



A random walk in the Bakken

Oil prices, investment and energy policy

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Introduction

- Forecasting future oil & gas prices
 - Extrapolation of recent trends
 - Models of random walks
 - Error correction models
- Modelling prices for investment decisions
 - The role of price volatility
 - Was there a permanent change in 2005?
- Policy analysis with volatile energy prices
 - Gas and the costs of renewable energy

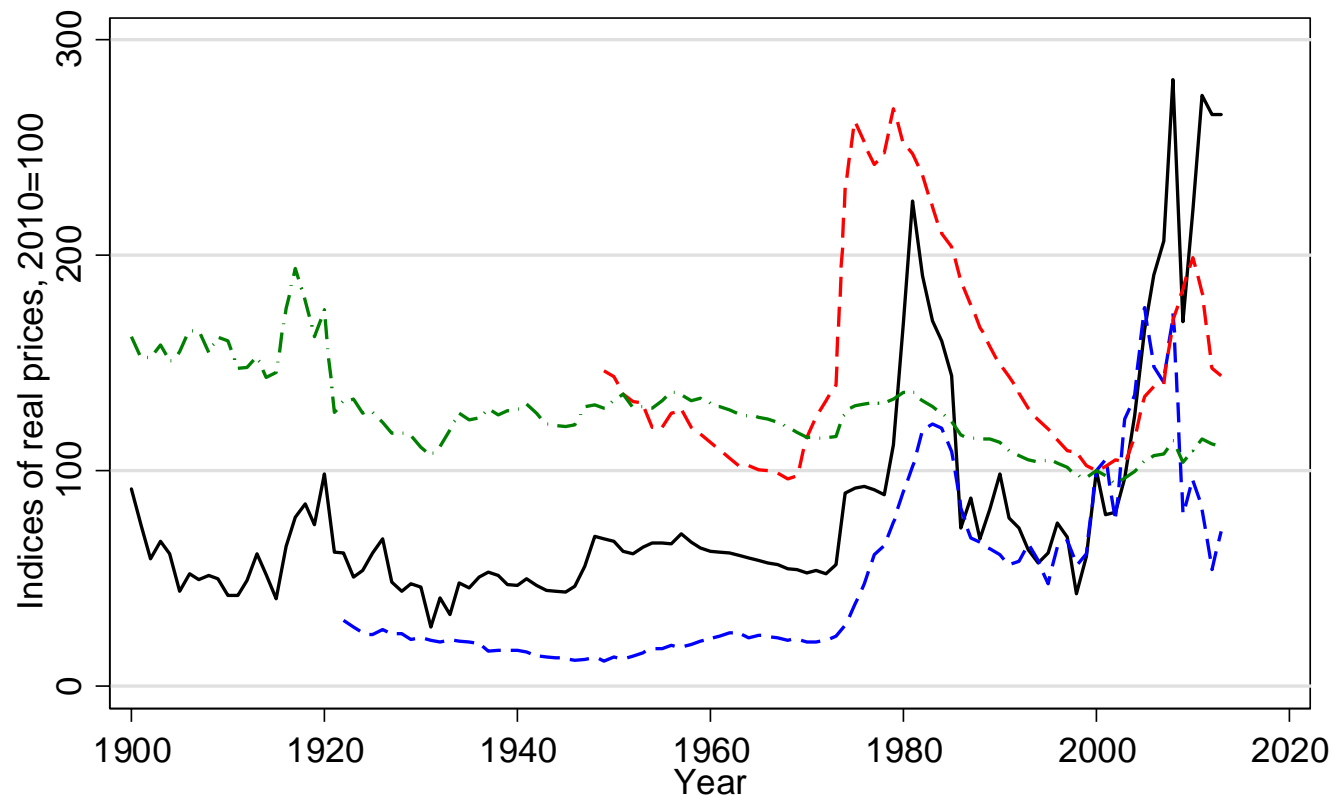


Section A

The behaviour of oil & gas prices

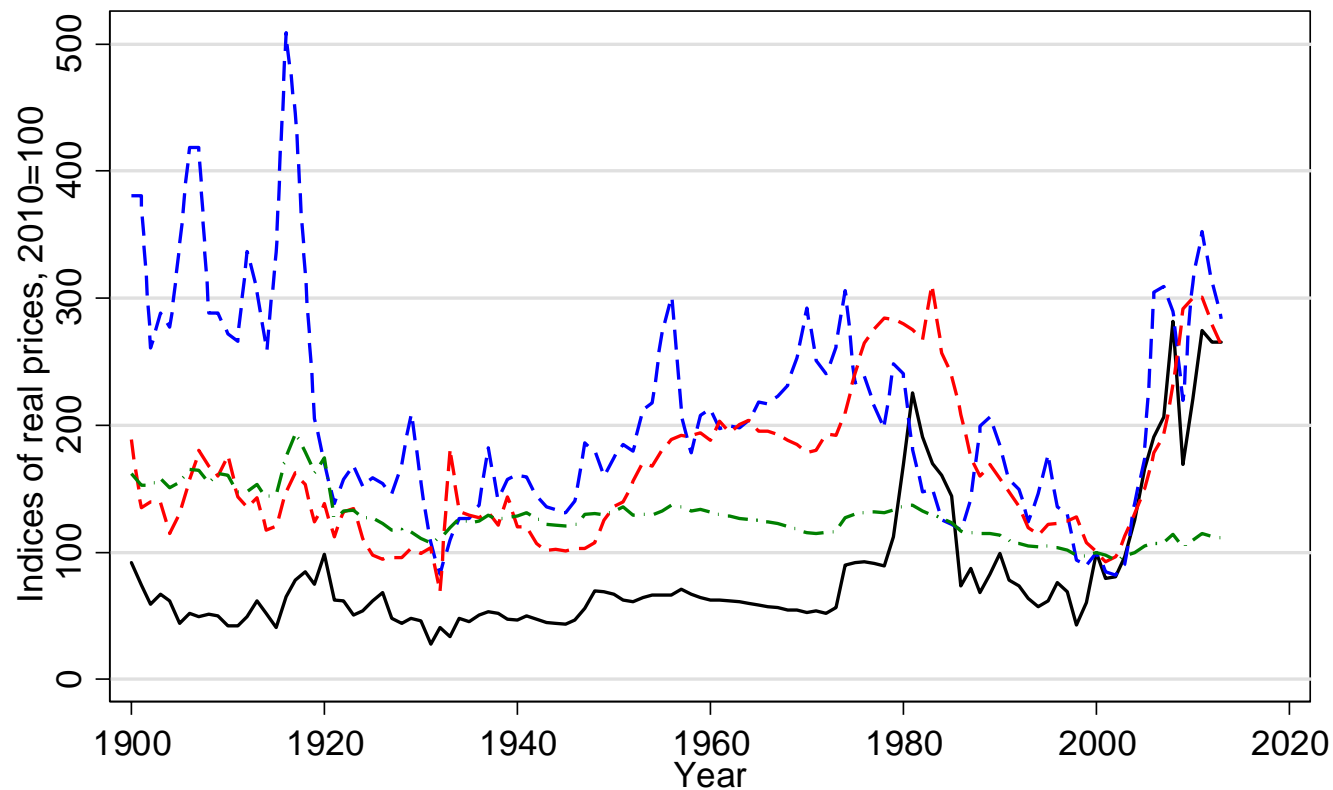
- Oil & gas prices are highly volatile but no more than for similar natural resources
- In the medium & longer term, real prices follow a random walk with high variance
 - Forecasting is essentially impossible
 - Focus on year to year changes
- Questions
 - Was there a fundamental change in 2005?
 - Evidence for error-correction such as reversion to a long term trend?

Large increase in the volatility of energy prices after 1970



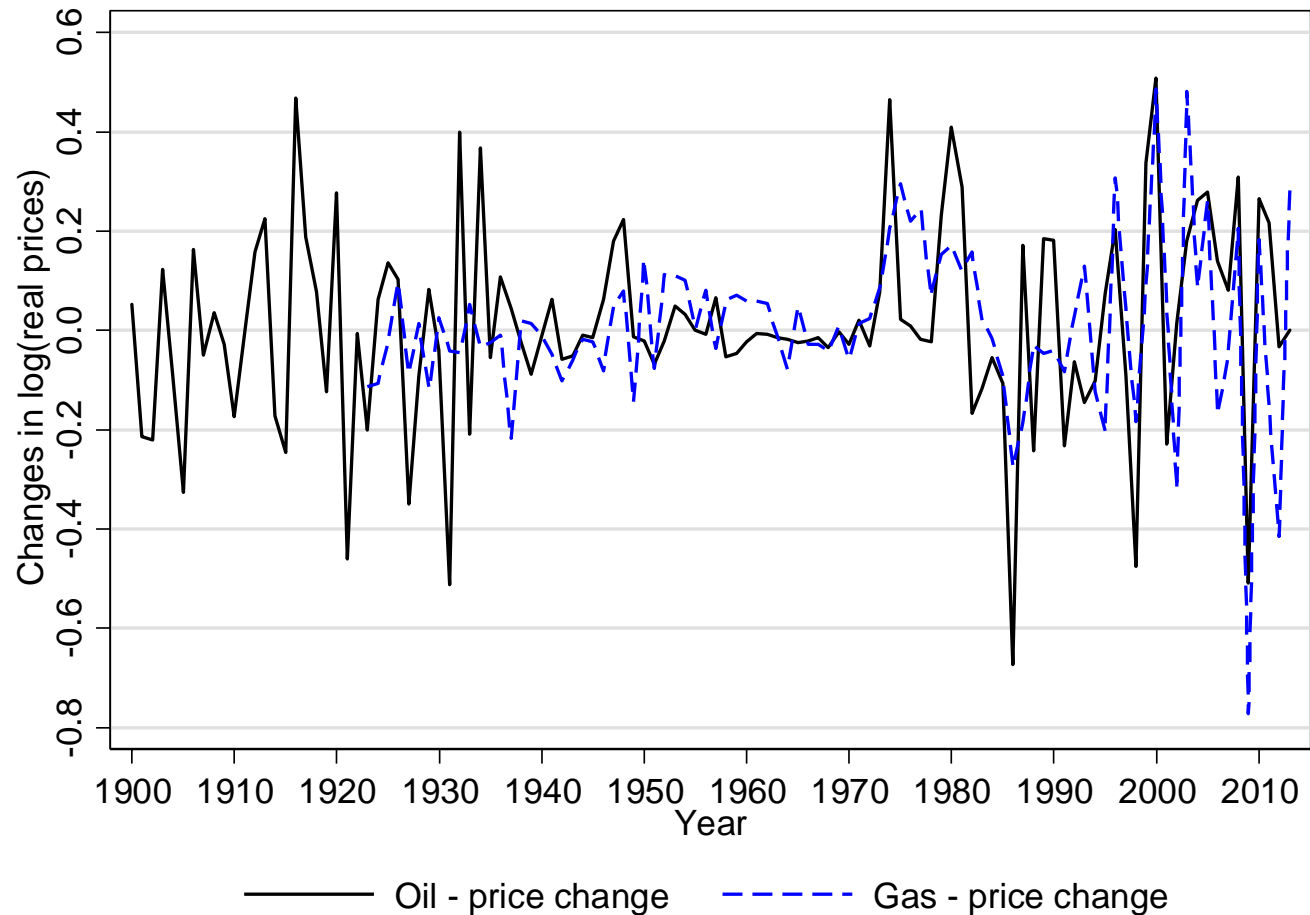
— Oil - real - - - Gas - real
- - - Coal - real - . - Industrial commodities - real

