

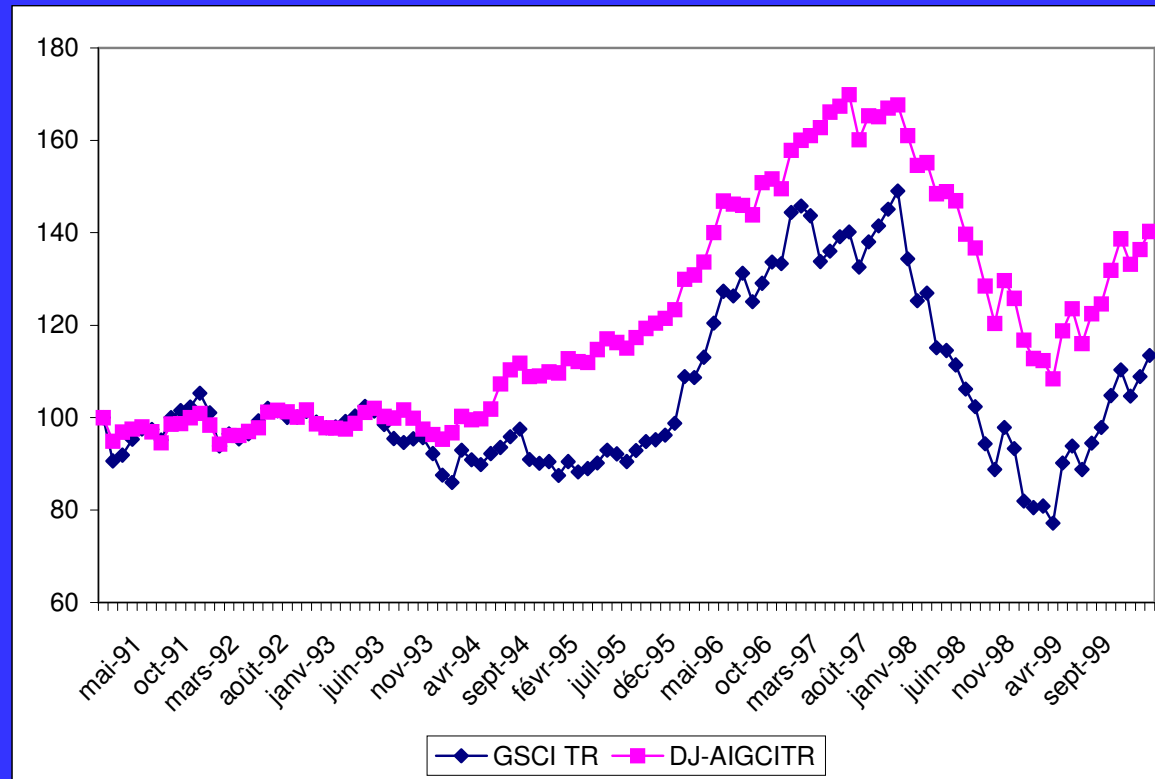
Inventory, Commodity Forward Curve and Spot Price Volatility

Helyette Geman

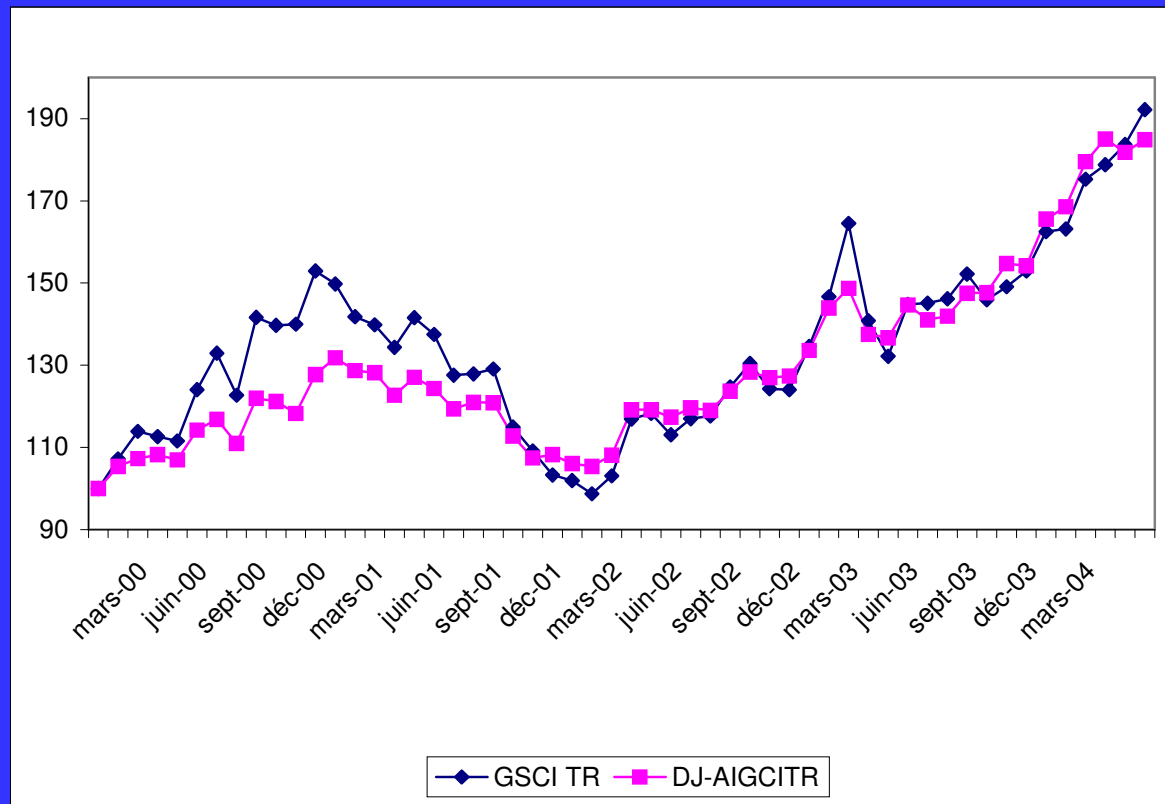
Birkbeck, University of London & ESCP Europe

Member of the Board of the UBS- Bloomberg Commodity Index

To be presented at the Workshop on Energy and Emissions
Fields Institute – April 9, 2010

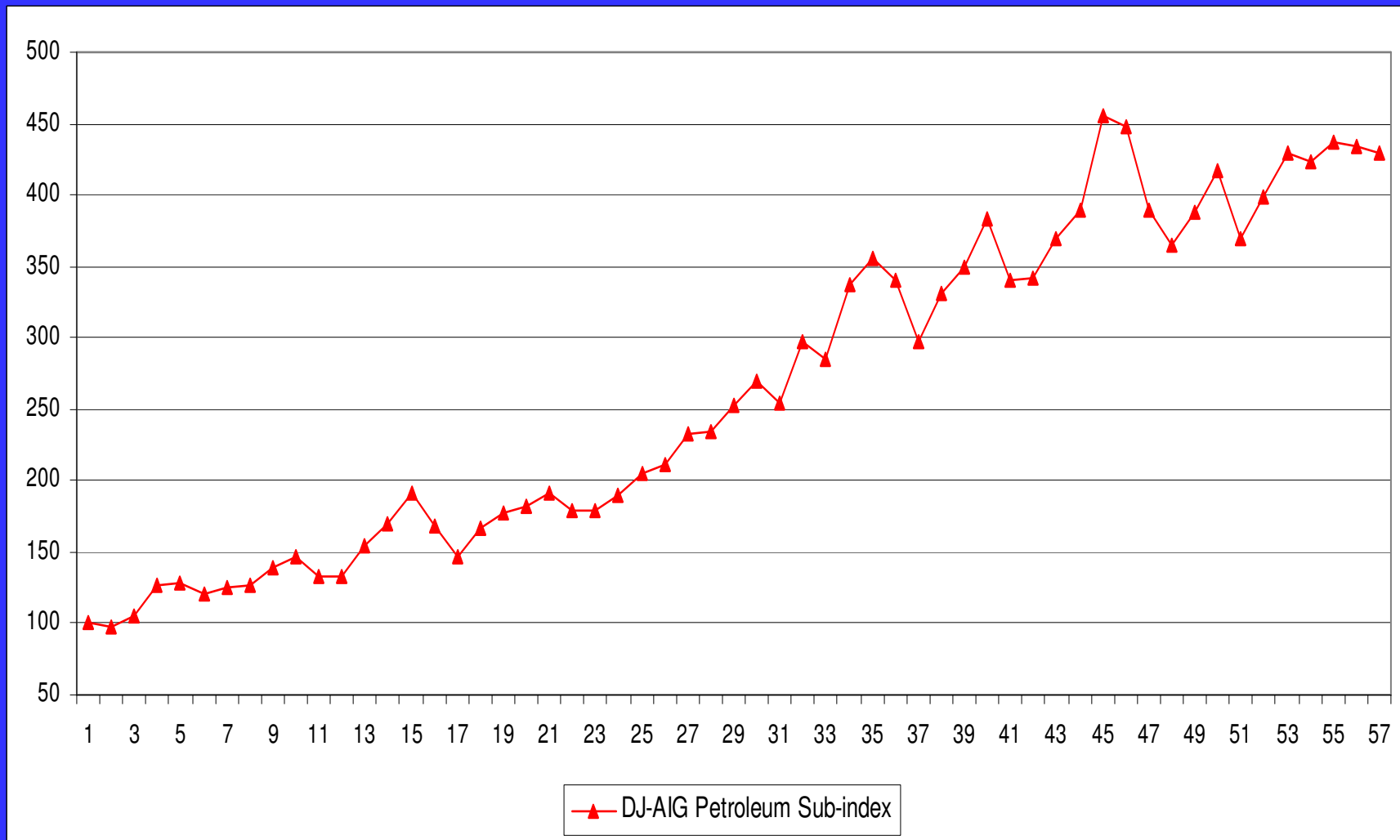


Growth of \$100 during 1991-1999 : *Mean – Reversion* in prices



Commodities as a Valuable Asset Class as of 2000

DJ – AIG Petroleum Index Dec 2001 - June 2006



Is Mean-Reversion Dead ? (Geman - Sept 2005, JAI)

