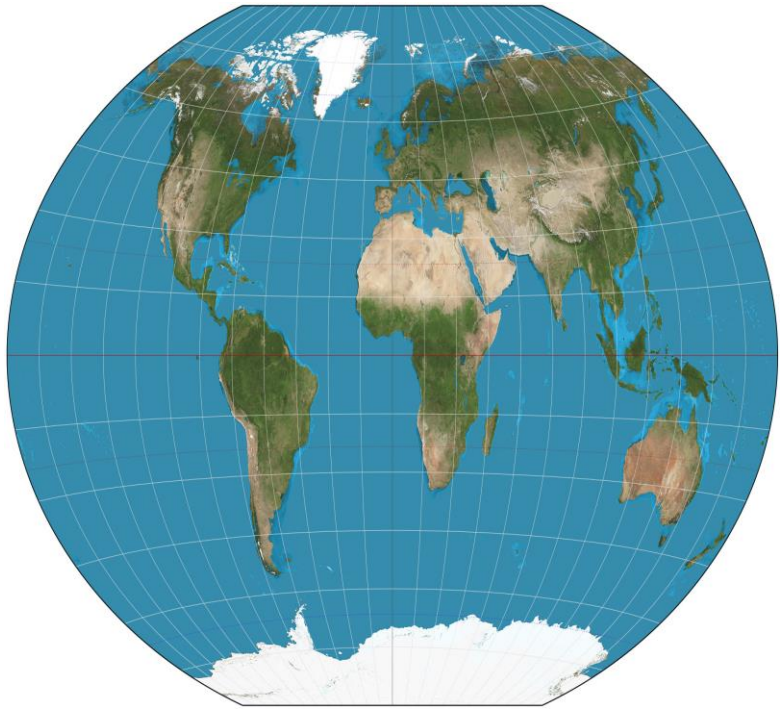
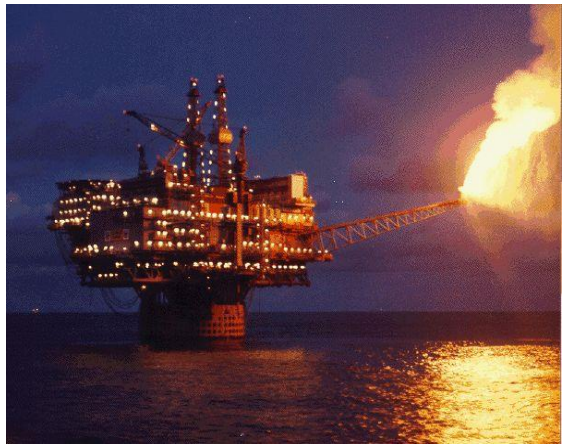
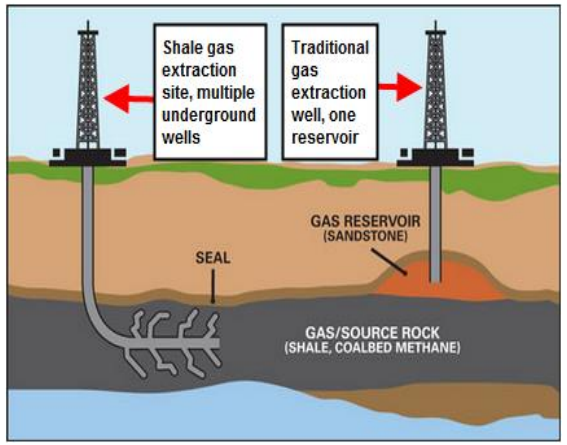
Not All Energy Agents Maximize Profits:

Modelling Complexity of Investment in Oil & Gas Projects







International Association of Energy Economists

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With help from

KAPSARC

مركز الملك عبدالله للدراسات والبحوث البترولية

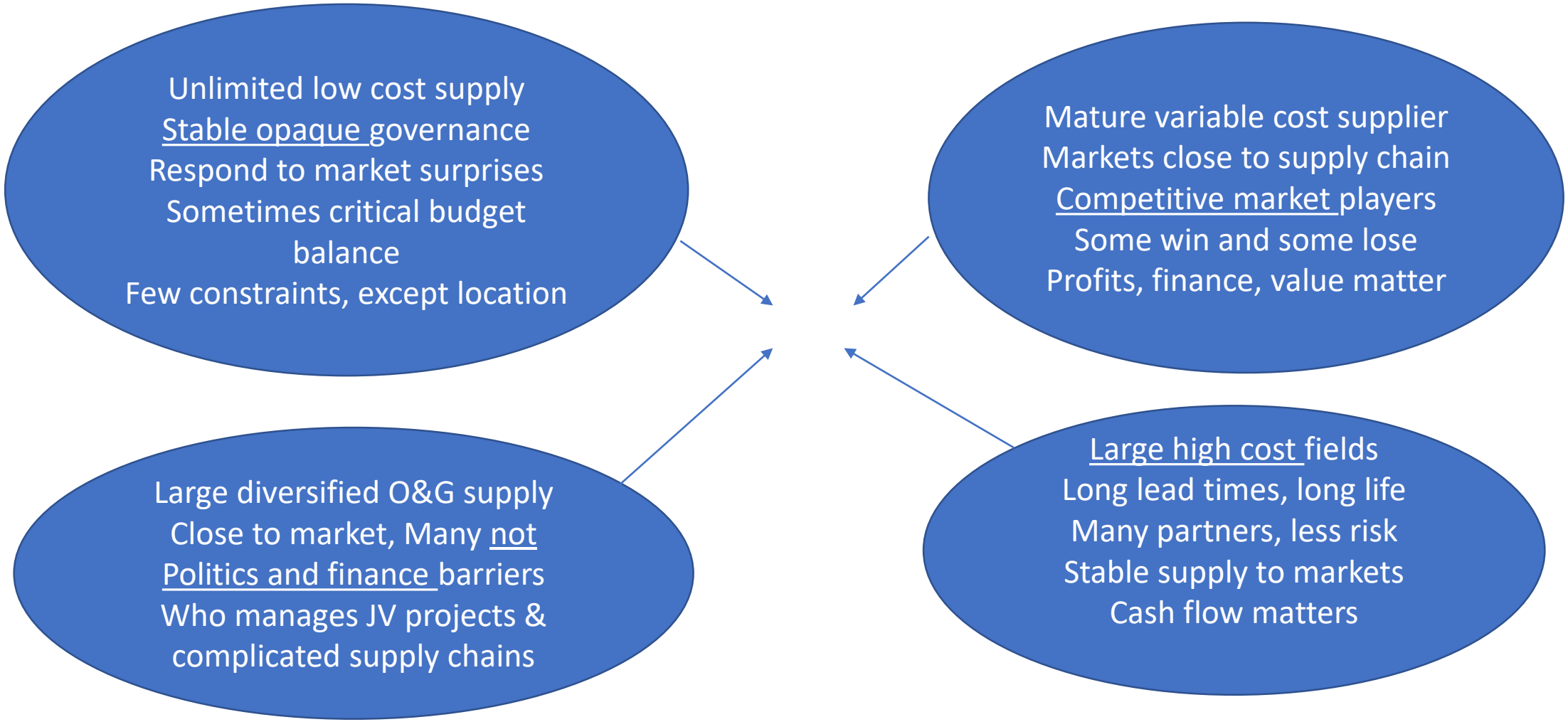
King Abdullah Petroleum Studies and Research Center

Energy Agent Based Model, NOT a profit maximizer

- The underlying premise of our approach is that an agent-based model (ABM) that uses a flexible structure can simulate market interactions and more particularly explain the investment and production cycles. In other words, energy producers have different investment / profit maximizing functions and the **heterogeneity** of agents investment matters.
- The investment, production, and cash flow actions of National Oil Companies, Independent Oil Companies and Shale producers, operating in fields with different costs affects energy supply and, of course, prices.
- Our agent based, fuzzy logic model lets us to run “what if” simulations by changing common language assumptions (e.g., behaviour rule: invest more in shale if prices are high/over $60 a barrel; expand low cost oil & gas fields if expected demand / price peaks in five years).
- By using field level data to estimate agent investment functions derived from heterogeneous profit expectations we explain the differences of oil production of individual agents and resulting market dynamics.

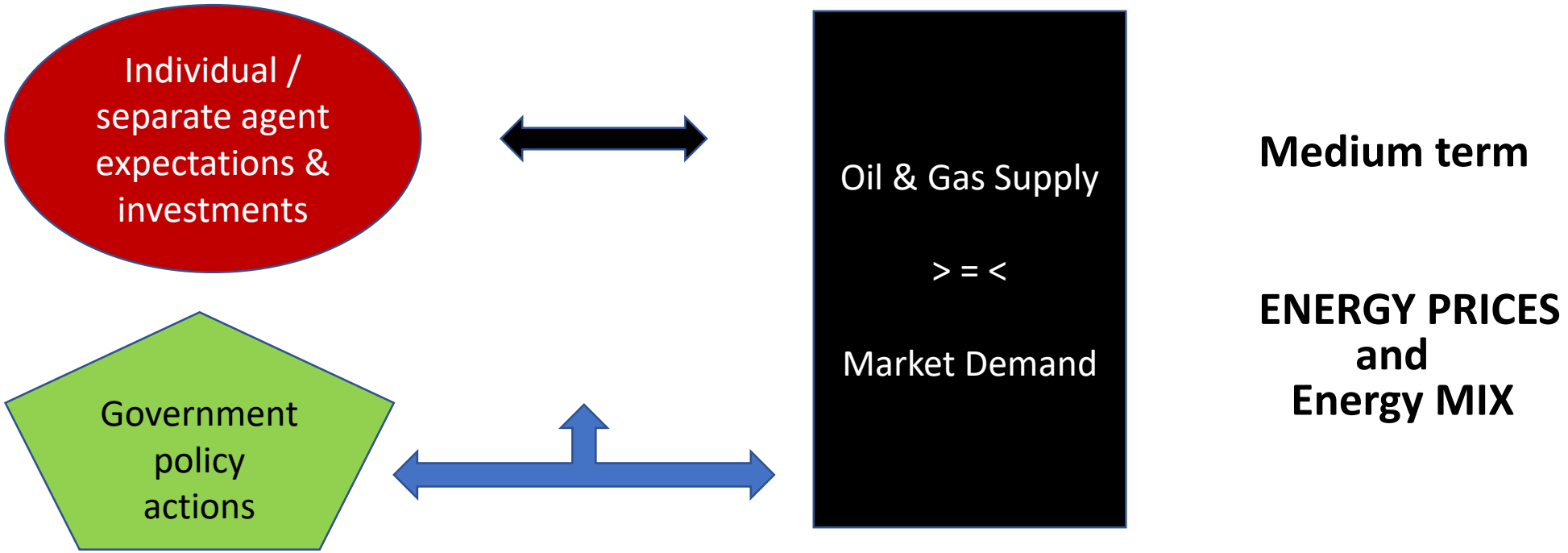
Heterogeneous Agents with Different geologies:

Invest Differently with Different production paths that changes Market Dynamics, Prices Volatility



Heterogeneous Agents Affect Supply Curve

- Changing agent expectations / interactions and Investment actions
- Energy supply dynamics / feedback loops and price volatility
- Longer run investment decisions and oil & gas supply curve



Today's Agenda: a work in progress

1. Problem / Challenge
2. Current Framework / Approach
3. Hypothesis, NOT NPV profit maximization
4. **The Data**: **Field / Projects and Agents**
5. Agents with Different Investment approaches
6. Preliminary ABM / Fuzzy Logic Workplan
7. Does it Matter? YES

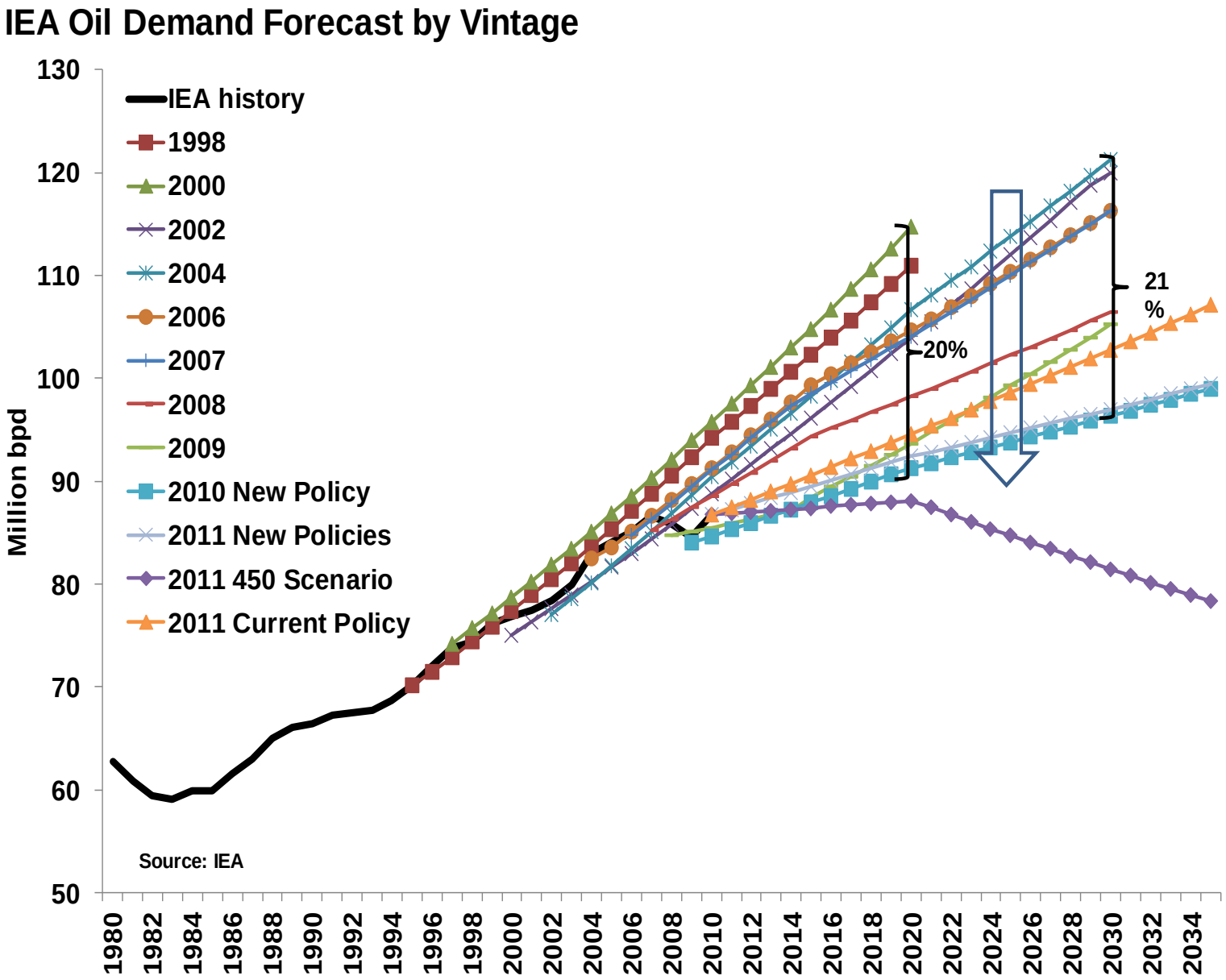
The Problem and Challenges

What demand, What supply, What price?

Lots of Energy Demand Scenarios that miss the mark by a lot

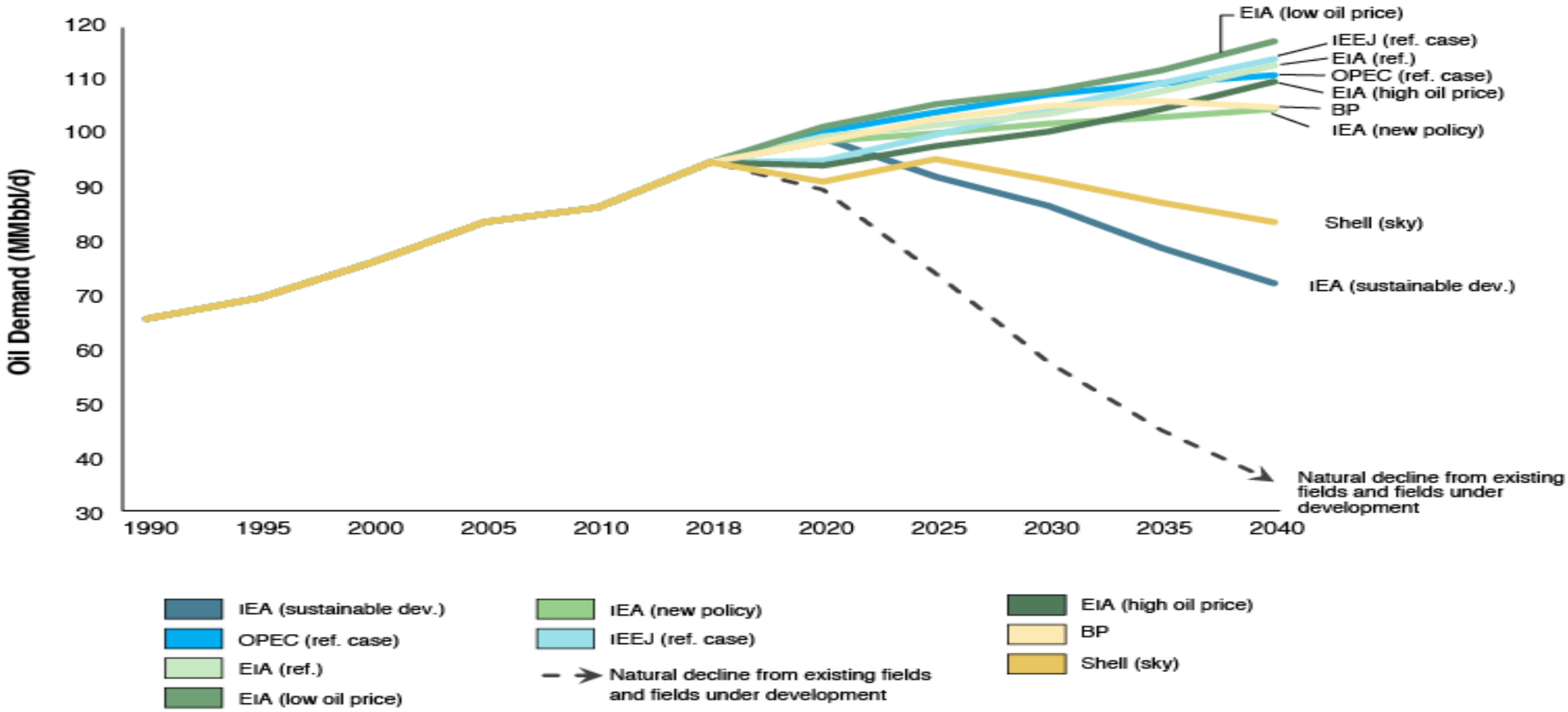
K. Lindemer, IHS Cera

- What Price?
- What Investment?
- What Demand?
- What Supply?
- What Future?

