain by 2%-5% of GDP.

- Conversely, major oil exporters such as Russia and the Middle East could see a significant worsening of their trade balances by around 4%-10% of GDP in the long run if they fail to develop their own shale oil resources.

- The potential emergence of shale oil presents major strategic opportunities and challenges for the oil and gas industry and for governments worldwide. It could also influence the dynamics of geopolitics as it increases energy independence for many countries and reduces the influence of OPEC.

- There are significant strategic implications along the value chain. Oil producers, for example, will have carefully to assess their current portfolios and planned projects against lower oil price scenarios.

- National and international oil producers will also need to review their business models and skills in light of the very different demands of producing shale oil onshore rather than developing complex "frontier" projects on which most operations and new investment is currently focused.

- Lower than expected oil prices could also create long-term benefits for a wide range of businesses with products that use oil or oil-related products as inputs (e.g. petrochemicals and plastics, airlines, road hauliers, automotive manufacturers and heavy industry more generally).

- The potential environmental consequences of an increase in shale oil production are complex and appropriate regulation will be needed to meet local and national environmental concerns. Shale oil could have adverse environmental effects by making alternative lower carbon transport fuels less attractive, but might also displace production from higher cost and more environmentally sensitive plays.

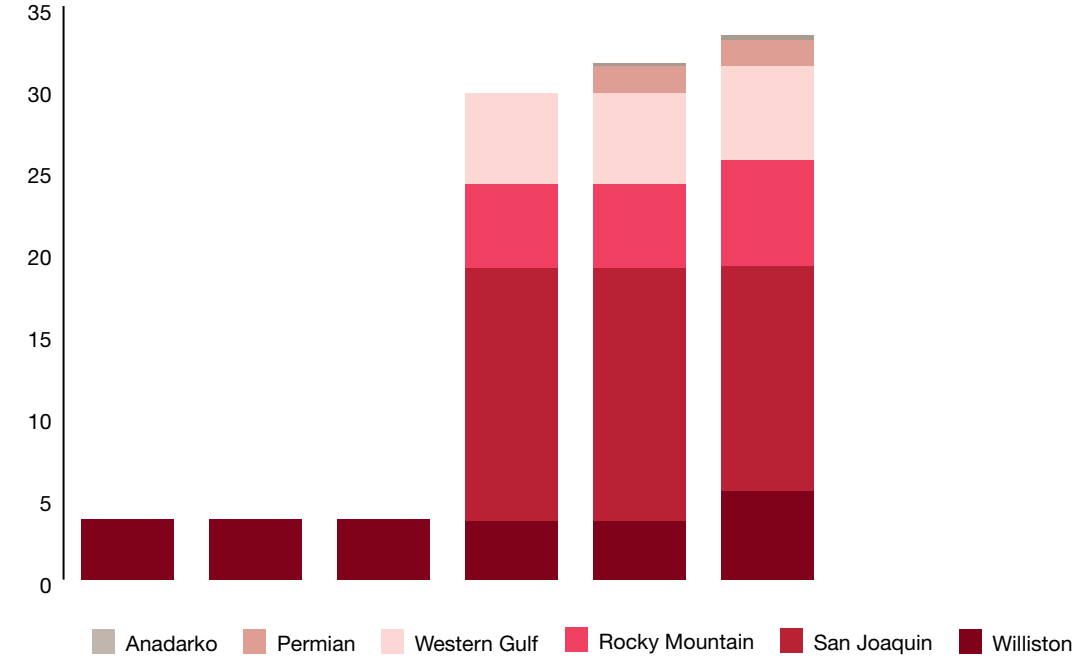
Shale in the US
The story so far

- Shale oil production has been accelerating in US, growing from 111,000 barrels per day in 2004 to 553,000 barrels per day in 2011 (equivalent to a growth rate of around 26% per year). As a result, US oil imports are forecast this year to fall to their lowest levels for over 25 years.

- Estimates by the US Energy Information Administration (EIA) suggest that shale oil production in the US will rise more slowly in the future to around 1.2 million barrels per day by 2035[1] (equivalent to 12% of projected US production at that date). However, these projections seem conservative relative to other market analysts who forecast US shale oil production of up to 3-4 million barrels per day by that date.[2]

- EIA estimates of the scale of total shale oil resources in the US have been revised upwards from 4 billion barrels in 2007 to 33 billion barrels in 2010, providing a significant contribution to increased US energy independence (as shown in Chart 1).[3]

Chart 1. EIA US technically recoverable shale oil assessments by basin made between 2005 and 2010



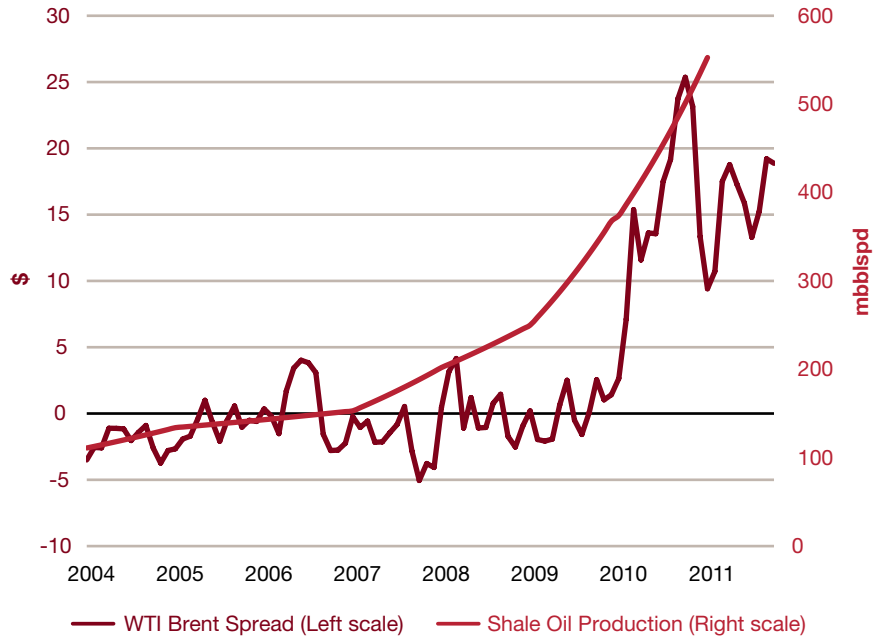
Source: EIA Annual Energy Outlook 2012

- Shale oil could make the largest single contribution to total US oil production growth by 2020, with the proportion of production from conventional sources remaining relatively stable.