Commodity Research Bureau (CRB) Index 1989 to 2009

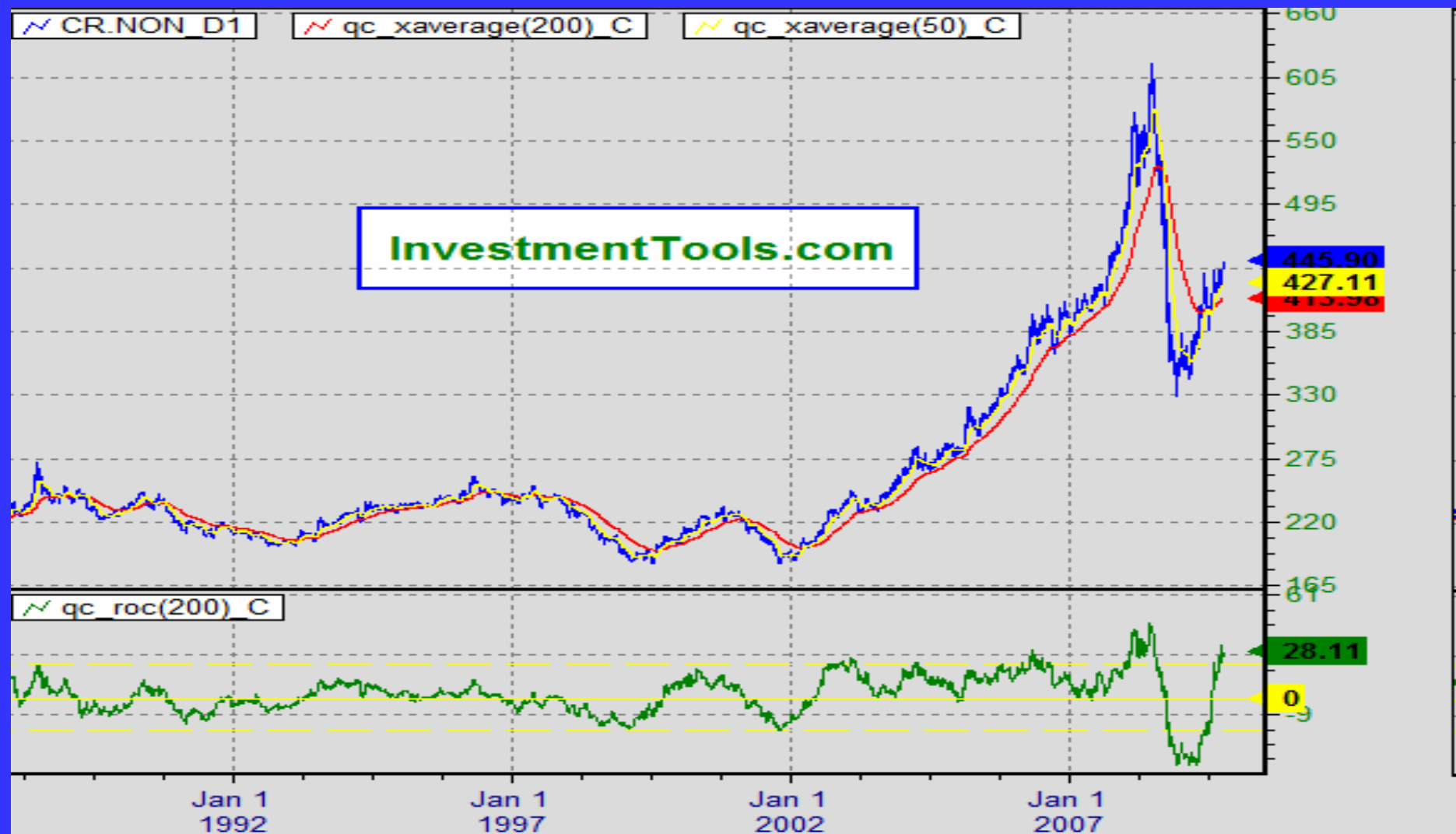
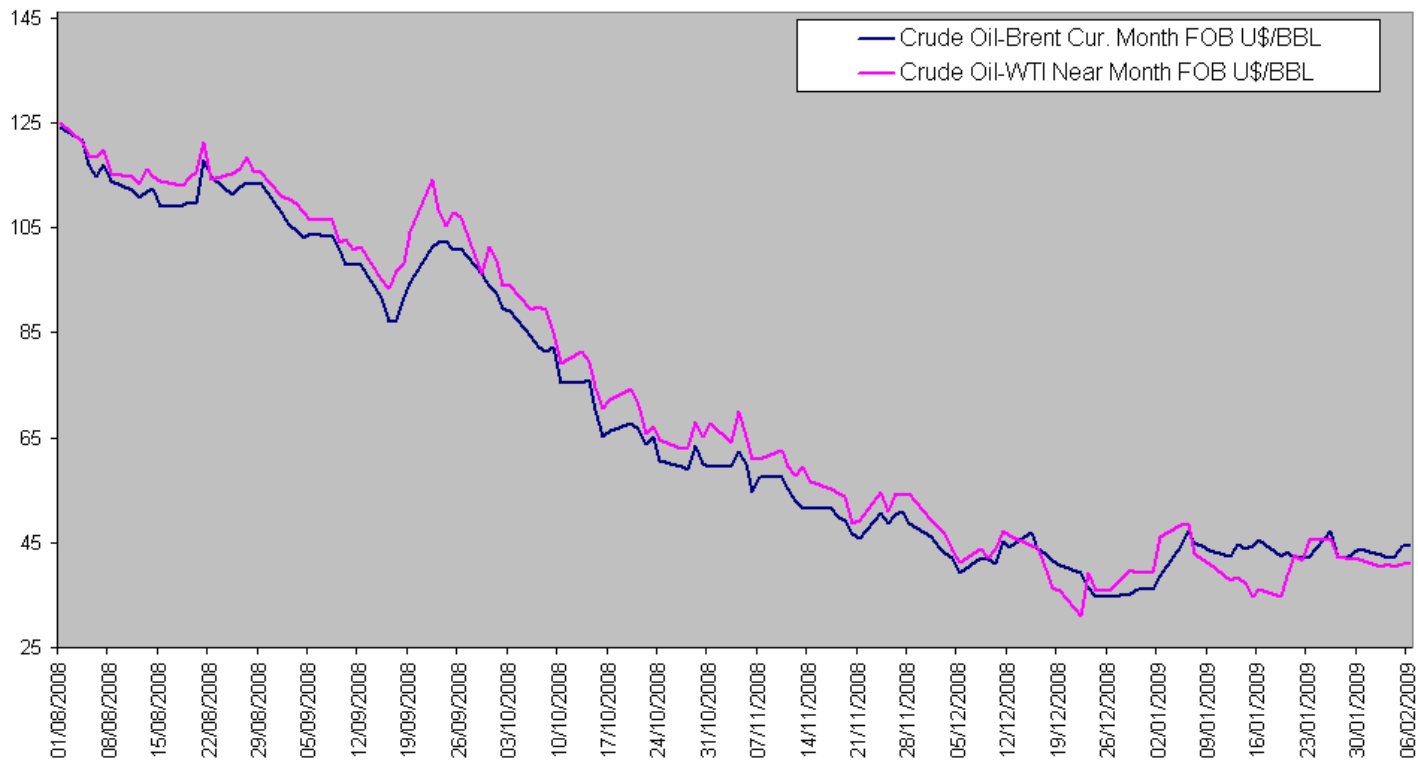


Chart created with NeoTicker EOD © 1998-2007 TickQuest Inc.

Comparative Moves of WTI and Brent Crude Prices

Crude oil prices for WTI and Brent (Aug 2008- Feb 2009)



A very unusual situation related to a large US *inventory* at Cushing, Oklahoma

Crude oil prices for WTI ,Brent and the difference (Aug 2008- Feb 2009)



Shipping and Freight as Part of the Commodity World

→ Two types of freight

- Dry bulk: Capesize, Panamax, Handymax
- Tankers: Suez-Aframax

→ Major actors in the spot and forward markets: Cargill, Louis Dreyfus, Total, Shell, Deutsche Bank, Morgan Stanley

→ Trading activity

- Baltic Exchange (London), used to offer Futures contracts, now only forwards
- Imarex (Oslo), provides daily quotes on maritime shipping
- LCH-Clearnet (London)
- Nymex (New York), very active for dry bulk

Freight Dry - Bulk Market

→ The *Baltic Capesize Index* (BCI) reached an absolute maximum (level 9000) in January 2005, then experienced a huge drop later that year:

– 5125	Oct 15
– 4637	Nov 15
– 3385	Dec 15
– 3018	Jan 15, 06

→ The annual volatility is of the order of 110%

→ Both spikes and volatility make this market similar to the electricity market

Baltic Capesize Index



Chart created with NeoTicker EOD © 1998-2007 TickQuest Inc.

Baltic Dry Index – 2000 to 2010



Theory of Storage

Kaldor (1939), Working (1949), Brennan (1958)

Three fundamentals results:

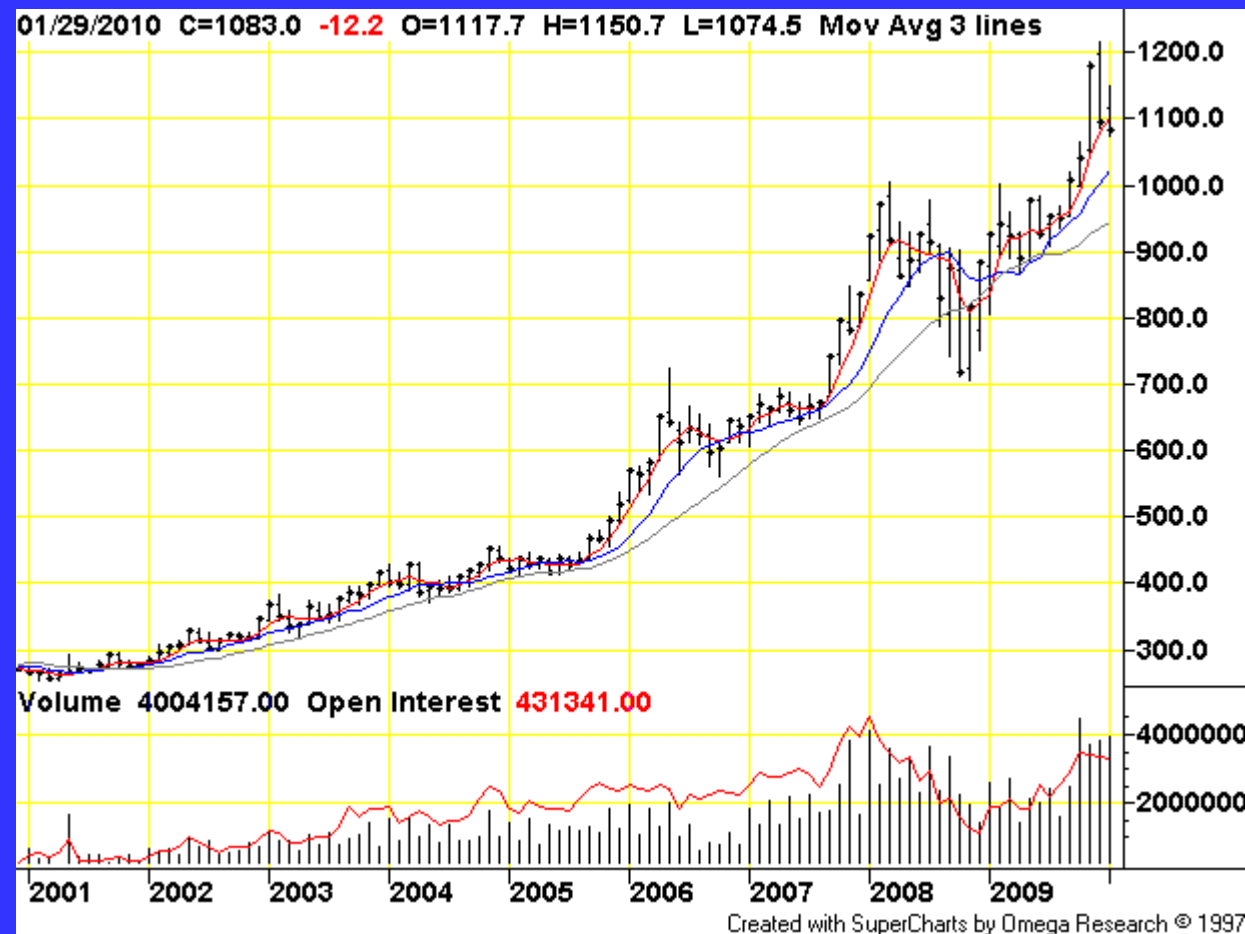
- The convenience yield accounts for the benefit that accrues to the holder of the physical commodity but not to the holder of the futures contract. It is represented as an implicit dividend
- The volatility of the commodity spot price is high when inventory is low
- The volatility of Futures contracts decreases with the maturity: "Samuelson effect"

Moreover, forward curves are viewed as being mostly in backwardation, the so- called "normal backwardation", due both to the convenience yield and an assumption of mean- reversion in prices

