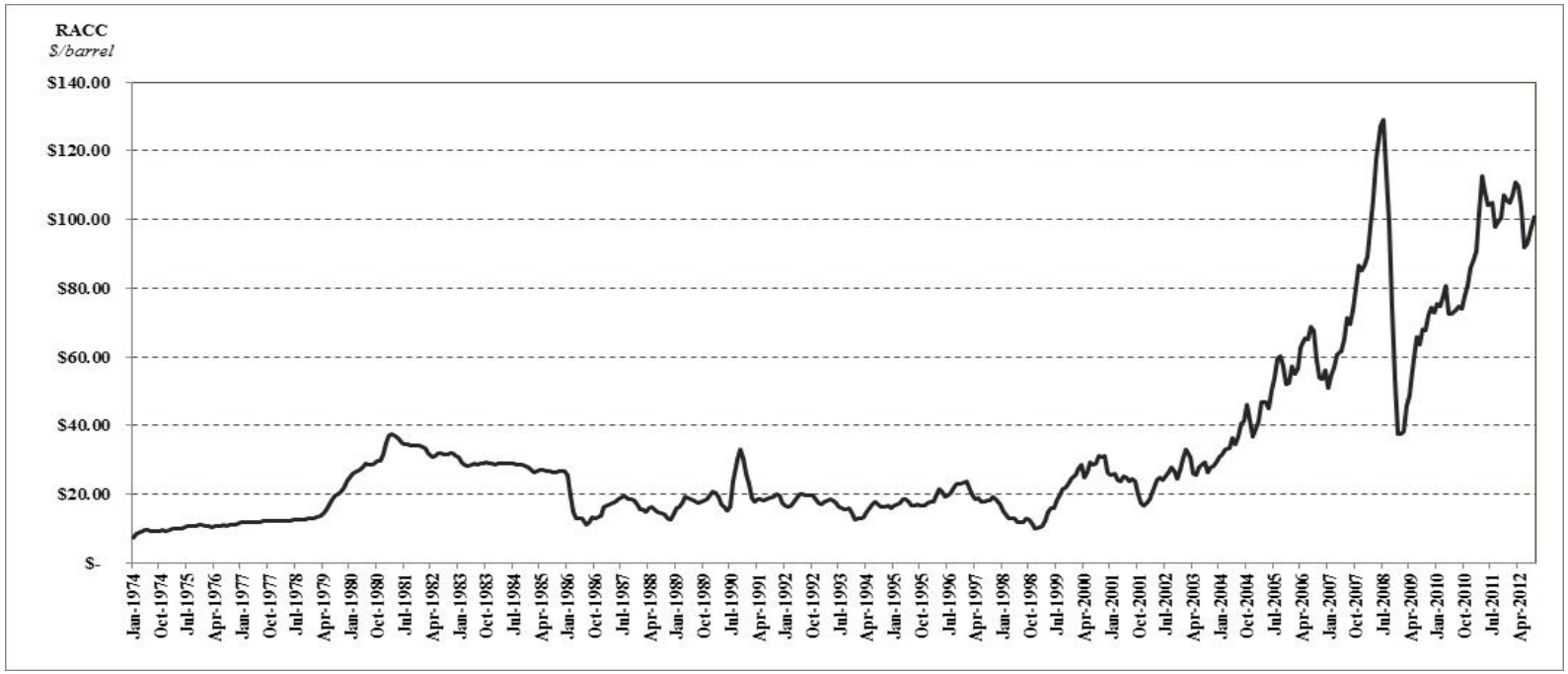
A Structural Approach to Oil Price Drivers: The Role of Fundamentals and Speculation

Kenneth B Medlock III

James A Baker III and Susan G Baker Fellow in Energy and Resource Economics, and
Senior Director, Center for Energy Studies, James A Baker III Institute for Public Policy
Adjunct Professor, Department of Economics
Rice University



November 9, 2012

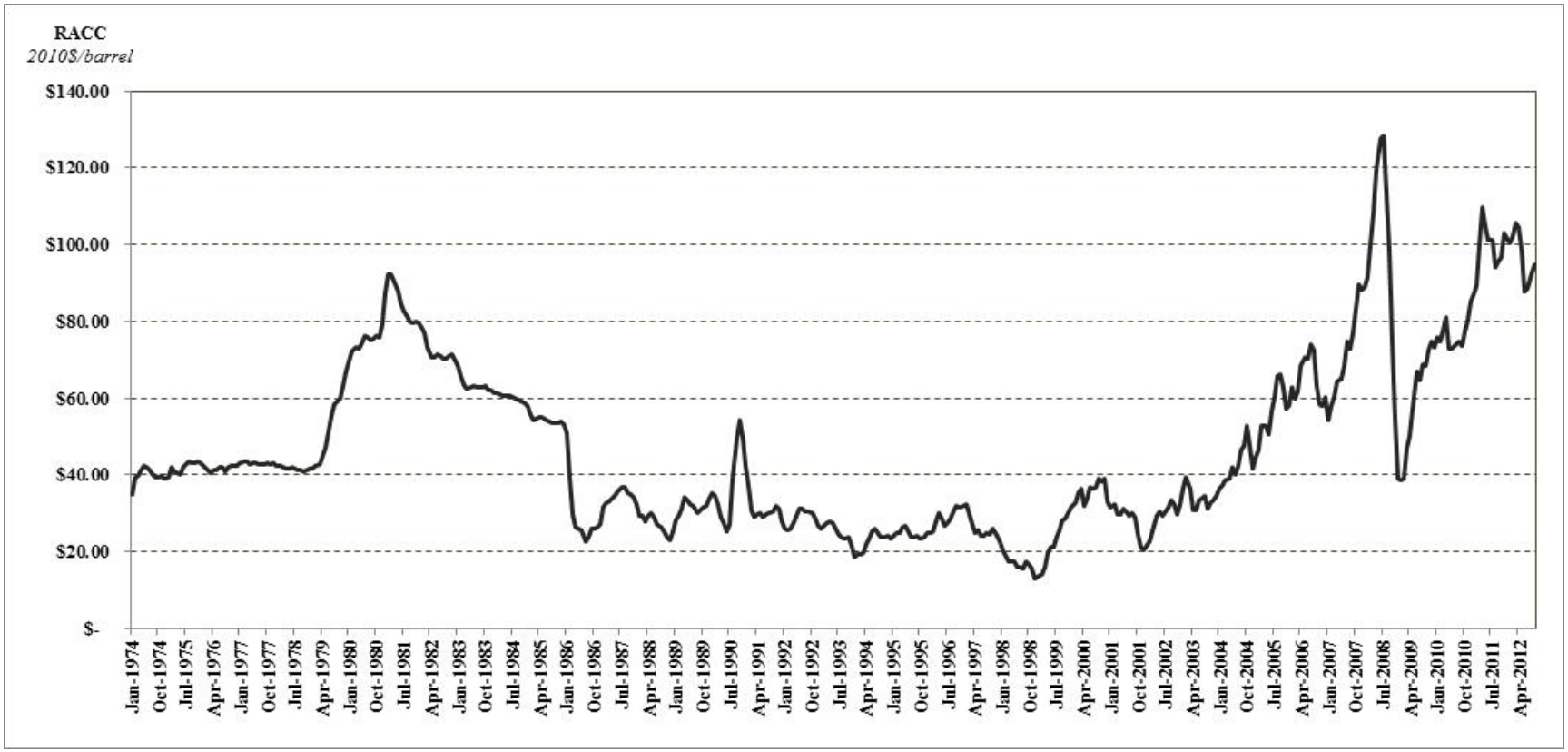
Discussion Points

- Price is high… Why?
- Peak oil and its influence on expectations
- Other important factors
- A response to high price: Unconventional resources
- A model to unite them all

Oil Market Developments

Rising Price

- Since 2000, the oil price has steadily risen, the exception being the economic and financial crash of 2008. Post 2008, despite weak economic growth in the developed world, price is higher today in real terms than it has ever been, except two months in 2008. Why?



Over the past few years the cause of high oil prices has been attributed to many factors…

- "Big Oil"
- "Peak oil"
  - Uncertainty of future supply exerts a "precautionary motive". Rising Costs
- National Oil Companies: Increasing control of global conventional oil resources by a smaller group of countries
  - Alternative objectives and lower efficiency implies that greater NOC control will require higher prices to maintain a given supply, much less grow production.
- Demand Growth
  - How will we fuel mobilization in China?
- Weak $
- Speculation

Peak Oil

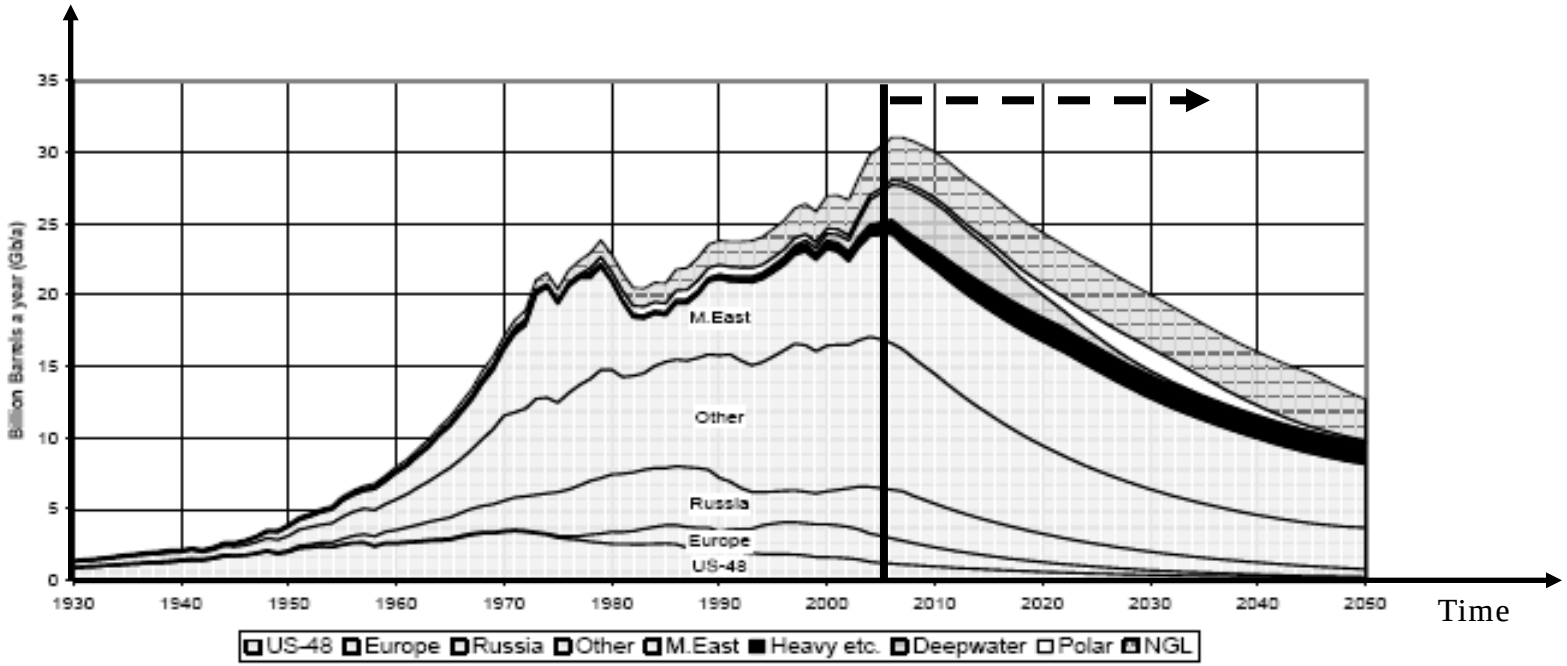
"The term Peak Oil refers to the maximum rate of the production of oil in any area under consideration, recognising that it is a finite natural resource, subject to depletion."