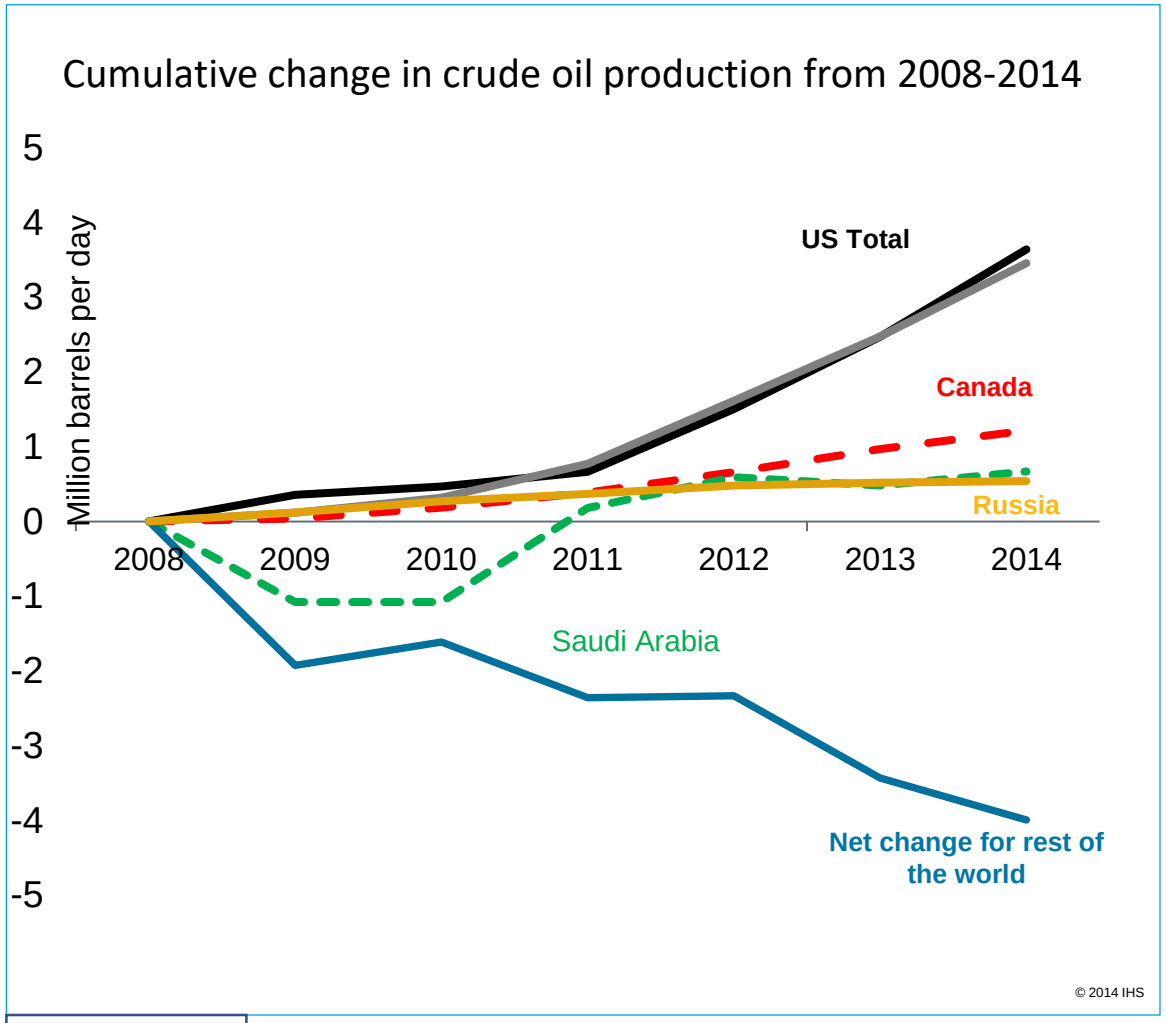


Global oil demand forecasts vary widely

Uncertainties in policy choices, economic outlook, technology shifts, and resource estimates lead to large variations in oil demand forecasts

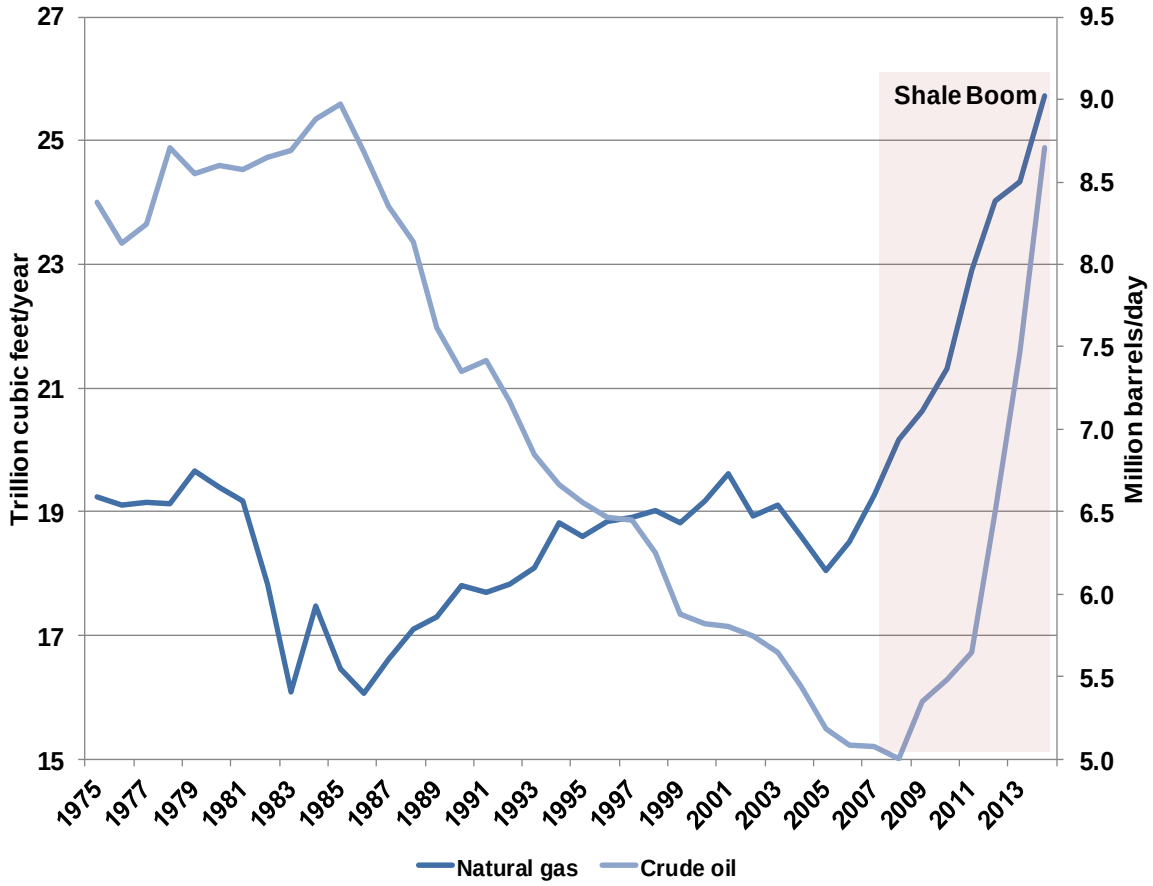


Shifting Oil Supply

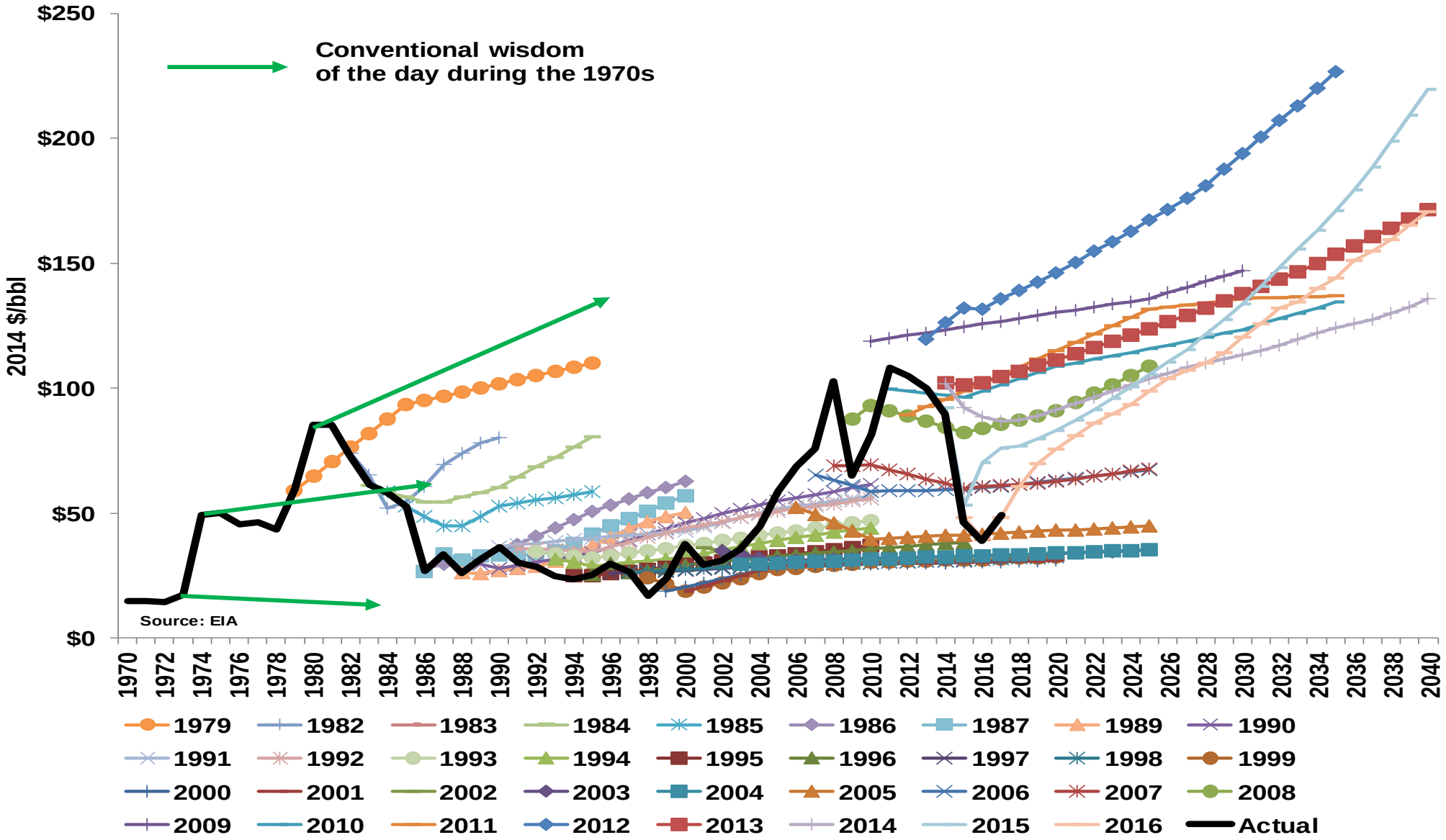


IHS/Lindemer

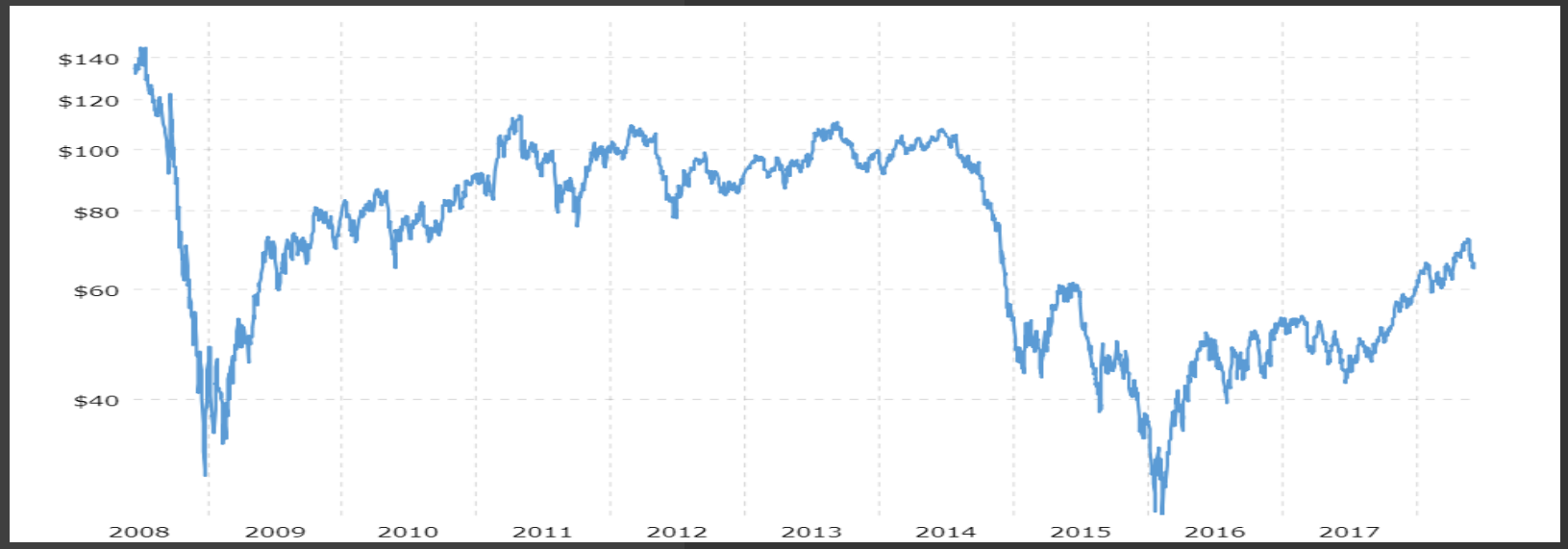
US shale production

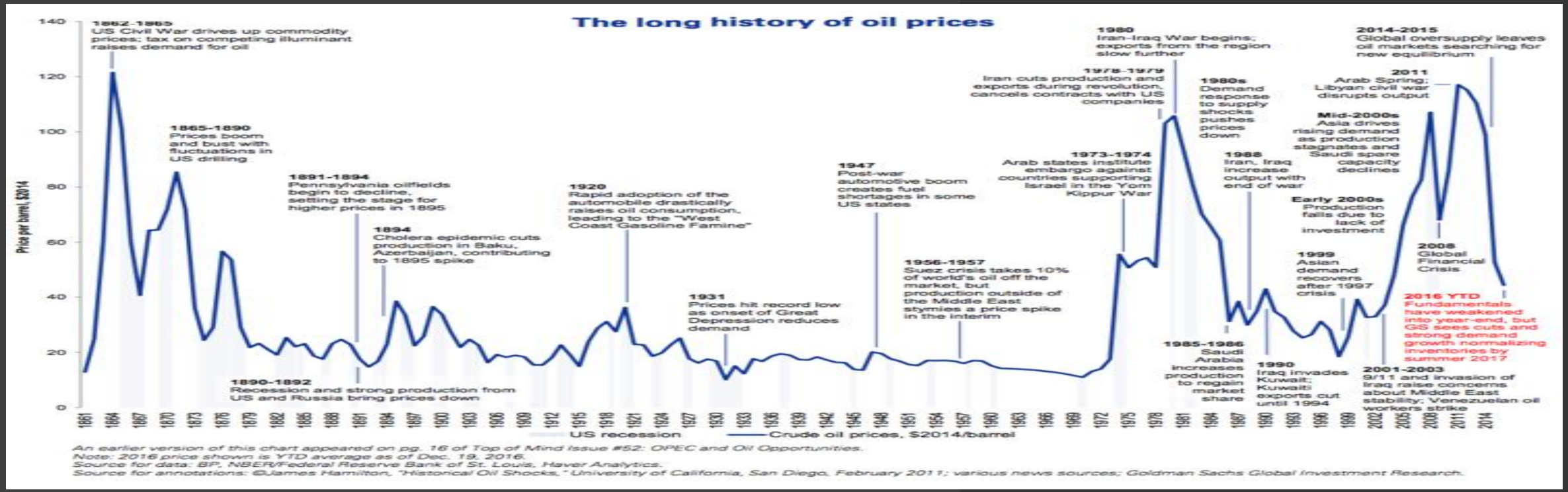


Oil Price Forecasting… **NOT** a smooth trend line!



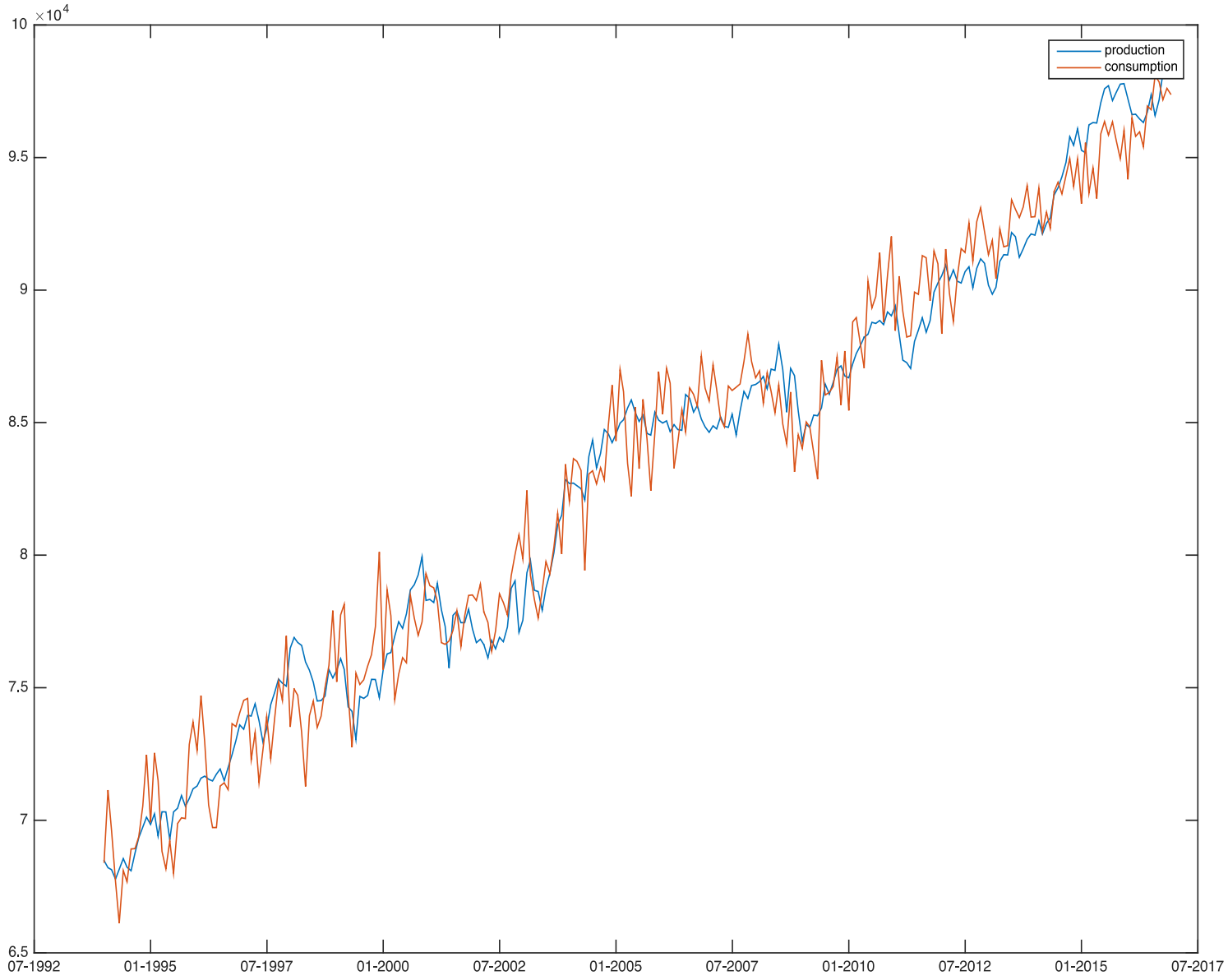
Price volatility: boom and bust





The Producers' Challenge: always market imbalances

- Match Production (blue) to Consumption (red)
- Invest with a long lead time and constraints and adjusting production
- And with no coordination?
- What price, what return?



Current Frameworks & Literature

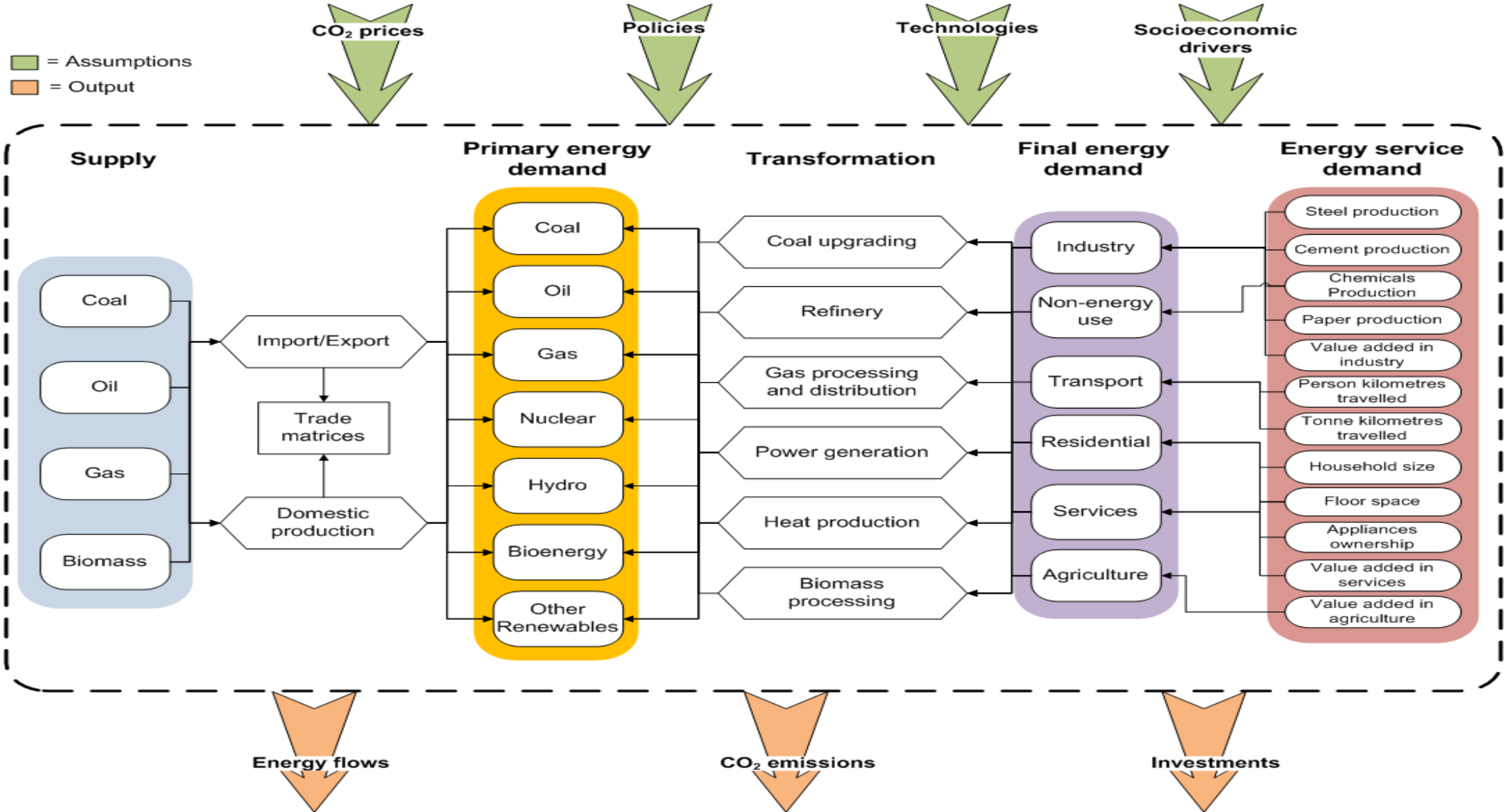
Market Equilibrium
and
Surprises & shocks