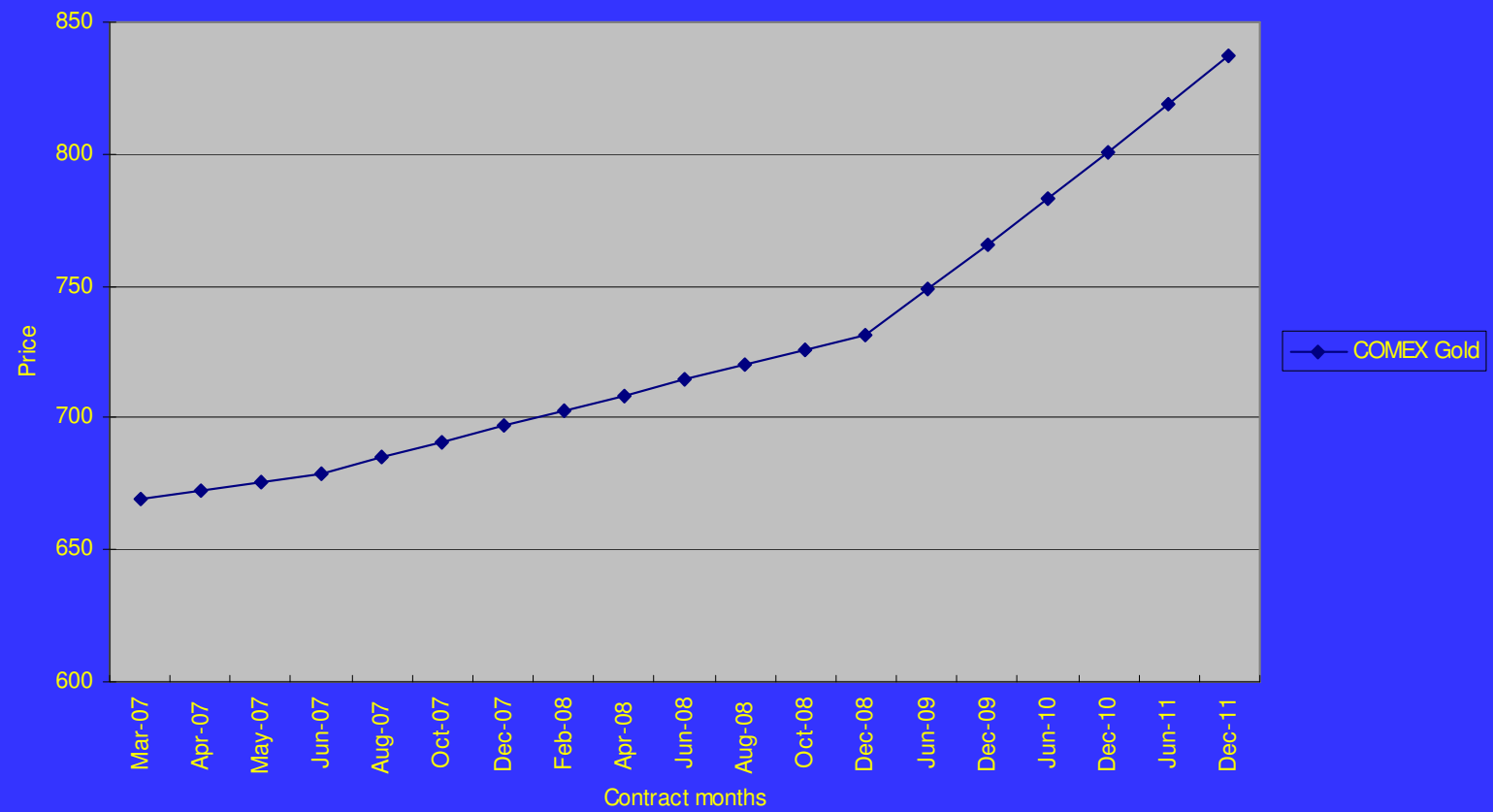
Gold in the recent period

- Bullion sales hit records as investors are buying record amounts of gold bars and coins amid renewed fears about the health of the global financial system
- Inflows into gold- backed Exchange- traded funds (ETFs) surged in January, pushing their bullion holdings to an all- time high of 1. 317 tonnes.
- For comparison, the flow of 105 tonnes in January 2008 absorbed half of the world's gold mine output during the month
- Interestingly, gold forward curves kept the same shape before and after the financial crisis

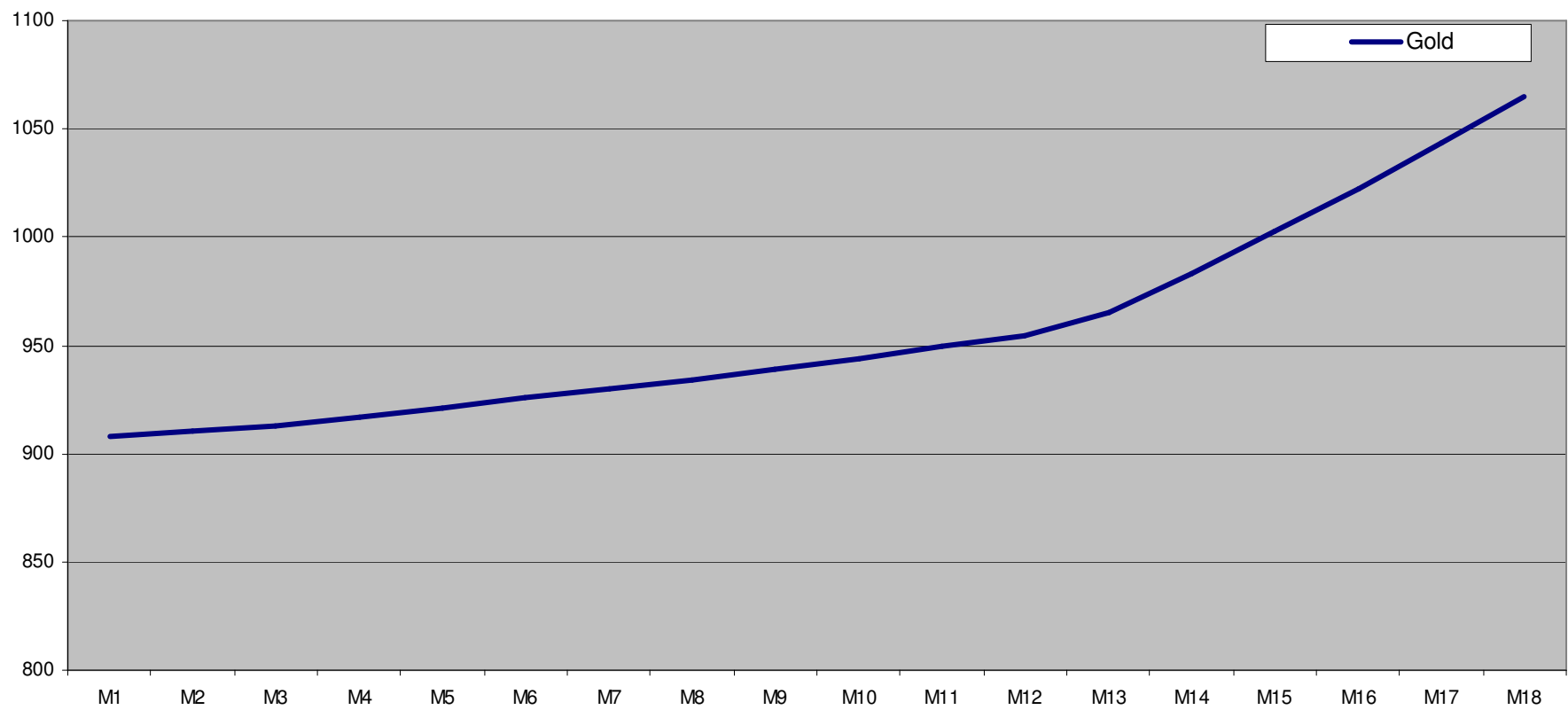
Comex Gold Prices – 2001 to 2010



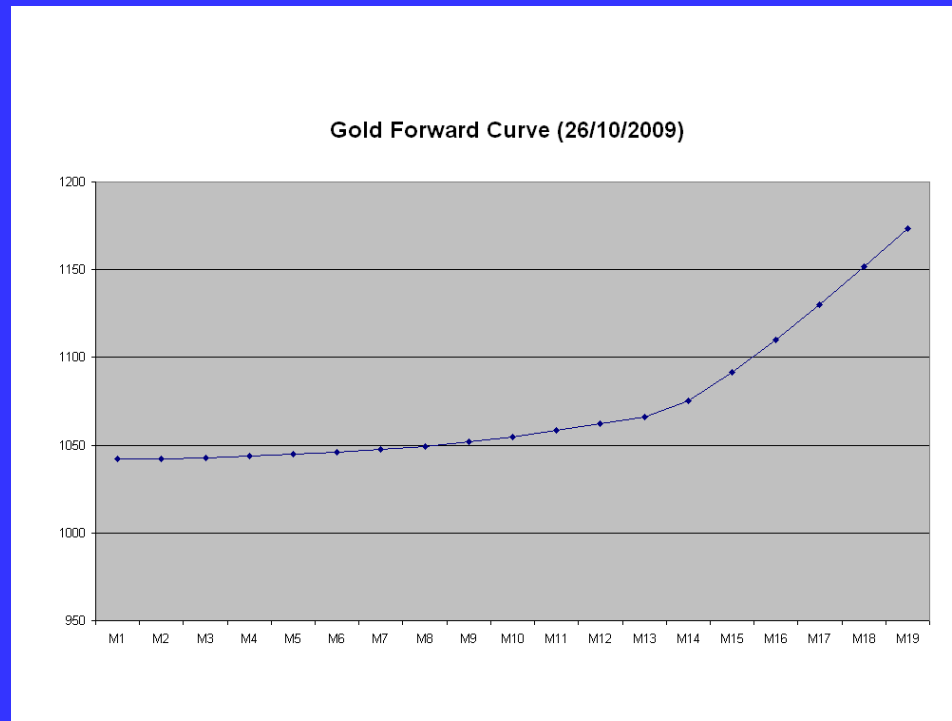
COMEX Gold 28/2/2007



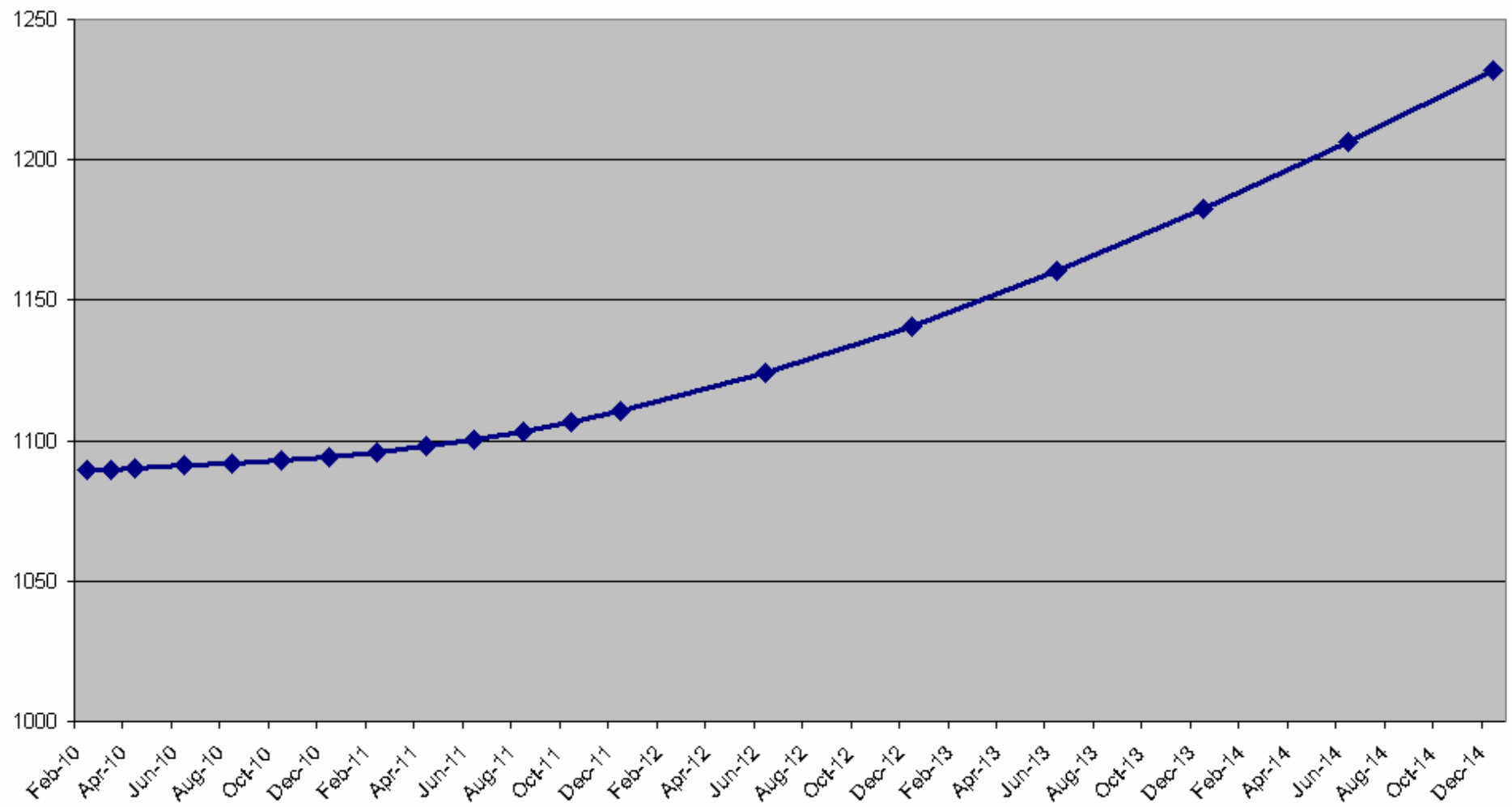
Gold Forward Curve - 27 May 2008



Gold Forward Curve, October 26, 2009



Gold (12 Feb 2010)



Natural Gas

- Natural gas, a fossil fuel, has long been prized for its ability to burn cleanly and provide relatively high levels of energy
- In 1821, the first well specifically designed to recover natural gas was dug in the US
- The pure form of natural gas consists of a mixture of hydrocarbon gases, mainly methane, a molecule consisting of *one* carbon atom and four hydrogen atoms
- Natural gas and oil are generally found together in deposits beneath the earth's crust
- A Btu refers to the amount of natural gas required to heat one pound of water by one degree at normal pressure. There are about 1,027 Btu in one cubic foot of natural gas