Oil prices are less volatile than the prices of metals and other raw materials



— Oil - real - - - - - Copper - real
- - - - - Iron ore - real - . - . - Industrial commodities - real

Oil & gas prices seem to follow a random walk with high variance

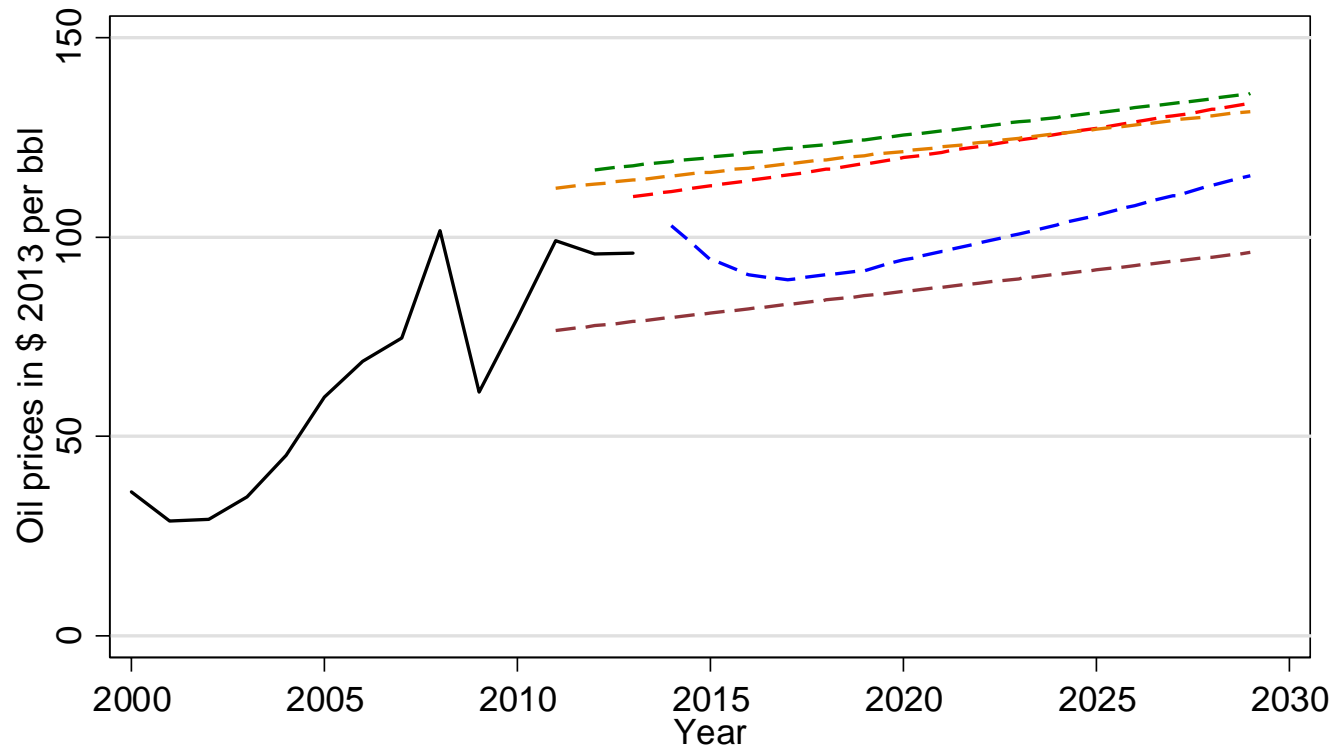




Why make projections/forecasts?

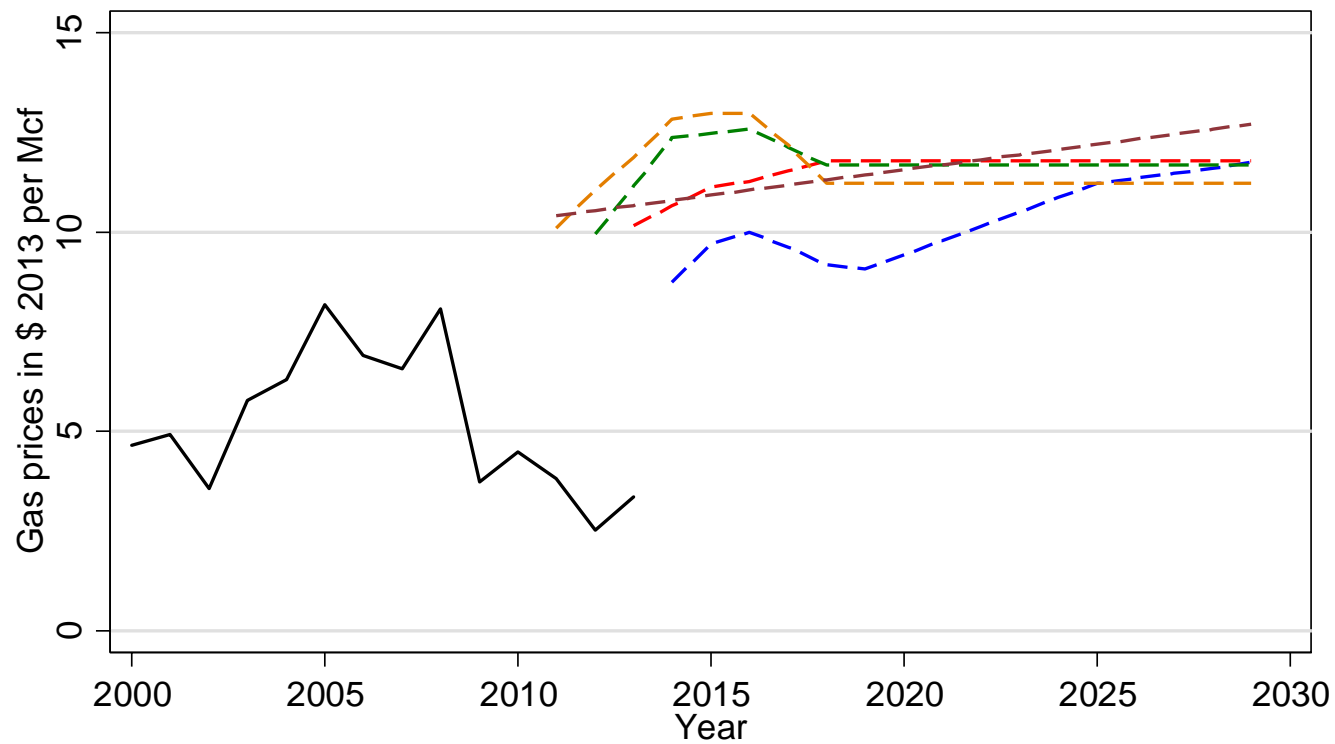
- Random walks are inherently unpredictable
 - Over 1 year – the same as this year
 - Over 5 years – trend (if any) +/- very wide confidence intervals
- So what are the options?
 - Use fan diagrams or Monte Carlo analysis to capture uncertainty
 - Investment or policy decisions – price ranges
 - Identifying or analysing structural breaks

DECC projections of real oil prices



- Oil - real
- Oil - DECC 2010
- Oil - DECC 2011
- Oil - DECC 2012
- Oil - DECC 2013
- Oil - DECC 2014

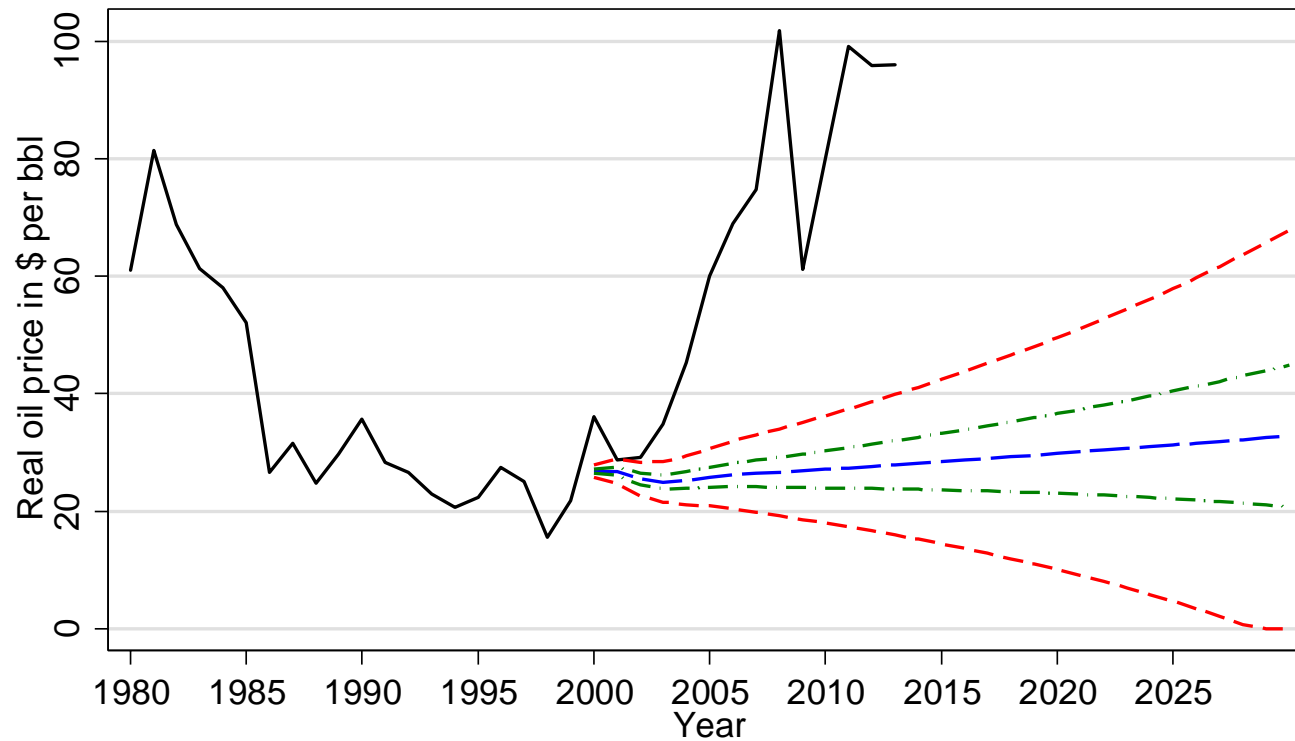
DECC projections of real gas prices



- Gas - real
- Gas - DECC 2010
- Gas - DECC 2011
- Gas - DECC 2012
- Gas - DECC 2013
- Gas - DECC 2014