(IEA, Shell, BP, EIA… and
Killian, et. al.. and
Oxford Energy Economics

General Equilibrium Macro Structure:

Supply > = < Demand

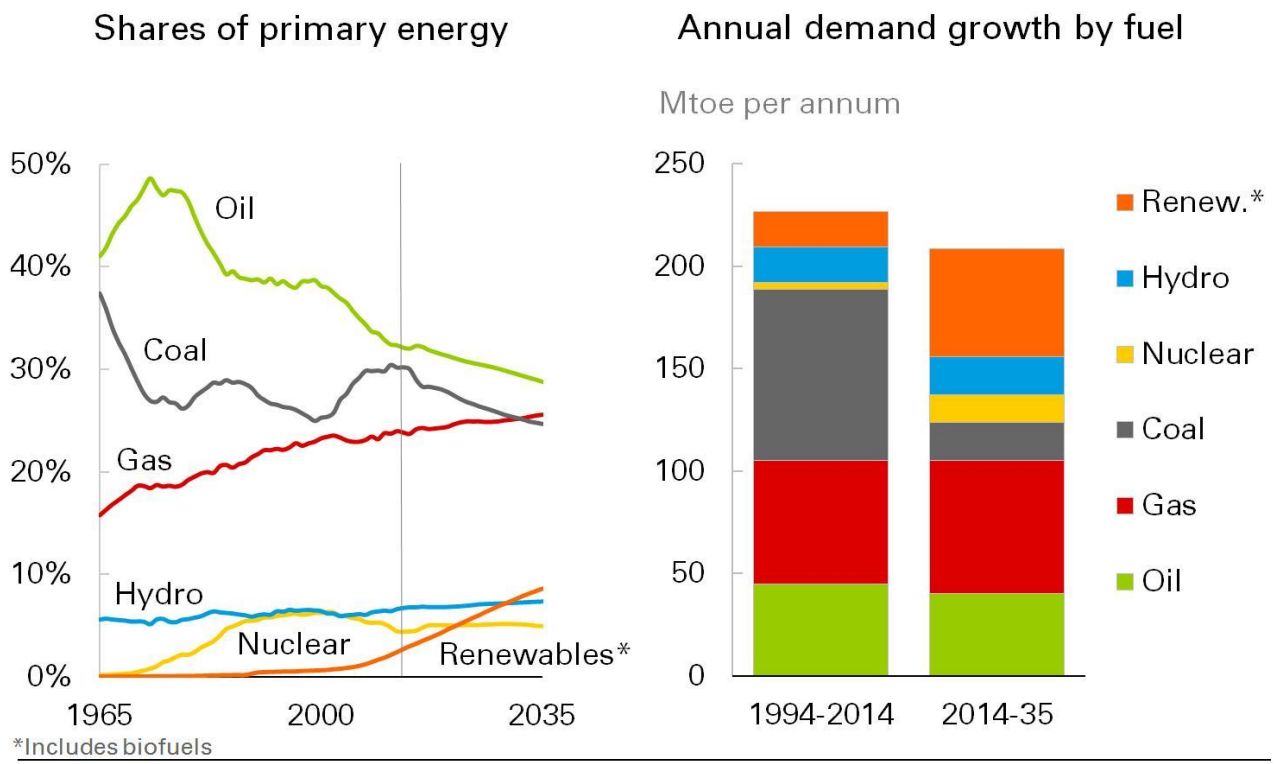
IEA, EIA, OPEC, Shell ➔ huge data gathering and estimation



Scenarios and What **IFs**

Base case: Primary energy

The fuel mix is set to change significantly…



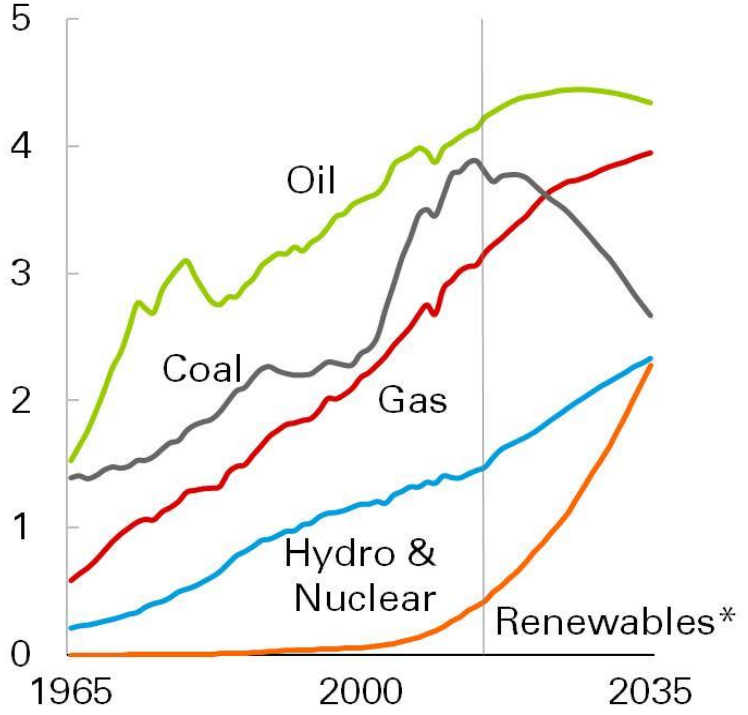
2016 Energy Outlook

OR

Faster transition

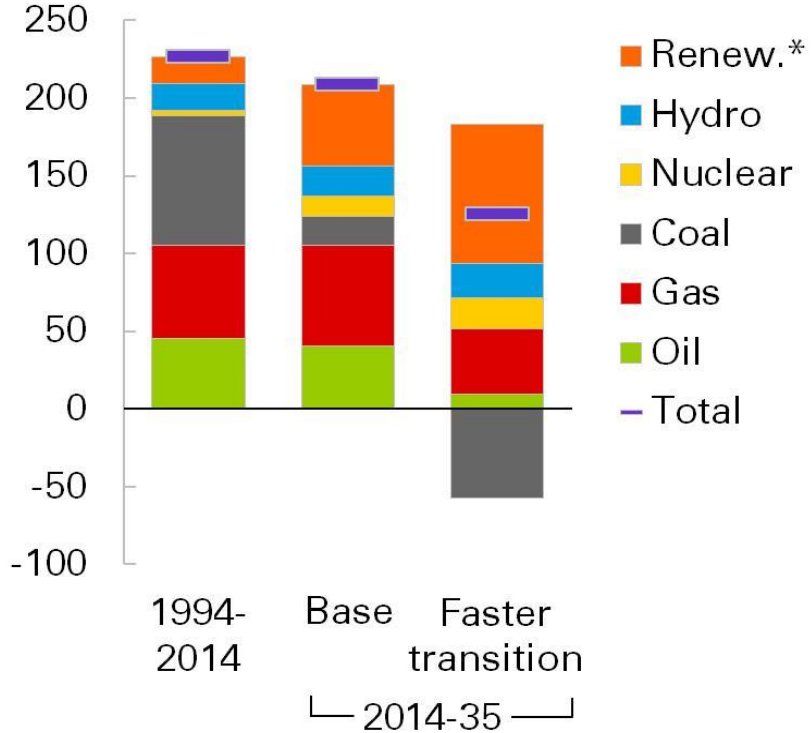
The faster transition has a significant impact…

Consumption by fuel

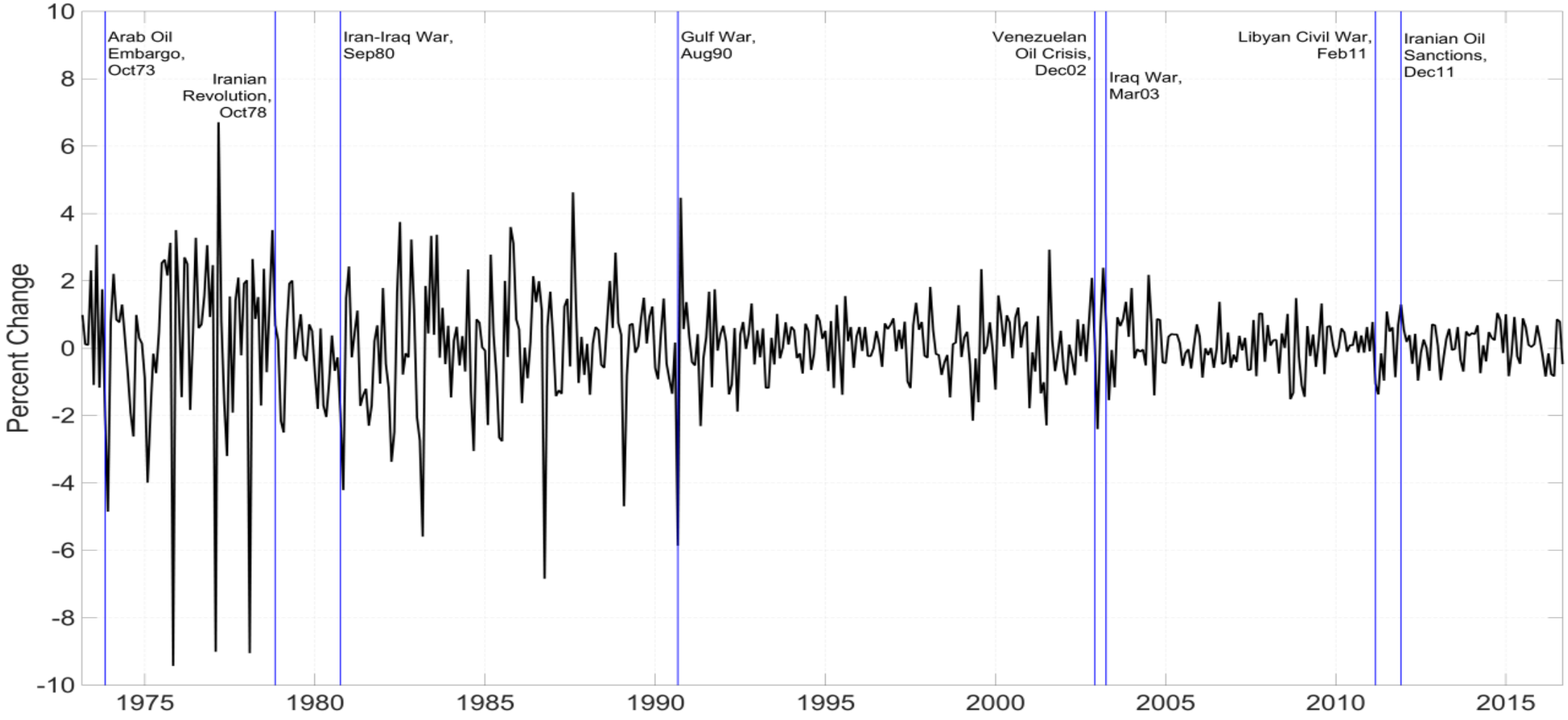


*Includes biofuels

Annual demand growth by fuel

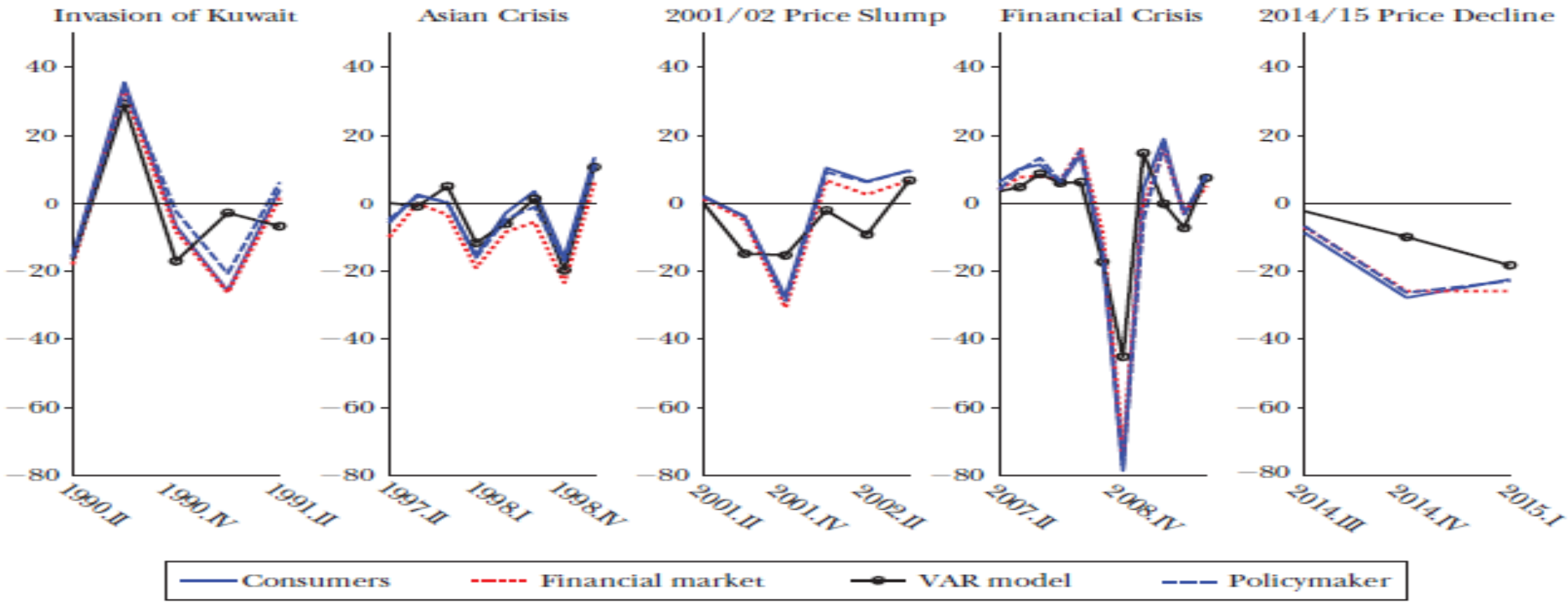


Supply & Demand shocks (VAR models):
World crude oil production in monthly percent changes, 1973 -2016



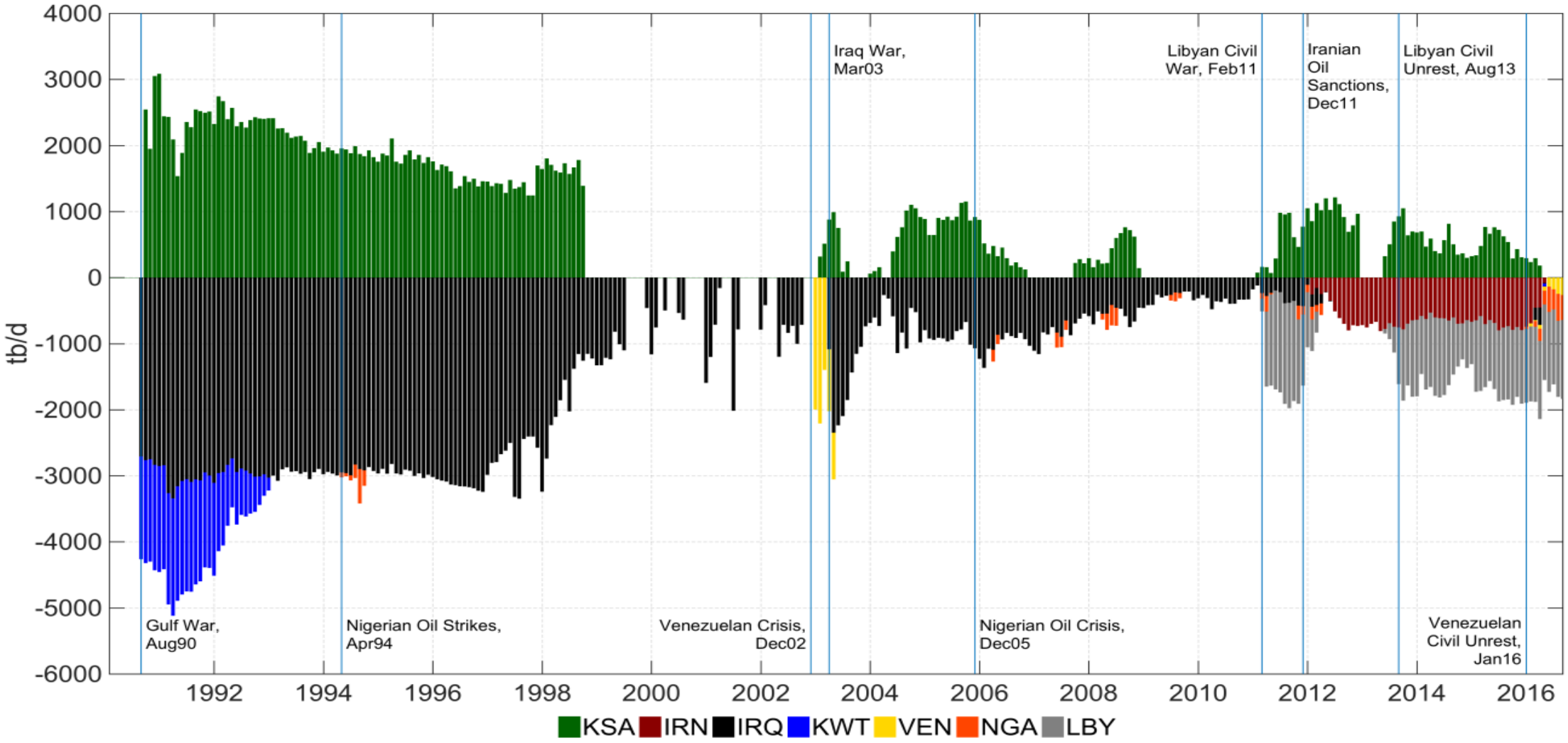
Quarterly Shocks to Nominal WTI Price of Oil by Episode

(percent)

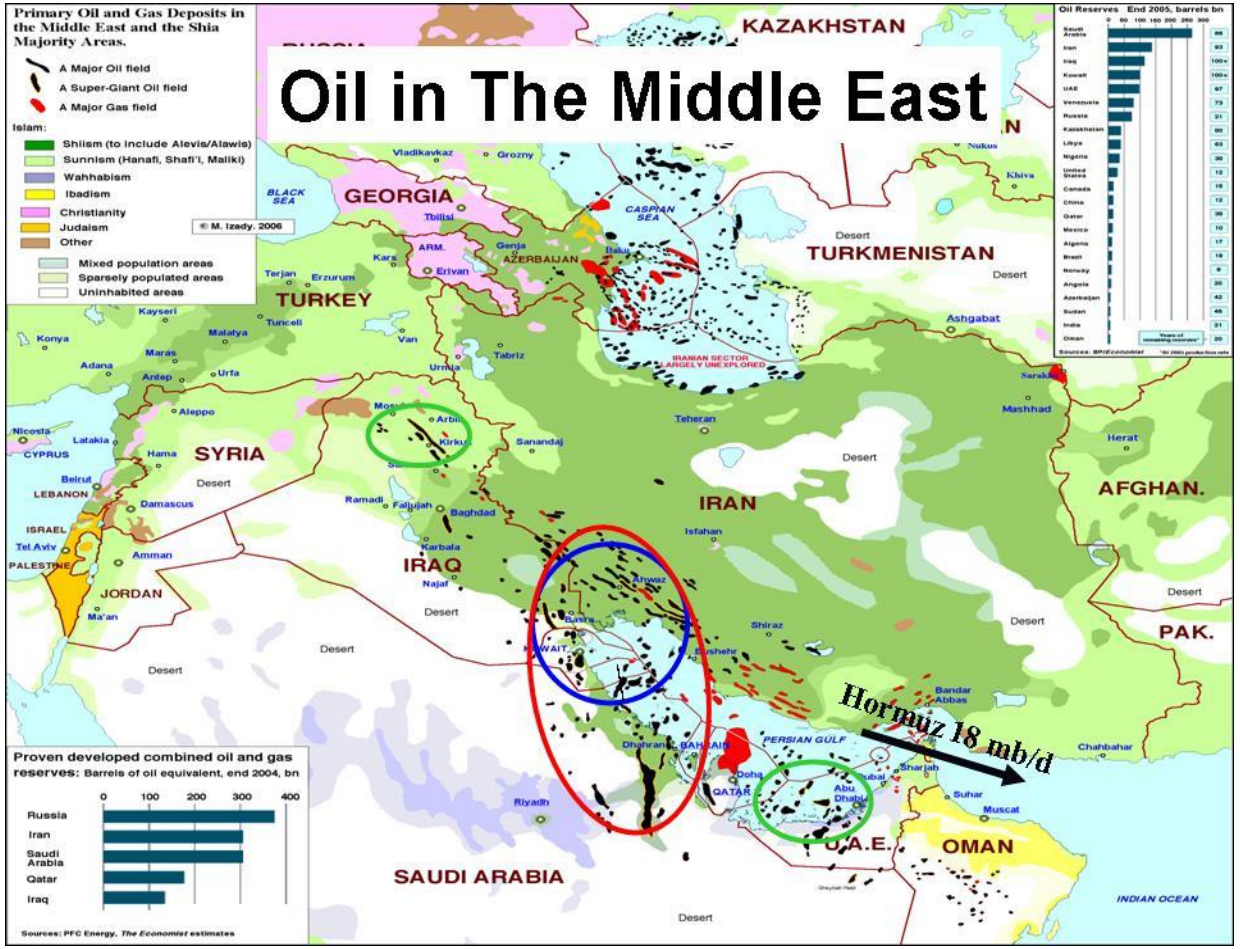


Notes: Each oil price shock series is constructed by averaging the monthly oil price expectations by quarter and expressing this average as a percent deviation from the quarterly average of the monthly oil price outcomes. The policymakers' expectation corresponds to the unadjusted West Texas Intermediate (WTI) oil futures price. The financial market expectation is constructed by subtracting the Hamilton and Wu (2014) risk premium estimate from the futures price. The consumer expectation is proxied for by applying a no-change forecast to the real price of crude oil and adding the expected rate of inflation, motivated by the results for gasoline price expectations in Anderson, Kellogg, Sallee, and Curtin (2011). The vector autoregressive model (VAR) expectation is constructed from the reduced-form representation of the oil market model of Kilian and Murphy (2014) estimated on the full sample. The