World Natural Gas Reserves

- In terms of remaining years the IEA provides the following estimates
- 65 years for natural gas
 - 40 years for crude oil
 - 155 years for coal

Natural Gas Reserves by region

Middle East	2,566
Eurasia	2,017
Africa	484
Asia	419
North America	277
Central & South America	241
Europe	179

Natural Gas Markets

→ Until recently, three regional markets could be identified in the world, with limited trade between them because of the cost of transportation of gas over long distances



→ As a comparison, it costs only \$2 to transport a barrel of oil around the world, i. e., less than 3% of the price of a barrel for prices over \$60. In the case of natural gas, it may represent 100% of the price

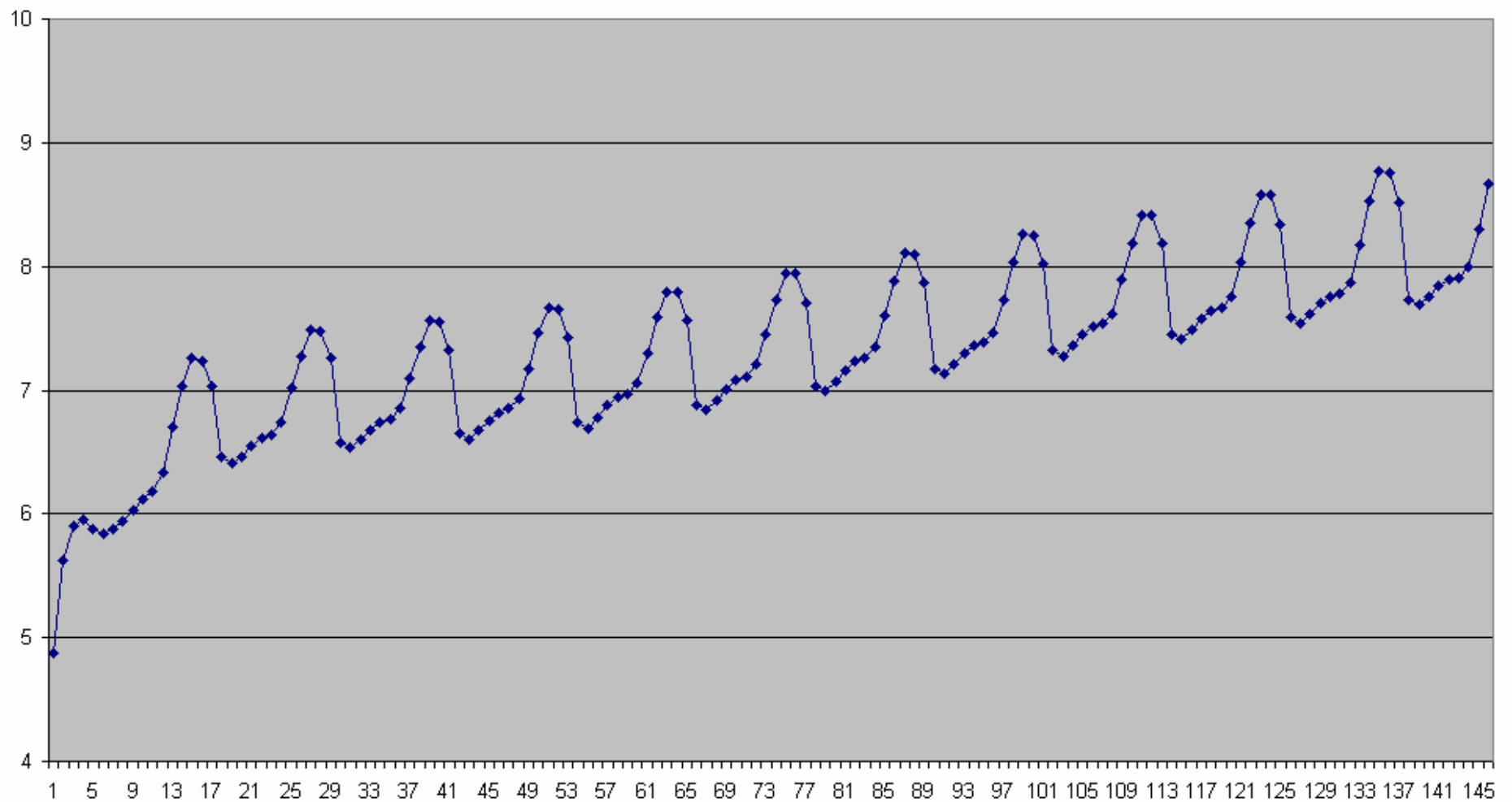
→ Increased LNG transport should help breaking down the barriers to current world segmentation

NYMEX Gas Prices – 2001 to 2010



Nymex Natural Gas Forward Curve, Oct 2009

Natural Gas Forward Curve



Coal

- It is a live and complex substance (some coarse version of diamond ...)
 - Steam coal is used for electricity production, industrial activities, residential sector
 - Coking coal is used for steel production
- It represents 23% of the world primary energy, 40% of electricity production (50% in the US), 70% of steel production
- Its demand has increased by 24% between 2000 and 2004 (compared to 10% for natural gas and 6.5% for oil)

Coal

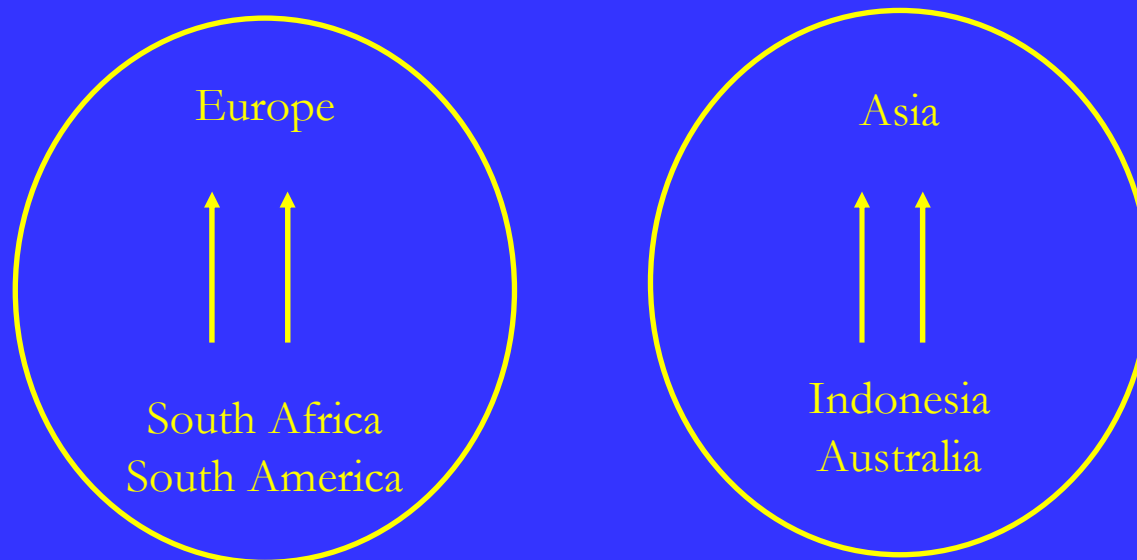
- 25 years ago, some experts had foreseen the disparition of coal by 2050!
- Coal is a commodity with a bright future ahead
 - represents today 25% of the world energy
 - its share is increasing in China, India, United States (and a little less in Europe)
 - Research on carbon capture and sequestration (CCS) is moving forward
- \$400 billion will be invested in coal production over the next 30 years (compared to \$1400 bn in electricity production)
- Strong growth of international trade, of steam coal in particular
- Forecast of rapid growth of thermal plants between 2030 and 2050 (more than gas fired plants)

- At the horizon 2050, the world consumption of energy will rise from 9950 Mtep in 2001 to 22047 and the share of coal from 2352 to 5678 China' share will rise from 636 to 1853 and USA from 545 to 1010
- Coal fired plants will represent 40% of the electricity production in 2050 across the world, 72% in India, 42% in the US and Germany
The yearly average growth will be 2%

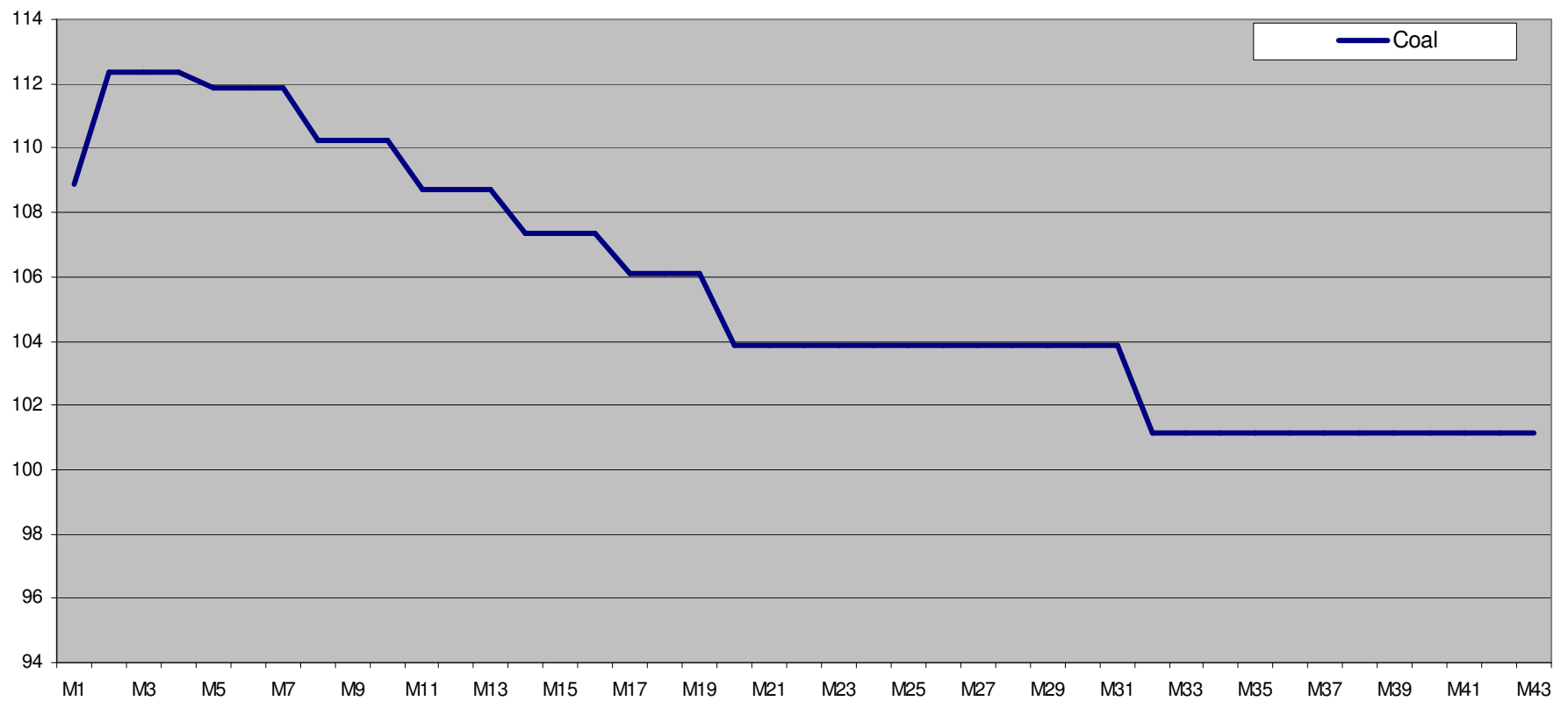
Recently, China turned into a net coal importer for the first time – a significant development as coal accounts for more than 70% of its total energy consumption. In the first nine months of 2009, the rise of Chinese coal imports reached the level of 167%, or 86.47 million tonnes.

Coal is a very competitive fuel for electricity production and represents the *baseload and semi-baseload* parts of the power stack function.