Forecasting oil prices – variant 1

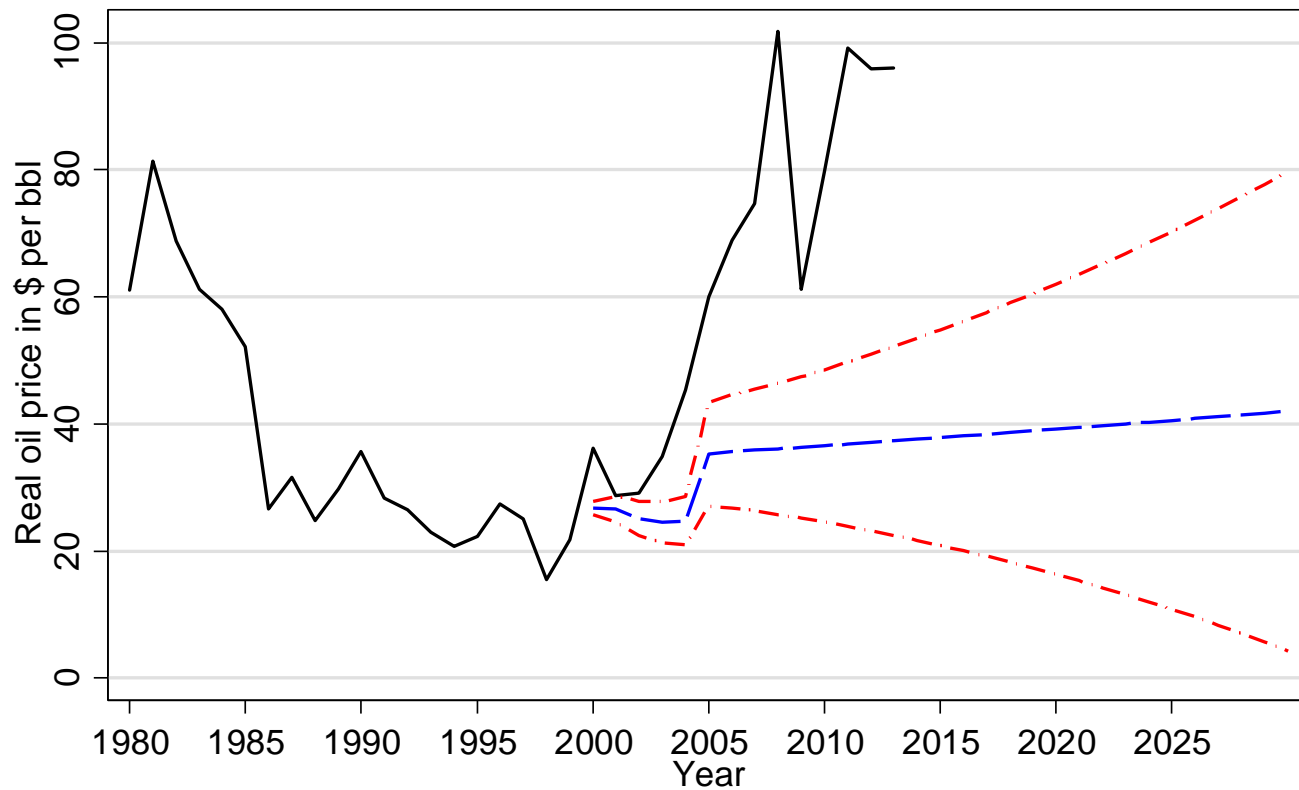
Large variations, no structural break



— Oil - EIA real
- - - ARIMA 1 - Upper 95% CI
- . - . ARIMA 1 - Upper Quartile
- - - ARIMA forecast 1
- - - ARIMA 1 - Lower 95% CI
- . - . ARIMA 1 - Lower Quartile

Forecasting oil prices – variant 2

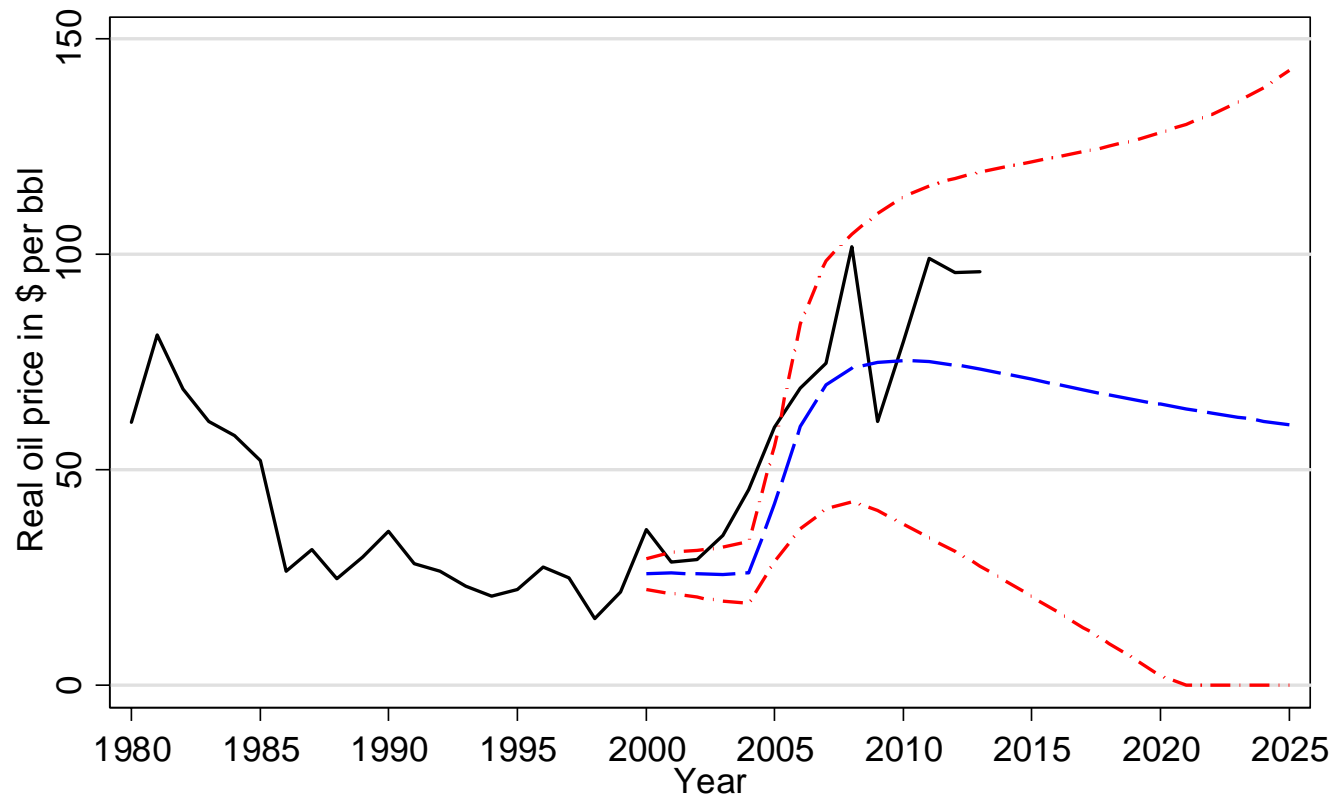
Structural break in 2005



— Oil - EIA real - - - ARIMA forecast 2
- . - . - ARIMA 2 - Upper CI - . - . - ARIMA 2 - Lower CI