- Colin Campbell

The nature of depletable resources

- Crude oil and natural gas are depletable resources, so we will eventually cease to use these resources as we do today.

Global Oil Production

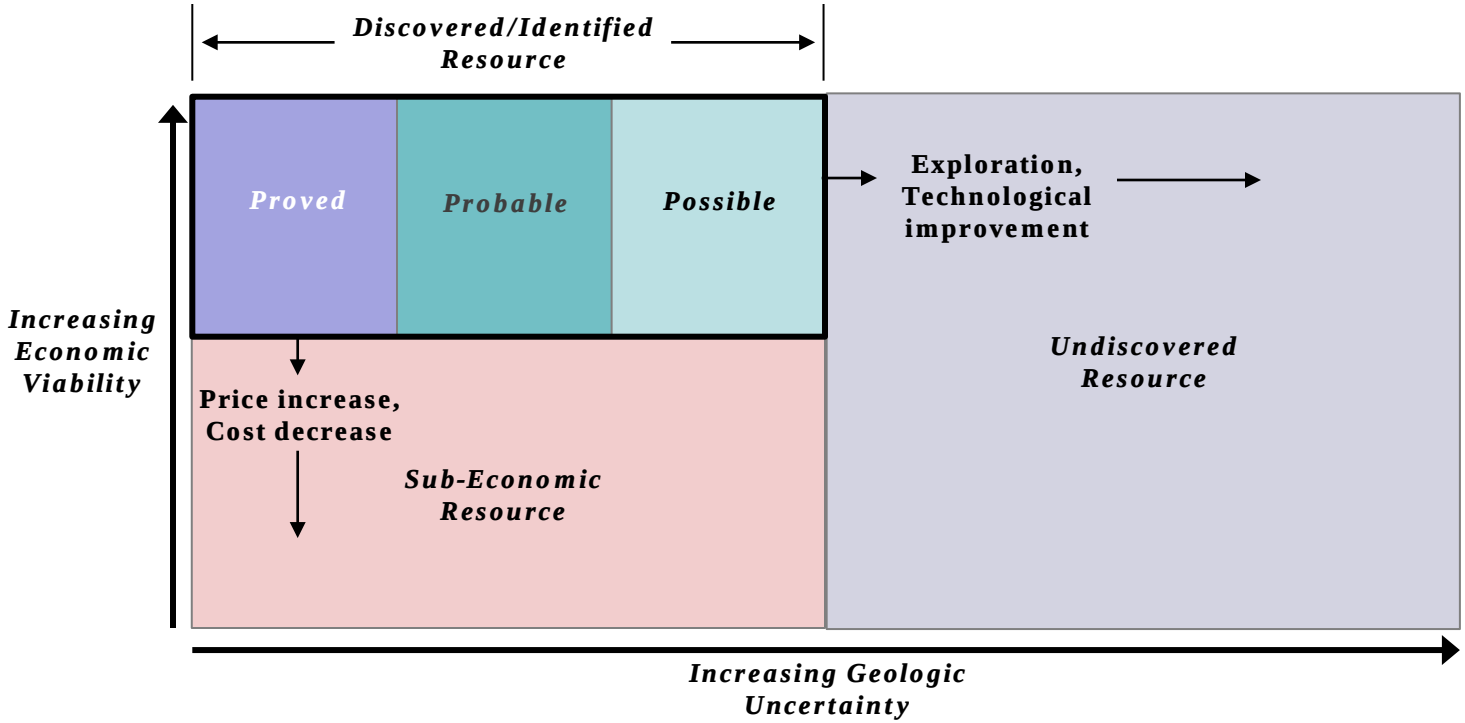


Note: Picture from the Association for the Study of Peak Oil

- But when is "eventually"? Are pictures such as these accurate depictions of supply?

Defining "Eventually"…

- Factors such as cost, market price, and the price of alternatives are often ignored, or at least marginalized, in the construction of Hubbert curves.
- Access to resources is a function of cost, technology, and effort.



Source: Modified from McKelvey, V.E., "Mineral Resource Estimates and Public Policy," *American Scientist*, 1972

Some comments on the "Peak Oil" graph

- Cumulative production is estimated from statistical fit of a curve that follows an equation of the form

$$Q(t) = \frac{Q_{\max}}{1 + ae^{bt}}$$

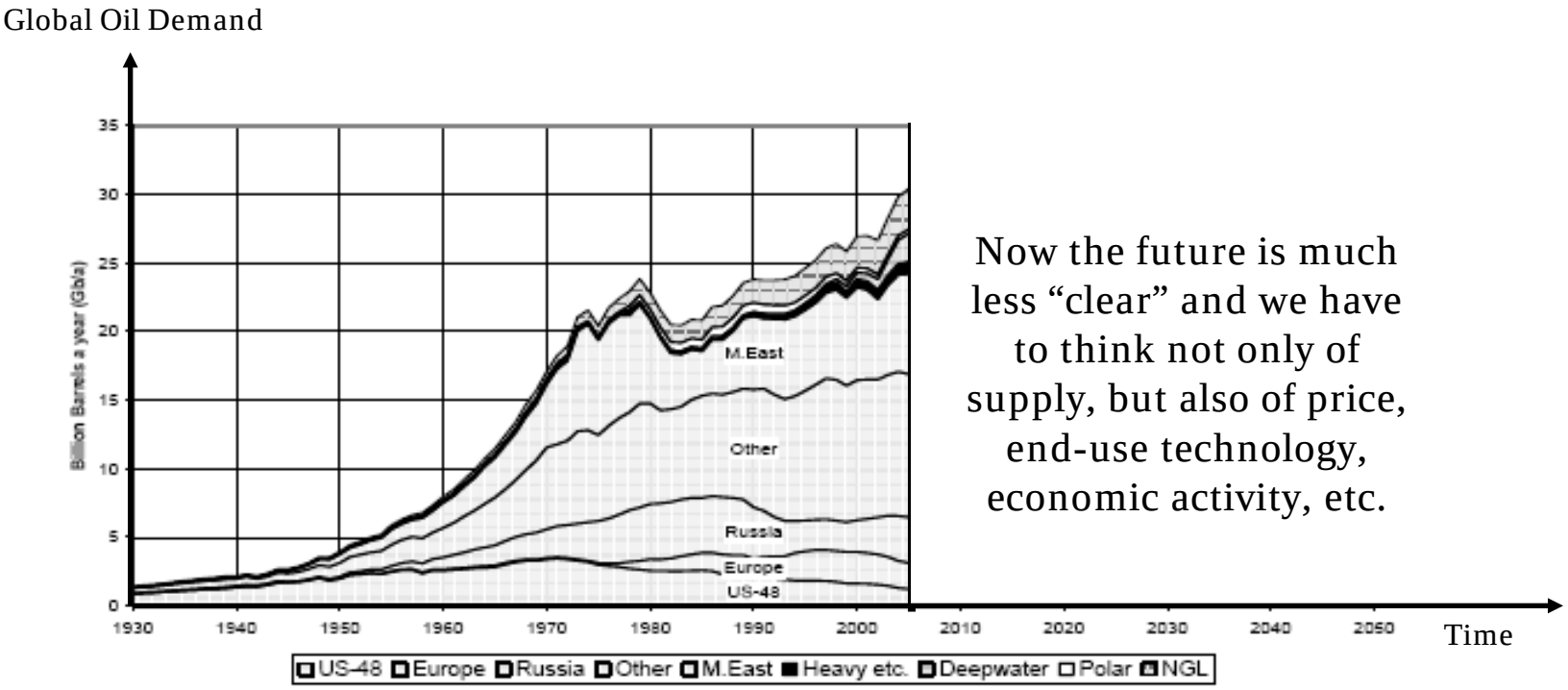
  is insufficient insofar as a and b (and even Q_{max}) are themselves functions of other variables which reflect structural elements.
- Technology effects both demand and supply, and politics complicates matters seriously.
- The unknowns matter, and historical extrapolations are simply not adequate indicators of where we might go.
  - Shift to unconventional resources is a structural shift in the energy supply system. Statistical analyses of historical data do not generally handle structural change well.

Alternate reading of the "Peak Oil" graph

- We must remember that markets balance supply ***and*** demand. Thus, there is also a demand-side element to the graph. In particular, one can interpret the history as a picture of demand rather than of supply...
- Pre-1970s: Transition to oil and growth in liquid transportation fuels
- 1973-1982: Prices rise to unprecedented highs
  - Demand response very substantial
    - Japan – power generation share down from 73% oil
    - US – on-road vehicle efficiency increases from 12 mpg to 20 mpg from 1979 to 1990.
- 1982-1998: Extended period of falling prices (with a brief exception)
  - This tends to discourage expansion of production while encouraging demand
    - In the US, the SUV revolution sees on-road vehicle efficiency stagnate from 1990 to 2000.
  - Cyclical nature of market sets stage for next price escalation
- 1999-2008: Prices steadily rising
  - Sluggish supply response (expectations slow to change from a $25 world)
- 2009- : Recession and uncertainty... what does the future hold?
  - Demand responses begin to materialize from recent run-up in price.
  - Development of NCV oil and gas is stimulated.

Alternate reading of the "Peak Oil" graph (cont.)

- Might the graphic of global oil production also be interpreted as a picture of global oil *demand*? It seems a matter of interpretation, and, truthfully, the two go hand-in-hand.