- There has been a boom in coal trade: 712 Million tonnes in 2005, up from 500 in 2000. The forecast is 1060 Million tonnes in 2030
- Development of cross-border land trade but more of maritime trade (2/3 of which in direction of Europe and Japan) and particularly for steam coal
- Two coal regions: Atlantic and Pacific, still disconnected today



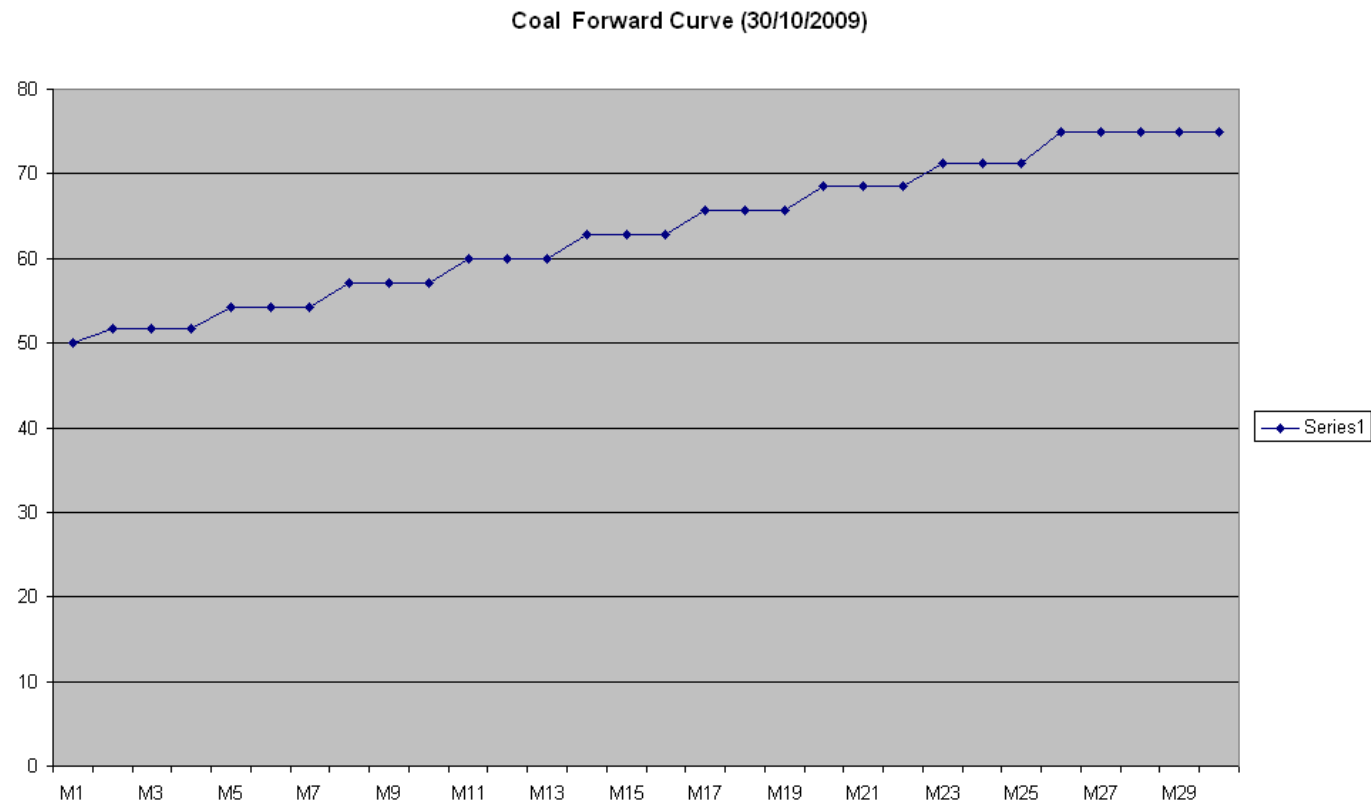
Coal Forward Curve - 27 May 2008



NYMEX Coal Futures Settlement Prices



Coal Forward Curve - Oct 30, 2009



Crude Oil

Matthew Simmons, *Twilight in the Desert*

- "Sooner or later, the worldwide use of oil must peak because oil, like the other two fossils - coal and natural gas - is non renewable"
- Over the past 30 years, daily oil consumption has risen by approximately 33 million barrels, Asia accounting for more than half of this growth in demand
- Current consumption levels suggest that the world's oil supply should last until around 2045
- The world's largest producers are Saudi Arabia (13% of world production), Russia (12%), the United States (7%), Iran (6%) and China (5%)
- The Gulf of Mexico region provides about 29% of the US oil production, hence the disruption created by the long shutdown of many oil rigs after hurricanes Katrina and Rita in summer 2005

NYMEX WTI Crude Oil – 2001 to 2010



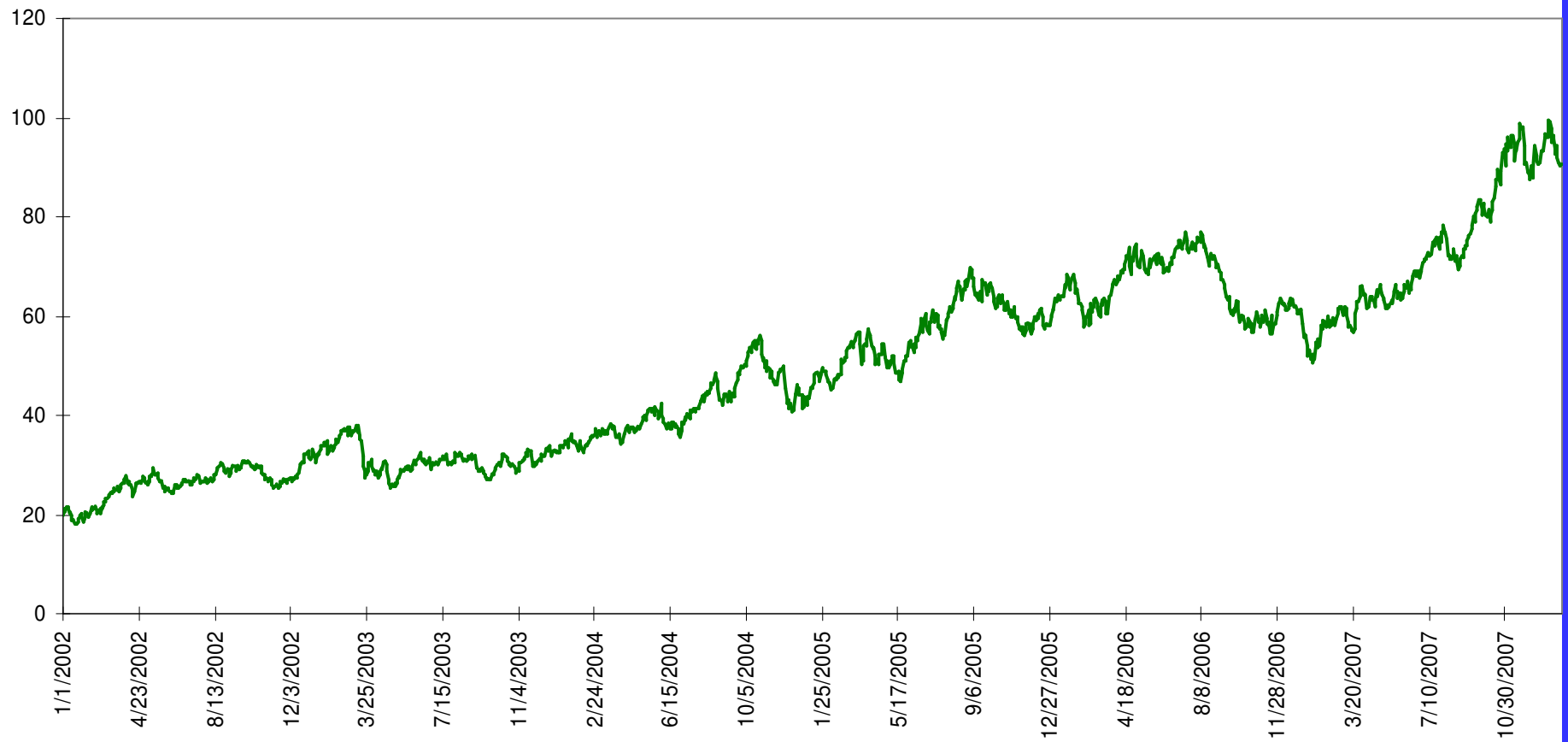
The Forward Curve

- The set $\{F^T(t), T > t\}$ is the *forward curve* prevailing at date t for a given commodity in a given location
- It is the fundamental tool when trading commodities, as spot prices may be unobservable and options not always liquid
- It allows to identify possible « carry arbitrage » : buy S , sell a future maturity T and pay the cost of storage and financing as long as the net cashflow is strictly positive
- The *shape* of the forward curve is at any date t in a one-to-one mapping with the convenience yield y
- It will reflect *the seasonality* in the case of seasonal commodities such as natural gas or Agriculturals

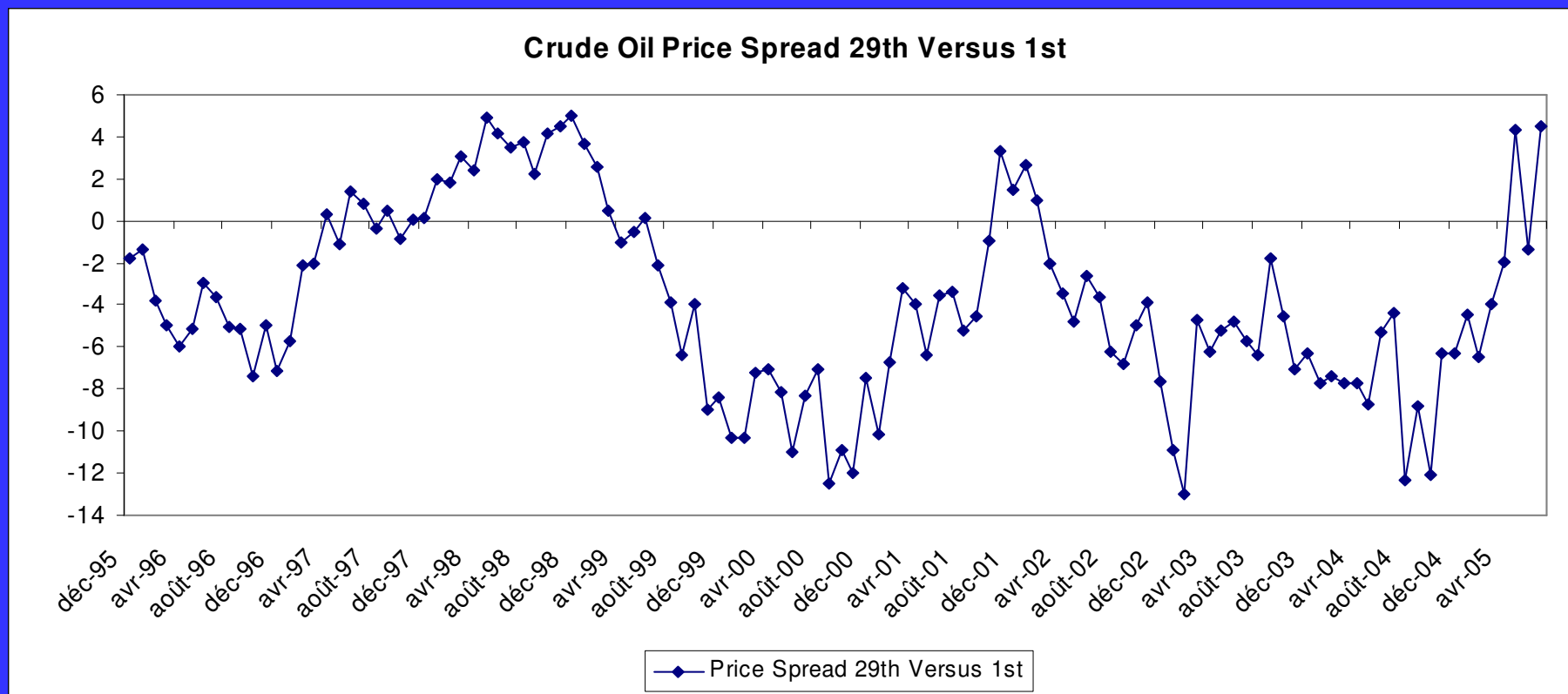
The oil market as a World Market

- Seasonality is not significant since tankers are rerouted to satisfy a surge of demand in a given region
- It is in the context of this crucial commodity that Brennan and Schwartz (1985), Gibson and Schwartz (1990) remarkably introduced in the valuation of derivative contracts the economic concept of *convenience yield*
- Gabillon (1991) shows the role of the convenience yield in explaining the role of oil forward curves