Forecasting oil prices – variant 3

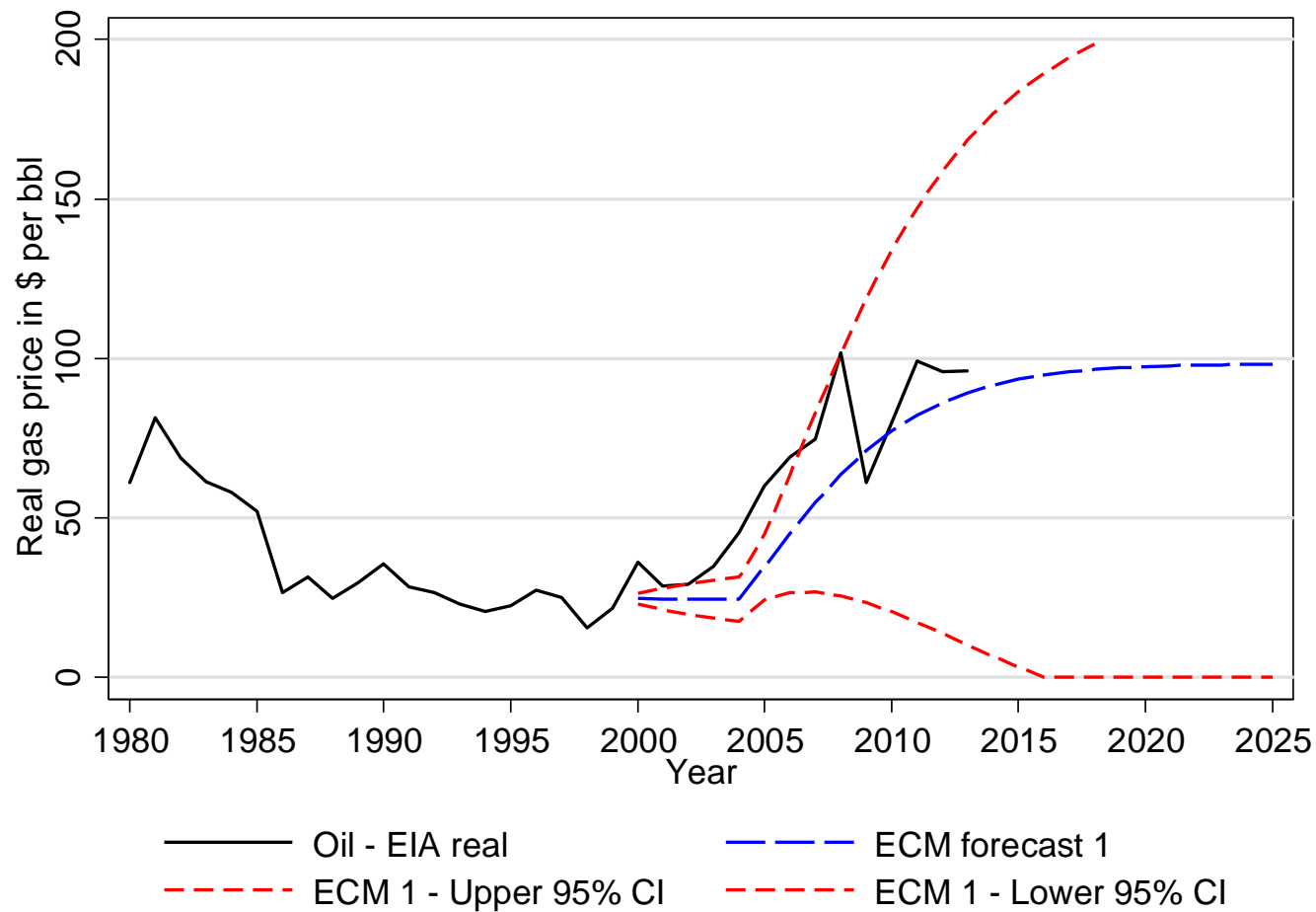
Giving more weight to recent events



Oil - EIA real
VAR Oil 2 - Forecast
VAR Oil 2 - Upper CI
VAR Oil 2 - Lower CI

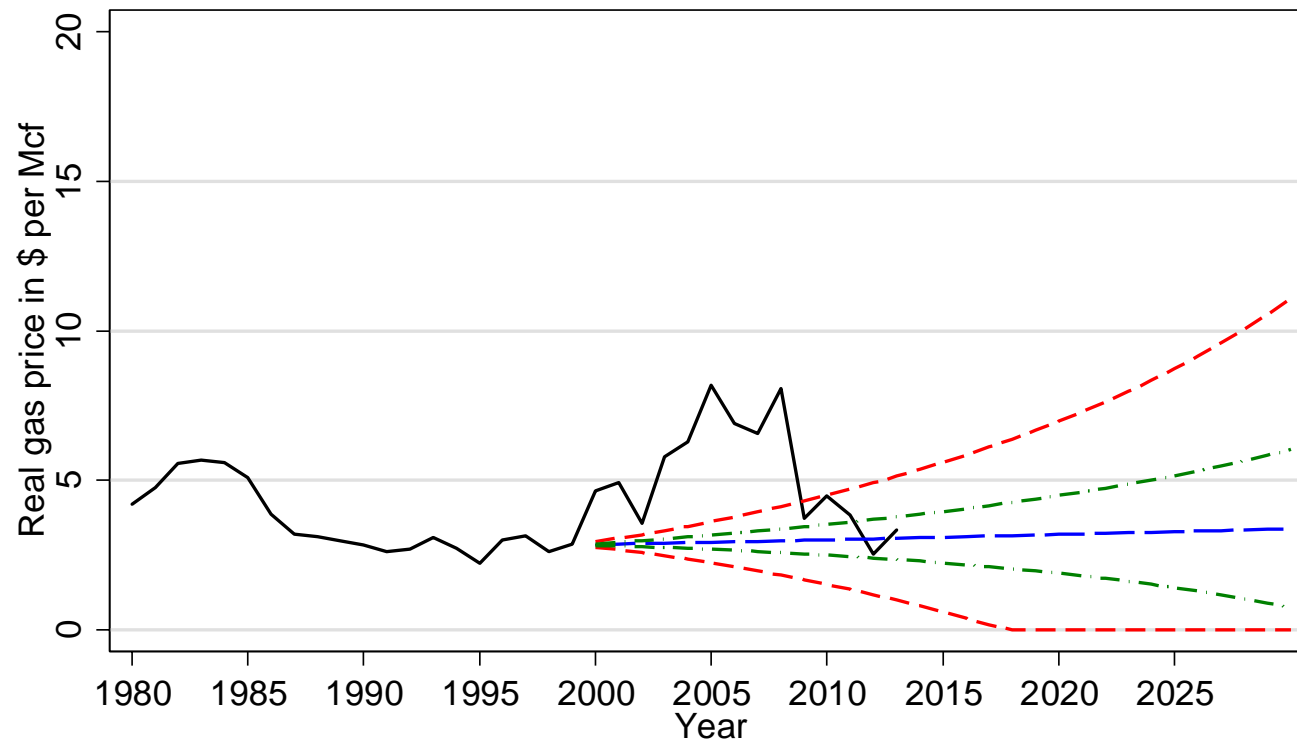
Forecasting oil prices – variant 4

Error correction, structural break in 2005



Forecasting gas prices – variant 1

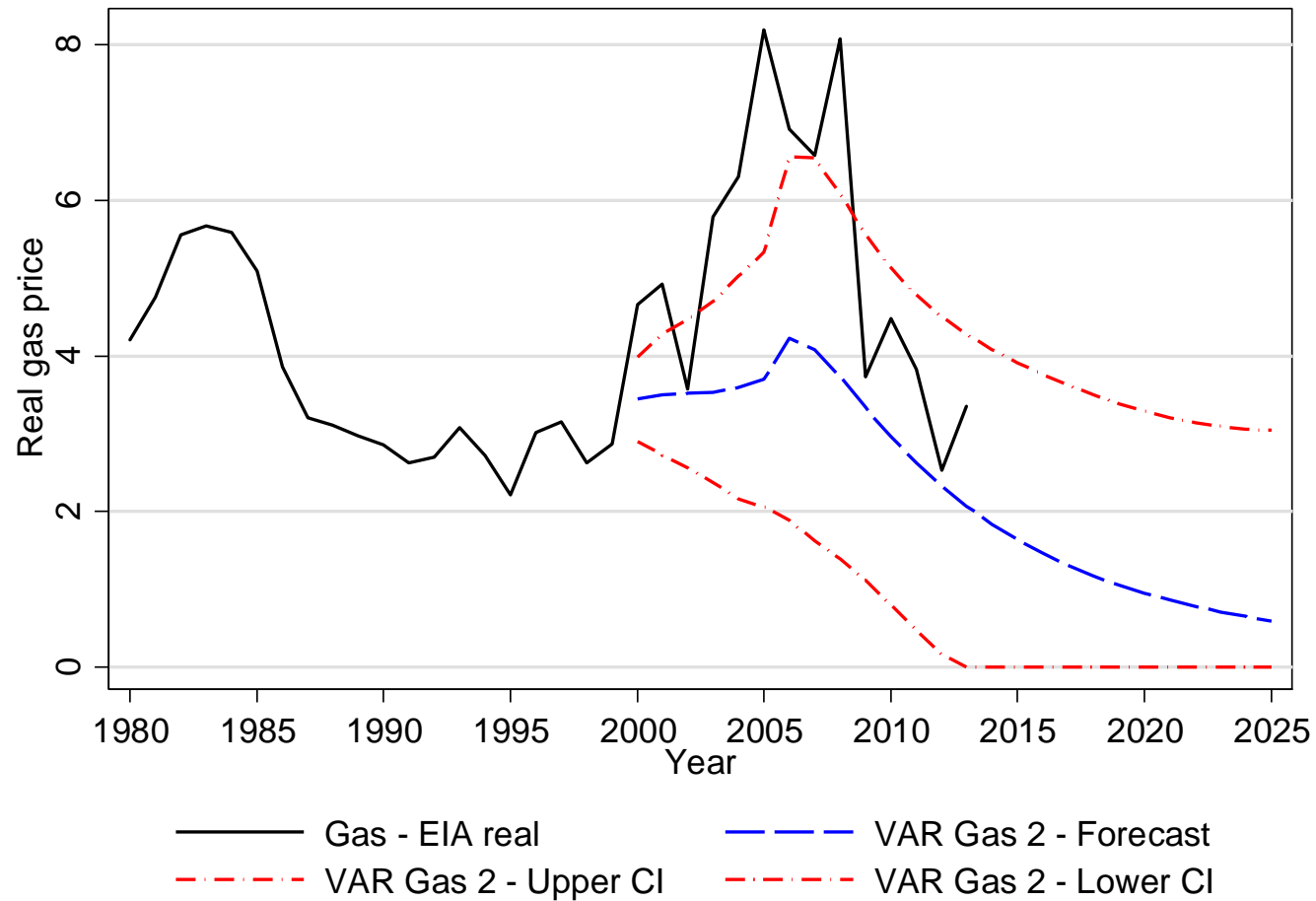
Extreme ranges for confidence intervals



— Gas - EIA real
- - - ARIMA forecast 1
- - - ARIMA 1 - Upper 95% CI
- - - ARIMA 1 - Lower 95% CI
- · - · ARIMA 1 - Upper Quartile
- · - · ARIMA 1 - Lower Quartile