- In the long term, we estimate that shale oil could displace around 35-40% of waterborne crude oil imports to the US. This would create additional effective supply to other locations such as China. However, should China start to exploit its own shale oil resources(as discussed further below) this would further decrease its import dependency and increase effective supply to oil importing countries.

- Rapid production growth in shale oil is having dramatic local effects on pricing in areas where shale oil is produced but access to export infrastructure is limited. The US domestic oil price has already decoupled from global indices and imports are forecast to decline (as shown Chart 2 below). Put simply, increased shale oil production could lead to oil prices that are significantly lower than projected in current forecasts.

Chart 2. WTI and Brent Oil Price Spread (2004-12)

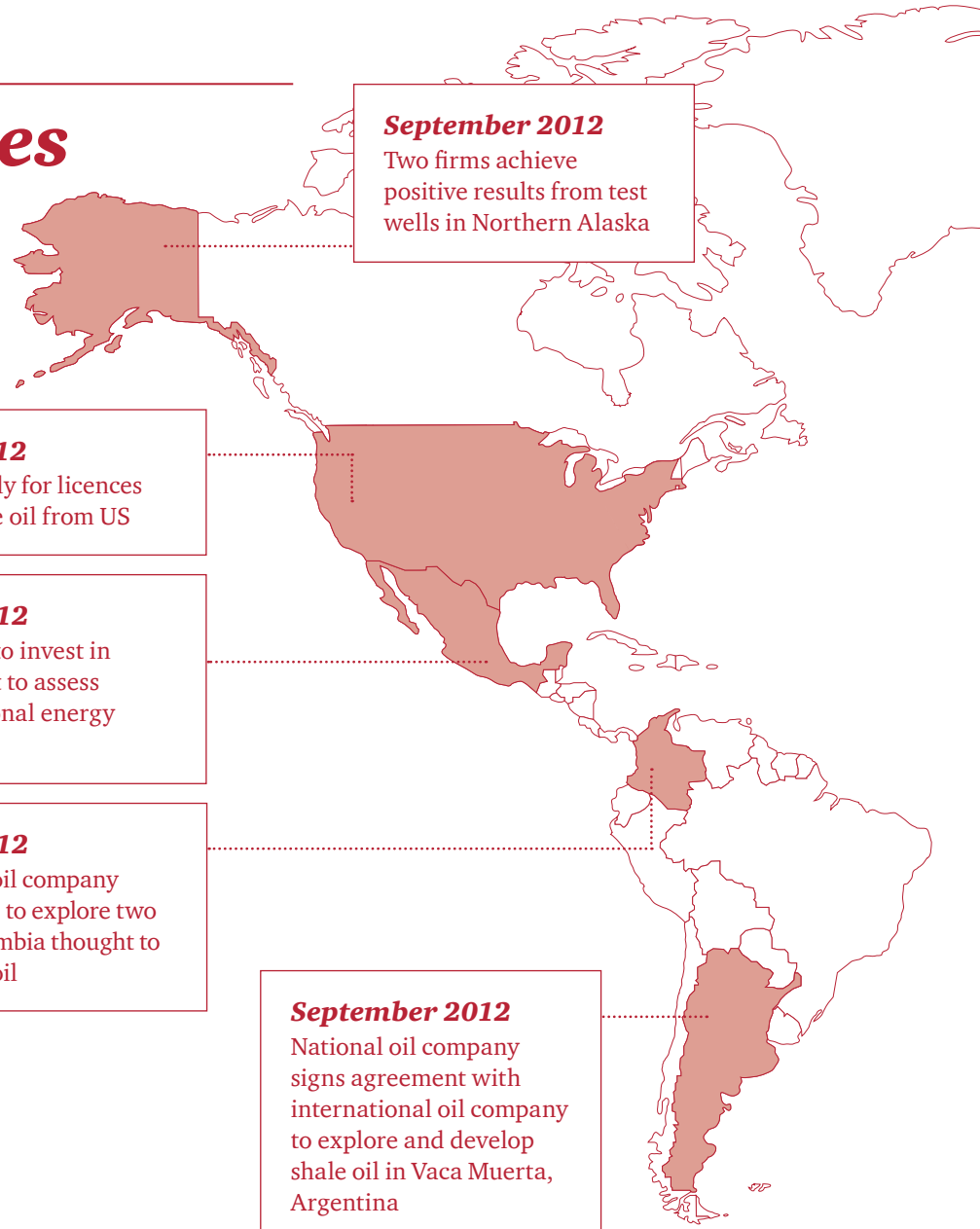


Source: EIA AEO 2009,2010,2011,2012, Baker Hughes

1. EIA Annual Energy Outlook 2012
2. See recent projections from Citi Energy 2020, IEA World Energy Outlook 2012, Credit Suisse US Oil Production Outlook (September 2012),IHS Cera, and BP Statistical Review 2012.
3. EIA Annual Energy Outlook 2012