Exogenous disruptions and OPEC / Saudi Arabia as swing producer in thousand barrels per day, 1990-2016

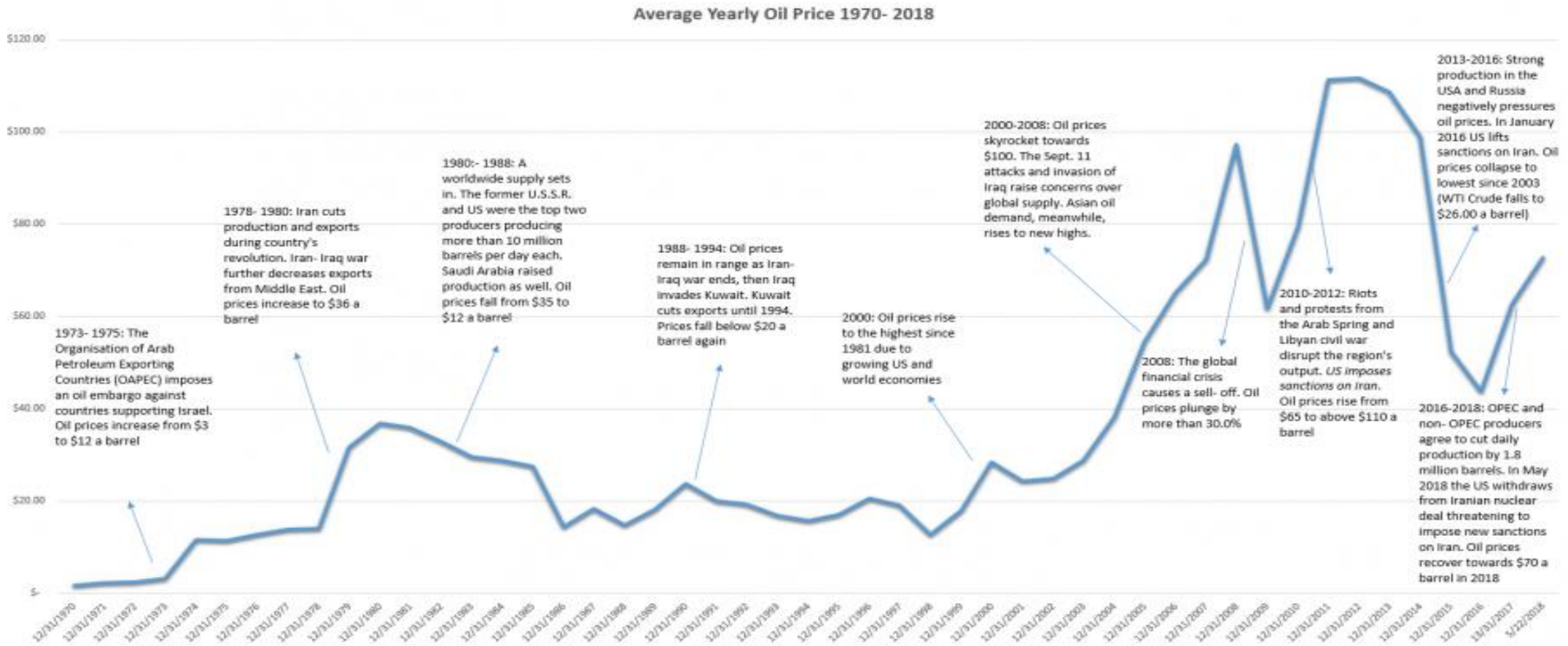


Politics again and again and again: Iran, Russia, Ukraine, Venezuela, Nigeria, Brazil, Qatar, Saudi Arabia, Israel, US, and …



Whys of Price Volatility

Shocks, behavior, changed expectation



Supply: Demand	Stagflation	IR up recession	New fields on	Asian FX crisis	Asian growth	Financial crisis	Sanctions
Political tensions	Yon Kippur	Iran revolution	Iran/Iraq, then Kuwait War	Russia Yeltsin, slow growth	9 / 11, Venezuela	IPCC climate Russia Crimea	Paris COP 15 Iran/JCPOA
Technology		Alaska pipeline North sea oil			Invest wind parity … solar	Shale fracking, Gulf rig explods	Horizonal drilling
Market players	OPEC, longer contracts	Saudi Arabia increase oil	Opec cuts, cheating	OPEC quotas	Saudi production	China gas pipelines	OPEC, Russia, Saudi, China

Limitations of these approaches

- **Simplified Shocks**, Demand == Supply and **Price Volatility** models
- **What short / long Price expectations**?
- **Supply chains** matter with known bottlenecks (not surprises)
- **Lags in investment, production**, **decline** rates by region, fields,

- **Endogenous actions of producers with different expectations**
- **Changing behavioral actions** of producers / consumers
- Always **politics** and **exogeneous producer** surprises

- **NPV** of investment…**Not** necessarily true of for all

Heterogeneous producer model in non-equilibrium oil markets

Where to invest? What to Invest? When Returns?

Conventional vs Unconventional FID Oil Investment

- When examining the committed investment of the energy firms, there is something not exactly proportional to the oil price occurring.
- For conventional projects, the expectations of the firms drives their decisions to commit funds
  - The two most notable spikes in conventionals are in 2004 and 2010
  - These years are in the middle of upward price swings.
- Unconventionals, however, remain very pro-cyclical
- This makes sense considering the development lag differences between the project types.

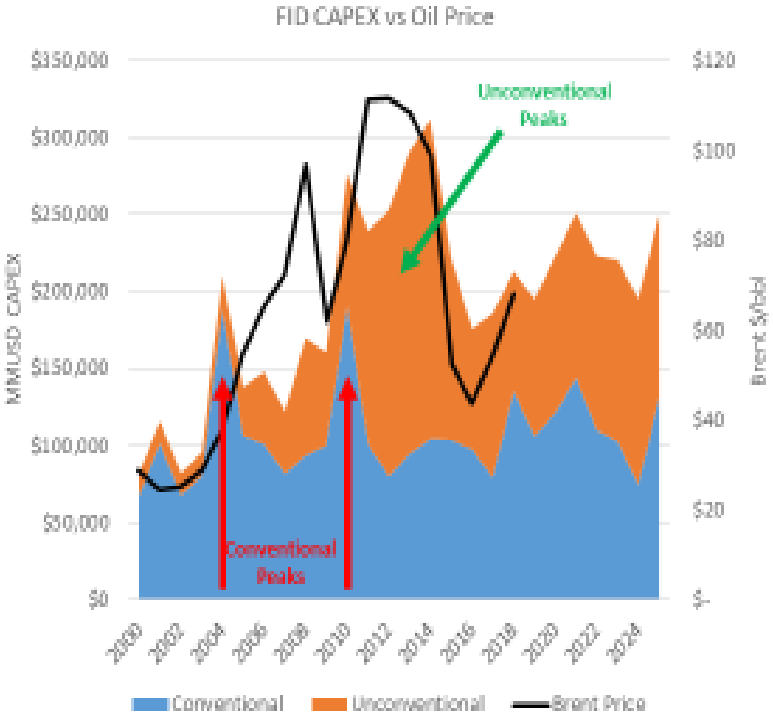
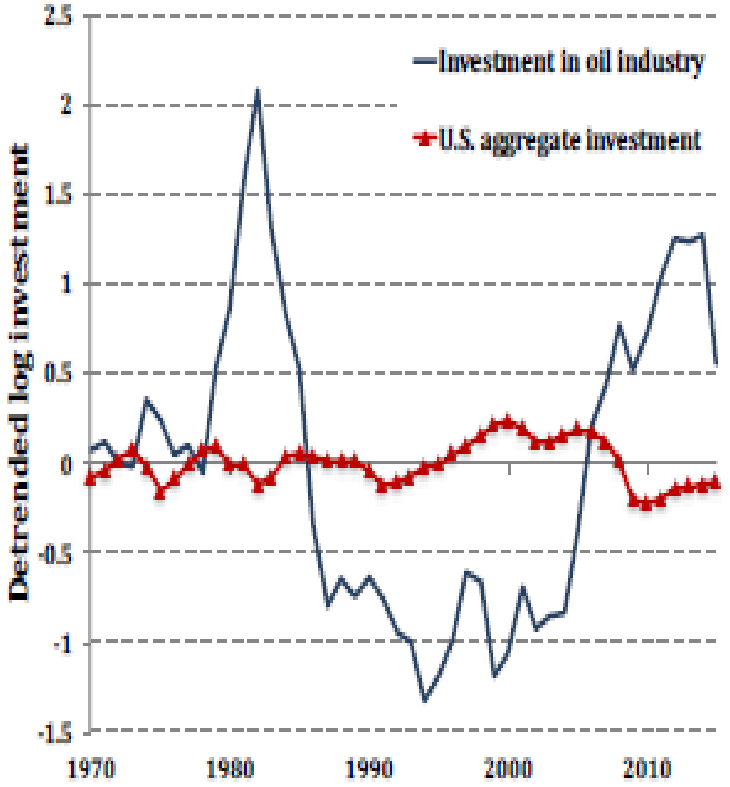


Figure 2: Detrended investment in the oil industry



[5]The only major U.S. manufacturing sector with volatility of investment similar to the oil industry in the period 1970-2015 is Motor vehicle manufacturing, a sector that has struggled to compete with foreign manufacturers and had to be bailed out by the Federal government in 2009.

NOT All Agents Maximize Project NPV

Modeling Complexity of Agent Based Investment / Production Behavior

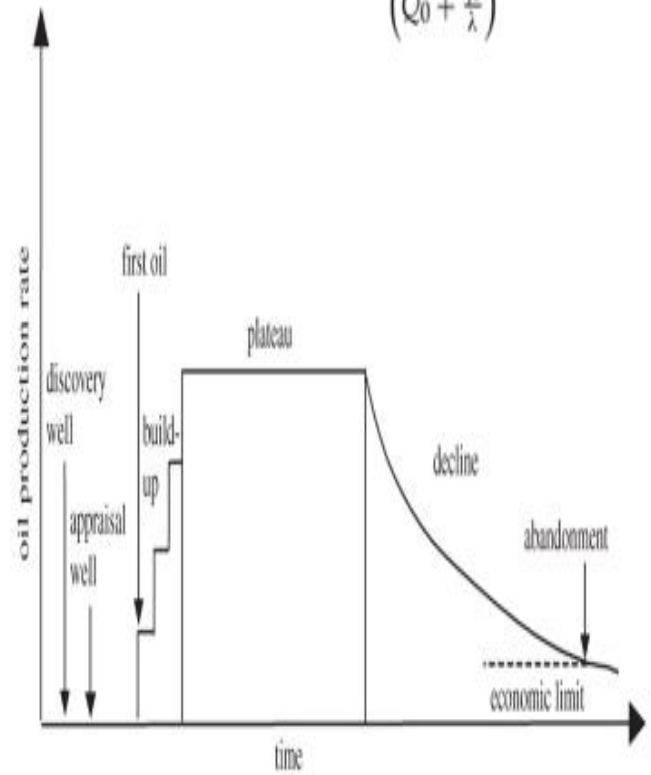
WHY IS IT SO DIFFICULT To MAXIMIZE FIELD VALUE?

$$d_{URR,t} = \frac{q_0 \exp(-\lambda(t - t_0))}{\left(Q_0 + \frac{q_0}{\lambda}\right)}.$$

- All producers need to do is

$$Max\ \mathrm{E}\left[\Sigma_t\, \beta^t \Pi(Q_t)\right]$$

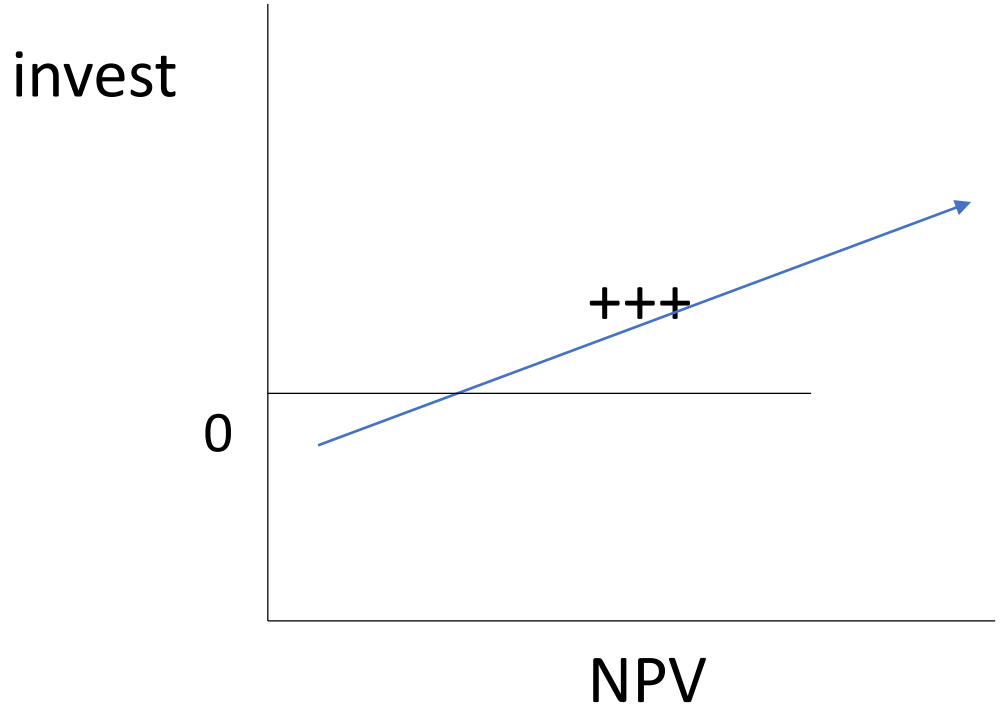
- Simple right?
- All we need to do is
  - model possible Q and costs at each point in time, either *assume* we sell all of them or model the inventory process,
  - solve for all producers and consumers simultaneously with different parameters,
  - come at the equilibrium price and production.
- Heterogeneous producer's, wells, functions and expectations.



Mikael Höök et al. Phil. Trans. R. Soc. A 2014;372:20120448

Investment patterns

- Ideally, an investment in positive NPV projects,…
  But hard to calculate (many assumptions)



The IHS / Vantage Field and Project Data

IHS data

- Specific data of
  - Discovery
  - Capex
  - Operating costs
  - Taxes / royalties
- Total costs
- Production over time
- Price and Barrels

Costs (real) and NPV calculations

- Breakeven costs
- Mean reversion
- Revenue – costs = Cash flow
  - P and Q history
  - Price assumptions
  - Discount rates
  - With and w/o taxes
- Oil & (Gas) and Shale
- Production (Q) and Price (P) over project life

Investment patterns / cycles

- Investment = F (costs/breakeven, quantity produced. NPV estimate, S:D balance, technology, and other factors, variables…)
- Sorting NPV and investment behavior (expected Price, Quantity, and NPV)

Quantity		
H	**HIGH NPV projects**	**Lower NPV because of costs (deep water)**
L	Lower potential and NPV due Q	Not necessarily positive NPV,
	Low	High

Breakeven

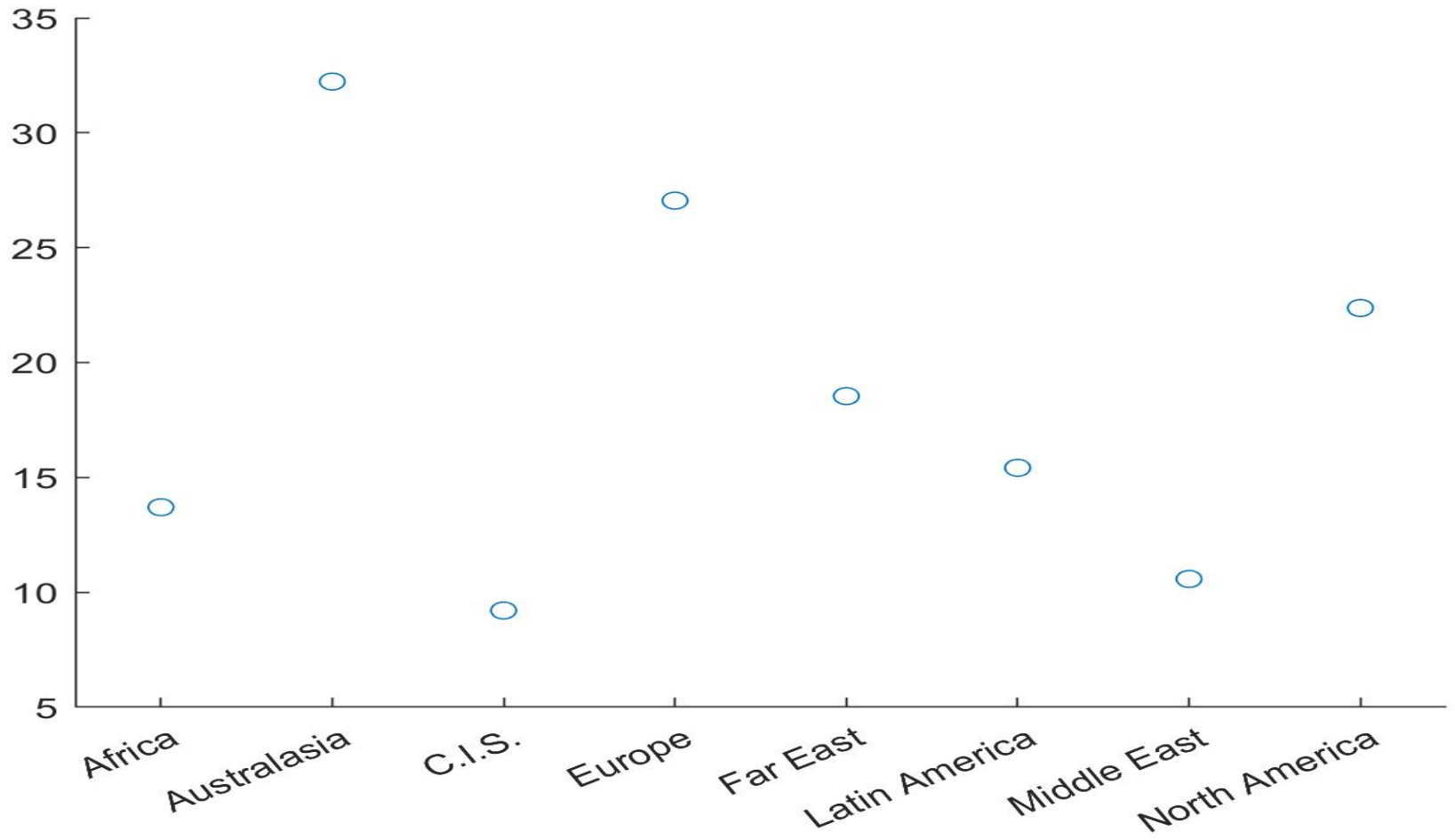
Graphs

Oil & Gas Field Data

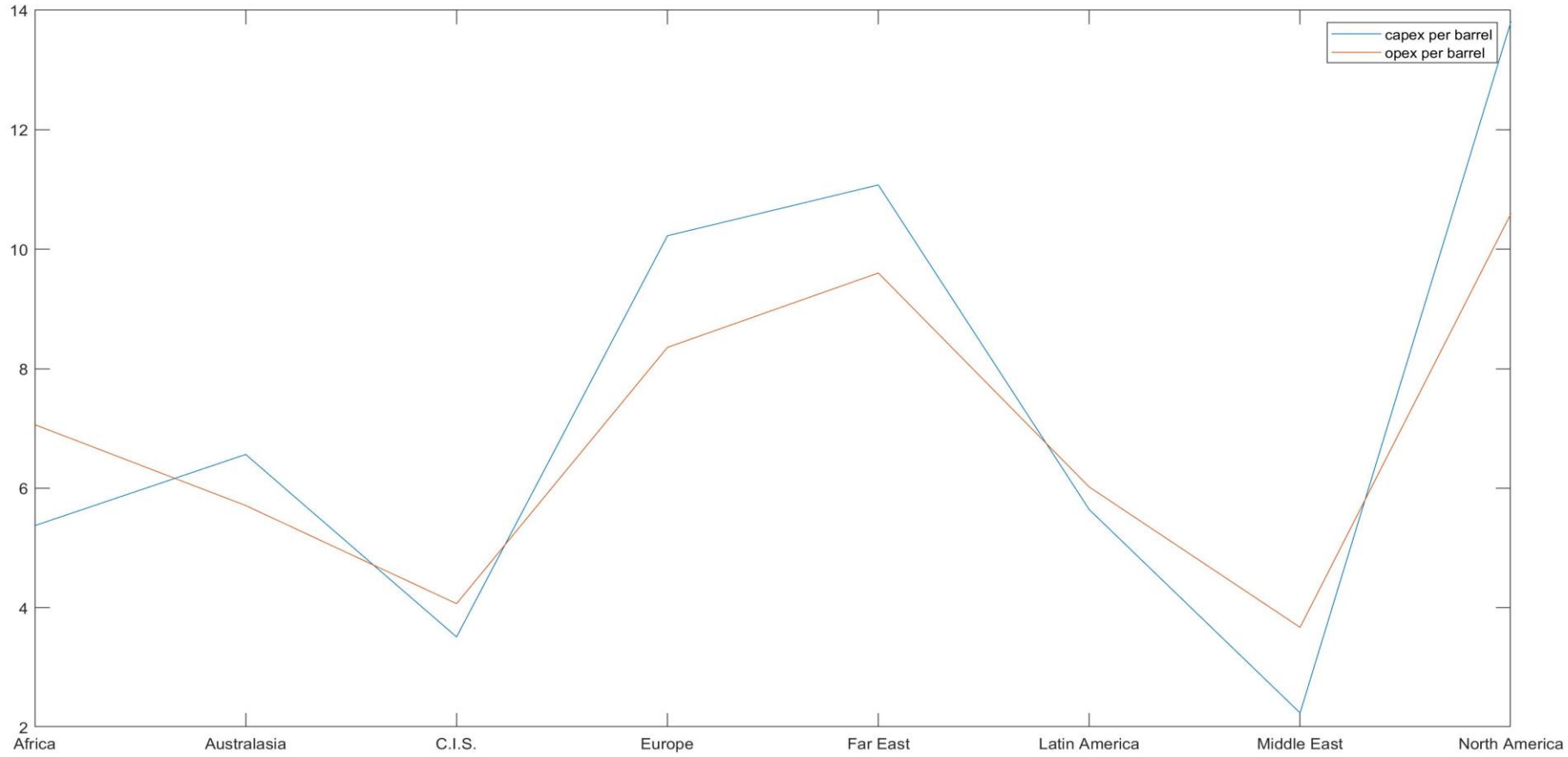
1. Mean breakeven & scatter diagram
2. CAPEX and Opex averages, regional differences
3. Changing breakevens and productivity
4. Different NPV / Investment decisions by region