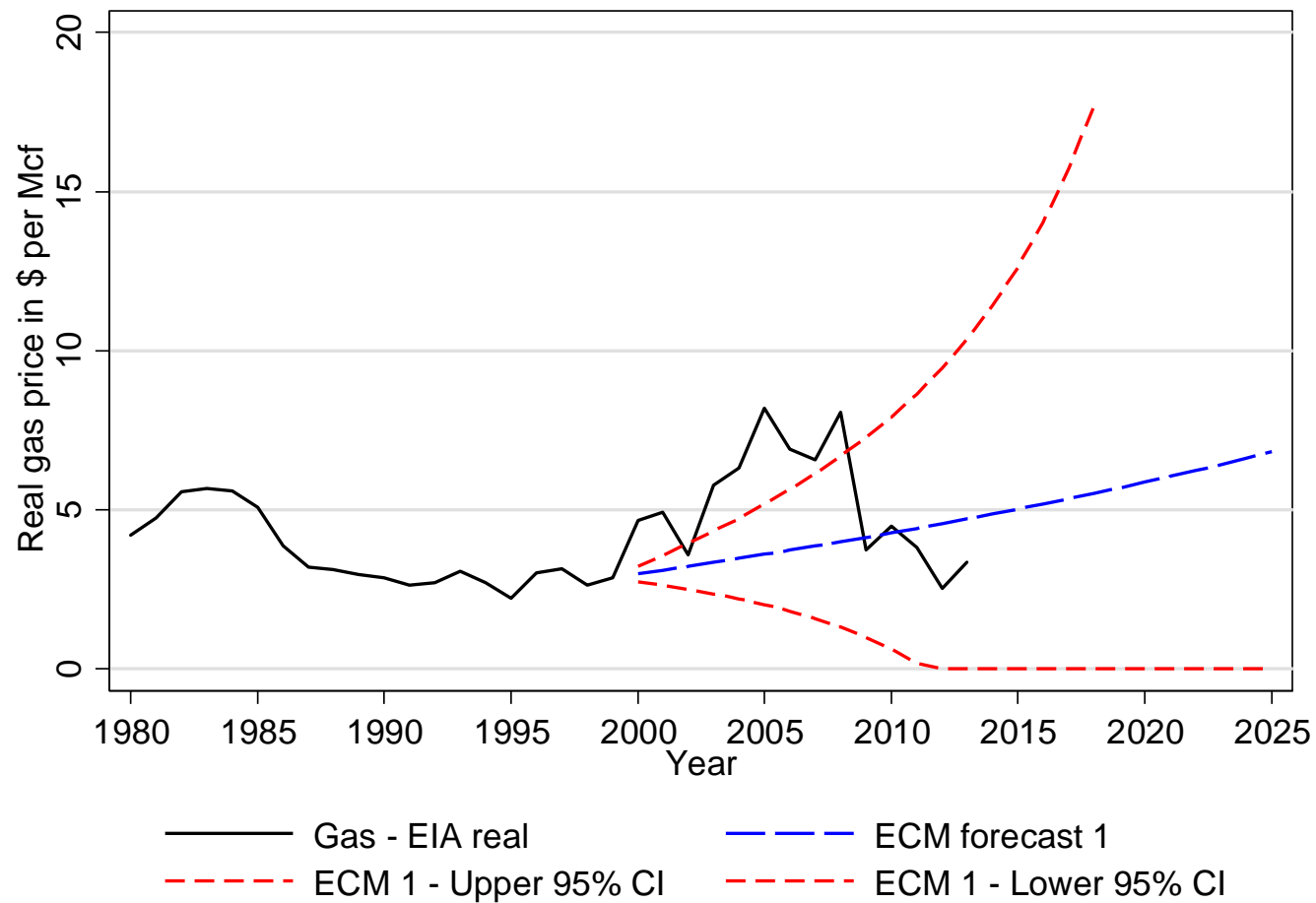
Forecasting gas prices – variant 2

Focus on recent events yields silly results



Forecasting gas prices – variant 3

Error correction model



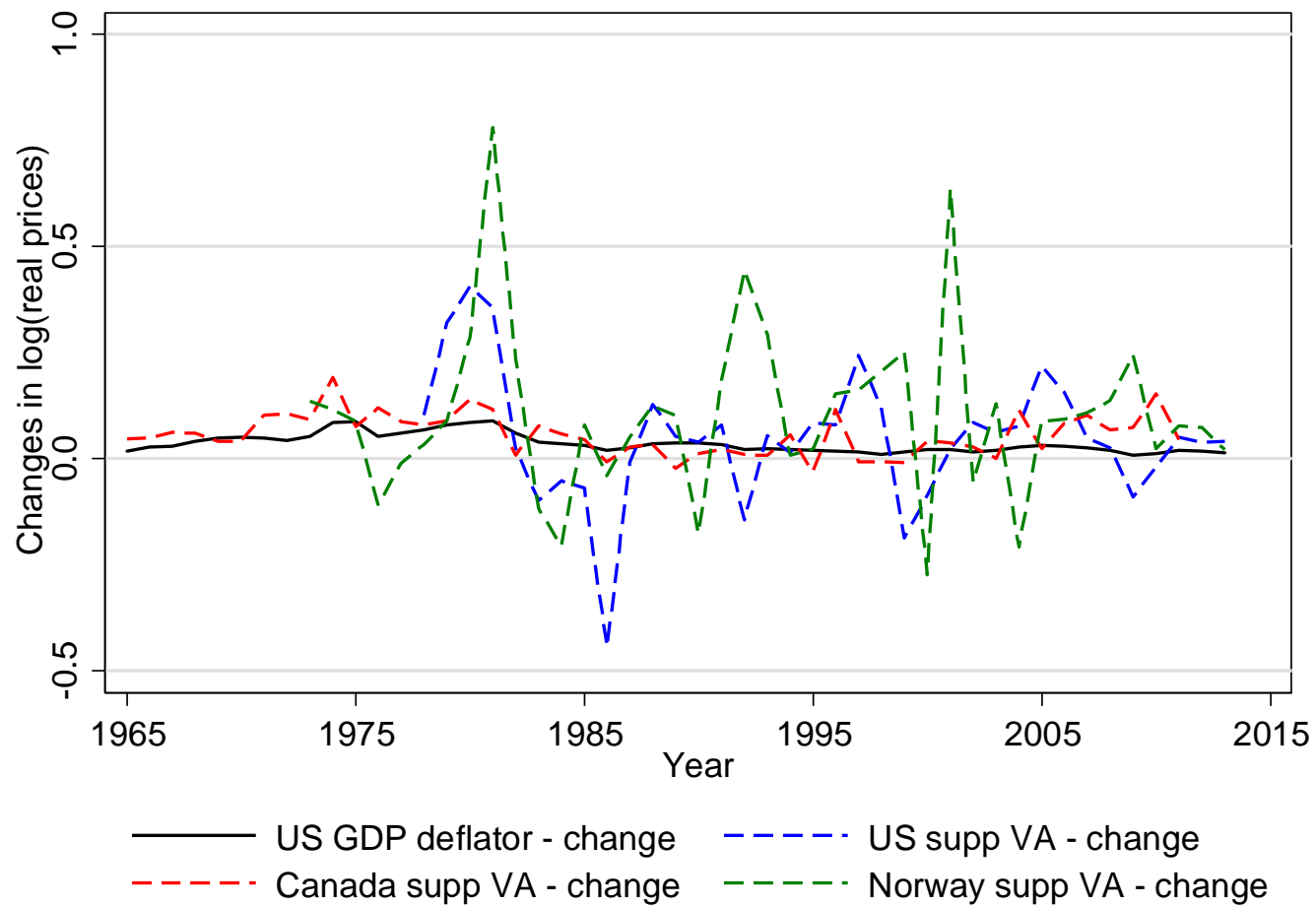


Section B

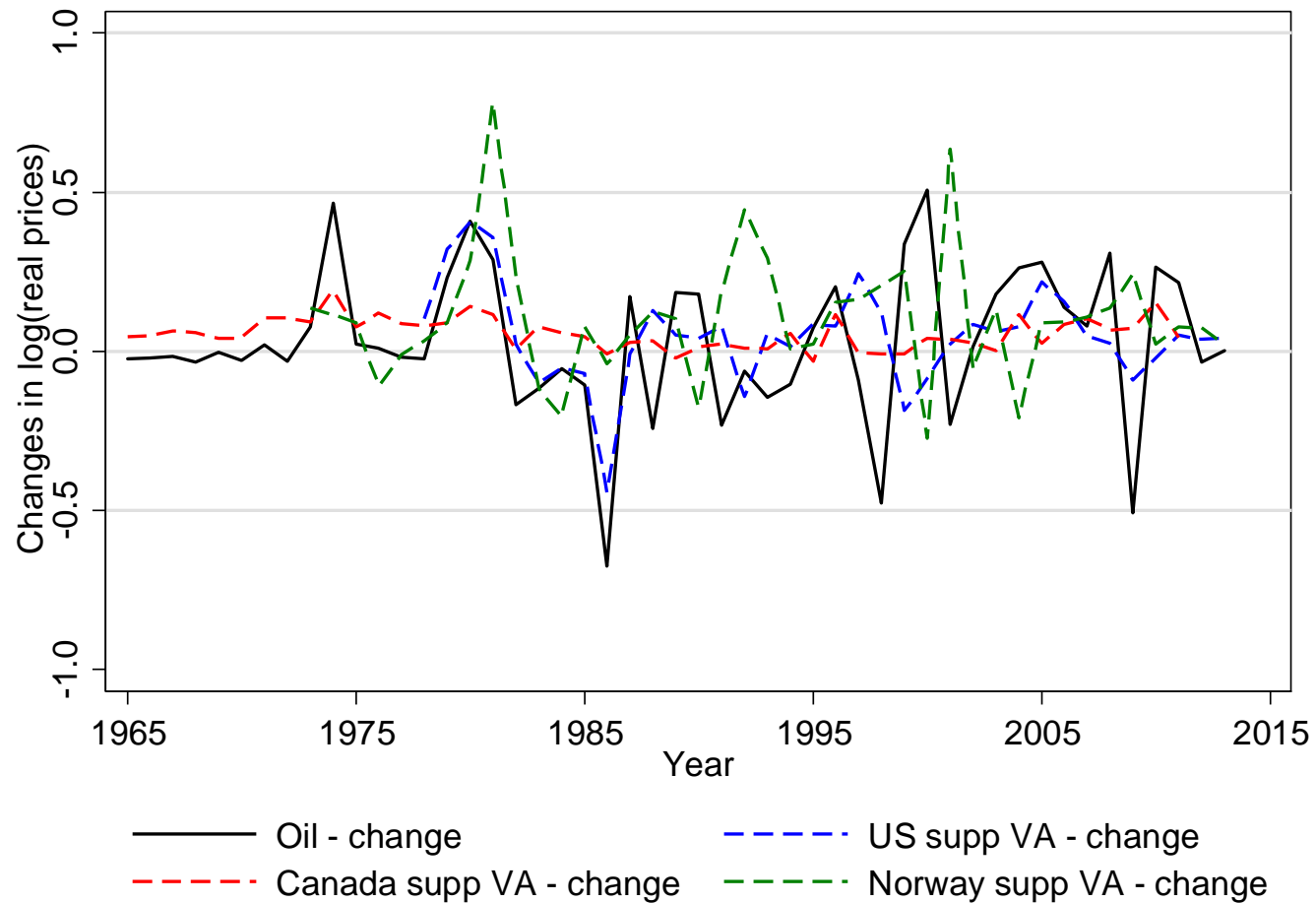
Analysing investment projects

- Capital and operating expenses are strongly linked to the prices of oil and/or gas
- Similarly, the effective tax take tends to vary with the profitability of past investments and prospects for new ones
- In combination with the dynamics of oil prices, these factors mean that standard risk analyses may generate misleading conclusions
- Need to focus on changes in the distribution of prices over time