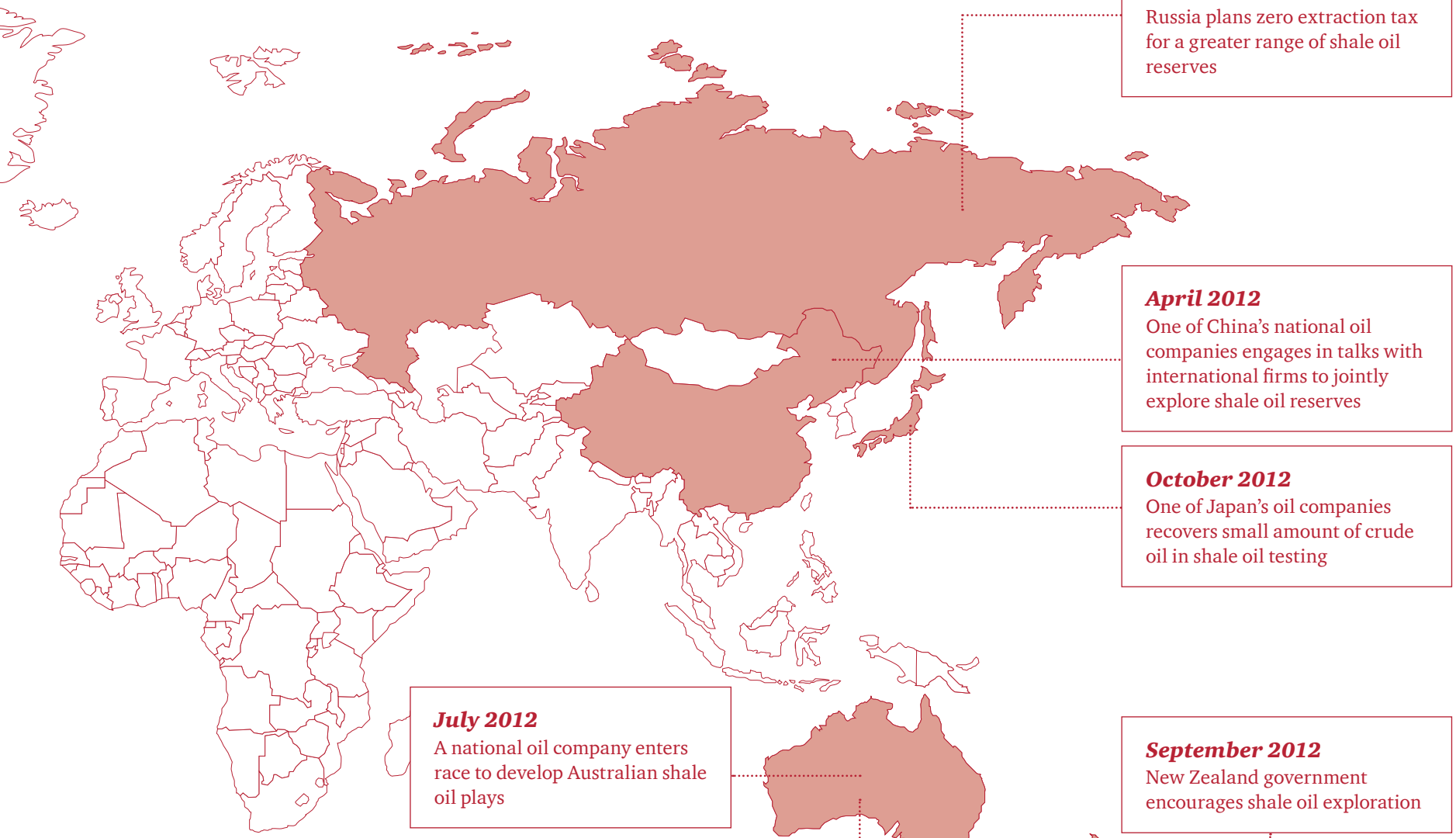
Beyond the United States

- Outside the US, the development of shale oil is still at an early stage. However, there are indications that point to large amounts of technically recoverable resources distributed globally.
- Global shale oil resources are estimated at between 330 billion and 1,465 billion barrels[4]. Investment is already underway to characterise, quantify and develop shale oil resources outside the US, for example, in Argentina, Russia and China[5].
- Since the beginning of 2012, there have been a number of announcements, from Argentina to New Zealand, of discoveries of shale oil resources as well as government initiatives to encourage the exploration and production of shale oil (see Map 1).



4. "A review of uncertainties in estimates of global oil resources", McGlade, C.E., UCL Energy Institute
5. International Gas Report, Dow Jones, SeeNews, Diamond Gas Report, Platts, Natural Gas Intelligence, EFE, APS Review, Upstream , Oil and Gas news, Oil Daily, Financial Times

Map 1. Shale oil investment is global



October 2012
Russia plans zero extraction tax for a greater range of shale oil reserves

April 2012
One of China's national oil companies engages in talks with international firms to jointly explore shale oil reserves

October 2012
One of Japan's oil companies recovers small amount of crude oil in shale oil testing

July 2012
A national oil company enters race to develop Australian shale oil plays

September 2012
New Zealand government encourages shale oil exploration

January 2013
Australian energy company announces discovery of 233 bn bbls of shale oil resources

Source: PwC research

Global shale oil scenarios

The potential impact of rising shale oil production on global oil prices

- We have developed scenarios that consider the potential impact of future growth in shale oil production on oil prices. We have then assessed how oil price changes of this magnitude could impact the wider economy up to 2035 at both global and national levels using a macroeconomic model.

- These long-term projections are subject to many uncertainties and are conditioned on a number of key assumptions as summarised in Box 1. The specific figures quoted for different scenarios should therefore be interpreted as being indicative of broad orders of magnitude rather than being precise numerical forecasts.

- The remainder of this paper summarises the key results of this research and outlines the potential implications for companies and governments.