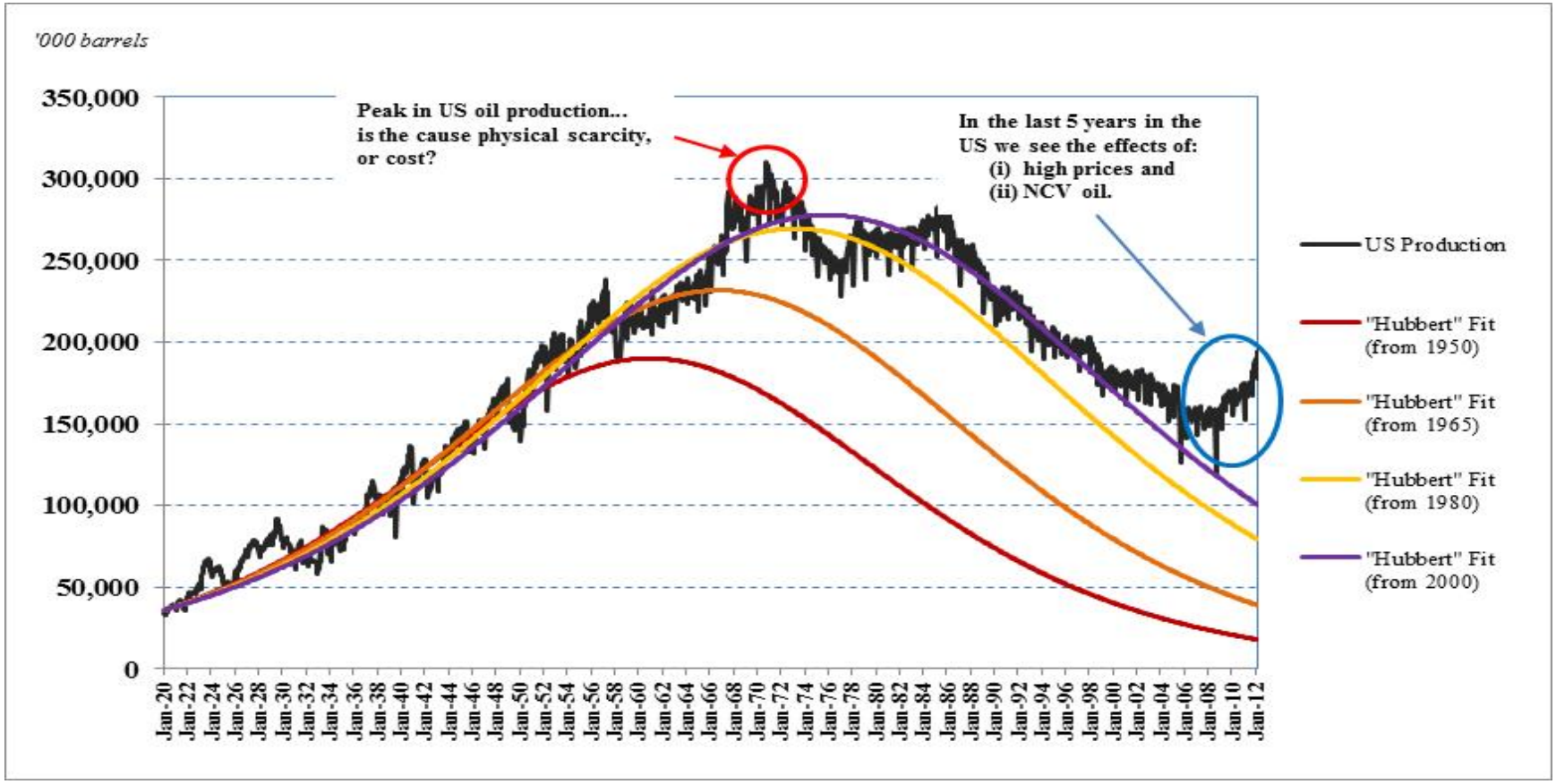


Now the future is much less "clear" and we have to think not only of supply, but also of price, end-use technology, economic activity, etc.

Note: Modified Picture from the Association for the Study of Peak Oil

Peak Oil and US Production

- The US entered a period of decline after the early 1970s not because it was out of oil, but because there was a cheaper alternative: imports.
- The last 5 years higher price has motivated exploration and development, leading to a resurgence in US oil production, from unconventional *and* old fields.



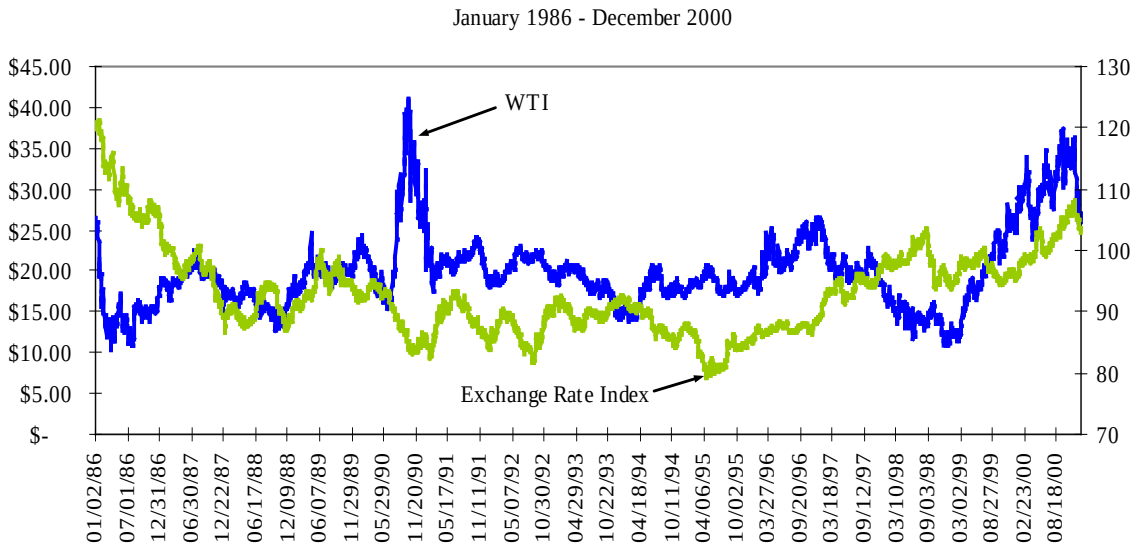
Nevertheless, price is an important signal – key signposts of a peak…

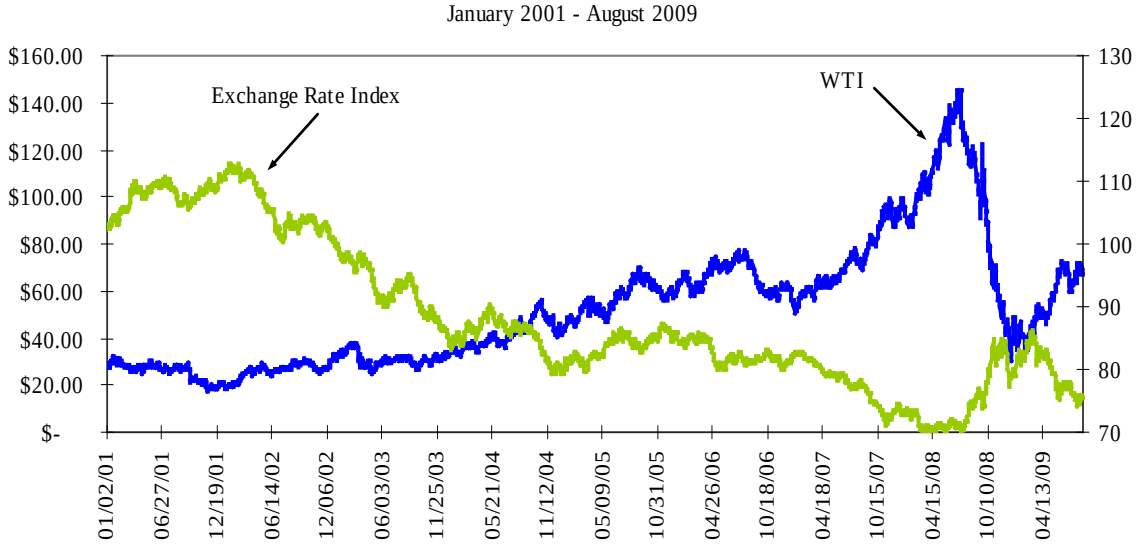
- Sustained rising price
  - As scarcity persists, price must rise to encourage subsequent extraction.
- Diminishing production capacity due to difficulty in replacing high quality reserves
  - Theory predicts, absent uncertainty, we extract the highest rent resources (or easy oil) first.
- Falling well productivity due to lower quality prospects
- Declining exploration success due to a lack of remaining targets
- Emerging constraints on equipment and personnel for exploration and development, which comes about from having to drill an increased number of wells to sustain a given level of production.