- 10,472 Oil projects that have minimal gas – worldwide all in production
- From 1900 to 2020
- Real IHS / Vantage cost data (opex, capex);
- Prices real from BP
- Risk adjusted discount rate 5 % (plus inflation)

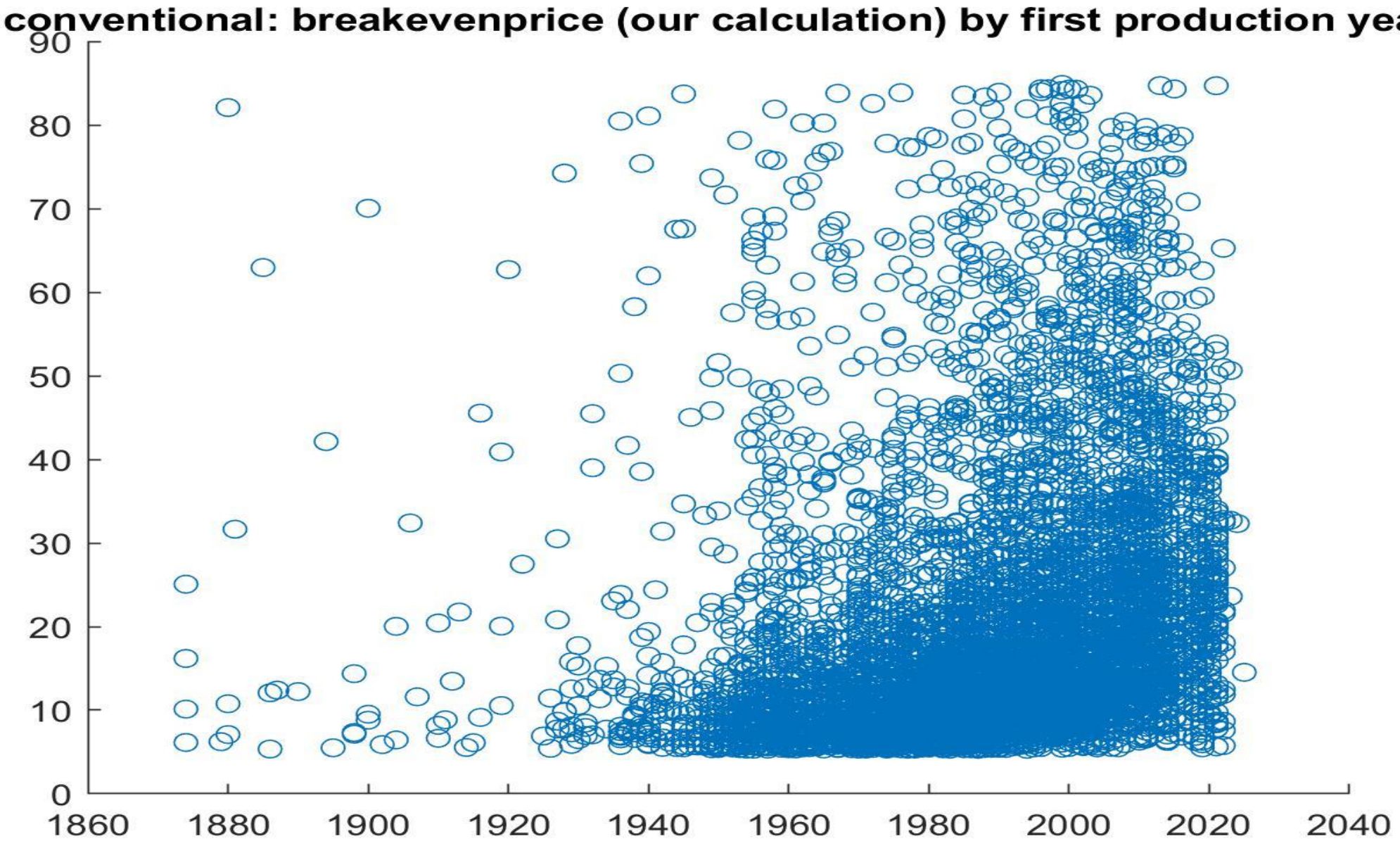
Mean break-even by country



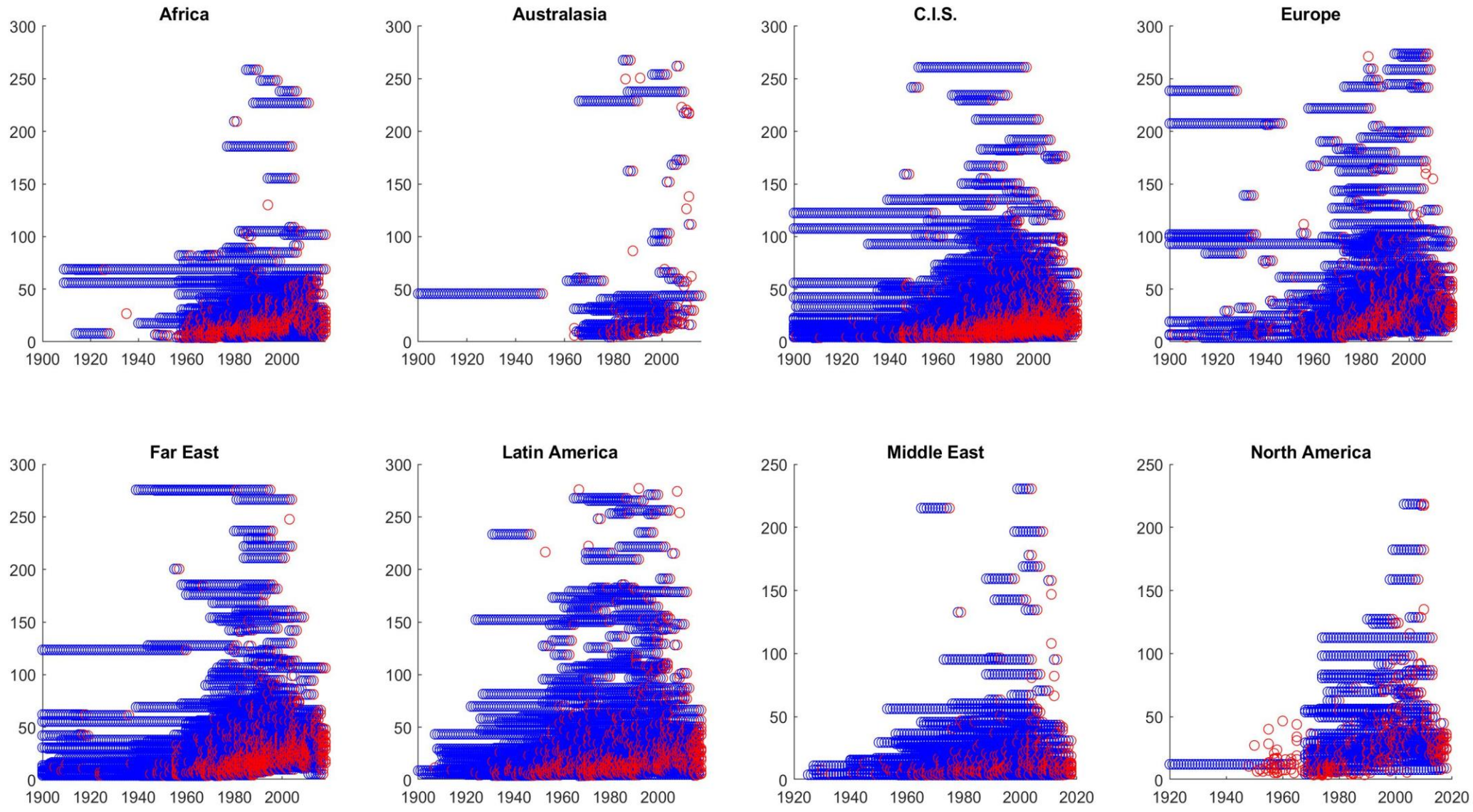
Capex and Opex averages



Breakeven scatter

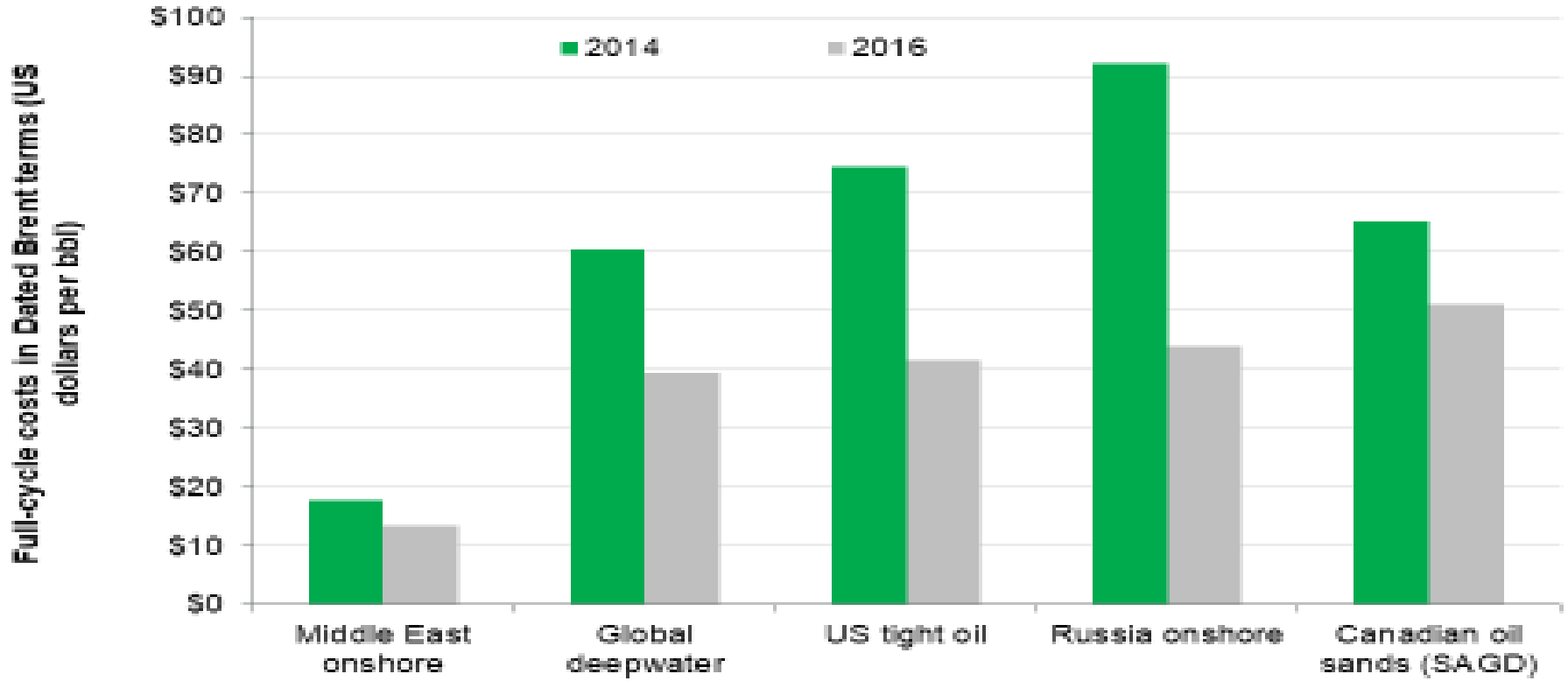


Breakeven costs by region – RED Invest, Blue No



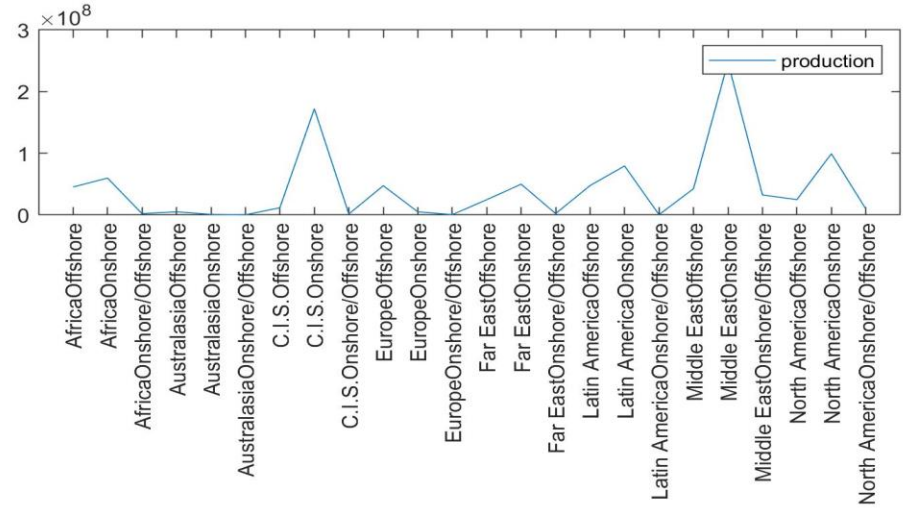
Oil and Gas Production Costs Have Fallen

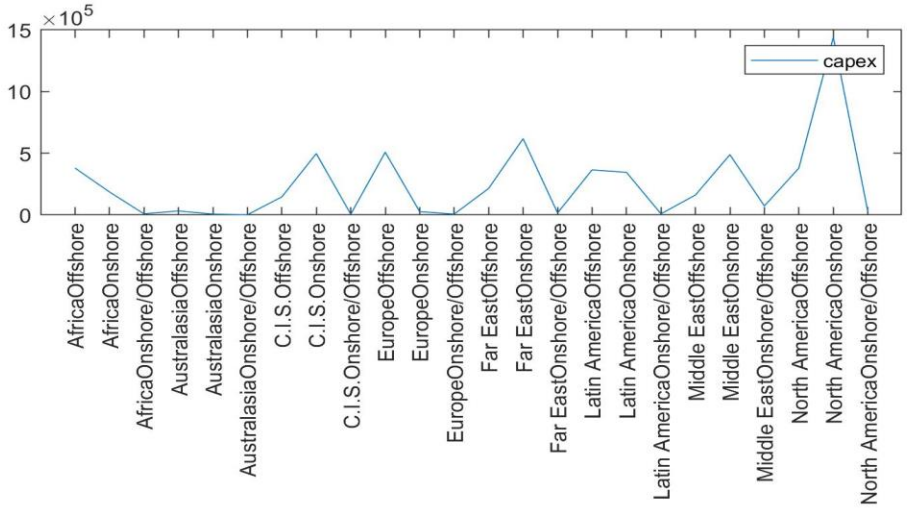
Break-even prices for representative new projects, 2014 and 2016

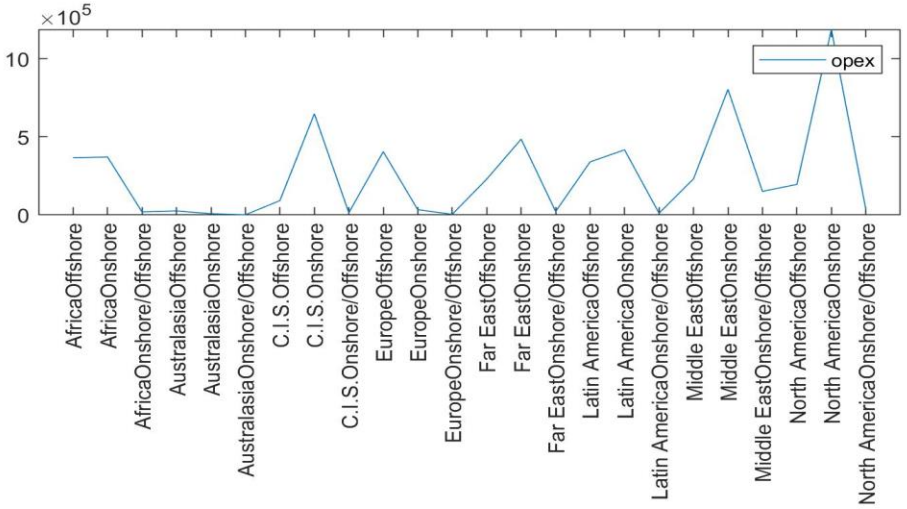


Notes: Full-cycle costs expressed in terms of Dated Brent price necessary for project to break even, assuming 10% internal rate of return. The 2014, 2016 breakeven estimates for supply sources are intended to broadly depict change from start of the oil price collapse in mid-2014 to latter part of 2016. See "How we estimated the break-even prices in this report" for details.
Source: IHS Markit