Box 1: Scenario assumptions and considerations

The scenarios presented in this report rest on a number of key assumptions:

- The successful development of shale oil resources is dependent on the presence of globally distributed, large scale, good quality resources, with overall technical and economic recoverability that is broadly in line with the produced shale oil resource in the US. Significant exploration and appraisal will need to be undertaken in future years to prove resource quantity and quality.

- The second key consideration is the timing of large scale development of shale oil resources. Development of shale gas outside the US has arguably been disappointing to date and the same issues (including regulatory obstacles, infrastructure, logistics and skills challenges) may also influence the pace at which shale oil opportunities are pursued outside the US. We assume that shale oil production outside the US is phased in several stages, starting with small scale production from 2015, building up to one million barrels per day by 2018 and continuing to grow thereafter.

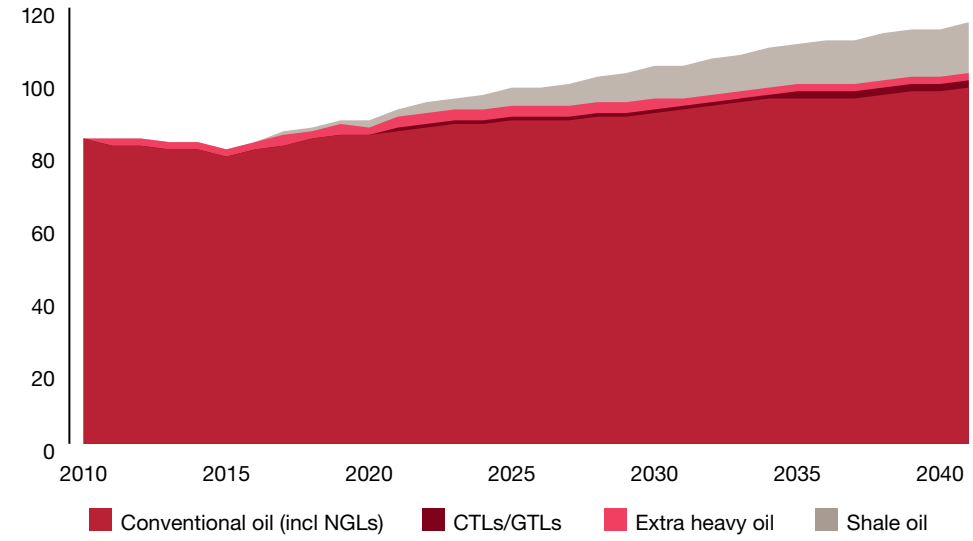
- The third key requirement for shale oil to be exploited effectively is a supportive regulatory framework. This also needs, however, to take account of local environmental concerns and to be consistent with national government objectives on decarbonisation and energy security. Different countries are likely to strike a different balance here and this is reflected, for example, in our assumption that shale oil production develops more slowly in the EU than in the US and some other territories.

Recent forecasts from the EIA and the International Energy Agency (IEA) suggest a marked rise in both global oil production and real oil prices over the period to 2035, due in particular to rising demand from China, India and other fast-growing emerging economies[6]. The IEA forecasts a 19% increase in global oil production by 2035, as compared to a 28% increase forecast by the EIA[7] (which is not that large a difference given the uncertainties involved in any such long-term projections).

The EIA and IEA's average global oil price predictions are even more closely aligned, with the IEA predicting a sharp short-term increase that gradually flattens off in the longer term to $127 per barrel by 2035 and the EIA predicting a steadier price increase to reach $133 per barrel by 2035 (both estimates are expressed in real terms adjusted for general US price inflation, which is also the case for all other oil price projections quoted in this report).

In deriving these oil price projections, both agencies assume relatively modest growth in shale oil as a proportion of total global production. Their projections in this respect are arguably conservative as they are based only on resources about which there is already a high degree of certainty. Past experience of shale oil and shale gas suggests that these resource estimates are likely to be revised upwards significantly over time as activity to new plays in the US and globally.

Chart 3. Global liquids production by resource



Source: EIA IEO 2011, PwC Analysis (main scenario)

Extrapolating from the available data (and drawing parallels with US shale gas experience) has enabled us to generate a number of scenarios which see shale oil production ramping up both in the US and around the globe. As shown in Chart 3, this analysis suggests that global shale oil production has the potential to rise to up to 14 million barrels of oil per day by 2035 in our main scenario, amounting to 12% of total oil supply at that date (using EIA projections for production other than shale oil).

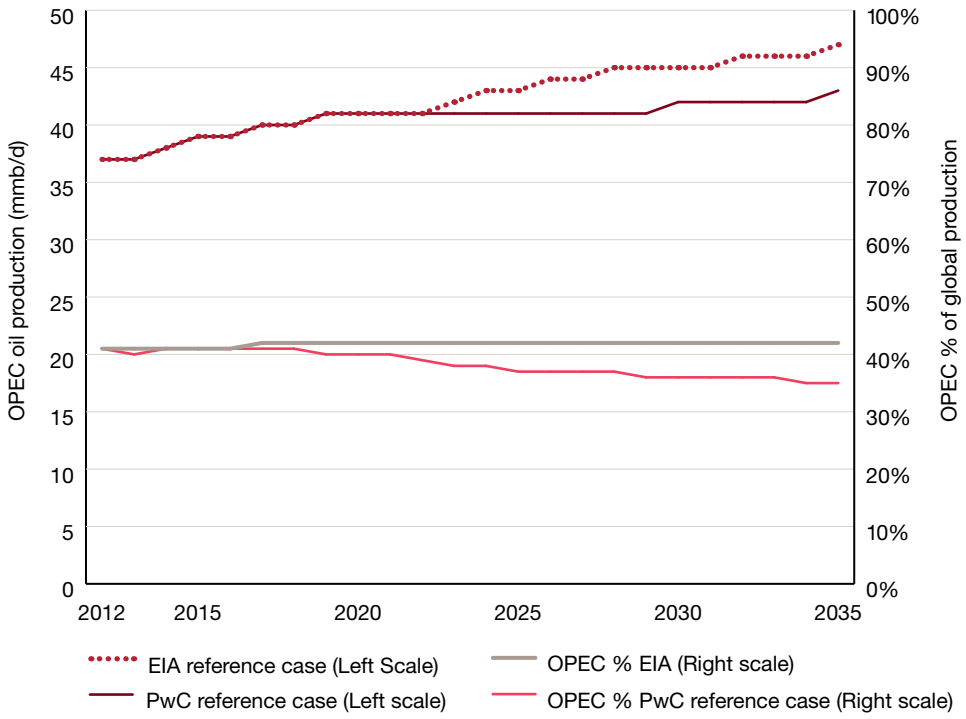
6. These global energy and oil demand projections are also broadly consistent with those derived from our own 'World in 2050' long-term economic growth model, as described further in this recent PwC publication: http://www.pwc.com/gx/en/world-2050/the-brics-and-beyond-prospects-challenges-and-opportunities.jhtml
7. Sources: EIA International Energy Outlook (IEO) 2011, EIA American Energy Outlook (AEO) 2012 and IEA World Energy Outlook (WEO) 2012.