Exchange Rates, Rising Costs, NOCs, Demand Growth, New Supplies, and Speculation

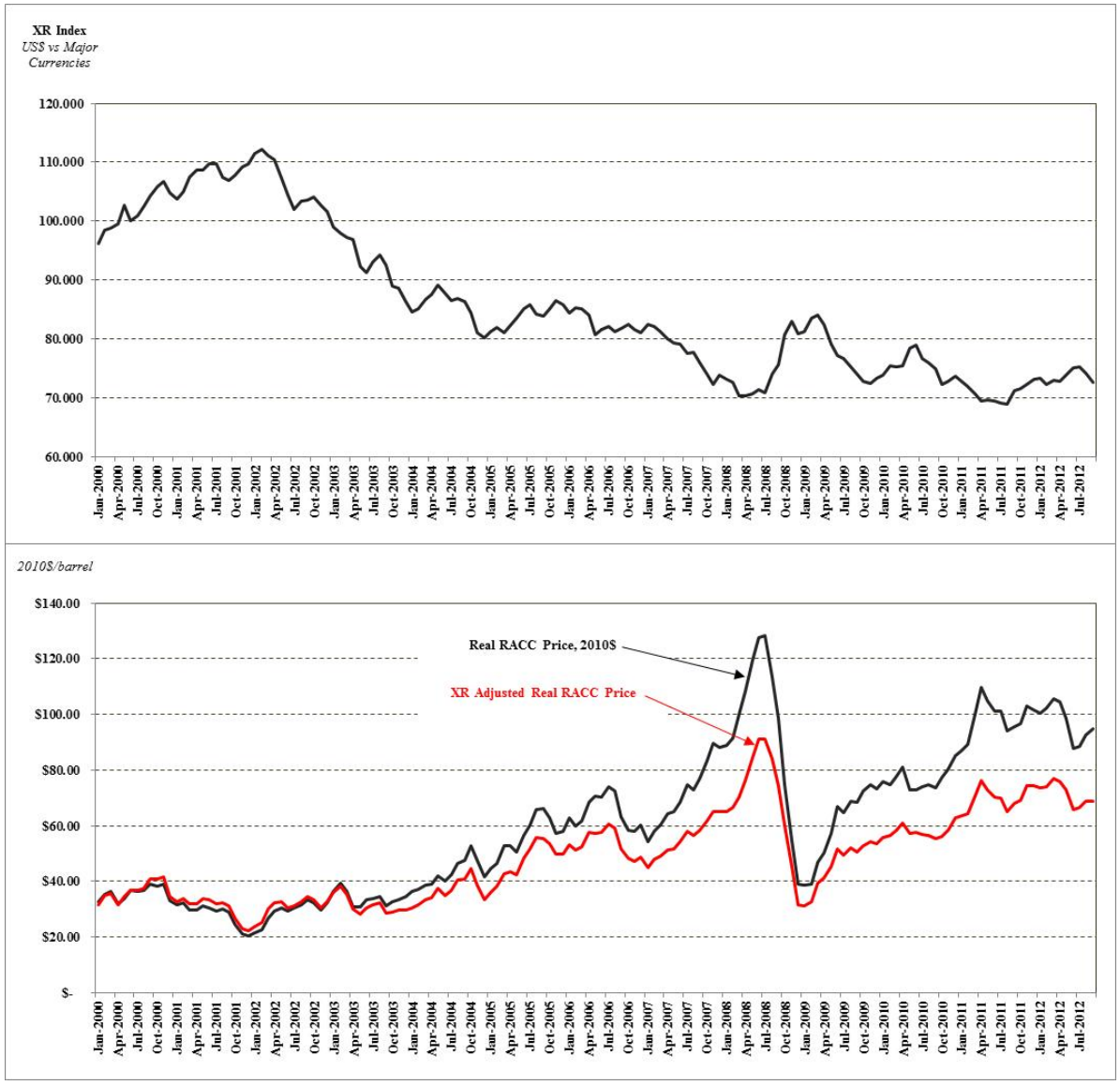
Exchange Rate Influence

- Since Jan 2001, the correlation between the XR and oil price is -0.84.
- From Jan 1986 to Dec 200o, the simple correlation is -0.08.
- Why did the relationship change?
  - One hypothesis asserts this is tied to the “financialization” of crude oil.
  - Note, this also applies to other commodities.





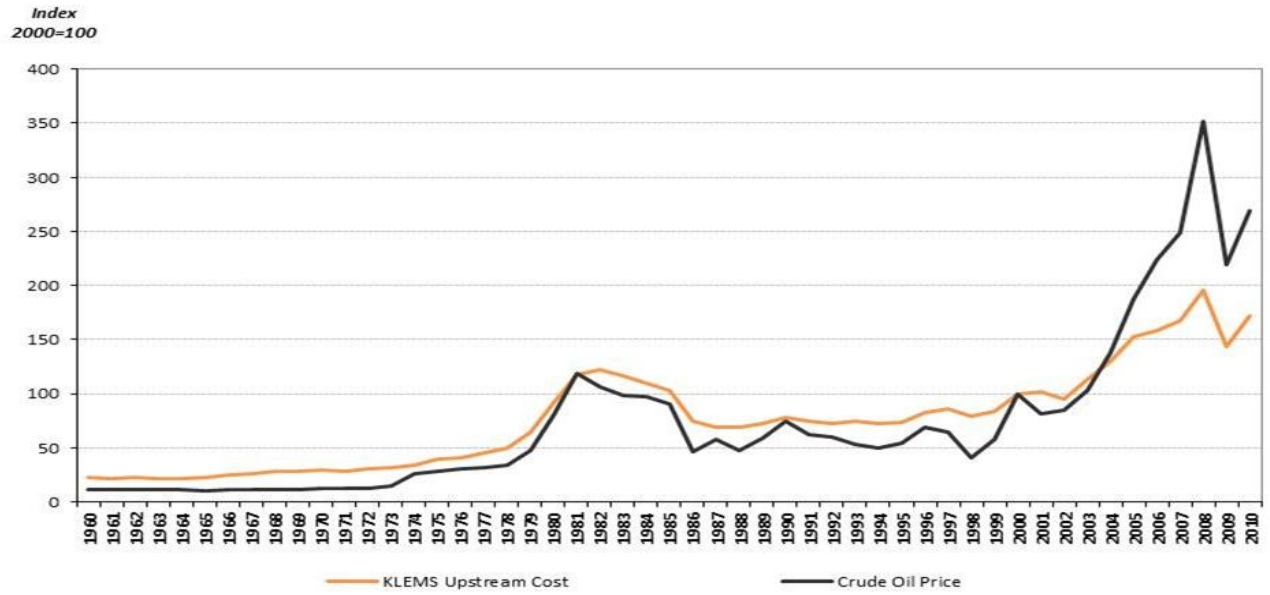
Exchange Rate Influence (cont.)



- US dollar measured against major currencies of US trading partners is the weakest it has been in 40 years.
- Why does this matter? Because the exchange rate helps determine the value of a barrel of oil, which is traded in US$ in international transactions, but products are bought and sold in domestic markets in own currencies.

Rising Costs

- Data revealed that well productivity was indeed in decline in many of the major producing regions around the world, and the early 2000s were characterized by rapid increases in drilling costs due to scarcity of rigs and qualified personnel. In addition, although there was general agreement that new discoveries would occur, they will be increasingly costly – a notion that is consistent with rising costs.

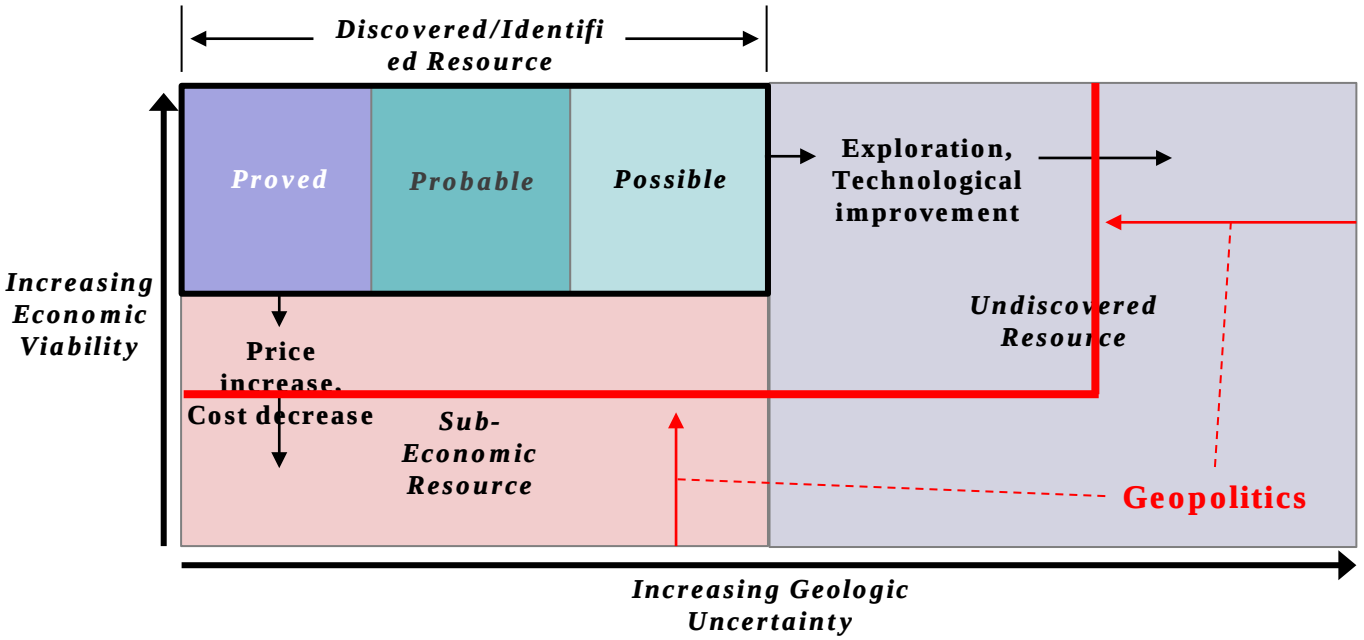


NOCs and Firm Efficiency

- Non-commercial objectives influence the ability of national oil companies to function as many of the international integrated oil companies.
  - NOCs may be "economically efficient" in the sense that they are maximizing some objective. However, the NOC likely faces a different objective than an IOC.
  - Theory suggests these objectives skew the firm's observed behavior away from the unimpeded outcome (Hartley/Medlock, "A Model of the Operation and Development of a National Oil Company," *Energy Economics*, 30(5)).
- Empirical analysis indicates the relative revenue efficiency of NOCs is lower than that of IOCs.
  - Eller/Hartley/Medlock, "Empirical Evidence on the Operational Efficiency of National Oil Companies," *Empirical Economics*, 2010
  - Hartley/Medlock, "Changes in the Operational Efficiency of National Oil Companies," *Energy Journal*, forthcoming

A note on what inefficiency means for supply

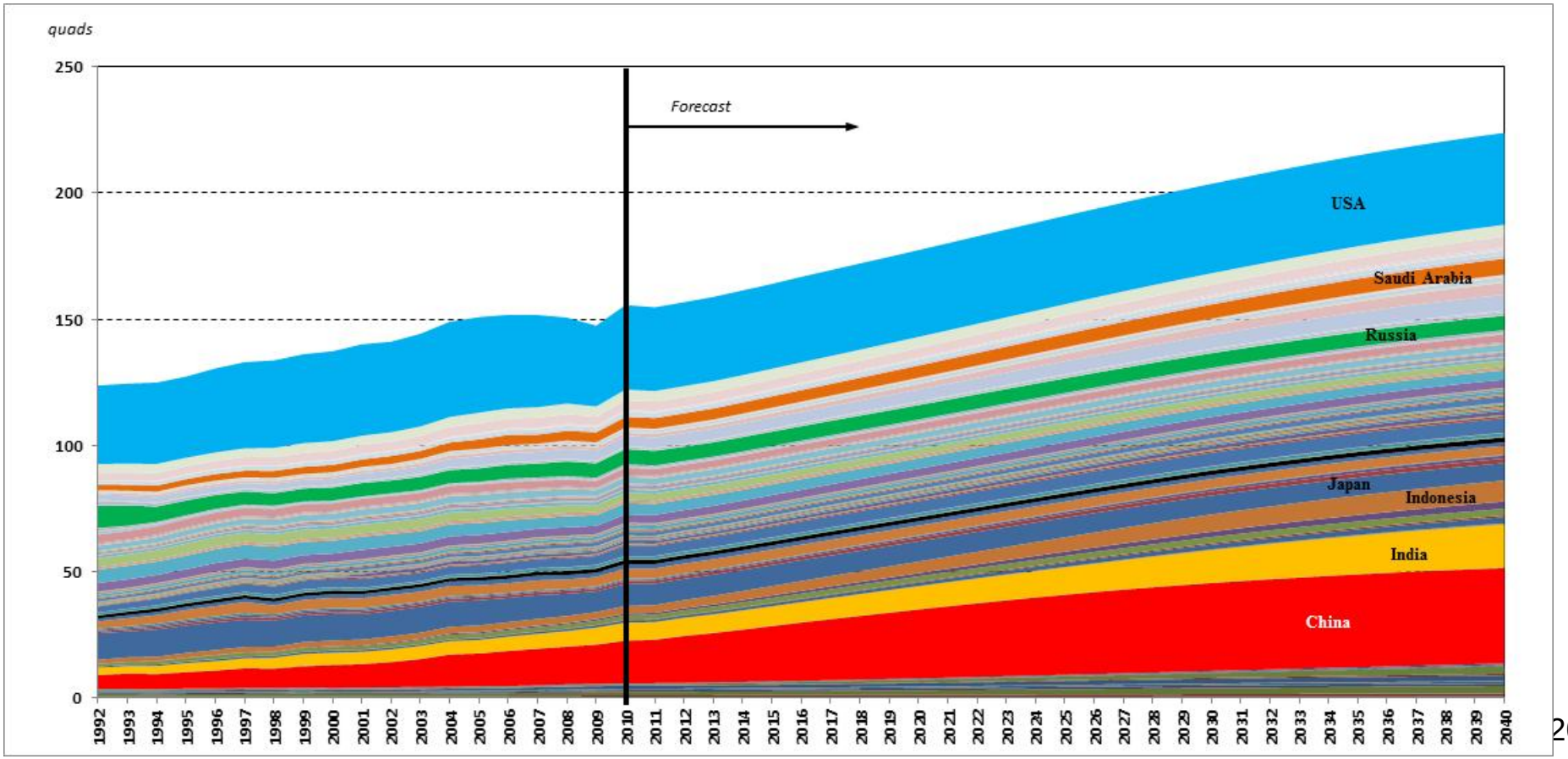
- Politics can present barriers to investment (risk premiums, limited access), effectively shrinking the size of the resource box (below).
  - Barriers to investment reduce the impact of exploration, limit the ability to respond to higher long run prices, and limit the impact of innovation
  - This also reduces production, and encourages the adoption of alternatives.
- A politically influenced market has a supply constraint that is realized more readily.
  - Will geopolitics render some supply never to be exploited?