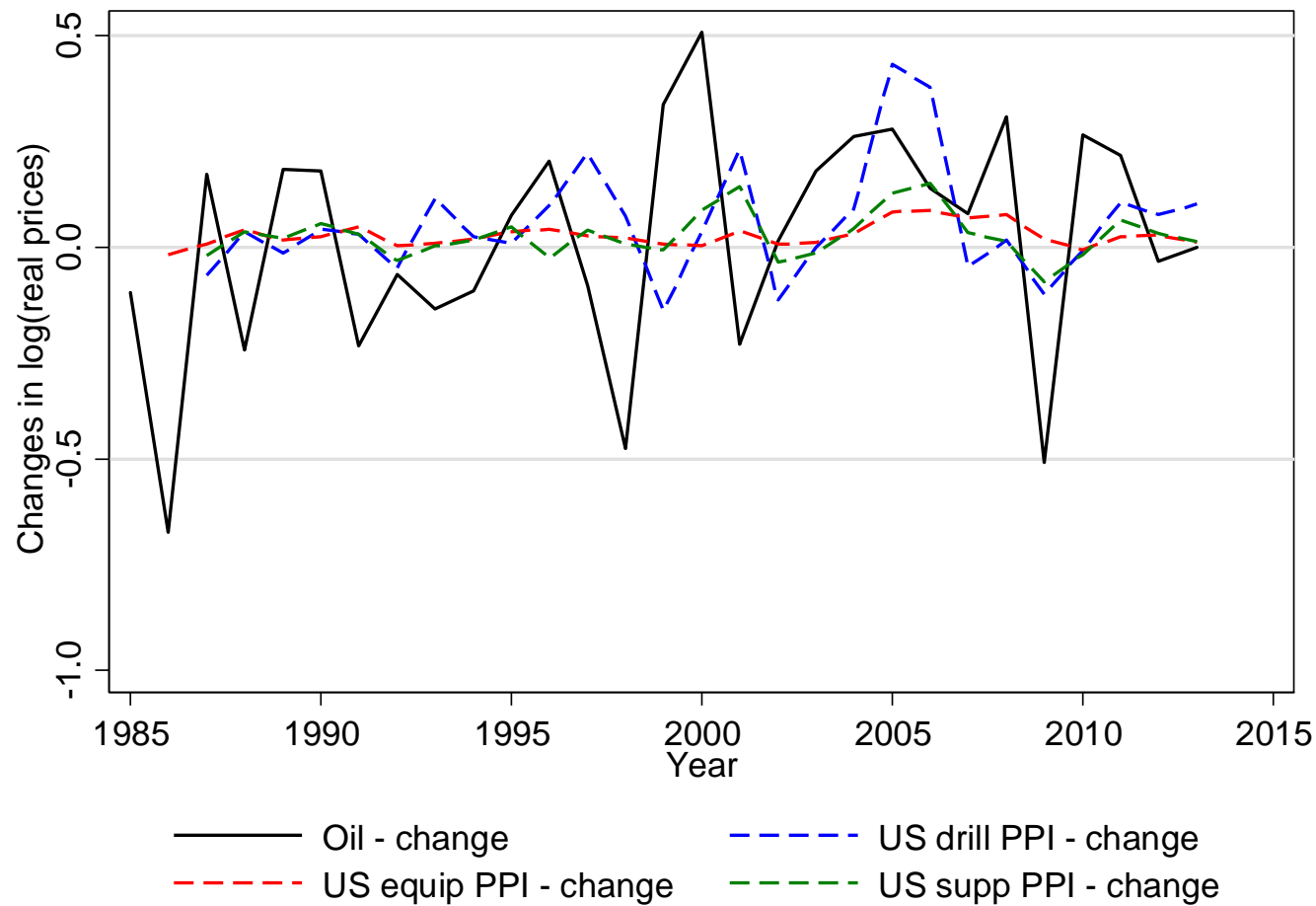
Changes in income in support services



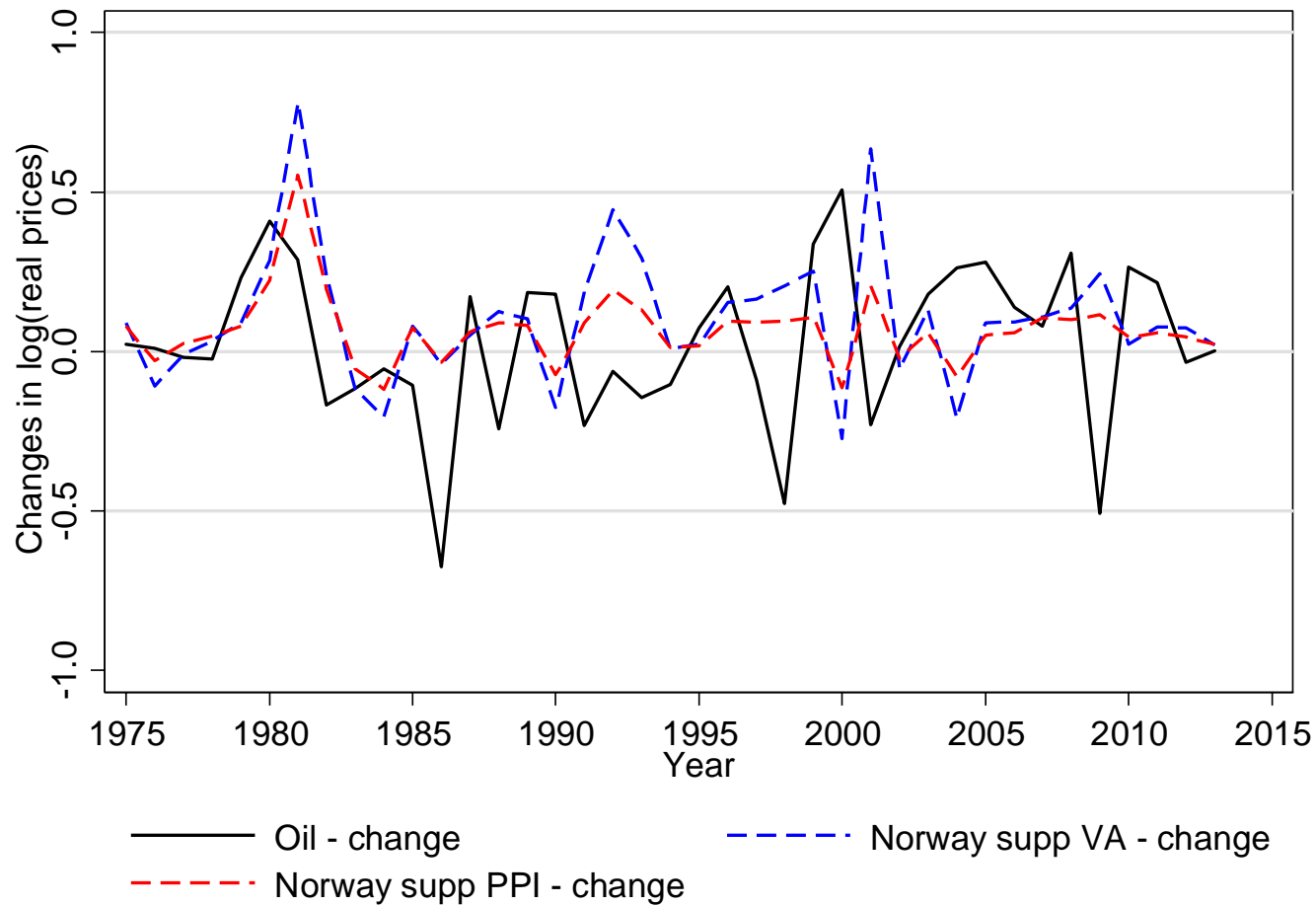
Oil prices and income in support services



Drilling costs follow oil prices - US



Support services and oil prices - Norway

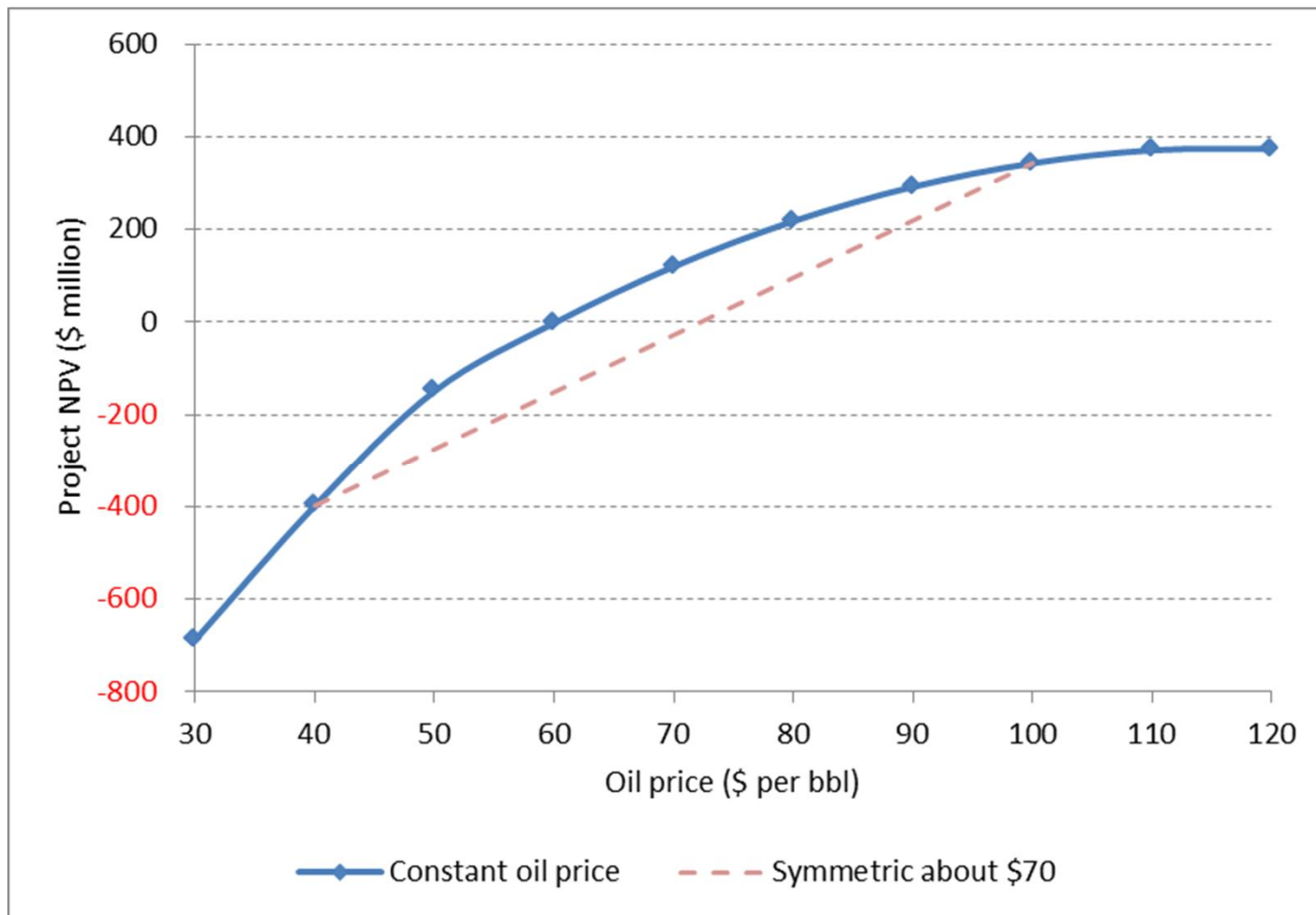




A basic investment project

- Investment of \$1 bln covers a real cost of capital of 10% at a constant price of \$60/bbl
 - Royalty rate of 12.5%, 100% capital allowances, base profits tax rate of 35%
 - Capex, opex & profits tax increase with oil price
- Basic risk analysis
 - Vary parameters individually or in combination
 - Fixed price profile over time
 - Average return for a symmetric price distribution < return for average of price distribution

Project returns with varying oil prices





Stochastic modelling of prices

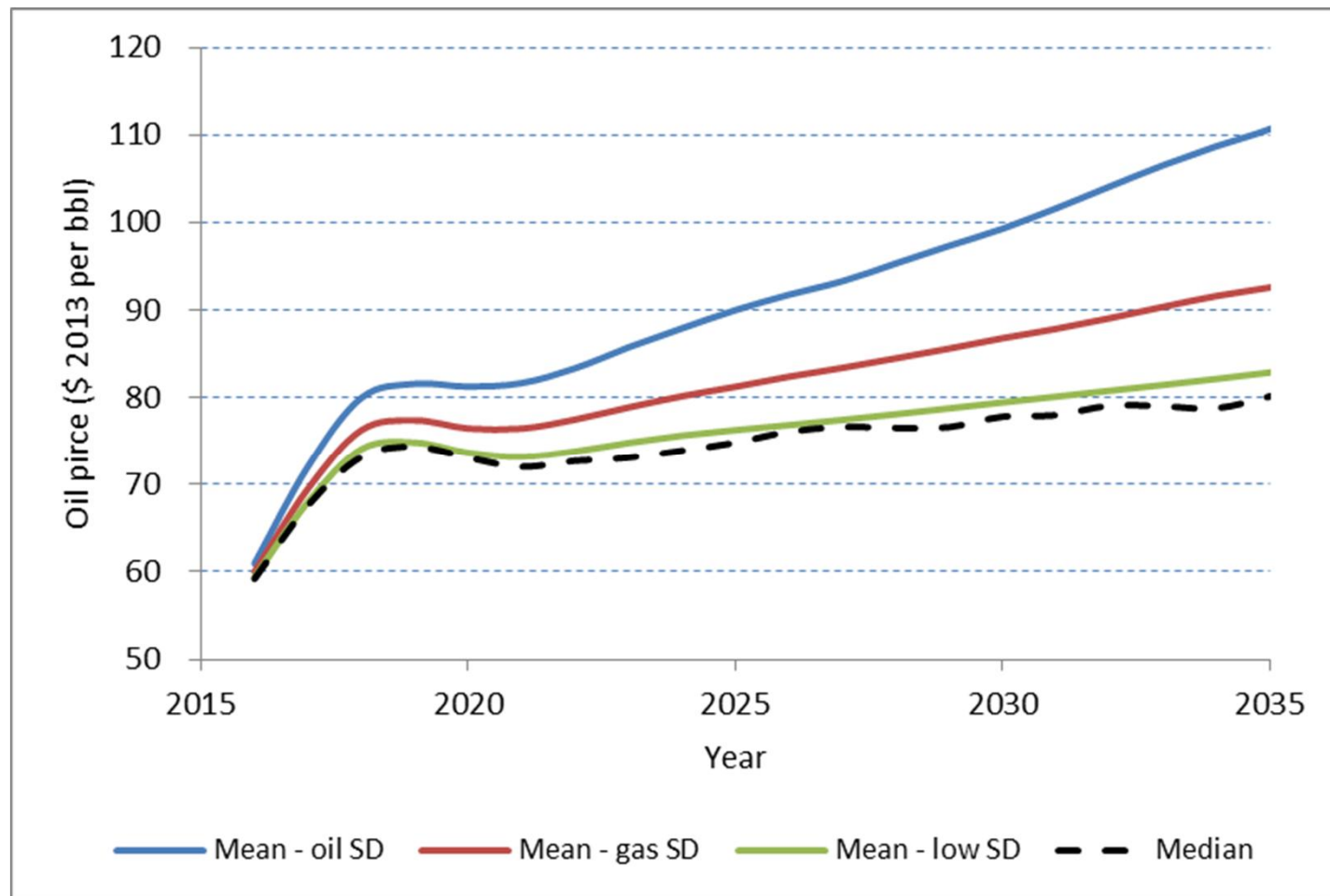
- Alternative specifications
 - Random walk with autoregressive and moving average errors – classic time series approach
 - Error correction – prices adjust towards a moving “equilibrium” value reflecting discovery & extraction costs (gap closure ~ 25% per year)
- Use Monte Carlo analysis to estimate distribution of project NPV
 - Examine the effect of the error variance and starting price level on project returns