We have developed two core oil price scenarios[8] based on this shale oil production outlook:

- The first scenario (the 'PwC reference case') allows for OPEC to respond to increases in shale oil production and consequent lower oil prices by limiting its own production to maintain an average price of around $100 dollars per barrel (in real terms). This supply scenario results in OPEC losing some market share, although OPEC member states continue to increase total production in absolute terms to meet rising demand (as shown in Chart 4).

- The second scenario (the 'PwC low case') does not include an OPEC response, so the increased overall oil supply results in a greater impact on oil prices, which fall by 2035 to around $83 per barrel in real terms.

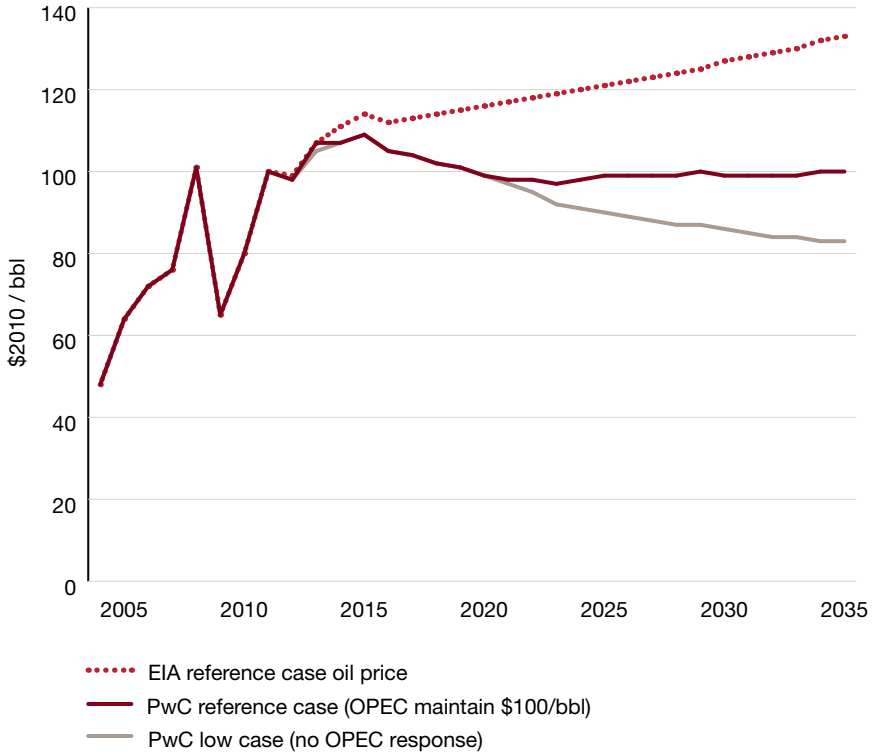
Chart 4. Forecast of OPEC production in PwC reference case vs. EIA reference case



Source: EIA IEO 2011, OPEC Website, OPEC Annual Report 2009, 2004, PwC Analysis

8. In the full analysis we developed a much larger range of alternative oil price scenarios, but for clarity of exposition we focus on two representative scenarios in this report.

Chart 5. Forecast oil price incorporating impact of shale oil production vs. EIA reference case



Source: EIA AEO 2012, PwC analysis

In both these scenarios, our model suggests a global real oil price that is significantly lower than the EIA reference case projections of around $133 per barrel in 2035 - by around 25% in our reference case, and by around 40% in our low case (see Chart 5). This corresponds to a real oil price fall of around $33-50 per barrel by 2035 compared to the EIA baseline projection. In our scenarios, the oil price falls by proportionately much more than the rise in oil supply. This reflects the well-documented empirical finding that oil demand is relatively insensitive to price changes, based on estimates of long-term price elasticities in our model drawn from past academic studies[9].

9. See, for example, the survey of oil price elasticity of demand estimates in J.D. Hamilton, 'Understanding Crude Oil Prices', Department of Economics, University of California, San Diego, May 2008 (Table 3, p.34).

The bigger picture
Global macroeconomic impacts of lower oil prices

Lower global oil prices of the magnitude indicated by our analysis suggest a major impact on the future evolution of global economy, given the key role that oil prices still play. These effects are not as great now as in the 1970s when oil price hikes had severe negative impacts on major oil-importing economies, helping to push the UK and many other countries into prolonged periods of 'stagflation', but are nevertheless very significant.