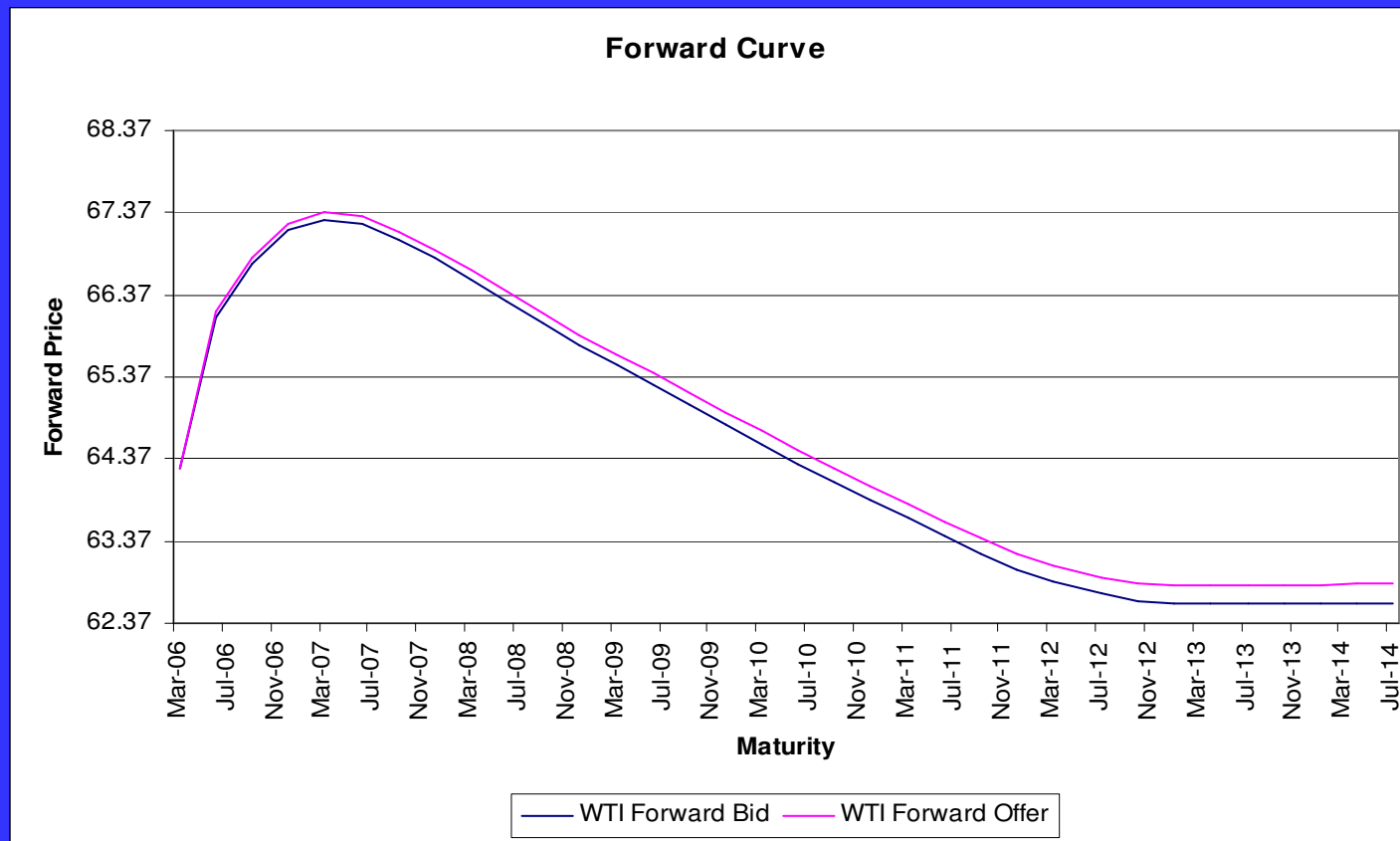
WTI Oil Prices Jan 2002 - Oct 2007



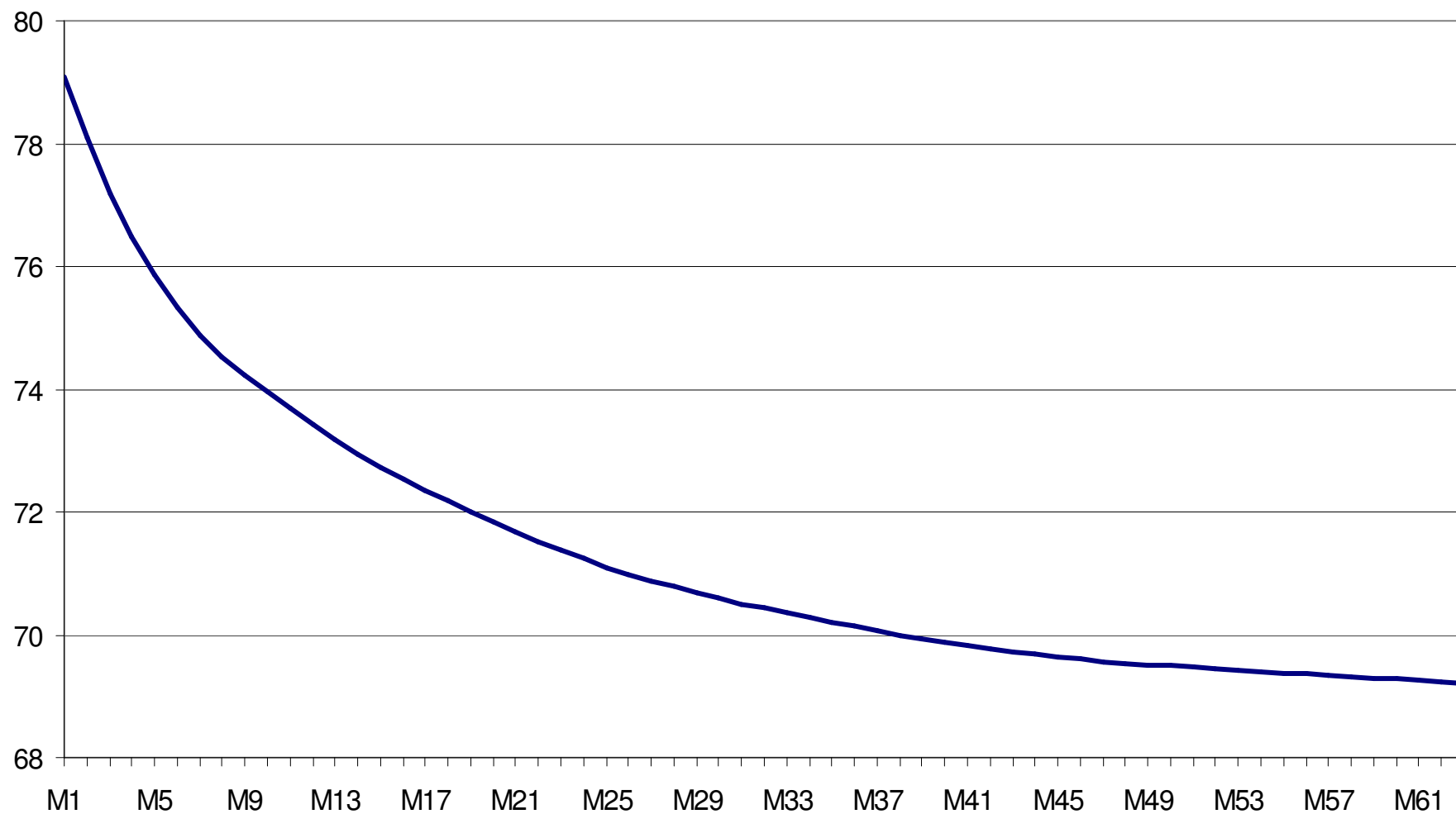
Spread of the Oil Forward Curve - Dec 1995 / Dec 2005



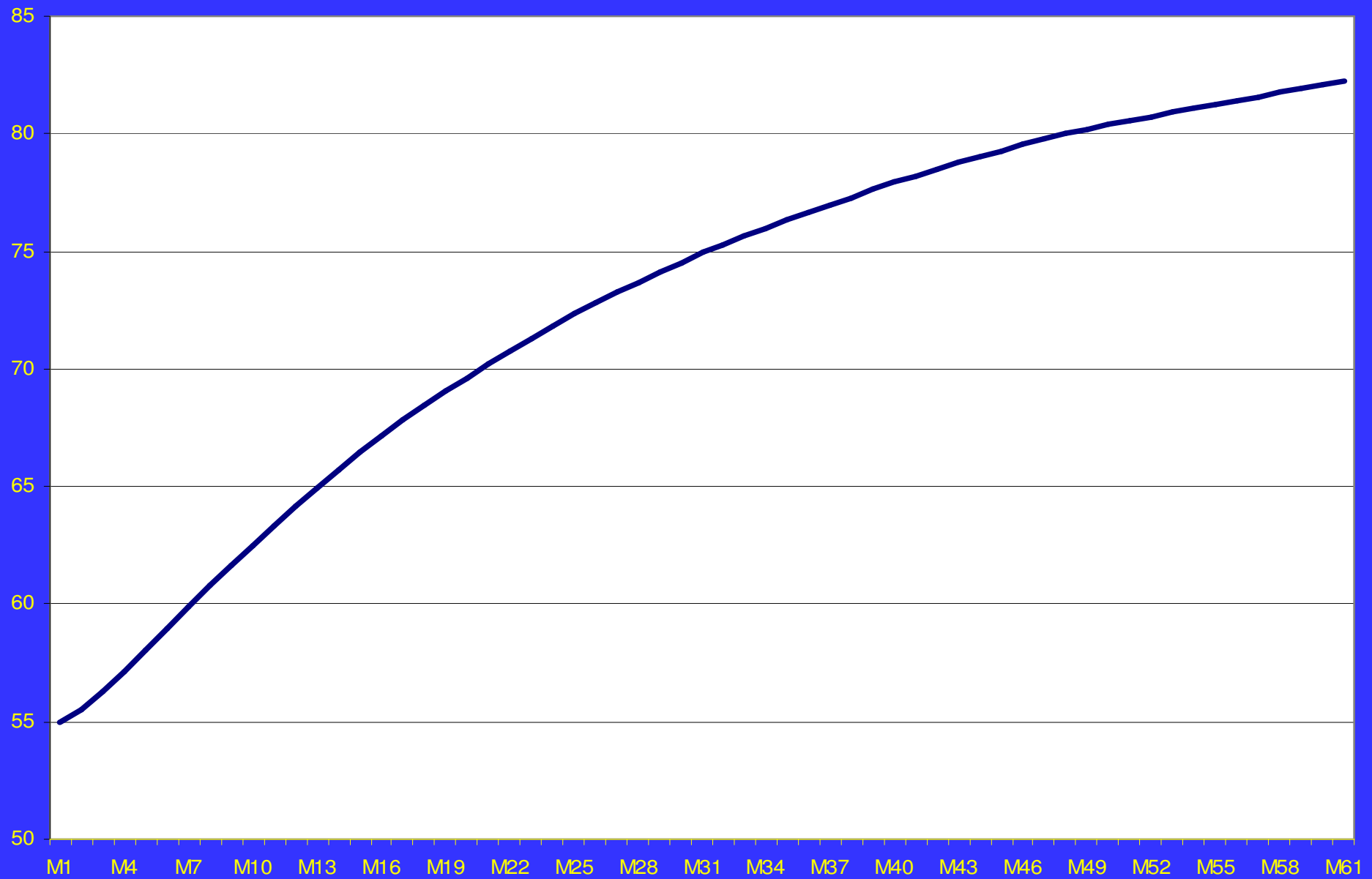
Oil Forward Curve - March 2006 (Bid and Ask)