Source: Modified from McKelvey, V.E., "Mineral Resource Estimates and Public Policy," *American Scientist*, 1972

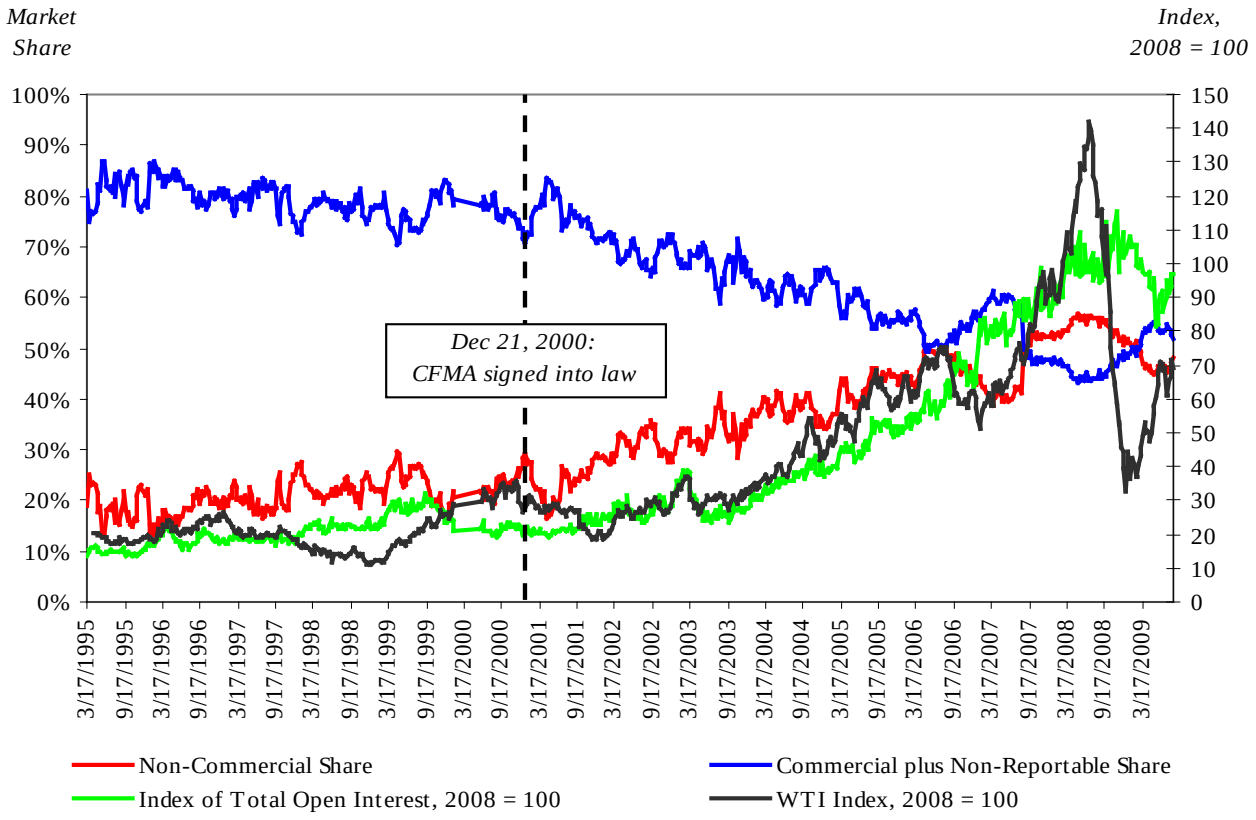
Oil Demand by Country

- Summary of global petroleum demand by country, 1992-2040
- Demand will continue to grow, driven largely by very populous developing economies such as China and India.



Speculation

- Trading requires both speculators (demanders of risk) and hedgers (suppliers of risk).
- Market composition began to change dramatically shortly after the Commodity Futures Modernization Act was signed into law.
- Many have claimed that the increase in open interest by market players with no physical commercial position in the market pushed price higher.



Source: CFTC COT Reports – CRUDE OIL, LIGHT SWEET - NYMEX

A Response to High Price: Unconventional Oil

Ongoing developments in Tight Oil in the US

- Resource potential in North America is distributed widely.
  - For example, North Dakota (Bakken), Texas/New Mexico (Permian – Avalon, Bone Springs, Wolfcamp, South Texas – Eagleford), Ohio (Utica), Pennsylvania (Marcellus), Colorado/Wyoming (Niobrara), Florida (Sunniland), Louisiana (Tuscaloosa), Oklahoma (Mississippi Lime), California (Monterrey).
    - Just as in gas, not all shales are created equal, but the total technically recoverable resource endowment may exceed 40 billion barrels.
    - To date, activity in the Bakken and Eagleford accounts for most US light tight oil production.
- Technical and cost hurdles still exist, but high oil prices provide lots of incentive. Room for lots of "learning by doing."

Other Unconventional Oil Sources

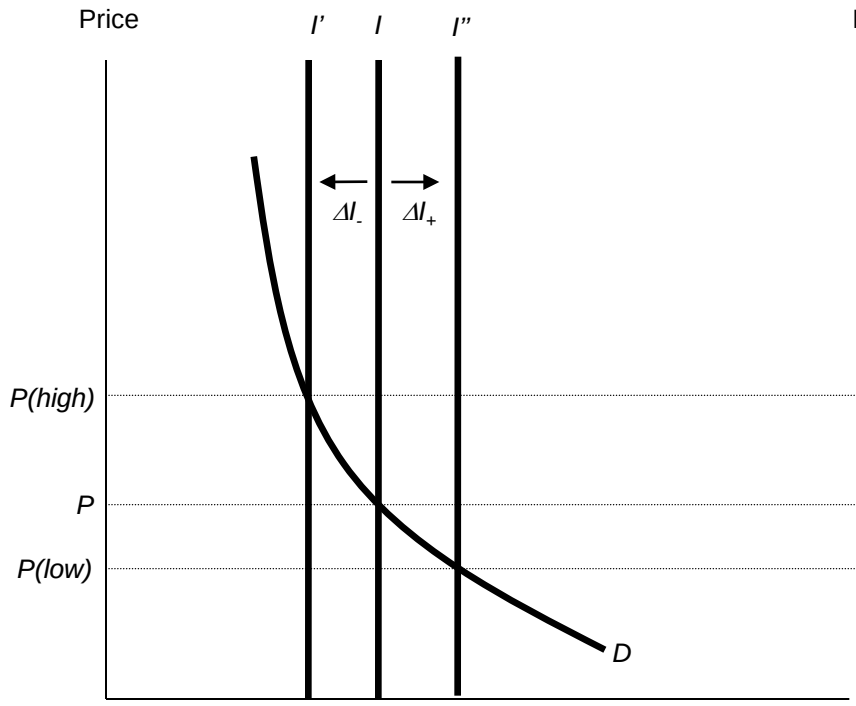
- Canadian Tar Sands are projected to grow dramatically in the next couple of decades. But, delivery infrastructure could present some short term bottlenecks.
- Oil shale in the US has enormous estimated potential, but environmental opposition (centered on land use) and cost are still impediments to development.
- Heavy oil in the Orinoco belt in Venezuela holds promise, but above ground factors their may limit the scale of development.
- Many sources exist in yet to be assessed regions where conventional oil still dominates (Russia, Central Asia, Middle East), but we won't know until economic forces provide the correct incentive to explore and adequately assess.

Bringing it all together: A Framework for Analysis

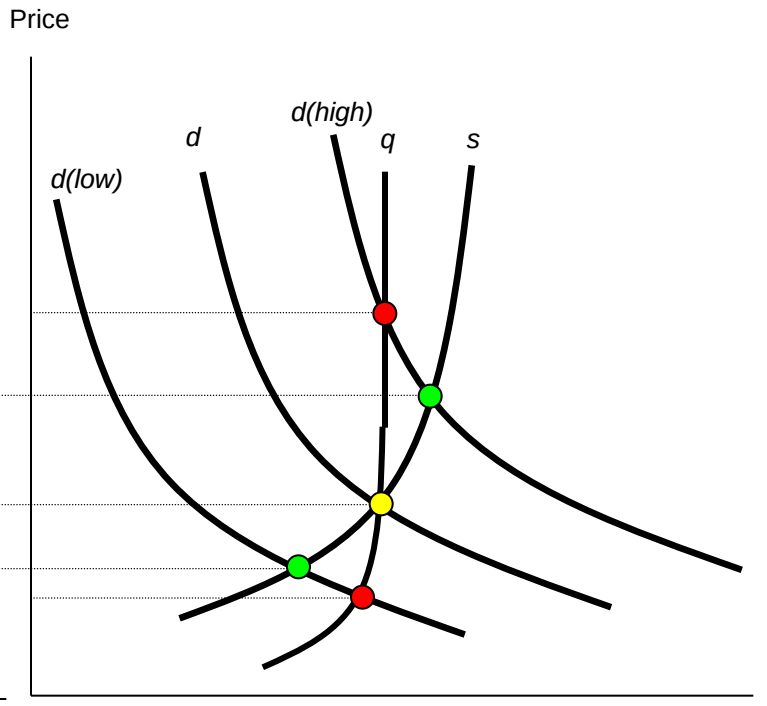
Key challenge: We must be able to explain short run price pressures against a backdrop of long run factors that determine supply and demand trends

A Role for Both Speculators and Fundamentals: The Stock-Flow Model

- Demand fluctuation leads to price variability. Variability is dampened with access to inventories and the ability to trade.
- A standard application in a market with a storable commodity...