We have used the National Institute Global Econometric Model (NiGEM) to help us understand the likely scale of these impacts[10]. We have explored the consequences of a lower oil price across the global economy and for selected major national economies covered by the model (in particular the US, Japan, Germany, the UK and the BRICs – Brazil, Russia, India and China).

Oil prices play three key roles within the NiGEM model:

1. Energy combines with labour and capital to produce economic output (as measured by GDP).

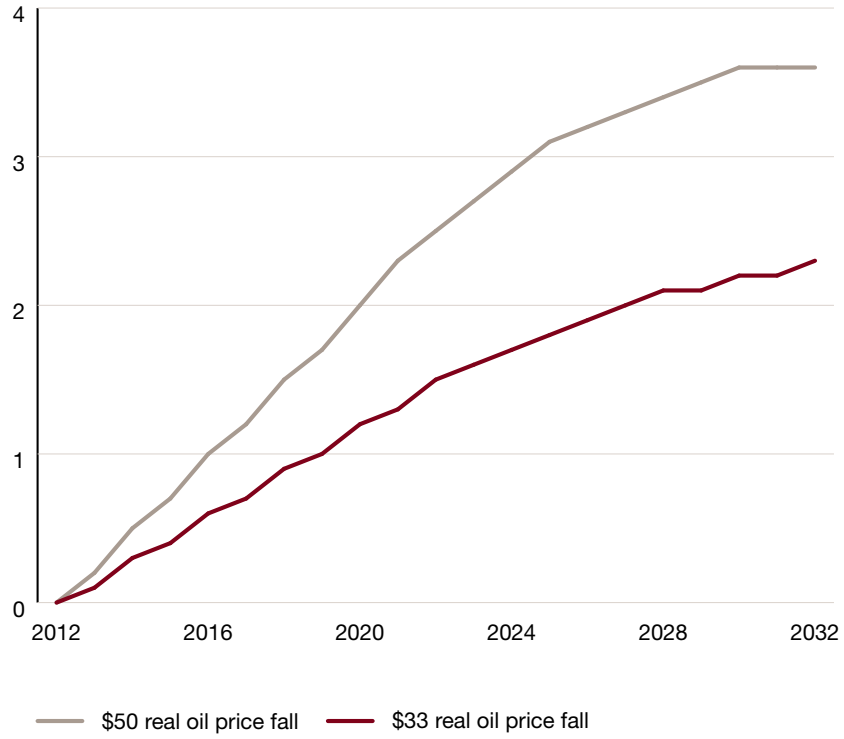
2. Import and export prices are modelled as a weighted average of commodity and non-commodity prices. A decrease in the price of oil will improve the terms of trade for a net oil importer, and conversely see them deteriorate for a net oil exporter.

3. Oil prices are directly and indirectly linked to consumer prices. Lower oil prices will generally boost consumer spending power, especially in net oil importing economies.

10. NiGEM is a global econometric model developed by the National Institute of Economic and Social Research (NIESR), one of the UK's longest established and most respected economic research institutes. Central banks, finance ministries and leading companies around the world use the NiGEM model. It enables them to understand the likely impacts of major economic shocks and how a range of macro-economic variables may react and adjust over time. However, it should be noted that the analysis in this report and the interpretation of the results is the sole responsibility of PwC, which has a licence to use NiGEM, rather than of NIESR.

We have used NiGEM to model the impact of the two different scenarios considered above – namely a decrease of either $33 or $50 in real global oil prices, phased in over two decades (the maximum time horizon of the model[11]). The model indicates that the level of global GDP could be between 2.3% and 3.7% higher at the end of the projection period (see Chart 6). At today's GDP values, this is equivalent to an increase in the size of the global economy of around $1.7-2.7 trillion per annum. This could imply a rise by 2035 in average global GDP per person of between $230 and $370 per annum (at today's prices) relative to the EIA baseline case with minimal shale oil production.

Chart 6. Global economic benefits from a lower oil price (% of world GDP)



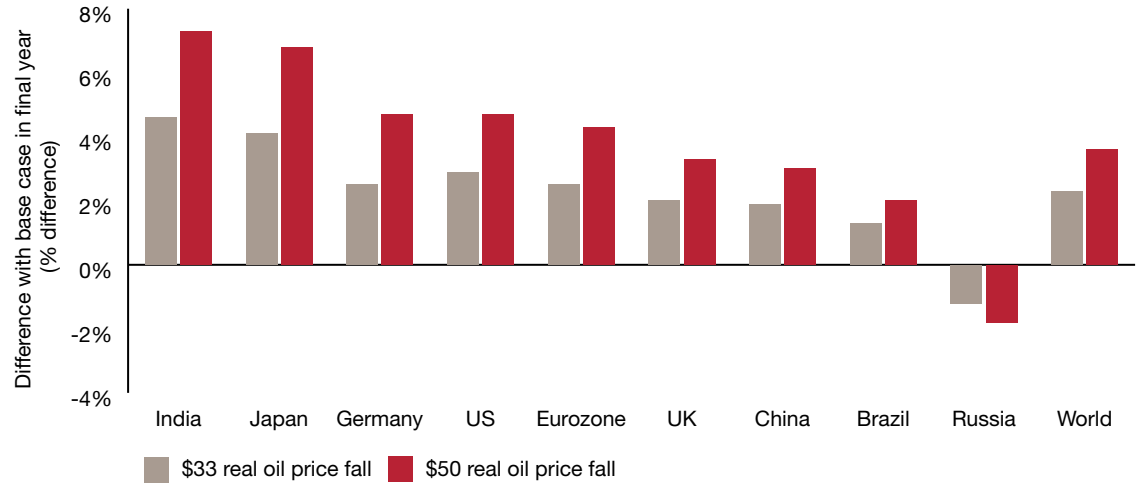
Source: PwC analysis using NiGEM

11. Strictly speaking the NiGEM model projections therefore end in 2032, but in the text we generally refer to these effects as relating to 2035 for consistency with our global oil price modelling and that of the EIA in their baseline projection. Looking so far ahead, the difference between potential effects in 2032 and 2035 is, in any event, not likely to be at all material compared to the uncertainties surrounding any such projections.