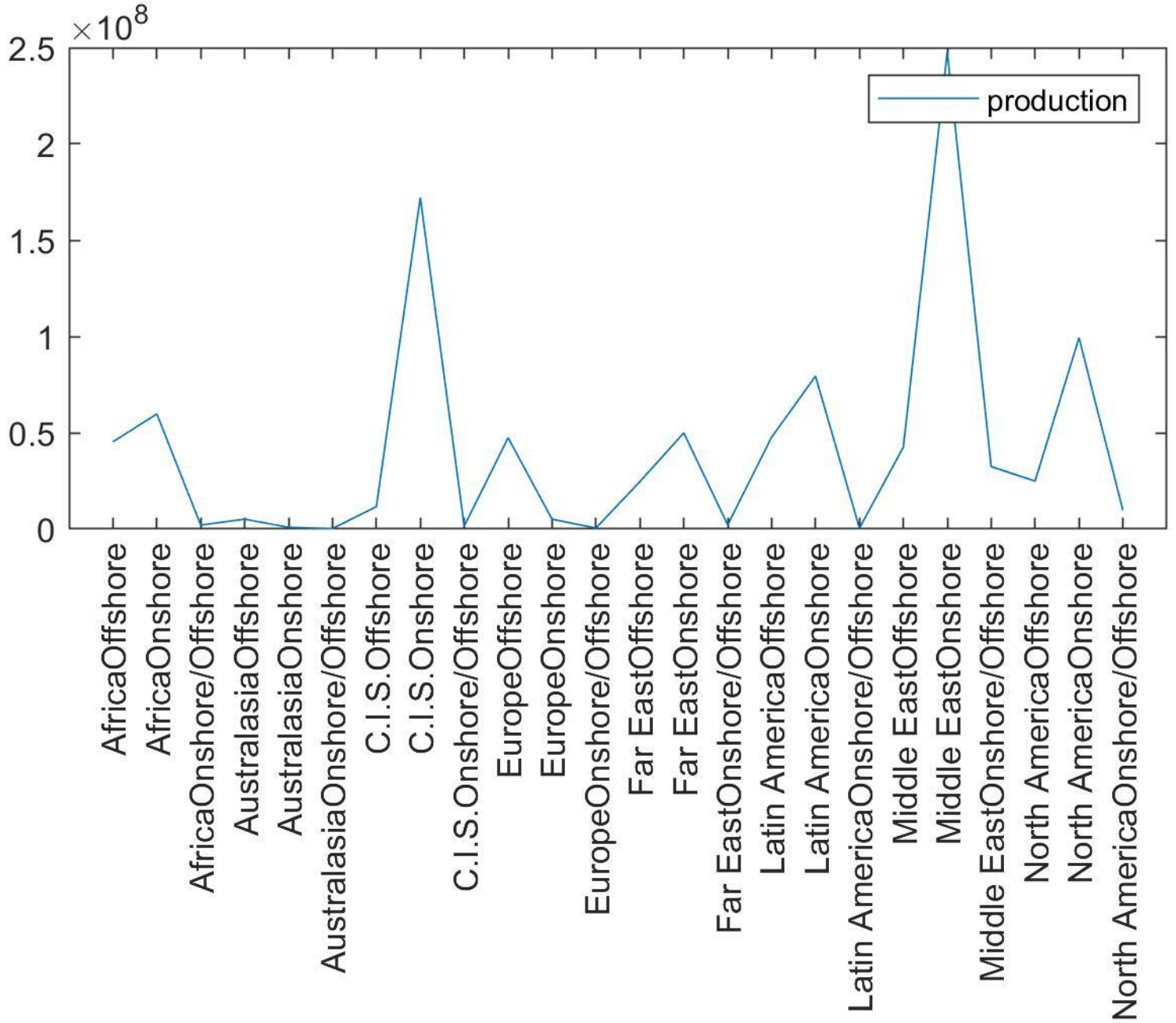
Regions: Production, Capex, Opex



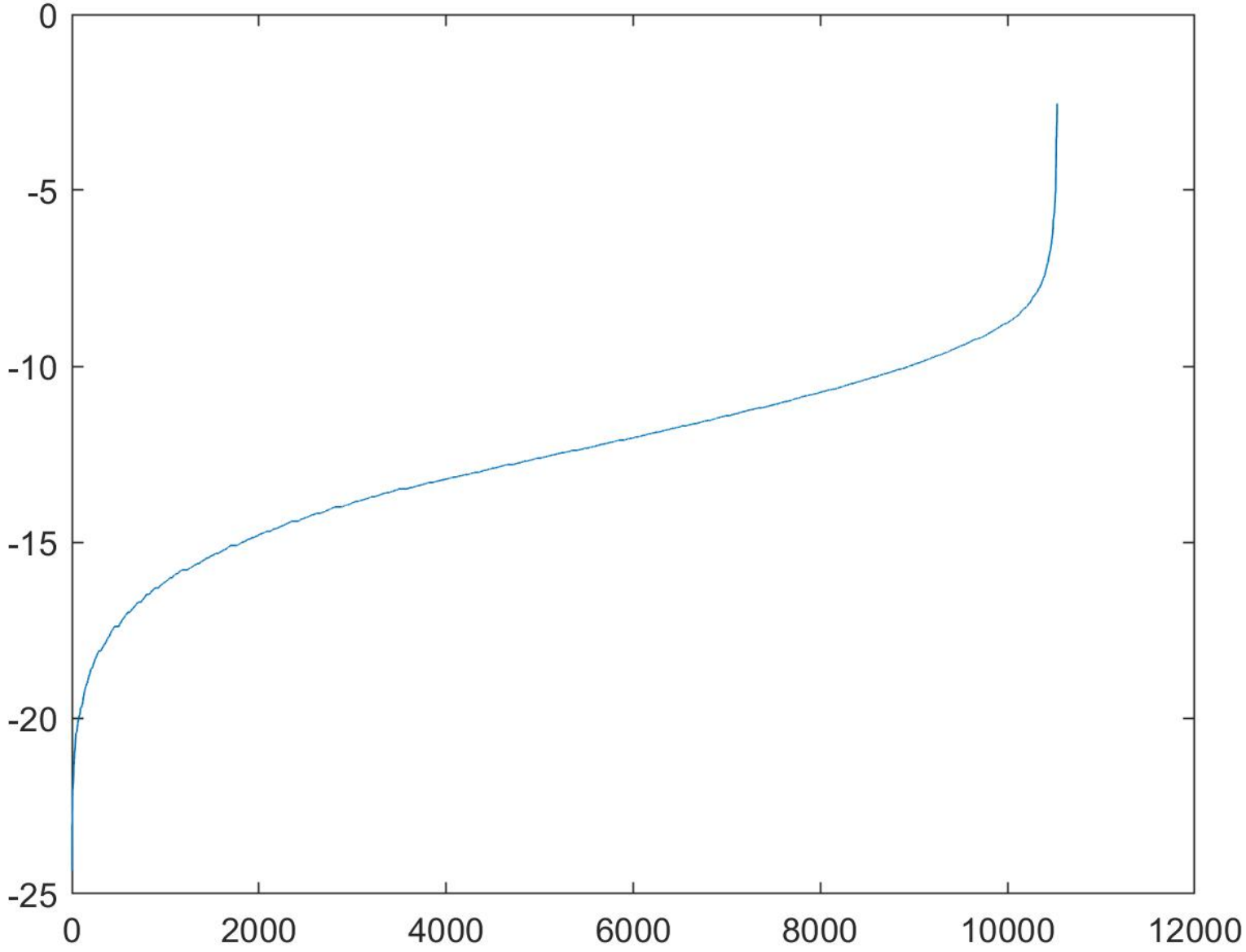




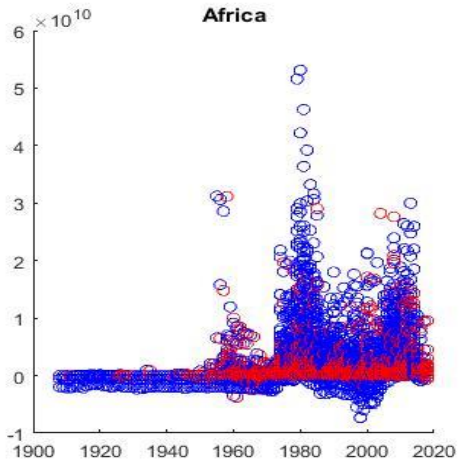
Cumulative Production

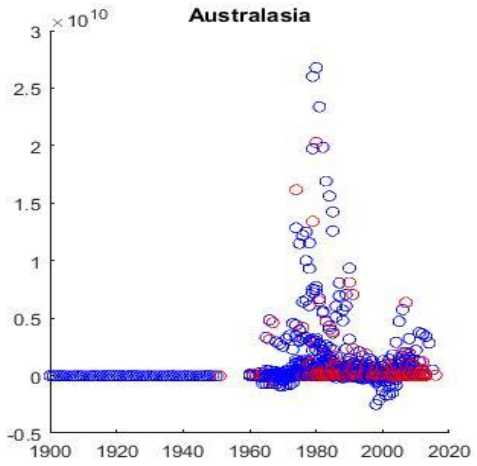


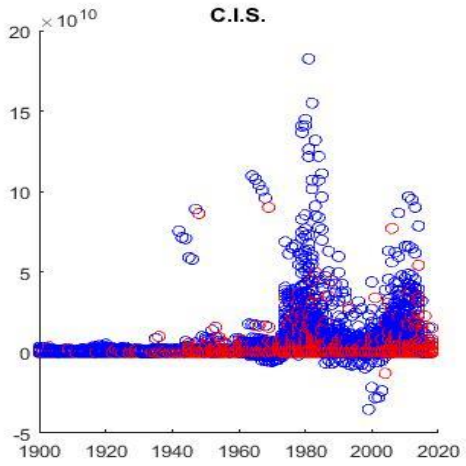
Distribution of reserves

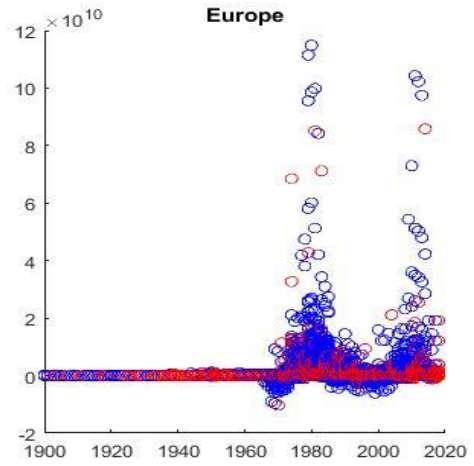


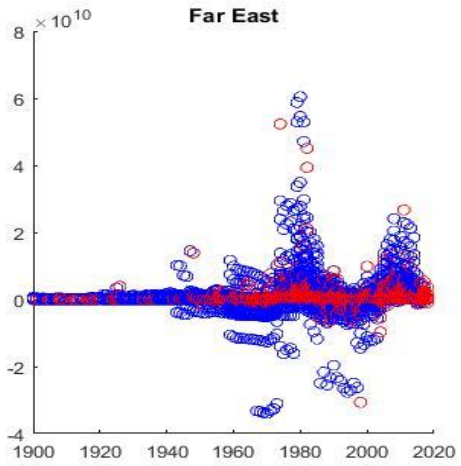
NPV regions: PQ – costs (Red invest, blue no)