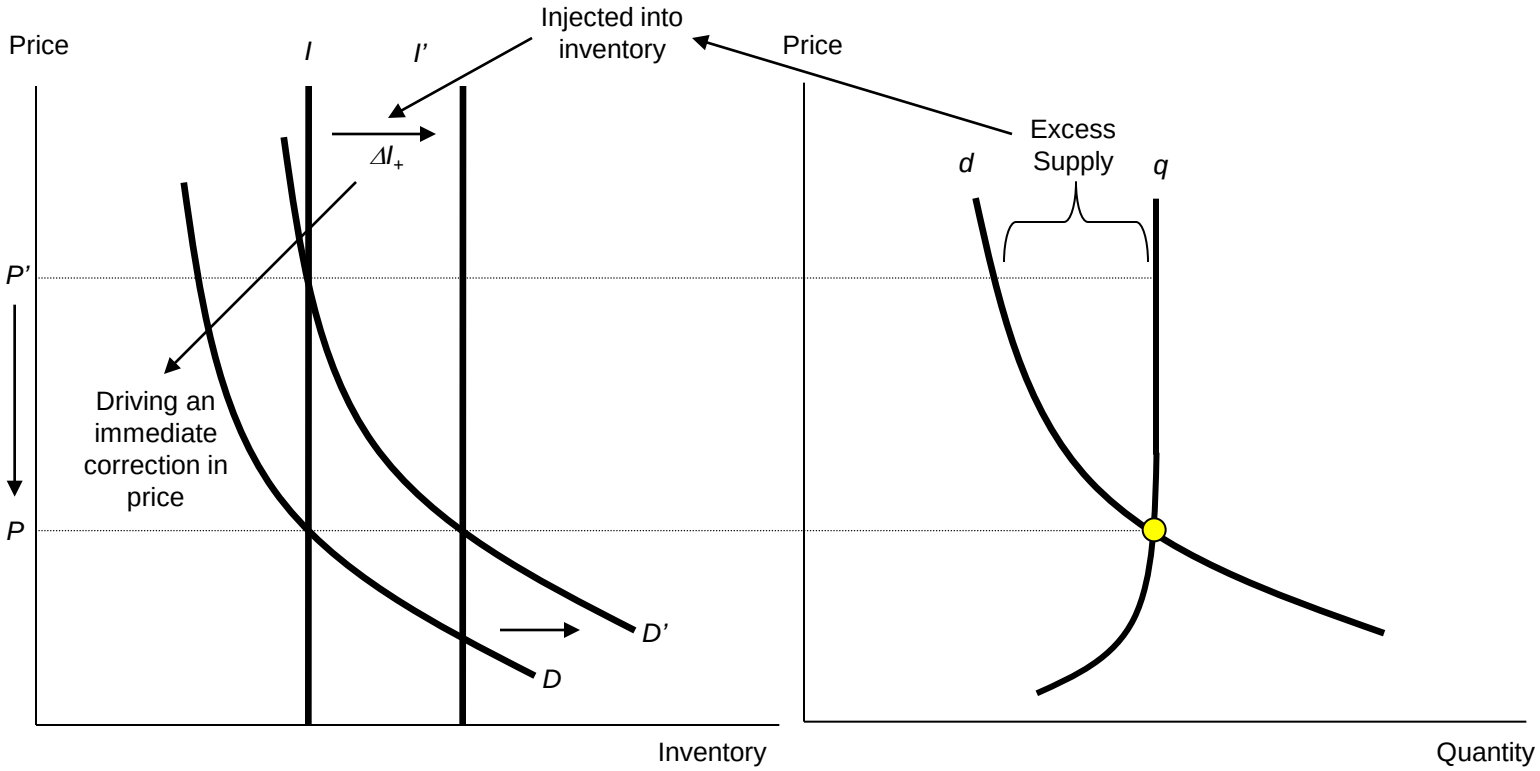
STOCK



FLOW

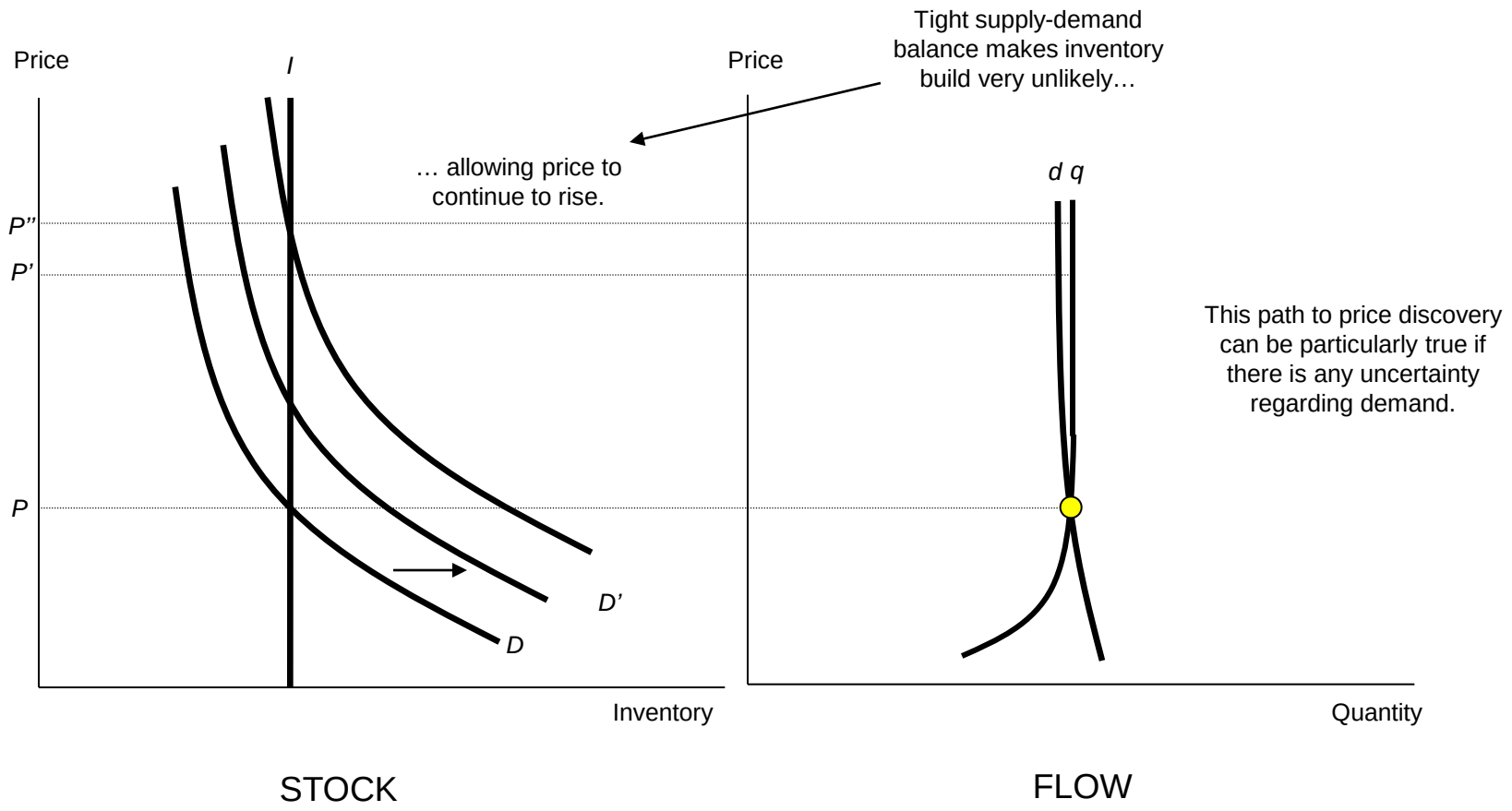
The Stock-Flow Model and Expectations

- The standard argument as to why speculation cannot have an impact on price...
  - Uncertainty about future adequacy of supply can lead to an outward shift in the demand for inventory (a precautionary motive). This should discourage demand through higher price and lead to inventory build.



The Stock-Flow Model and Expectations (cont.)

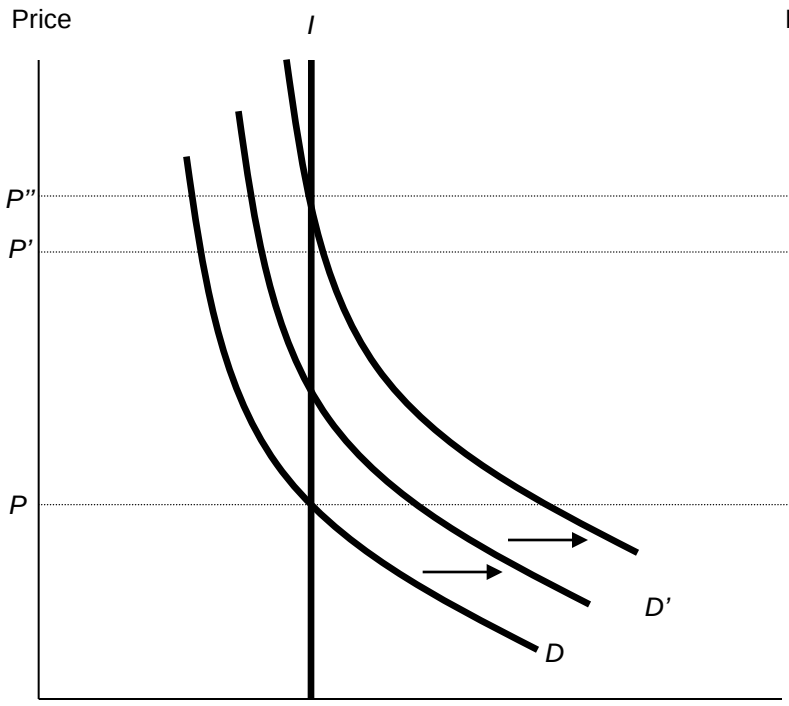
- But, tsame picture with *inelastic demand* indicates an inability to build inventory. This reinforces expectations about inadequacy of future supplies, leading to additional pressure and ever higher value placed on "what we have".