Back to Backwardation in September 2007

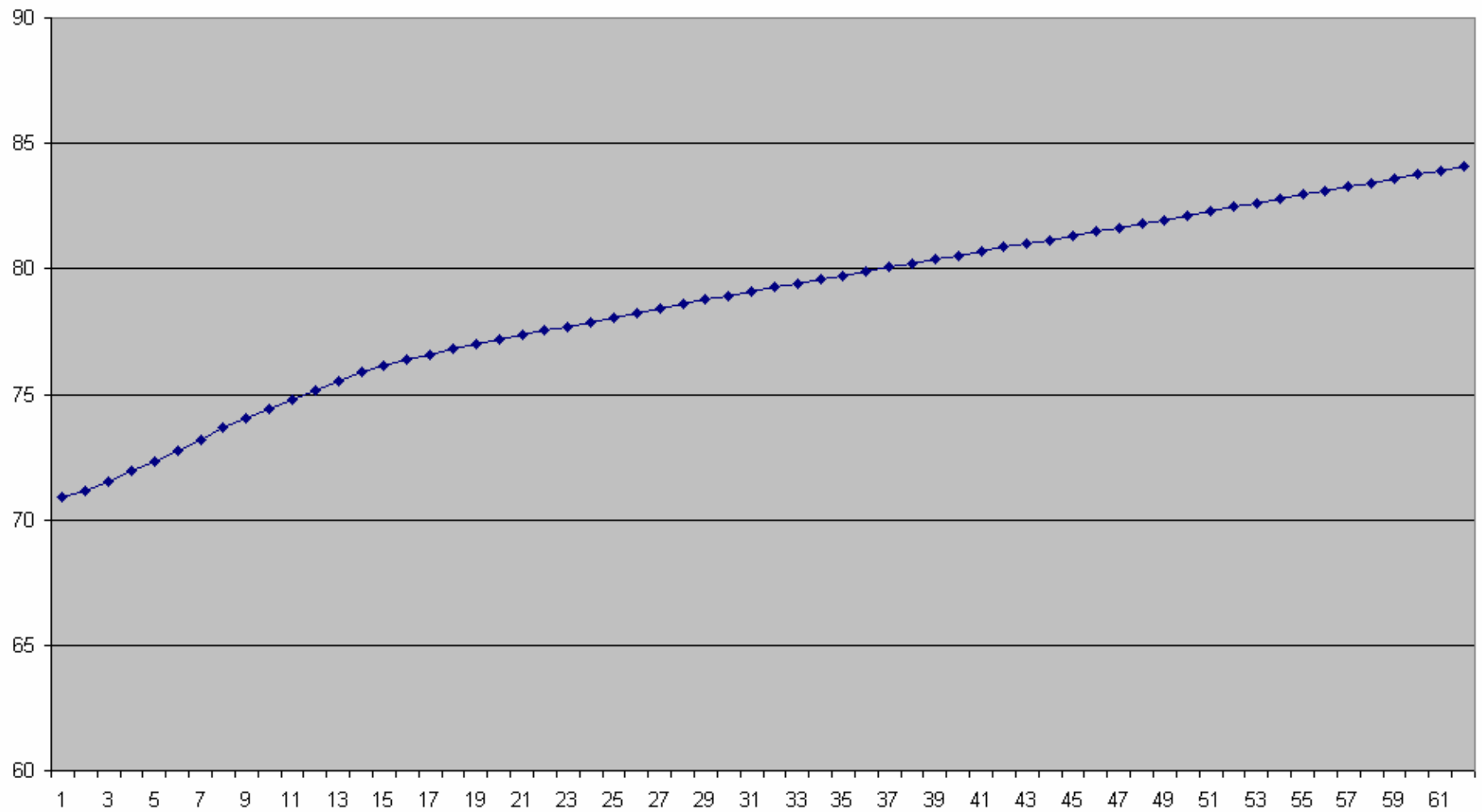


Crude Oil Future curve (17/11/2008)



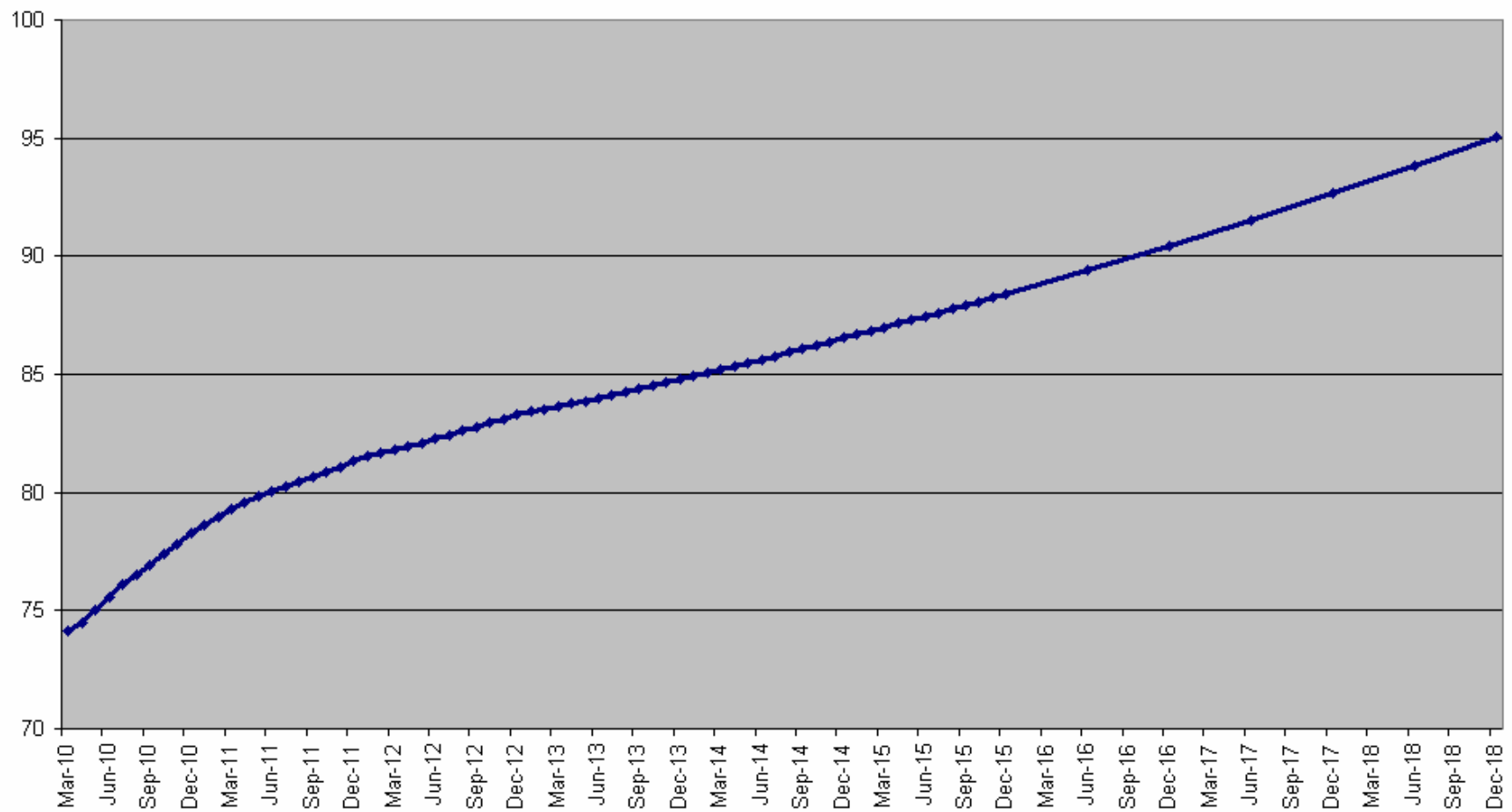
Crude oil Forward Curve, Oct 2009

Oil Forward Curve



Crude Oil Forward Curve – Feb 2010

Oil (12 Feb 2010)



Theory of Storage revisited

- At a fixed date t , a single value $y(t)$ of the process $(y(t))$ is not compatible with the hump-shaped forward curve observed in 2006 in the oil market (and other commodity markets)
- One possible modeling answer is to introduce a term structure $y(t,T)$ of convenience yields at date t , deterministic in the maturity argument T and stochastic in t (see Borovkova & G, 2007)
- This approach is certainly beneficiary in the case of seasonal commodities such as natural gas where, assuming today = April 2007, $y^T(t)$ should be different for $T = \text{September 2007}$ or $T = \text{December 2007}$

A Three-State Variable Model for Oil Prices

- The first state variable is naturally the spot price of the commodity
- Stochastic volatility is a good candidate for the second state variable
- The third state variable may be the long-term value of the commodity, translating in particular the forecast on long-term supply
- A three-factor model with stochastic volatility and a rising long-term price ($\mu > 0$)

$$dS_t = a(\ln L_t - \ln S_t) S_t dt + \sigma_t S_t dW_t^1$$

$$dU_t = \alpha(b - U_t)dt + \eta \sqrt{U_t} dW_t^2 \quad \text{where } U_t = \sigma_t^2$$

$$dL_t = \mu L_t dt + \xi L_t dW_t^3$$

and the three Brownian motions are possibly correlated

Forward Curves and Inventories

- The importance of inventory in explaining spot price volatility has been widely documented in the economic literature
- Brennan (1958) and Telser (1958) analyze in the context of several agricultural commodities the spread between a long-term future and the prompt month divided by the prompt month
- They exhibit a *negative correlation* between this "relative spread" and the variance of the commodity

- Fama & French (1987) take as a given the property of the spread being an adequate proxy for inventory. This allows them to analyze 21 commodities, including metals, for which good inventory data were missing in their period of analysis
- Ng & Pirrong (1994) examine four industrial and one precious metals over the period 1986-1992 and use the same proxy for inventory to conclude that fundamentals drive metal price dynamics
- G & Nguyen (2005) reconstruct a world database of soybean inventory (with Brazil and Argentina having become more important than the US in the last few years) and establish a quasi perfect affine relationship between *scarcity* defined as inverse inventory and spot price volatility

Inventory and Forward Curve Adjusted Spread in Oil and Natural Gas Markets

- As said before, crude oil is not a seasonal commodity, natural gas is a very seasonal commodity
- G- Ohana (2009) choose the maturity of the “distant” Future on criteria of liquidity and ability to filter out the seasonality

$$\text{adjusted spread} = \frac{\text{Futures 13M} - \text{Futures 1M} \cdot (1 + \text{rate 1Y})}{\text{Futures 1M}}$$

- We use a price database consisting of daily NYMEX Futures prices
 - for the oil from January 1990 to August 2006
 - for natural gas from January 1993 to August 2006
- We use for inventory data the EIA website
 - for crude oil, we collect the volume of all stored petroleum products in OECD countries at the end of each month from the end of December 1989 to the end of July 2006. This volume is expressed in billion barrels for oil
 - for natural gas, the website provides the volume of stored natural gas in the United States at the end of each month during the period end of December 1992 - end of July 2006

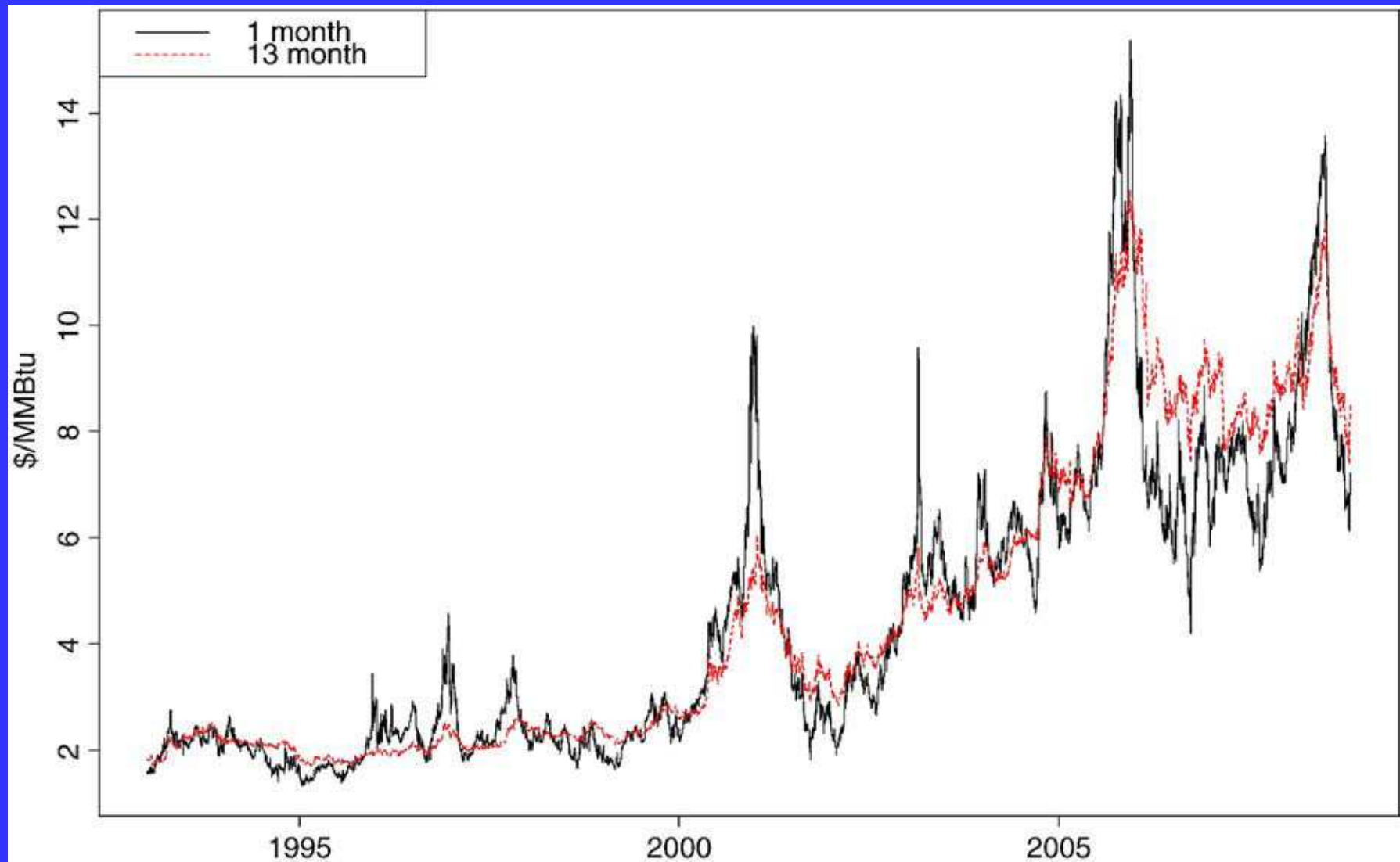
This inventory is expressed in Trillion cubic feet