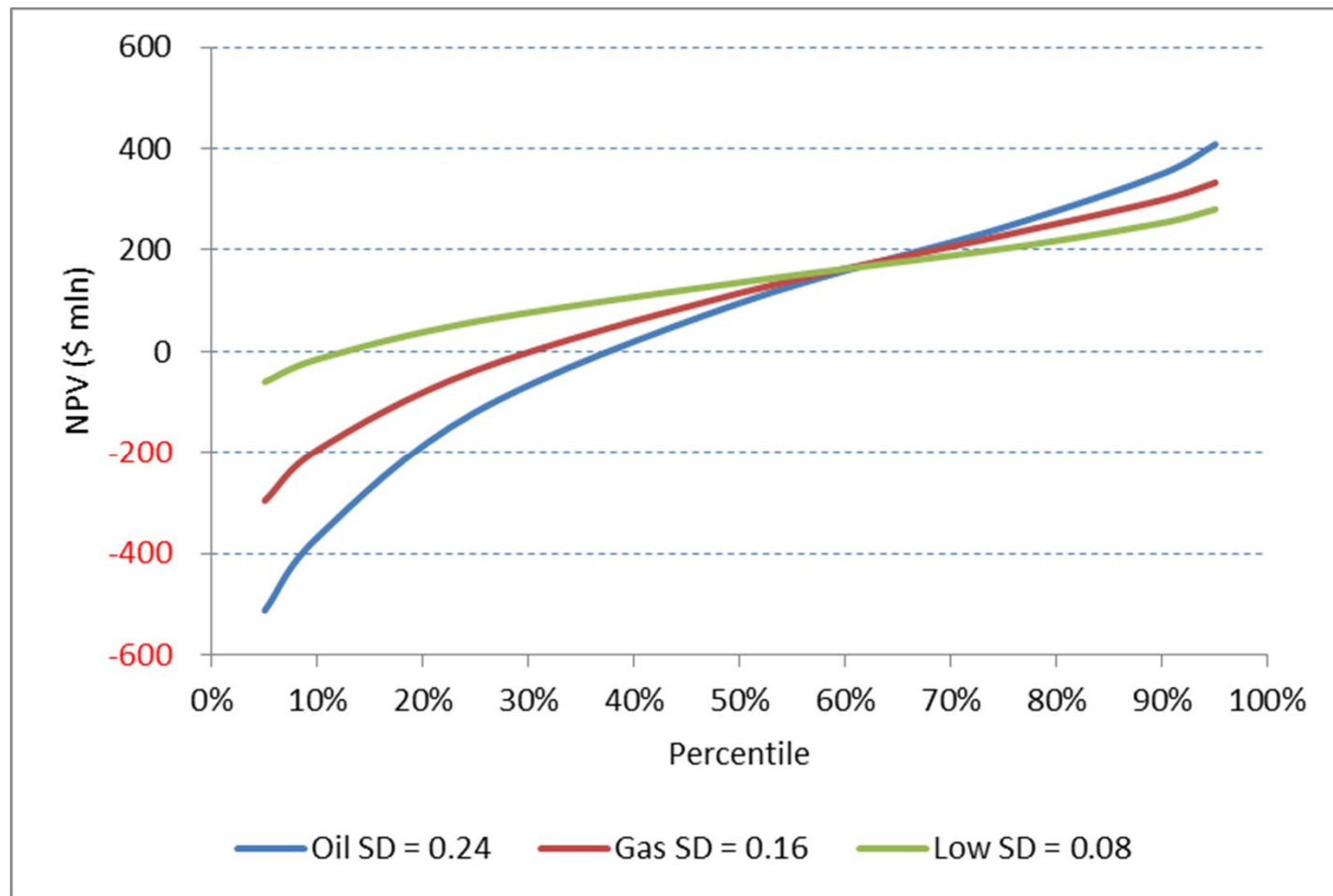
Higher price volatility is not always bad

- Higher volatility – e.g. for oil prices compared to gas prices – increases the gap between average and median prices
 - If costs and taxes do not increase too much, the gain from periods of high prices can outweigh the losses at the other end of the distribution
 - A risky strategy because governments and/or regulators almost always try to claw back what they see as “excess” profits
 - Even then, volatile prices yield a higher return than constant over 60% of cases – good in a risk pool, but less good for an operator with correlated price risks

Random walk – the gap between median and average prices increases over time



Random walk - risks increase with variance but mainly at the lower end

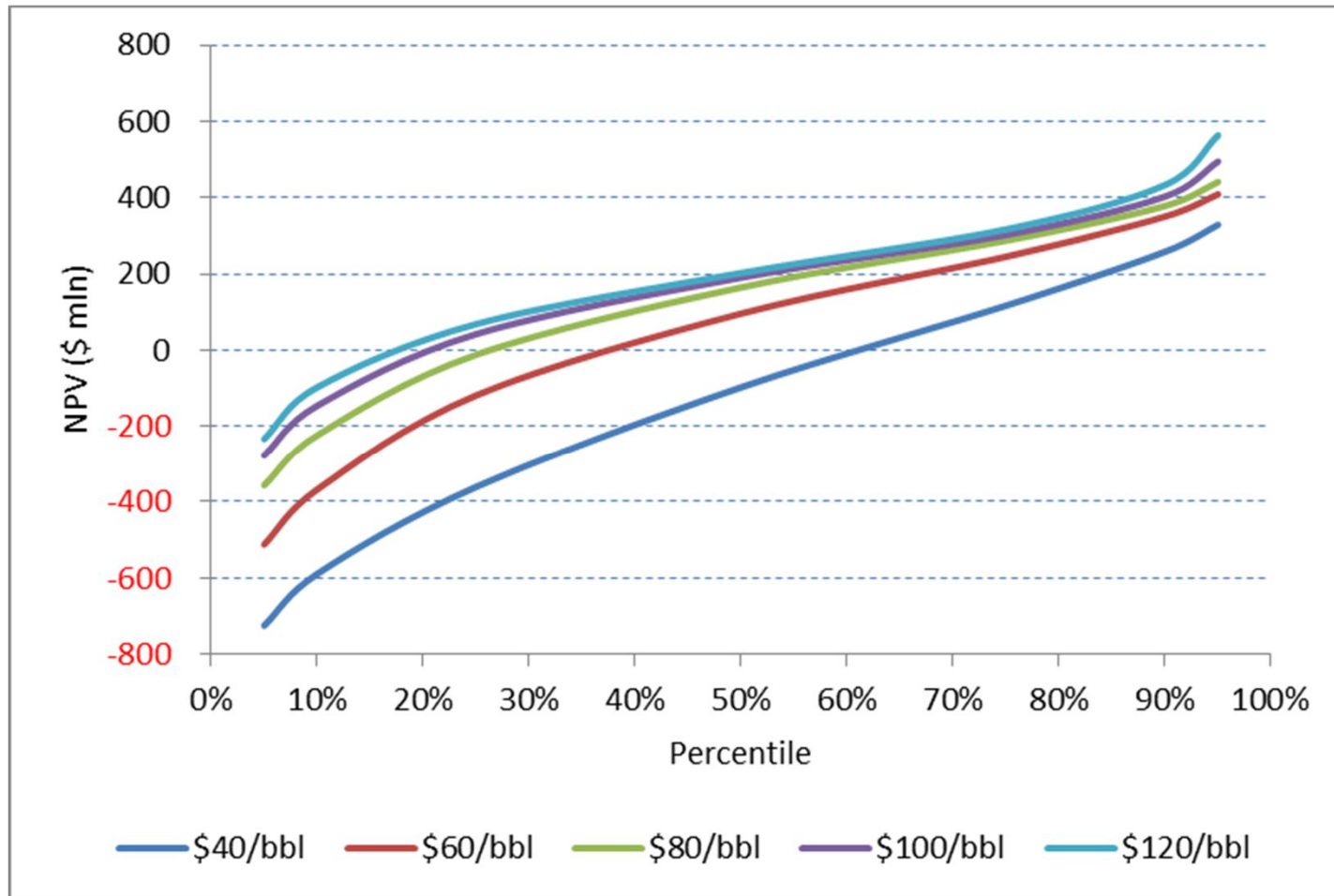




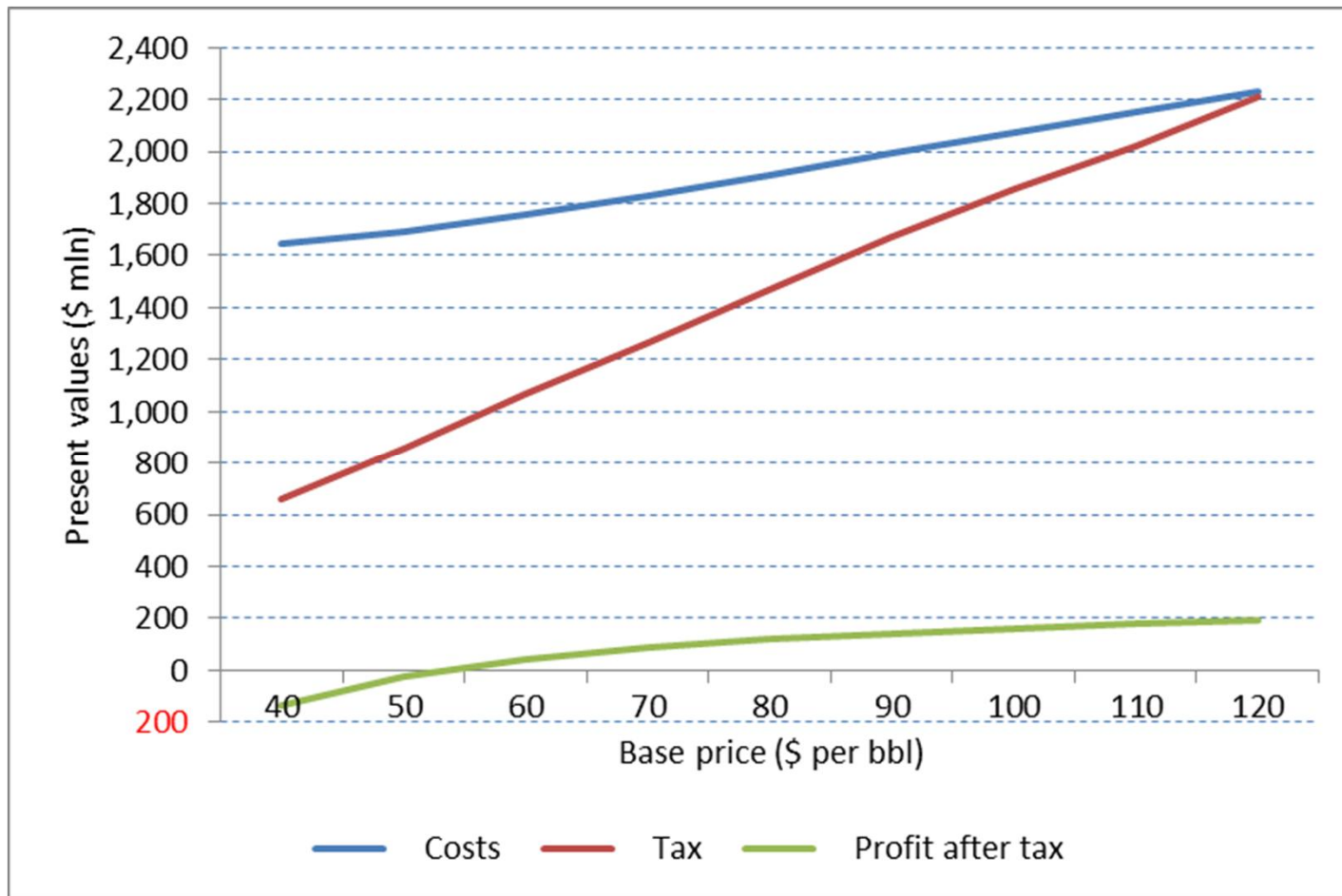
Who benefits from higher oil prices

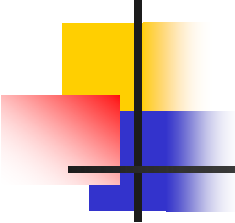
- Initially, investors because of sunk costs and slow adjustment in tax rates
- In the longer term
 - The largest share of greater revenues will benefit the exchequer via higher royalties & tax payments
 - Costs and value-added in oil construction, services, etc will tend to increase significantly
 - At the margin, expected profits may increase by 10-15% of additional revenues
 - Net gain above \$80 per bbl is very small