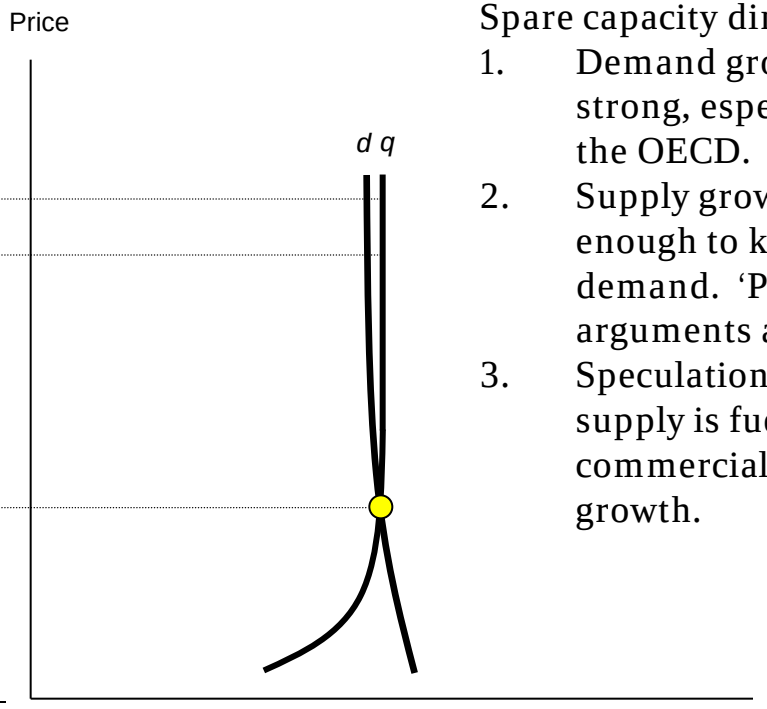
The “Stock-Flow” Model applied to the Crude Oil Market

Price goes up…

- The ability to expand production, peak oil, exchange rates, and uncertainty all play a role.
- Key point: Market fundamentals are tight, so speculation begins to exert an influence.



STOCK



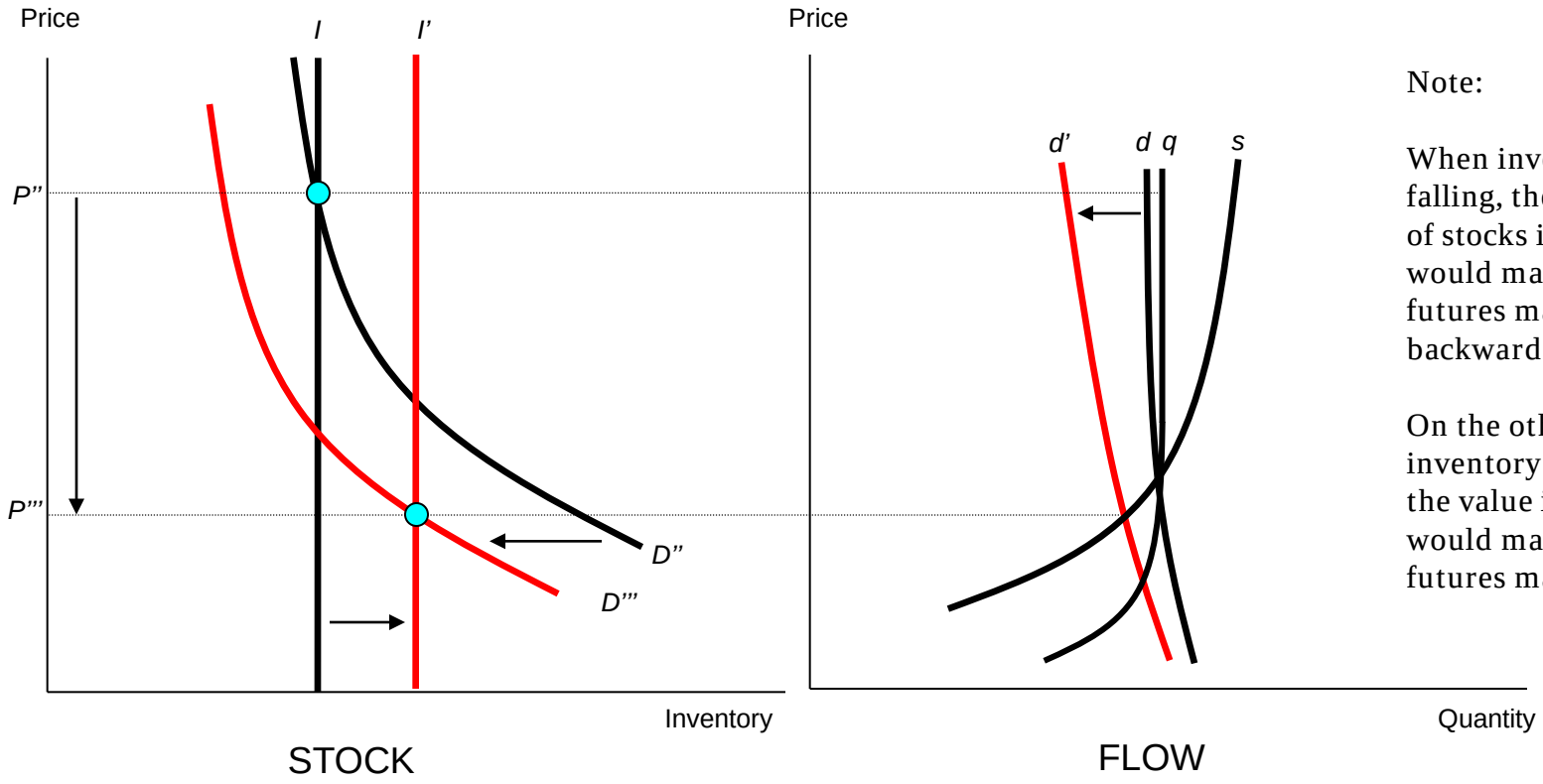
FLOW

Spare capacity diminishes as:

1. Demand growth is very strong, especially outside the OECD.
2. Supply growth is not enough to keep pace with demand. 'Peak Oil' arguments abound.
3. Speculation about available supply is fueled by a lack of commercial inventory growth.

Price comes down…

- Degradation of demand and inventory build.
  - Economic malaise pulls demand down, and adjustments to higher prices emerge.
  - Global economic crisis and demand *forecast* revisions ⇒ lower expectations.
- OPEC can support price now by holding back capacity.



Note:

When inventory demand is falling, the perceived value of stocks is declining. This would materialize in the futures market as backwardation.

On the other hand, when inventory demand is rising, the value is also rising. This would materialize in the futures market as contango.

The Model

The Model

"Flow" Market

Demand is expressed as a function of price and other factors, which may be things such as income and seasonal drivers.

$$d_t = b_0 - b_1 p_t + b_2 x_t$$

Supply is expressed as a simple declining function of last period's production level and new investments in production.

$$q_t = i_t + \gamma q_{t-1}$$

New investment in production is modeled as a function of producers' expectations about future prices, the lead time to production and the cost of the activity. The responsiveness of upstream investment is also important. The investment problem is modeled as

$$i_t = \eta\left(E^p\left(p_{t+1}\right) - c_{t+1}\right)$$

where η denotes the propensity to invest given a profit margin. The term $E^p\left(p_{t+1}\right) - c_{t+1}$ is expected marginal profit where $E^p\left(p_{t+1}\right)$ is the representative producer's expectation of price in final periods and c_{t+1} is the cost of development in future periods. Note that η will indicate how rapidly expected profit margins influence production. So, as η shrinks, the expected marginal profit must rise to maintain a given level of production.

"Stock" Market

$$I_t = I_{t-1} + \left(q_t - d_t\right)$$

$$D_t = a_0 - a_1 p_t + a_2 F_{t,t^*}$$

Equilibrium

We know that $s_t = q_t - \Delta I_t = d_t$ in the flow market, so the only equilibrium condition we need to consider is the "stock" market equilibrium, which states that $I_t = D_t$ at p_t^*. This follows because the equation of motion for inventories is the "flow" market equilibrium.

$$I_{t-1} + \left(q_t - d_t\right) = a_0 - a_1 p_t + a_2 F_{t,t^*}$$

$$I_{t-1} + \eta\left(E^p\left(p_{t+1}\right) - c_{t+1}\right) + \gamma q_{t-1} - b_0 + b_1 p_t - b_2 x_t = a_0 - a_1 p_t + a_2 F_{t,t^*}$$

$$p_t = \left(\frac{a_0 + b_0}{a_1 + b_1}\right) - \left(\frac{I_{t-1}}{a_1 + b_1}\right) - \left(\frac{\eta\left(E^p\left(p_{t+1}\right) - c_{t+1}\right) + \gamma q_{t-1}}{a_1 + b_1}\right) + \frac{b_2}{a_1 + b_1} x_t + \frac{a_2}{a_1 + b_1} F_{t,t^*}$$

The Model (cont.)

Market Clearing

Breaking down equation (1) yields some insights into the manner in which price might evolve. To begin, we can re-write the long-form expression for price as

$$p_t = \underbrace{\left(\frac{b_0 + a_0}{a_1 + b_1}\right)}_{(i)} + \underbrace{\left(\frac{b_2 x_t}{a_1 + b_1}\right)}_{(ii)} - \underbrace{\left(\frac{\eta\left(E^p\left(p_{t+1}\right) - c_{t+1}\right) + \gamma q_{t-1}}{a_1 + b_1}\right)}_{(iii)} - \underbrace{\left(\frac{I_{t-1}}{a_1 + b_1}\right)}_{(iv)} + \underbrace{\left(\frac{a_2 F_{t,t^*}}{a_1 + b_1}\right)}_{(v)}$$

or

$$p_t = \alpha_0 + \alpha_1 x_t - \alpha_2 q_t - \alpha_3 I_{t-1} + \alpha_4 F_{t,t^*}$$

Note, each of the terms can be described as…

i. The minimum price we could see if all other variables took values of zero.
ii. The effect of exogenous influences of demand.
iii. The supply response impact. Notice if prices are expected to increase, then the sensitivity of supply to those expectations is critical in preventing price from rising. If $\eta \to 0$ then the supply response is negligible and price will likely rise in response to increases in demand.
iv. The effect of inventories. This reveals that the state of the world in the prior period is important in determining price today.
v. The influence of futures markets. If $\alpha_4 \to 0$, then the futures price has little impact on current spot price. However, if $\alpha_4 \to \infty$, then the futures price will dominate current spot price formation.