Winners and losers by country

Clear 'winners' emerge when considering the impact at a national level. India and Japan, for example, could under these scenarios see an increase in GDP of between 4% and 7% by the end of the projection period (see Chart 7). Other net oil importers such as the US, China, Germany and the UK could also see GDP gains of the order of 2-5% of GDP in the long term due to lower global oil prices relative to a baseline with minimal shale oil.

Chart 7. Change in national GDP in oil price scenarios (relative to baseline)

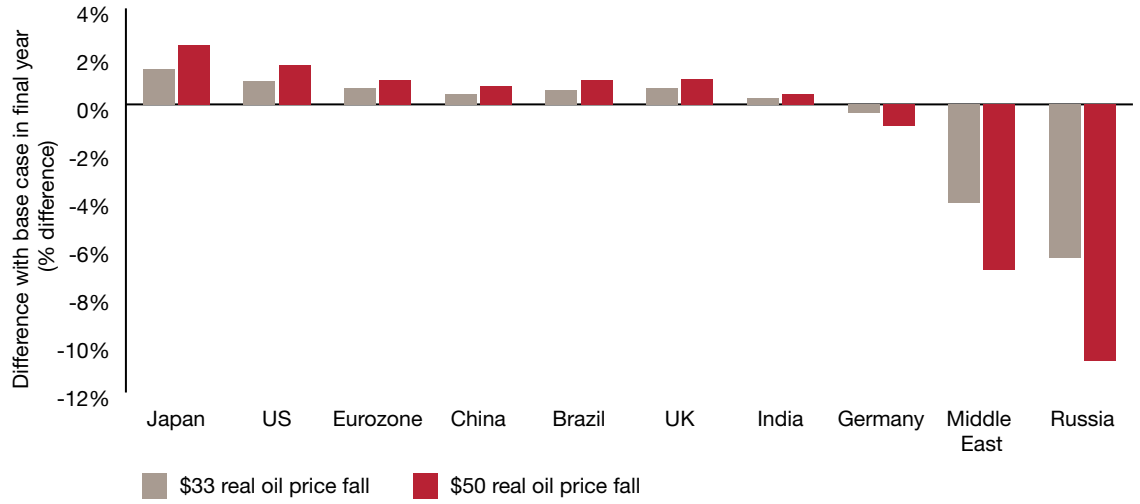


Source: PwC analysis using NiGEM

At the other end of the spectrum, the model shows that some major net oil producers could see their current account balances deteriorate significantly as a result of lower oil prices (see Chart 8 for Russia and the Middle East). However, the NiGEM model takes no account of which particular countries will be producers of shale oil. And Russia could limit its projected losses were it to exploit its estimated resources, the largest in the world.

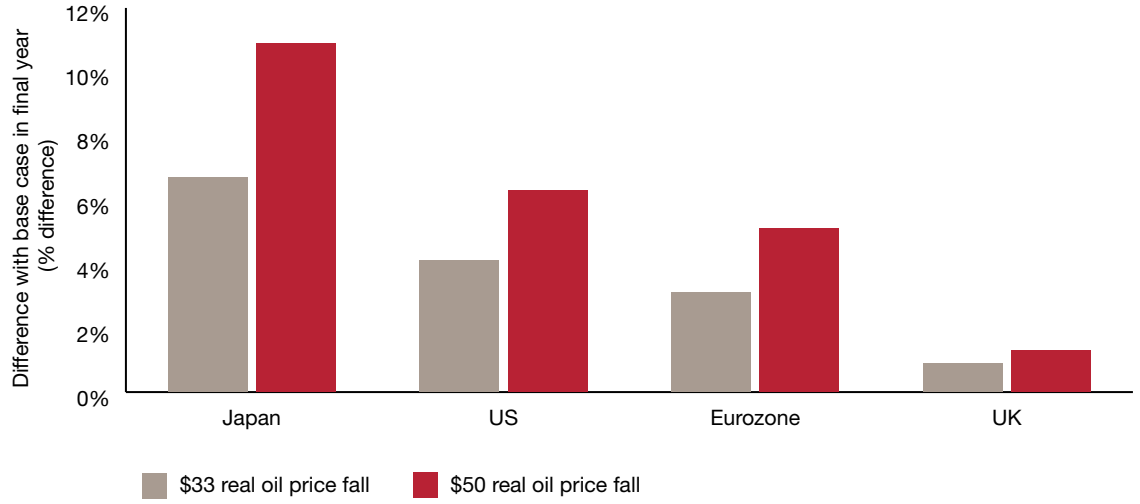
A lower oil price acts as a boost to consumers' real disposable income similar to an indirect tax cut, with a consequent positive effect on real household spending levels. In Japan, for example, the model results suggest a fall of $50 in the real oil price could increase private consumption per head at the end of the projection period by the equivalent of more than $3,000 per year (when compared to the EIA baseline with minimal shale oil production). Gains in the US and the Eurozone would also be significant, although net gains to UK consumers would be lower in part because there are also losses on existing North Sea oil and gas revenues if global energy prices fall (see Chart 9).