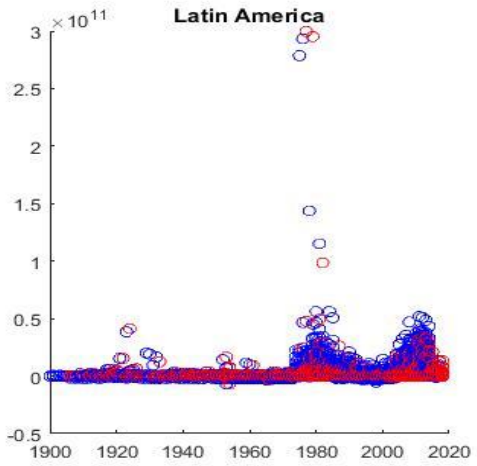


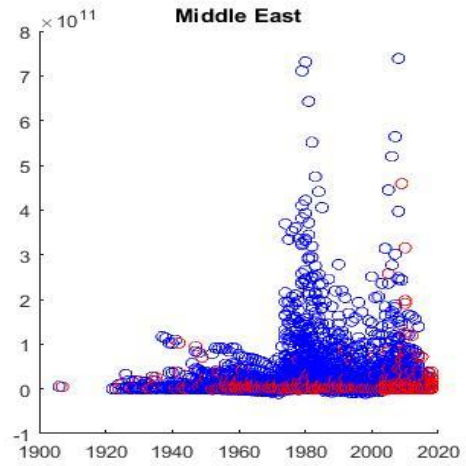


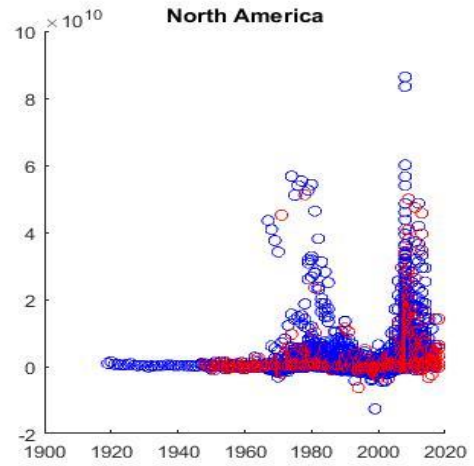




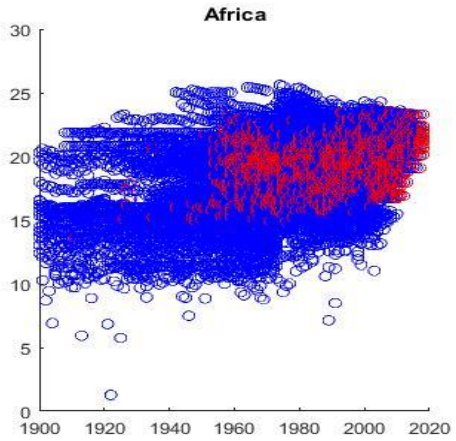


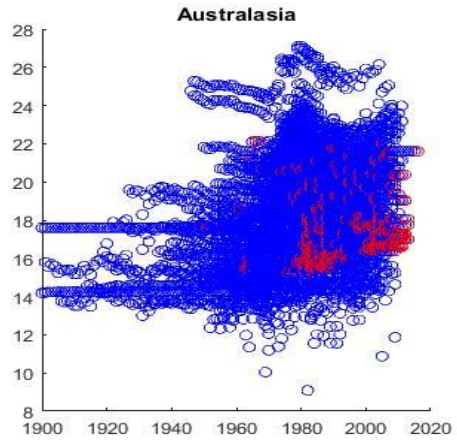


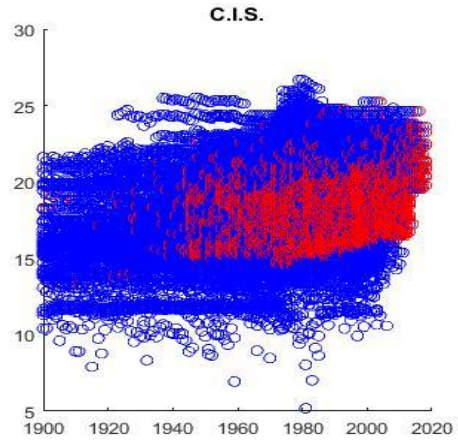


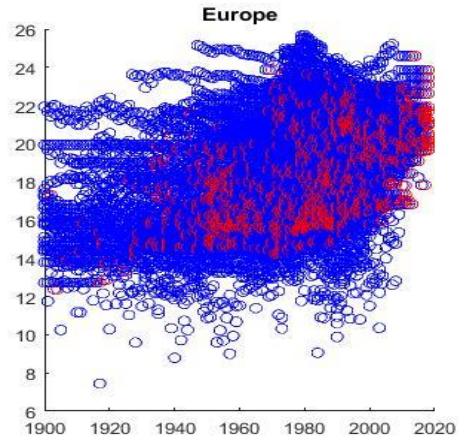


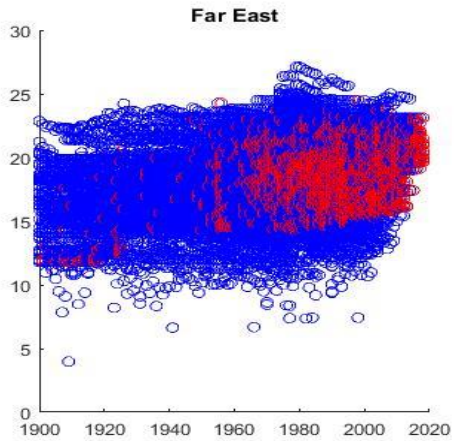
Regional NPV reversion to mean, logs

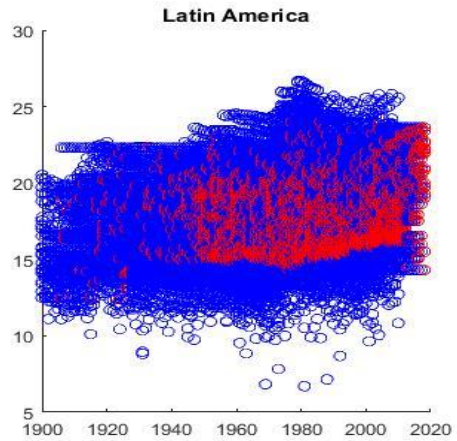


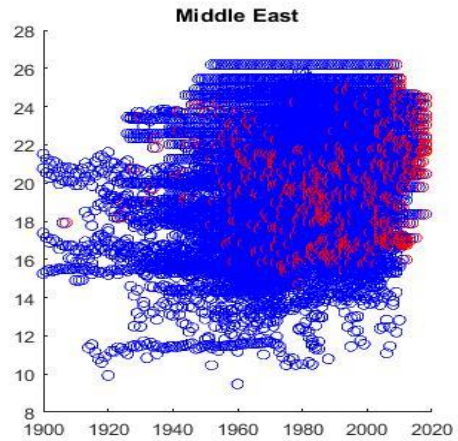


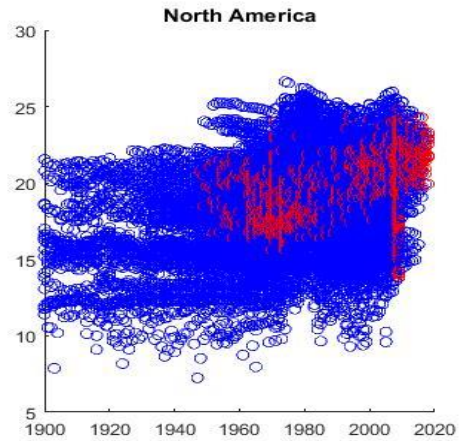




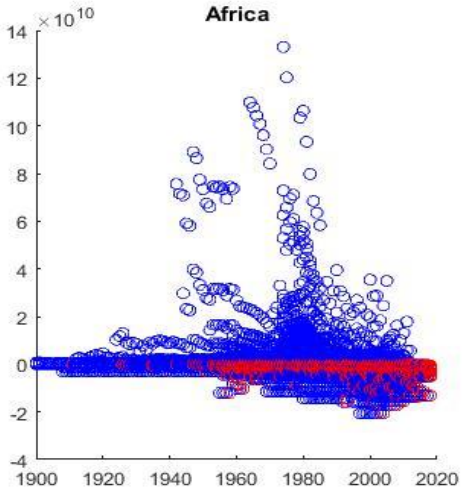


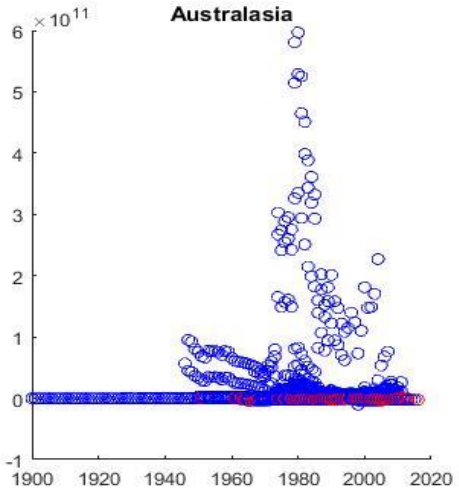


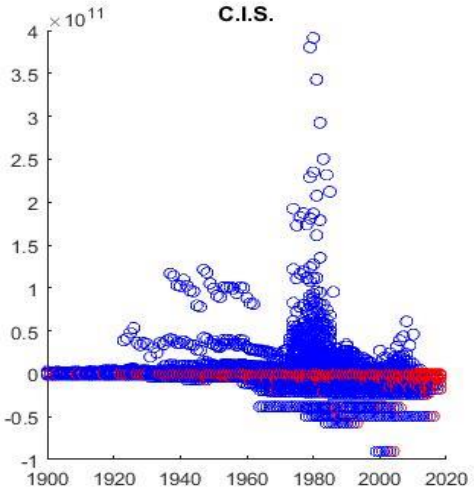


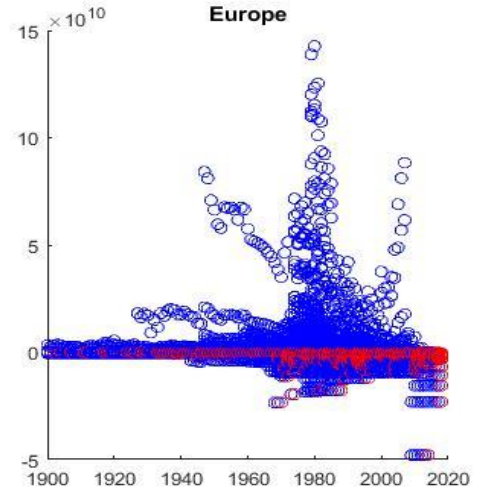


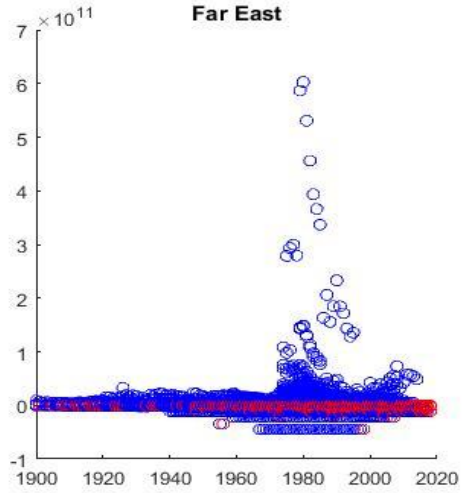
NPV values – mean reversion with taxes

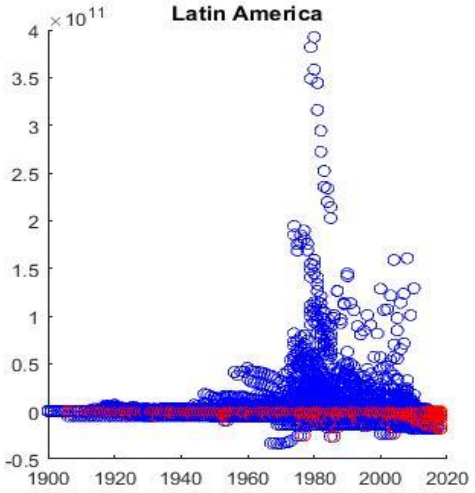


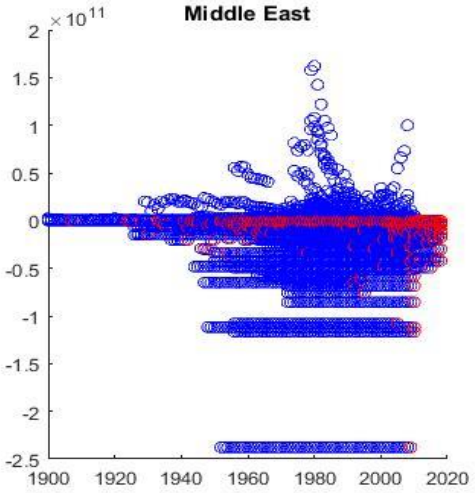


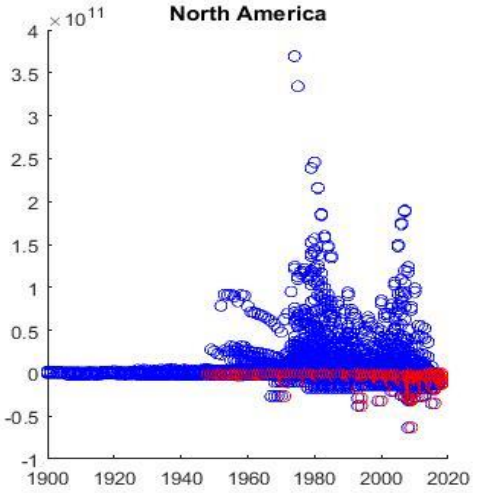


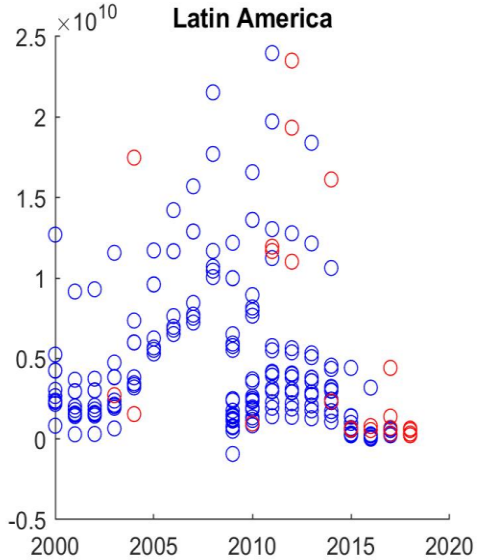


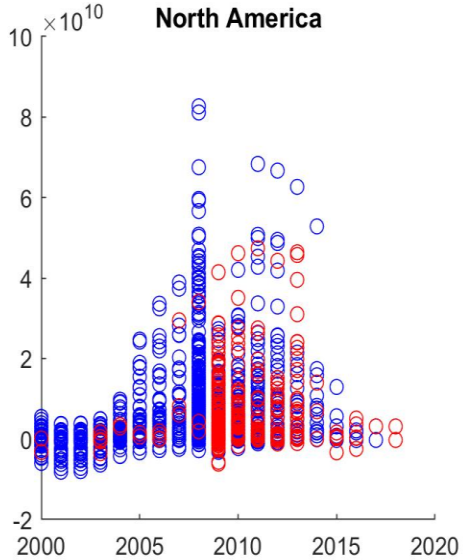






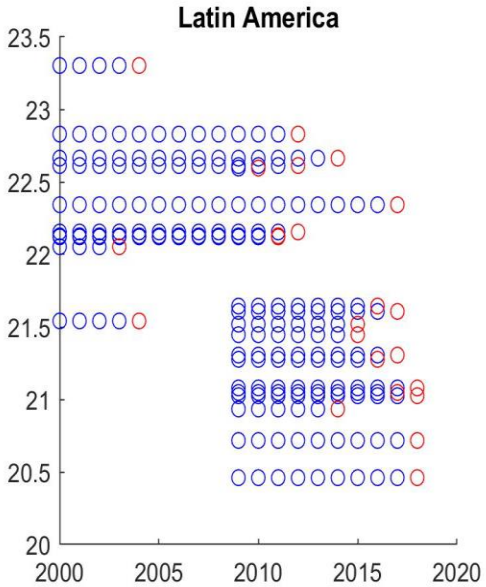


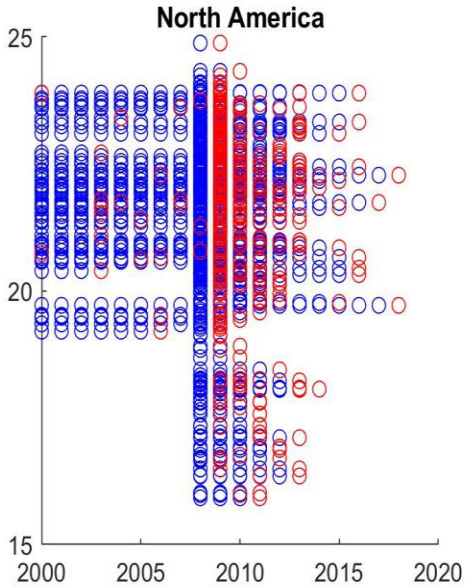




Shale NPV sildes
Red investment

High prices 2010 and
lower in 2015



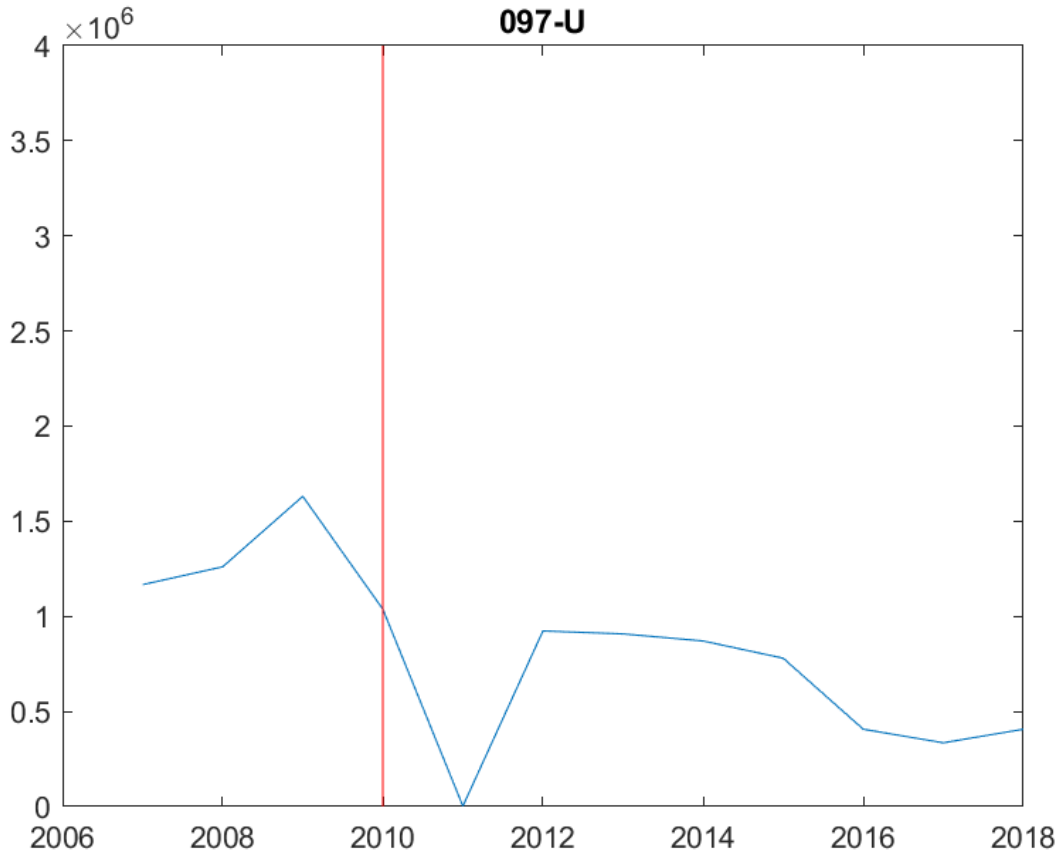


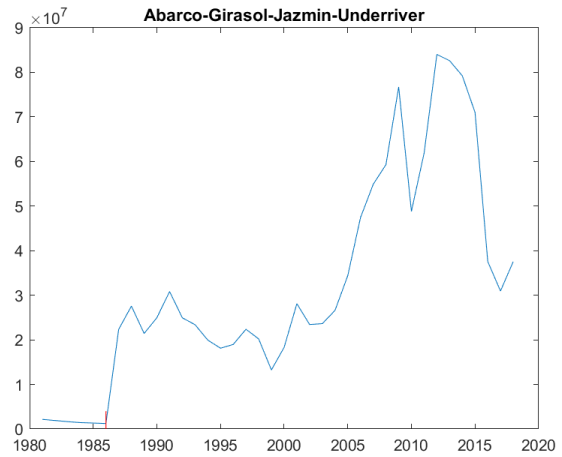
Shale Mean Revision in logs wide dispersion:

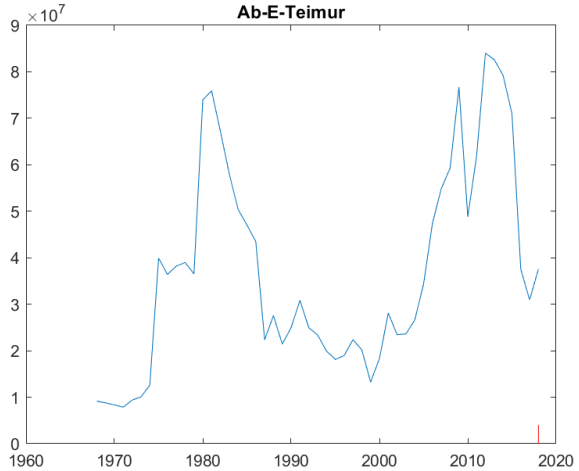
many investment decisions. Why?

Individual project NPVs

- Methodology: start each project from discovery year
- Assume: production and cost profile was known
- Discount production and costs
- For each year from discovery , calculate that year's NPV based on expected price (current price, so for 2010 NPV using 2010 oil price, 2011 etc..)
- Plot NPVs, red line shows where actual development happened
- There were periods of positive NPV, why did they wait?
- Main Problem: expect a different NPV – or production/cost profiles




Abarco-Girasol-Jazmin-Underriver
×10^7
9
8
7
6
5
4
3
2
1
0
1980
1985
1990
1995
2000
2005
2010
2015
2020


Ab-E-Teimur
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1960
1970
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2010
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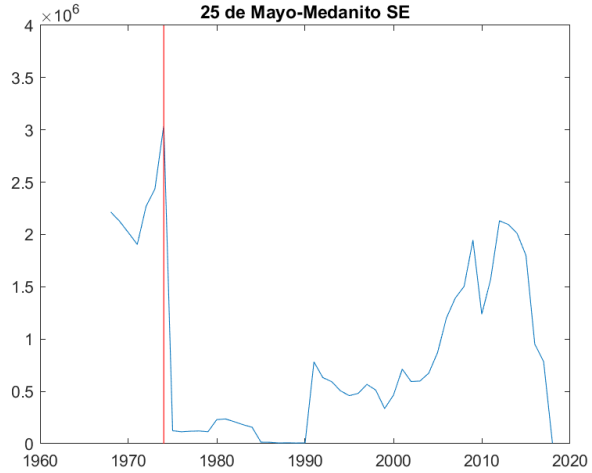
25 de Mayo-Medanito SE
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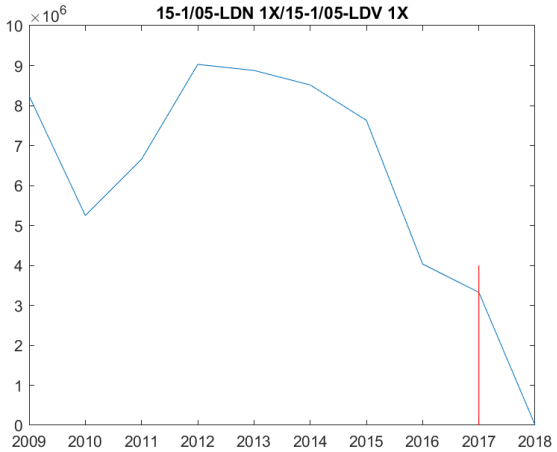
15-1/05-LDN 1X/15-1/05-LDV 1X
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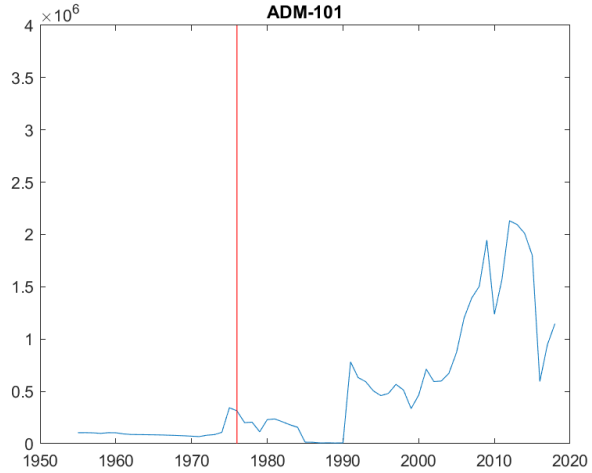
ADM-101
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3.5
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2
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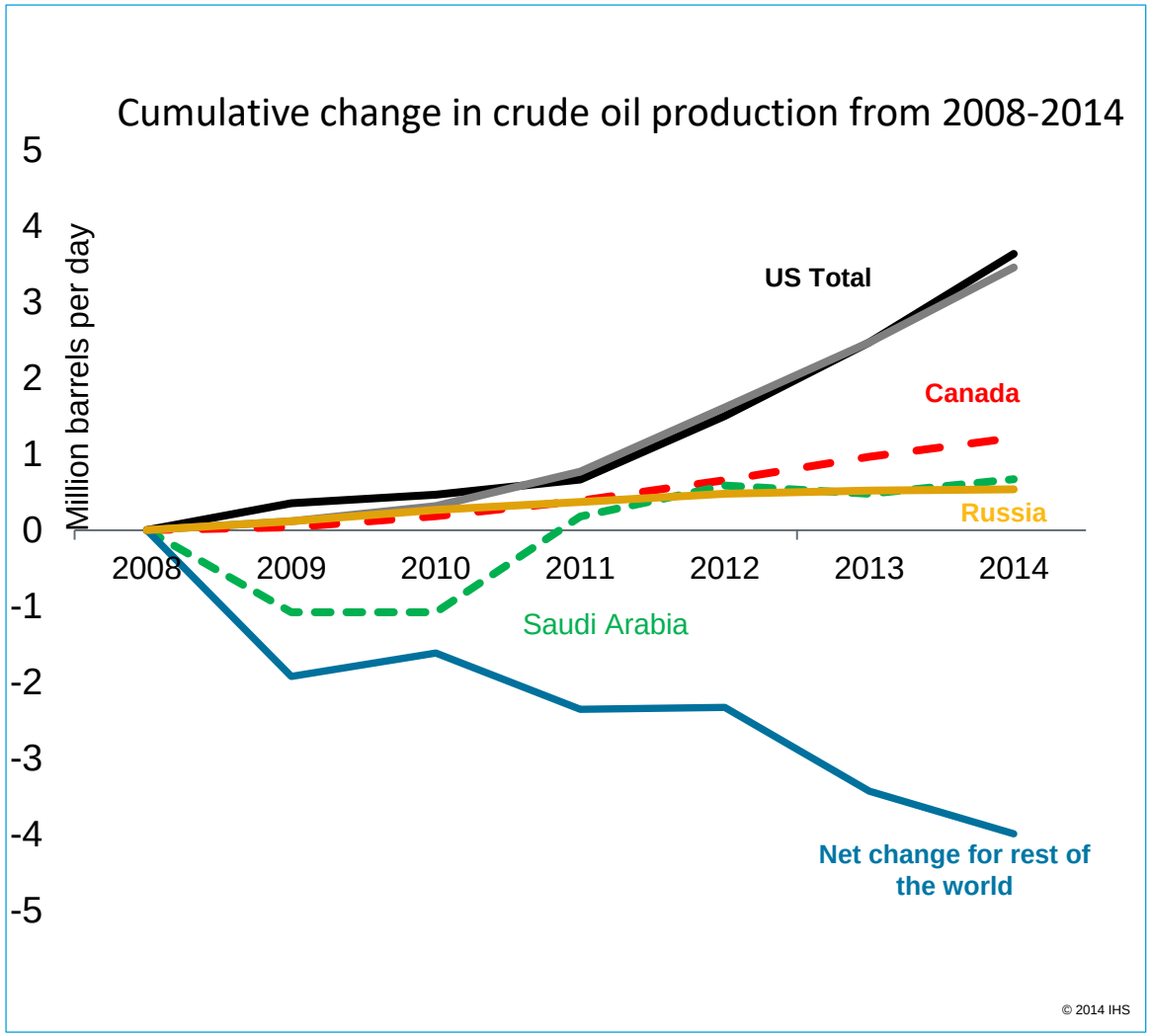
1
0.5
0
1950
1960
1970
1980
1990
2000
2010
2020

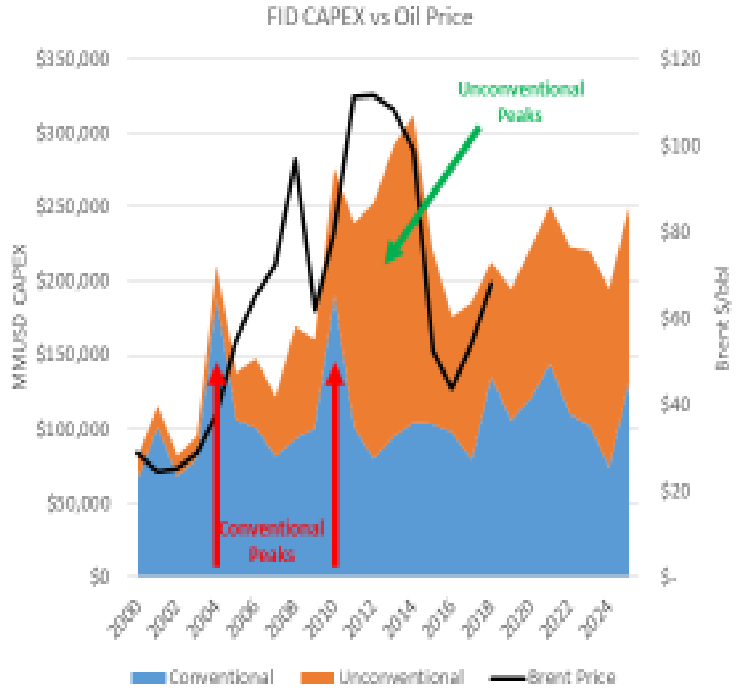
Investment ➔ Production



IHS/Lindemer

Conventional vs Unconventional FID Oil Investment

- When examining the committed investment of the energy firms, there is something not exactly proportional to the oil price occurring.
- For conventional projects, the expectations of the firms drives their decisions to commit funds
  - The two most notable spikes in conventionals are in 2004 and 2010
  - These years are in the middle of upward price swings.
- Unconventionals, however, remain very pro-cyclical
- This makes sense considering the development lag differences between the project types.



Comparing OIL & Gas NPV Projects and Shale

NOT All Agents

Invest to Maximize NPV?

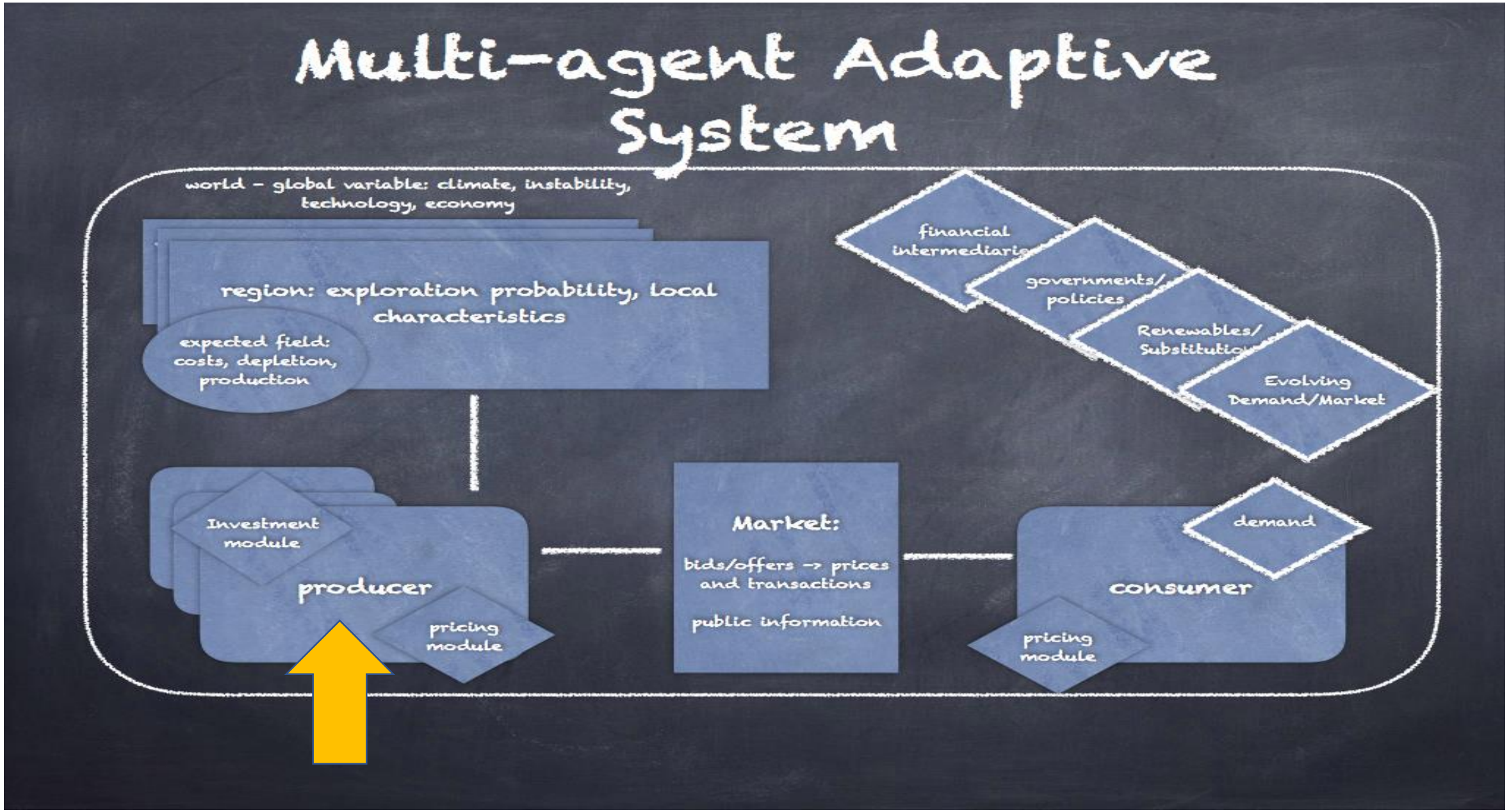
- Agents act **differently**
- Different investment and production behaviors
- Different expectations and NPVs
- **QED**

Modeling Complexity in Oil Markets

Why Agents Matter & How Invest

Our Agent-based Fuzzy Logic Approach

Building Producer module in Agent Based System



How Build Agent Based Model?