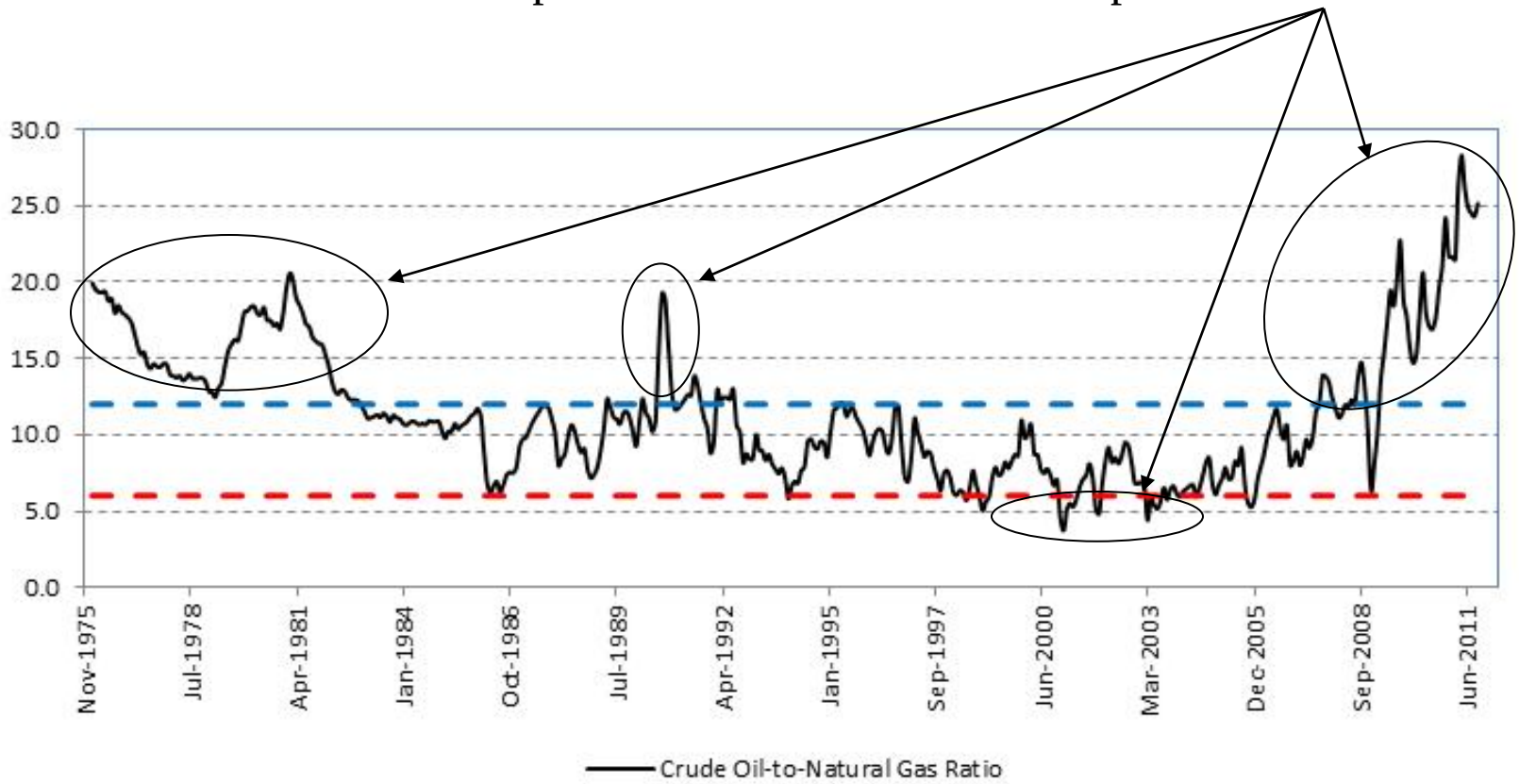
But,
what's good for the goose…

So, can we explain natural gas price?

Yes. More elastic supply and demand curves will tend to force "corrections" faster in the stock-flow framework. This can contribute to disconnects between markets when substitution opportunities are limited. Moreover, Hartley and Medlock (2012) show that the exchange rate also matters.

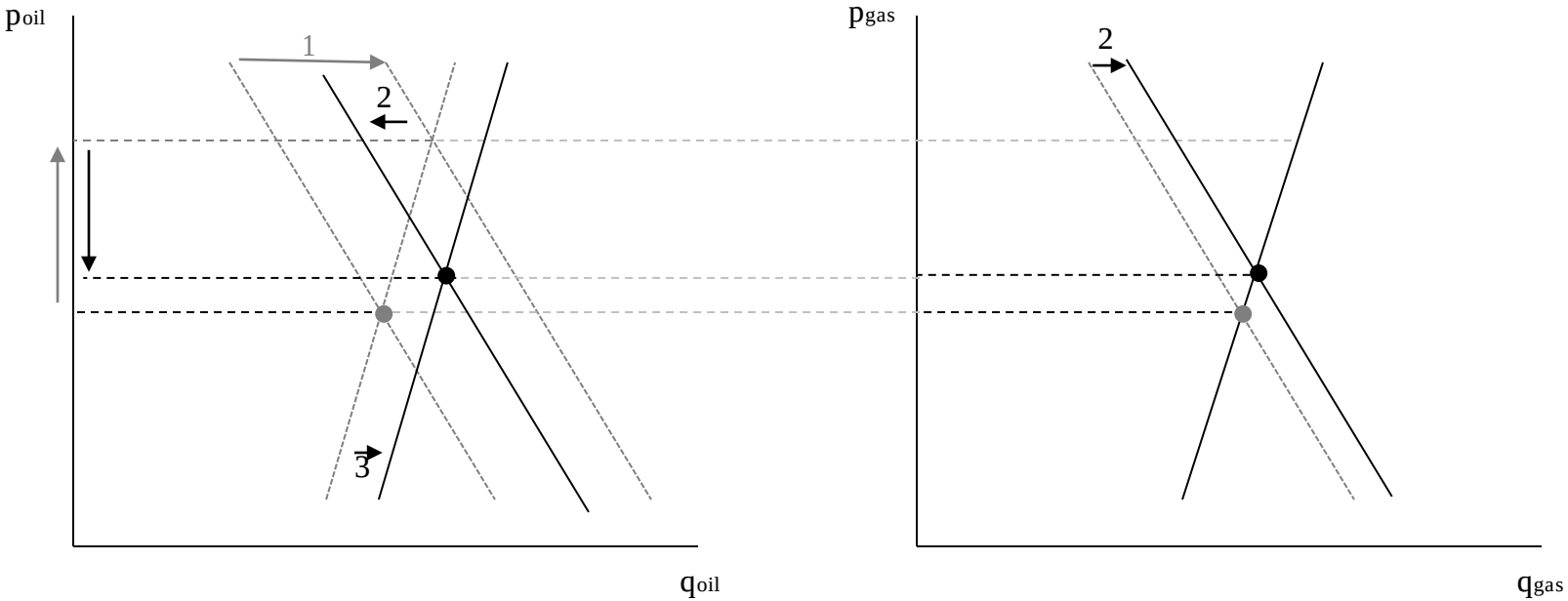
The Crude Oil-Natural Gas Price Relationship

- The ratio of crude oil price to natural gas price has been anything but stable.
- Often, the focus is on the 1990s, giving rise to the 12:1 to 6:1 "rule-of-thumb".
- This worked fairly well from the mid-1980s to the mid-2000s, but it would be good to have a framework that helps us understand *all* relative price movements.



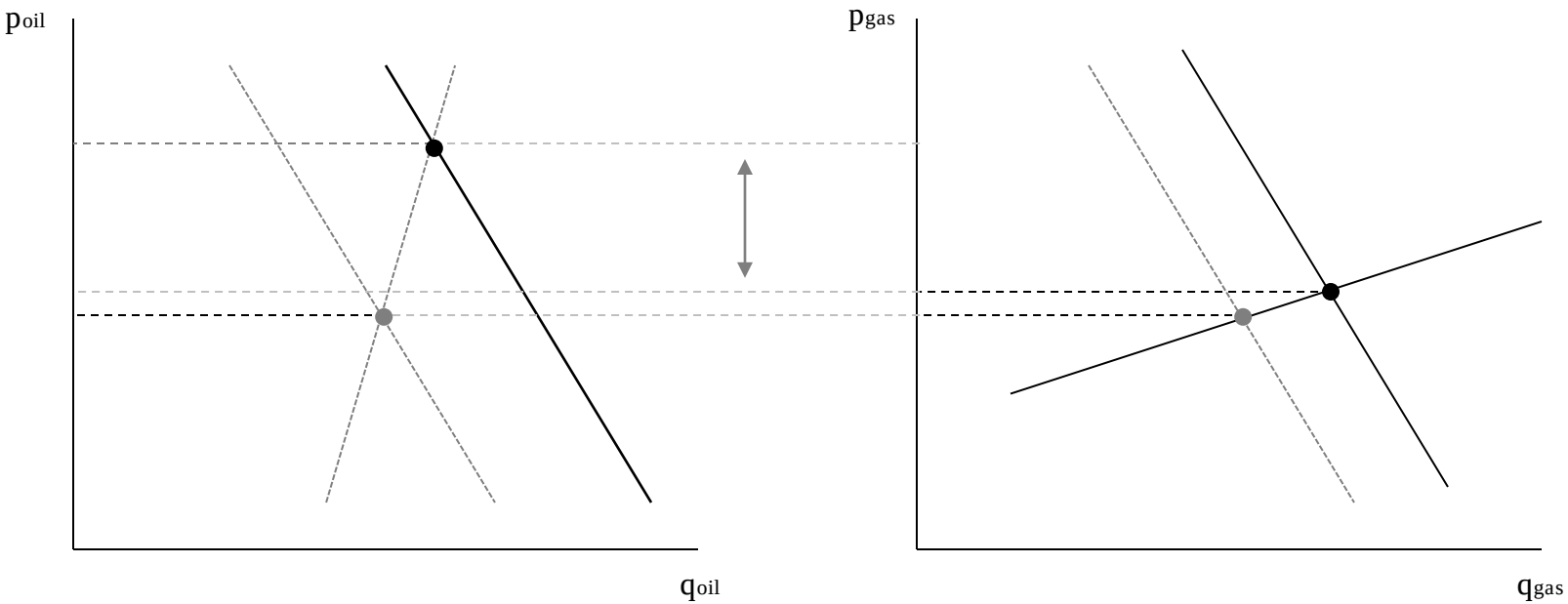
The Traditional Causality in Relationship

- Why should crude oil and natural gas prices even have a relationship?
  - Substitutes in end-use.
  - Co-products at the wellhead could encourage wellhead adjustments.
  - Extraction techniques are similar allowing for shifting industry focus.
- Consider the following example…
  1. Demand for oil increases
  2. Long run (capital stock adjustments) and short run fuel switching occurs as relative prices change
  3. Supply-side adjustments occur
  4. A new "equilibrium" is eventually established with both prices being higher.



In any case, shale developments in the US have made the natural gas supply curve more elastic…

- Increasing elasticity in the gas market, without similar changes in the oil market, can drive a disequilibrium.
  - Continued cost reductions in shale gas developments exacerbate the spread.
- In fact, large sustained differences can emerge if adequate fuel switching capacity is not available (which would induce changes in demand) and supply-side adjustments are slow to occur.



Questions/Comments