Chart 8. Change in current account balance as % of GDP in alternative oil price scenarios



Source: PwC analysis using NiGEM

Chart 9. Change in real household consumption in alternative oil scenarios



Source: PwC Analysis using NiGEM

Opportunities and challenges
For governments and companies

The possibility of increases in shale oil production and the potential macroeconomic impact raises challenging questions for all stakeholders in the energy industry:

- **Governments in current net oil importing countries with potential shale oil resource** will need to understand the likely economic payback from creating policies to encourage exploitation of shale oil (both on its own and relative to other unconventional resources).
  - With a lower oil price, the financial investment case for renewables becomes relatively less attractive; governments will have important choices to make as to how to realise the benefits from shale oil production in a way that balances potentially conflicting objectives of energy affordability and decarbonisation. For example, if oil prices are lower than expected due to shale oil, governments could keep fossil fuel taxes higher than would otherwise be acceptable and recycle the proceeds from this into, for example, funding for R&D for low carbon technologies.
  - Shale oil could displace other new oil supply sources that could be argued to have higher associated environmental costs. The potential environmental impact of shale oil is complex and there will be challenging regulatory, fiscal and other policy decisions for governments to make in this area over the coming years and decades.
- **Governments in OPEC nations and other major net oil exporters** need to assess the likely impact of shale oil on global oil prices and their own revenues, budgets and economies. They need to consider how best to respond in terms of potentially limiting growth in oil production to counteract the potential price effects of increased production outside OPEC. Another priority may be the mitigation of the long-term impacts on governments' revenues more generally of oil prices below current projections. Where feasible, they also need to consider pursuing their own shale oil exploration and production options.
- **Oil companies** have to assess their current portfolios and planned projects against lower oil price scenarios. They need to understand the likely impacts of lower oil prices on the investment case for high cost projects. In addition, they need to review their business models and skills in the light of shale oil's industrialised production process which makes very different demands of operators than today's remote and challenging locations.

- **Businesses that support national and international oil companies with services and equipment** need to consider the implications for their strategy and operating model as their clients shift focus from offshore to onshore operations with very different implications for the services and capabilities required. Already many IOCs are starting to invest in shale oil exploration and production outside the US, including sites in China, Argentina, Australia and Russia.

- **Major downstream operations,** such as refineries and petrochemical plants, which rely on oil and oil products, need to consider new sources of supply and the potential for lower feedstock prices, both of which may influence the performance of existing assets and investment decisions in new ones.

- **More generally, companies across the economy which rely on oil and related products** (e.g. plastics, airlines, road haulage, automotive manufacturers and heavy industry more generally) could see significant favourable shifts in their cost structures over the next couple of decades. These will need to be factored into longer term business planning and investment appraisal decisions.

Conclusions

The potential availability and accessibility of significant reserves of shale oil around the globe - and the potential effect of increased shale oil production in limiting growth in global oil prices - has implications that stretch far beyond the oil industry.

At a global level, shale oil has the potential to reshape the global economy, increasing energy security, independence and affordability in the long term. However, these benefits need to be squared with broader environmental objectives at both the local and global level. Consequent changes in policy and regulatory regimes will have important knock-on effects on oil producers and consumers.

The effects of a lower oil price resonate along the entire energy value chain, and investment choices based on long-term predictions of a steady increase in real oil prices may need to be reassessed. The potential magnitude of the impact of shale oil makes it a profound force for change in energy markets and the wider global economy. It is therefore critical for companies and policy-makers to consider the strategic implications of these changes now.

We would be happy to arrange individual meetings to discuss the results of our research in more detail and to help you consider what it might mean for your organisation.

Contacts

Adam Lyons
Director – PwC

Tel: +44 (0)20 7804 3175
Mob: +44 (0)7850 907625
Email: Adam Lyons@uk.pwc.com

Adam has 20 years' experience in the oil and gas sector strategy, having worked with global companies in the Upstream and Midstream and Downstream parts of the value chain, as well as oilfield services.

Adam leads engagements focusing on strategy development and implementation, competitor and market assessment, technology strategy, mergers and acquisitions, due diligence and corporate integration and separation.

Adam has worked on projects in Western Europe, Eastern Europe and the former Soviet Union, Africa and North America. This has provided wide industry exposure to the various perspectives and challenges of major international oil and gas companies, independents, infrastructure developers and oil and gas services companies, as well as investors.

Michael Hurley
Partner – PwC

Tel: +44 (0)20 780 44465
Mob: +44 (0)7710 319445
Email: michael.hurley@uk.pwc.com

Michael Hurley is a Partner at PwC with over 20 years' experience within the energy sector. He is the global leader of the Energy Utilities and Infrastructure strategy team and has directed a large number of assignments globally for major energy companies and governments.

Michael is a regular speaker at industry forums globally, including recently at CERA-week, at the World Petroleum Congress in Doha and for the World Energy Council. Prior to joining PwC Michael was a UK government advisor, responsible for regulatory and commercial advice covering upstream oil and gas activities in the North Sea.

John Hawksworth
Chief UK economist – PwC

Tel: +44 (0)20 7213 1650
Email: John.c.hawksworth@uk.pwc.com

John Hawksworth specialises in global macroeconomics and public policy issues. He is Chief Economist in PwC's UK firm, editor of our Economic Outlook reports and lead author of our 'World in 2050' on long-term prospects for the world economy.

He is also the author of many other reports and articles on macroeconomic and public policy topics and a regular media commentator on these issues. He has carried out economic consultancy assignments for a wide range of public and private sector organisations both in the UK and overseas over the past 20 years.

William Zimmern
Senior manager– PwC

Tel: +44 (0)20 7212 2750
Mob: +44 (0)7730 146 351
Email: william.zimmern@uk.pwc.com

William is a Senior Manager in PwC's Economics Consulting practice in London. He specialises in macroeconomic modelling and economic strategy for clients in the public and private sectors.

He has worked with a range of multinational and public sector clients on economics, investment, valuation and strategic issues. He works cross sector and his clients have been some of the biggest companies in European retail and investment banking, global transportation and global mining. In the public sector he has worked for Beijing Government and Saudi Arabia Investment Authority among others.

Before PwC, William worked as a senior UK government economist.

Designed by The Design Group 21398 (02/13)