Complexity in Energy Markets:

- Stylized facts don't fit!
- Agent changes in investment and supply

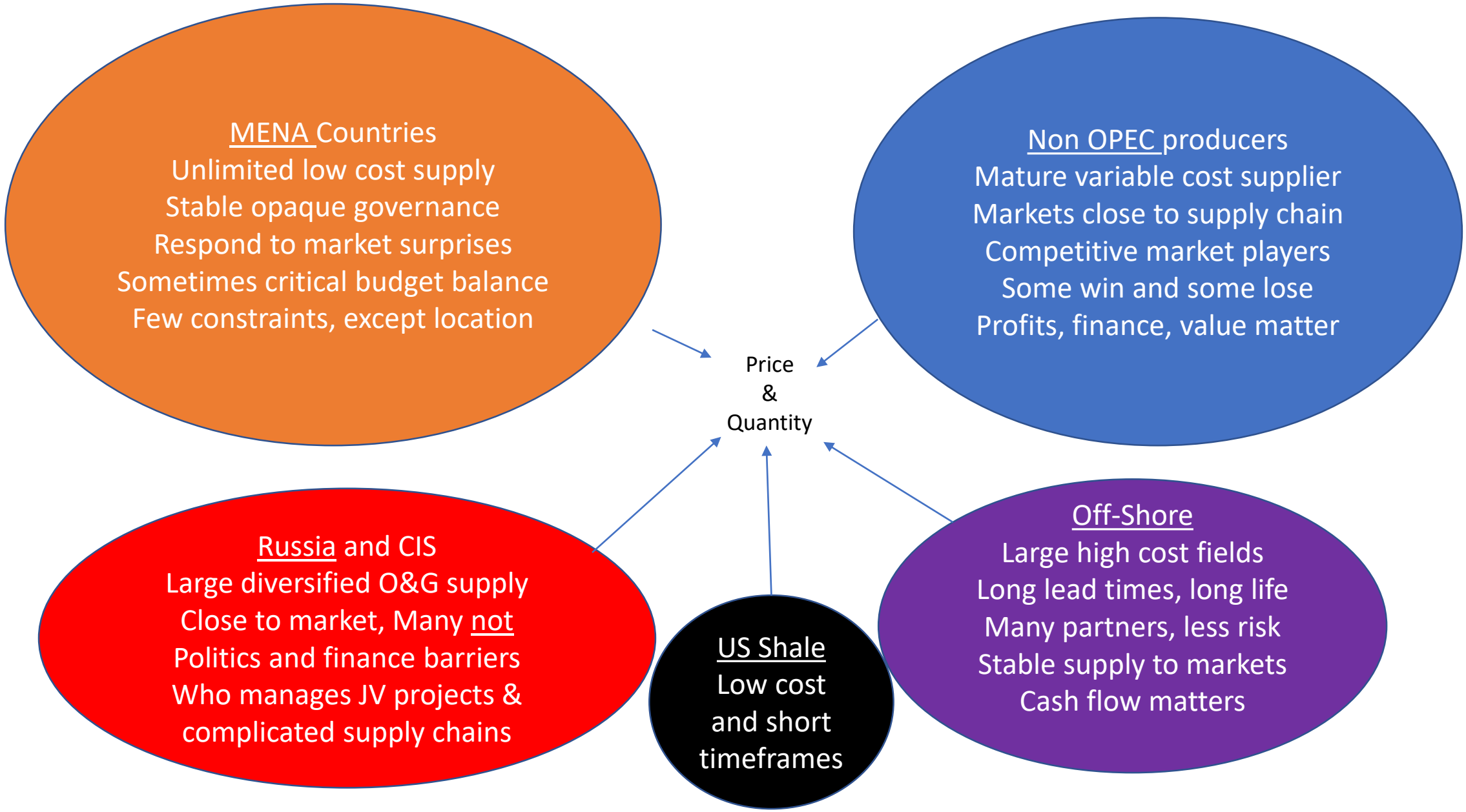
Use Agent-Based Methodology

- Realism & Flexibility
- Medium range market dynamics

Need for **different modelling** paradigm

- **Modular** to deal with different features
- Applies with uncertain/noisy data
- Highly non-linear interactions with feedback loops

Heterogeneous Oil & Gas Agents – how many? 4-5?



Possible Agents and Behaviors

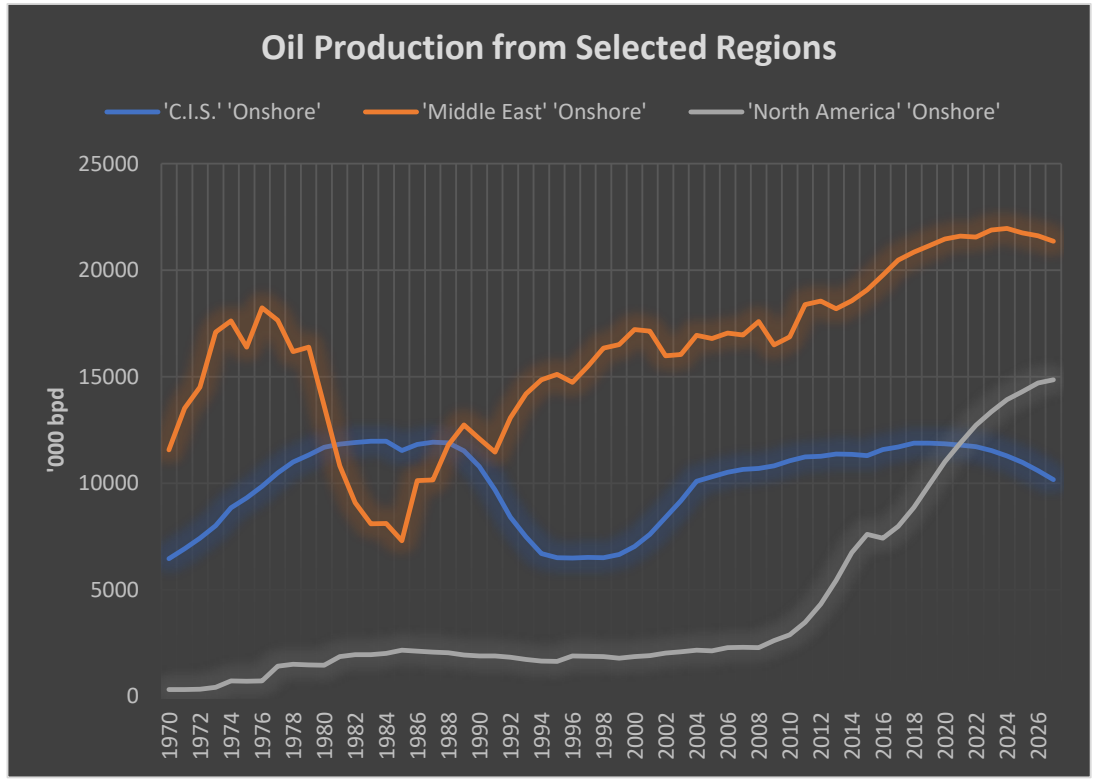
Simplified agent / regions

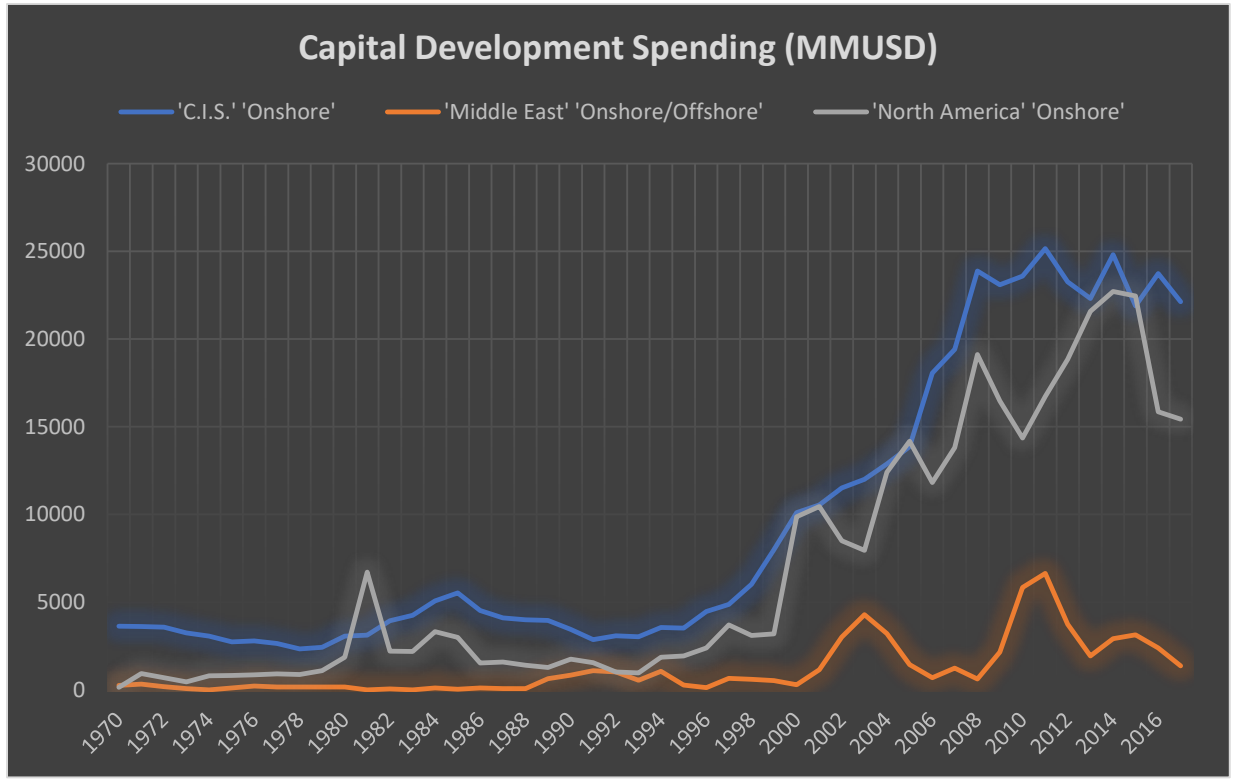
- National Oil Companies
- Independent Oil Companies
- OPEC and Saudi Arabia
- Russia
- Shale Producers

Differentiated agent behavior

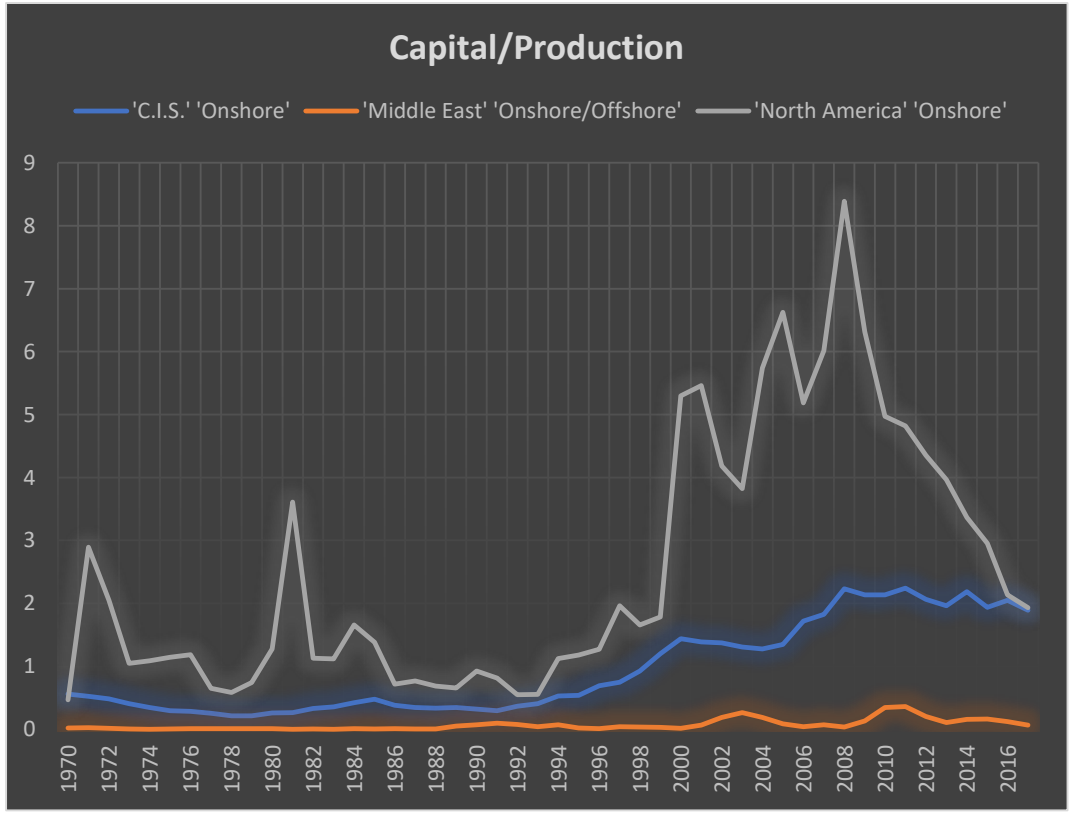
- **Geology** (IHS data available)
  - production
  - decline rate
  - investment
  - reserves
- Financial (many gaps)
  - price
  - costs
  - cash flow (profits)
  - fiscal deficit / other
  - expectations
- other

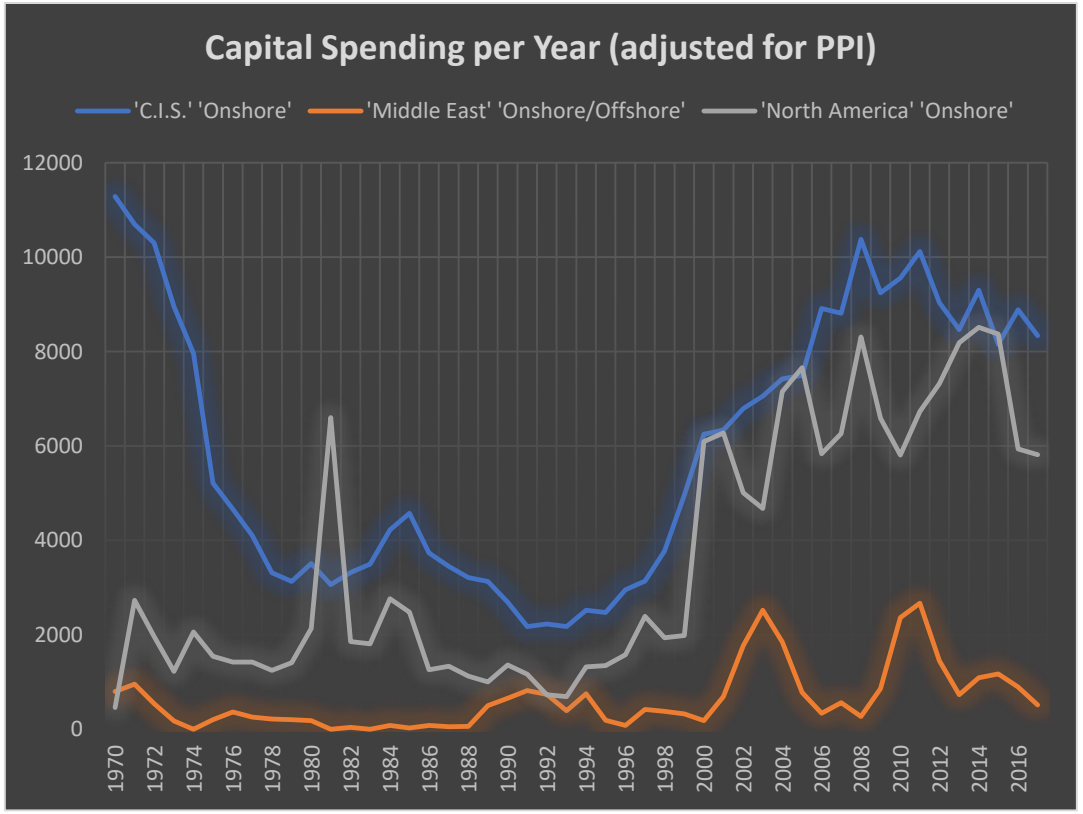
Are agents so different?
(IHS well / field data)





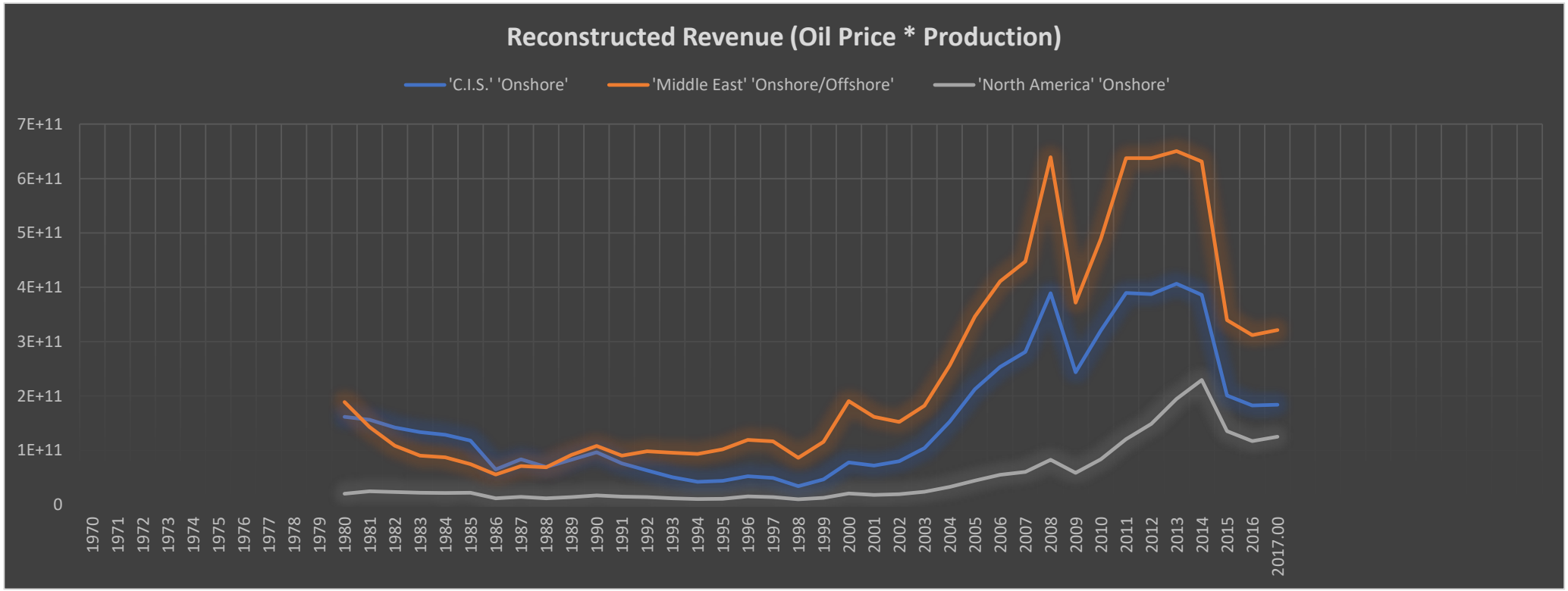
Are agents so different?
(productivity and investment cycles)





Agent Cash Flow to Invest?

(Revenue – costs = Free cash flow – capex)



Geology of Fields and Agent Behavior

- Invest IF Price over $50 a barrel….for xx years
- Invest IF $$ finance available and JV partners
- Produce More IF Price over $60 a barrel and Inventories low
- Hold production stable - Invest as fields decline
- Produce more IF deficits grow
- ….

NEXT Our Simulated Agent Behaviors & Interactions