Random walk – the benefits of a higher base price fall off rapidly above \$60/bbl



Random walk - distribution of higher oil revenues favours the exchequer

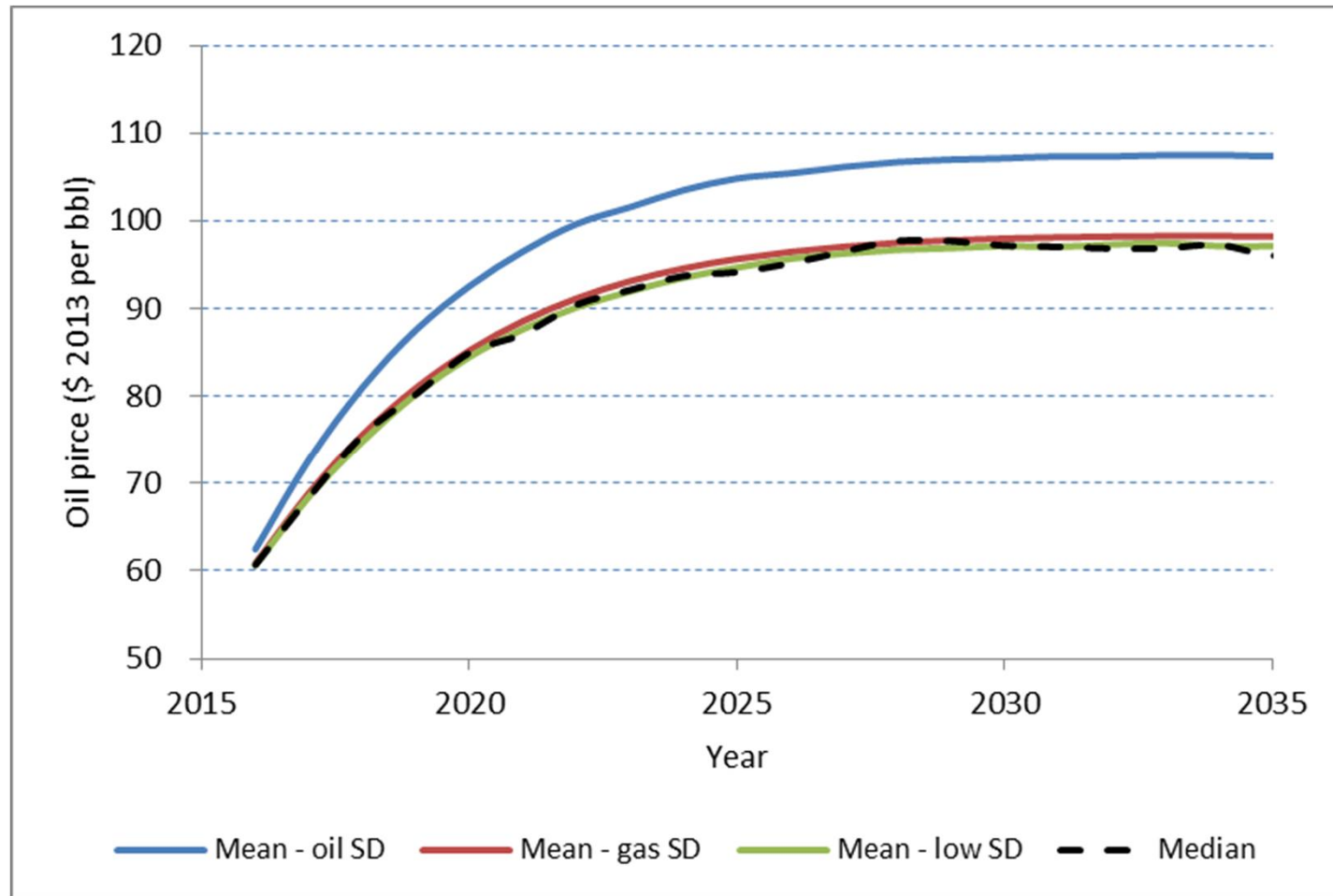




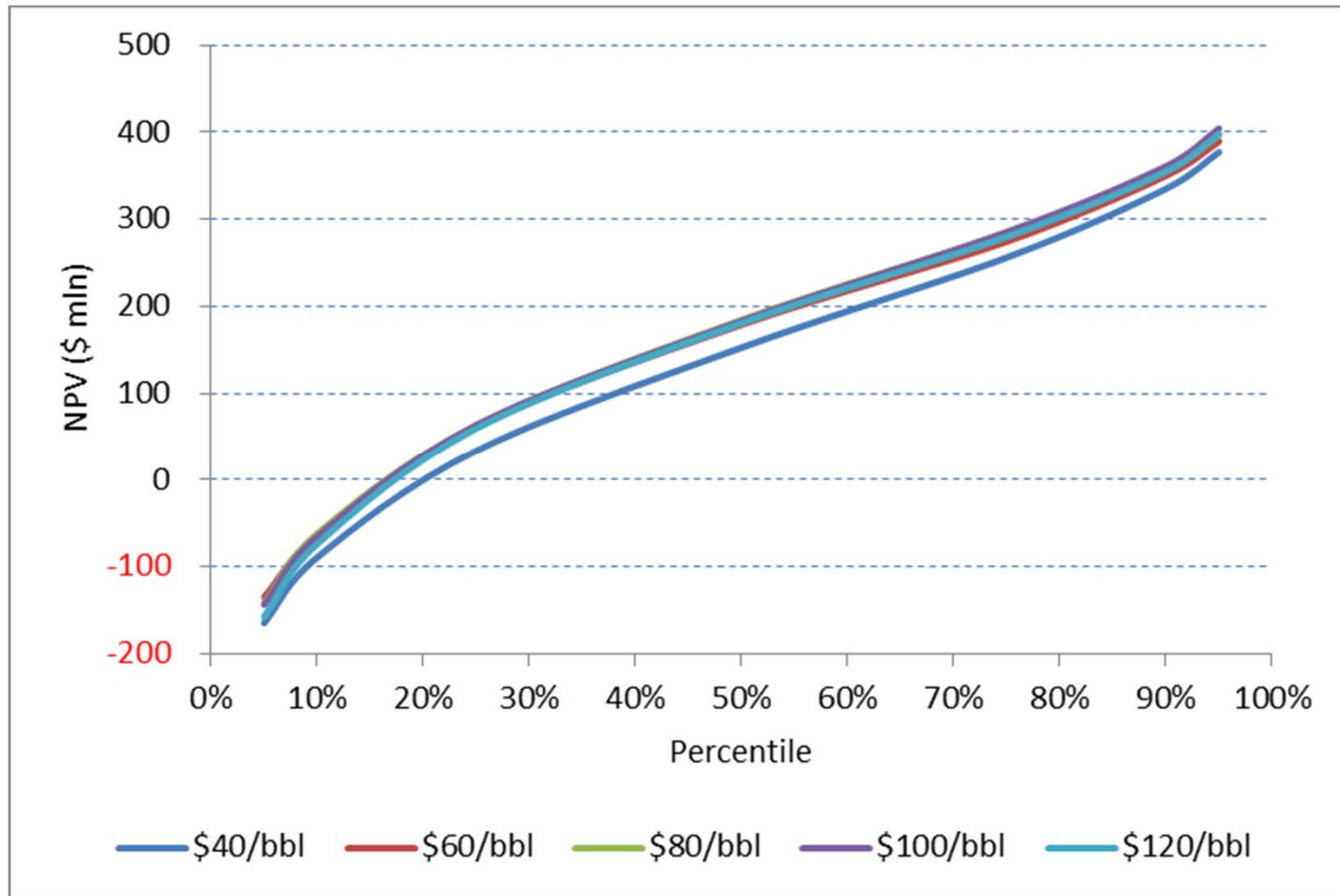
Error correction model – prices tend to revert to some “normal” path

- Adjustment more rapid for oil than for gas
 - Gap closure of 75% over 5 years for oil vs 36% for gas, so gas has much longer excursions
- Was there a structural break in 2005 for oil?
 - If there was, the normal price path for oil implies a median price in 2025 of \$94 per bbl
 - Suppressing the structural break the median price in 2025 in \$36 per bbl
- “Normal” price path for gas implies median price of \$7.0-7.5 per Mcf in 2025 with real increase of ~2.7% pa from 2025

Error correction – gap between mean and median prices with high volatility



Error correction – base price has no effect on distribution of NPV above \$60 per bbl



Error correction – impact of base price on distribution of gross revenues





Section C

Lessons for companies and policymakers

- Don't rely upon extrapolative forecasts!
 - But, separating the random walk and error correction models is difficult
 - How can we tell whether there was a genuine structural break in 2005?
- Scenario analysis is not good enough
 - Risk models must take account of (a) high year to year volatility of price, and (b) the probability distribution of cumulative deviations from central forecasts
 - Risks for oil and gas are quite different: lower volatility for gas plus much smaller error correction coefficient means path deviations are smaller but more persistent



Rethinking the tax regime for shale & other nonconventional resources 1

- The tax regime, in reality, is poorly designed for high price volatility and high risk projects
 - Focus on taxing “windfall” gains due to price volatility penalises projects with high dispersion returns
 - Ring-fencing rules limit scope for pooling uncorrelated risks
- Need to move away from adopting special provisions to distinguish between different operators
 - Essential to recognise that intermittent periods of high prices are critical to the economics of some – even many – projects
 - If non-linear compression of returns at the upper end cannot be avoided, then loss offsets must be more generous



Rethinking the tax regime for shale & other nonconventional resources 2

- One tax structure proposed by fiscal specialists extends the deduction of interest to cover a basic cost of capital applied to unamortised capital
 - An broadly similar approach is to increase the amount of outstanding capital allowances & tax losses each year by the basic cost of capital
 - This means that profits tax is only paid after a project has covered the basic cost of capital
 - Should the basic cost of capital be risk-adjusted? In principle, yes, but in practice this would be a matter of great dispute and lead to potentially arbitrary boundary differences.



Implications for the design of renewable energy policies 1

- Both price models imply that the potential cost of price guarantees (CfDs) is much larger than forecast
 - Gas price determines the size of the liability
 - Normal price path for the ECM well below DECC scenarios
- Policy leads to a large transfer of risk from renewable generators to electricity consumers via levy payments
 - Large consumers will exit because they can't benefit from low gas prices
 - Strong negative correlation between tax revenues and levy costs, so policy tends to neutralise the macro benefits of lower energy prices



Implications for the design of renewable energy policies 2

- Shift in the structure of the domestic gas market
 - Power generators have to rely more on the spot market
 - Seasonal volatility must increase to pay for higher storage
 - Decline in load factors for gas plant will put more weight on capacity payments.
 - Will capacity payments be high enough to replace CCGTs forced to retire before end-2022?