→The seasonality of oil inventory over the period is not statistically significant, but there is an upward trend that we had to filter out in order to get a stationary inventory

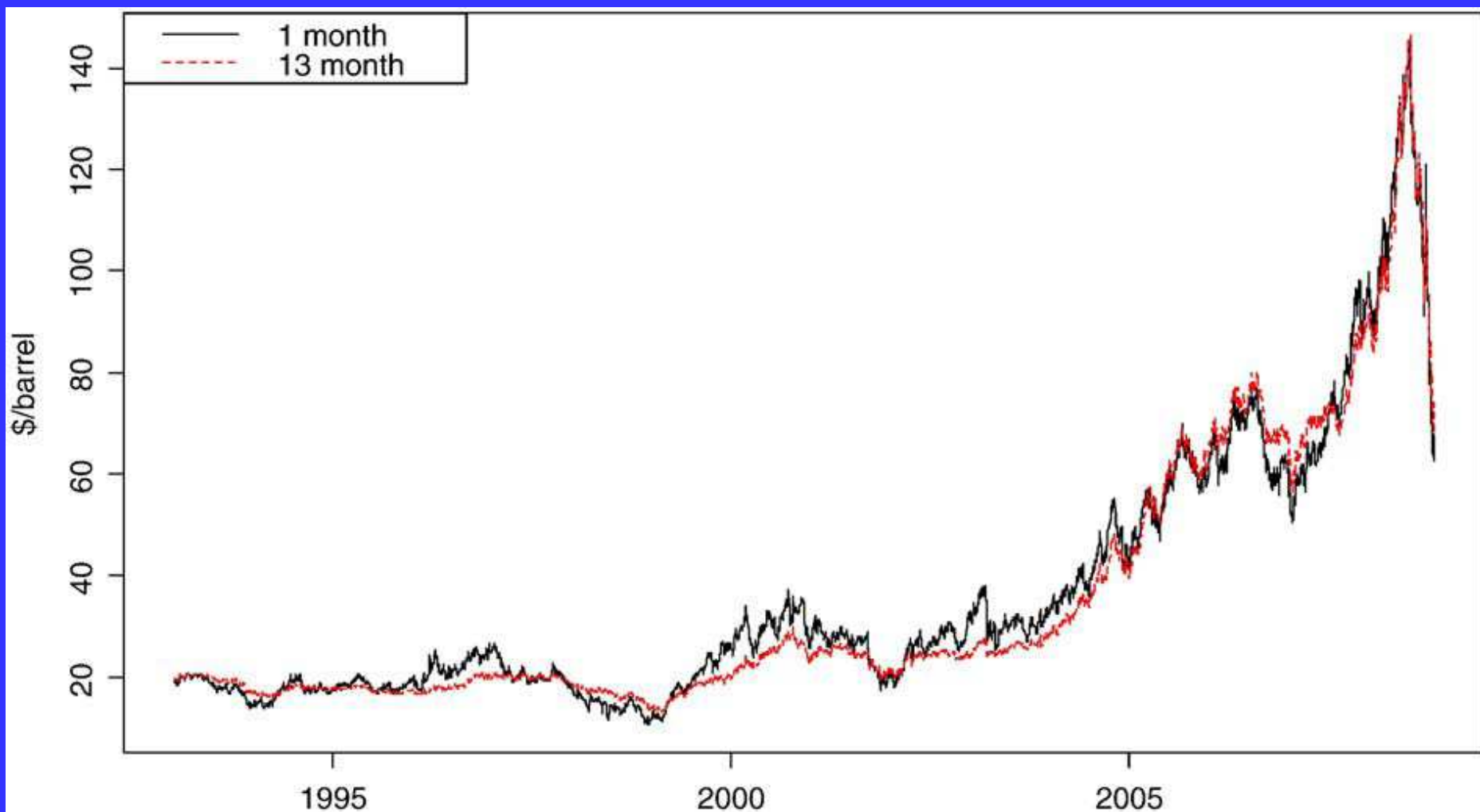
Detrended inventory of petroleum products in OECD countries in billion barrels



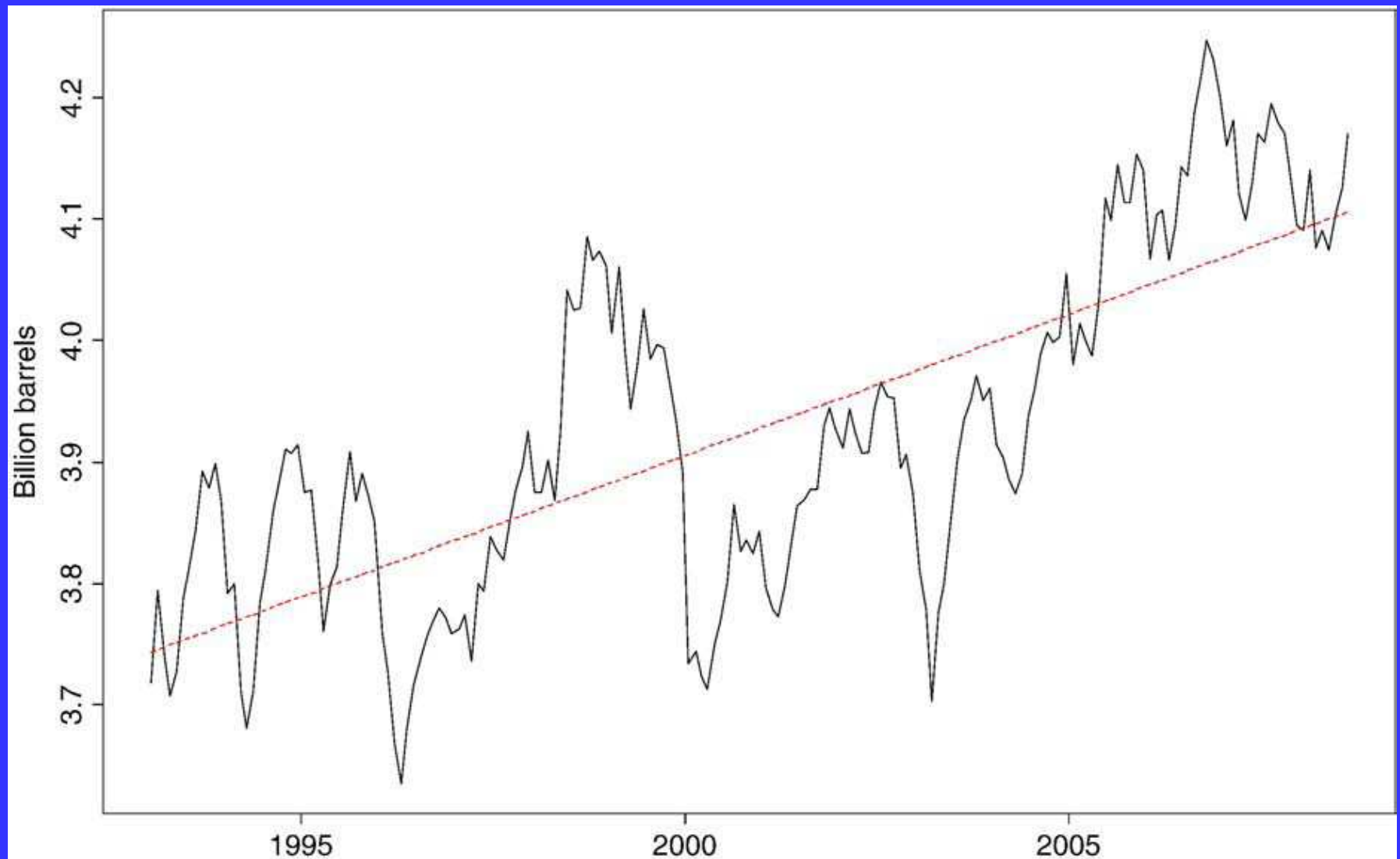
Frontmonth and 13th month Natural Gas Futures Prices



Frontmonth and 13th month Crude Oil Future Prices



End- of- month Petroleum Products OECD Inventory and Linear Fit



Regression Results

→ For natural gas, the relation obtained between the relative spread and *deseasonalized inventory* is the following

$$\text{Adjusted -spread} = 0.91 - 0.445 \text{ Inv}$$

where

- ♦ the residual standard error is 0.10
- ♦ $R^2 = 0.54$

→ For crude oil, the relationship between the relative spread and *original inventory* is

$$\text{Adjusted -spread} = 1.139 - 0.285 \text{ Inv}$$

with

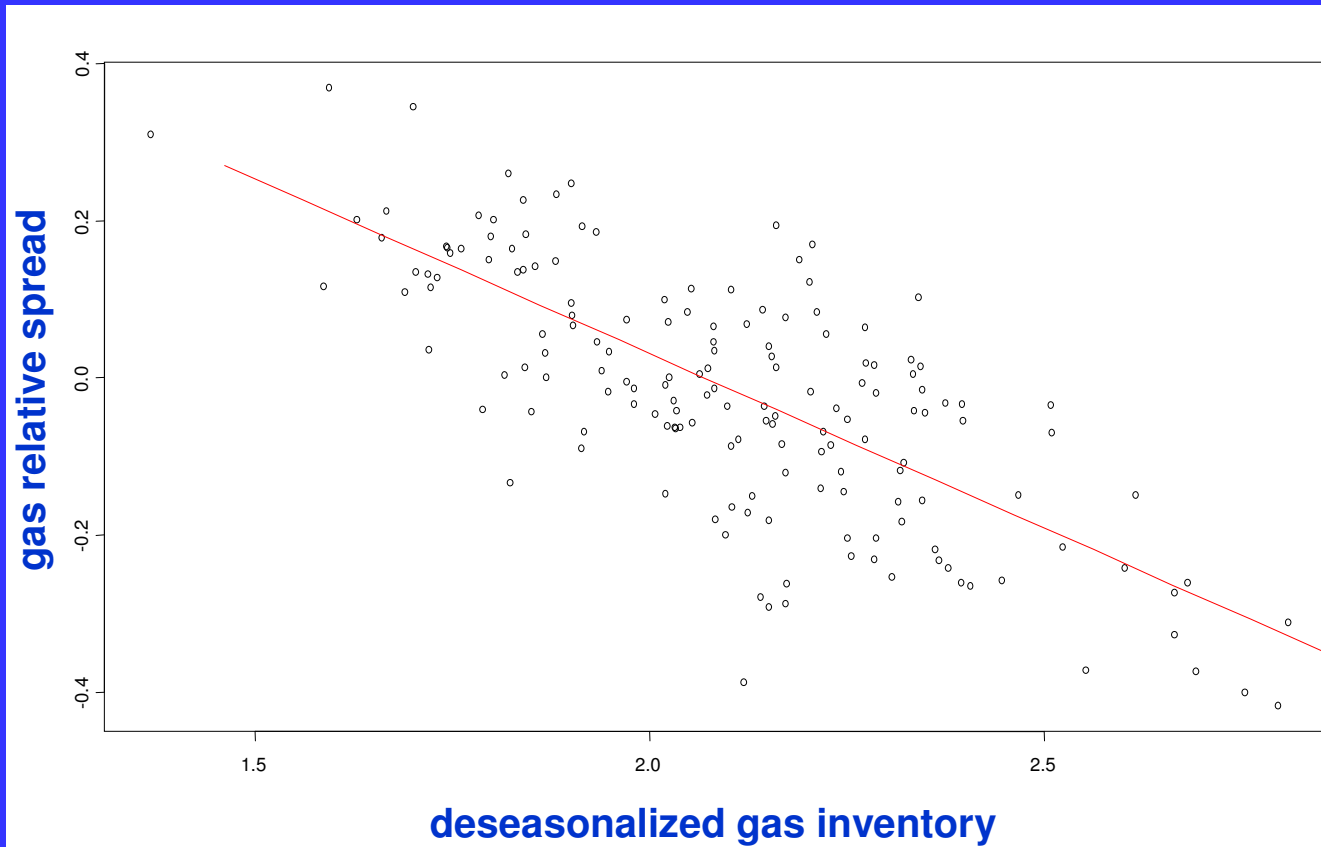
- ♦ residual standard error = 0.10
- ♦ $R^2 = 0.12$

→ Using *detrended inventory*, it becomes

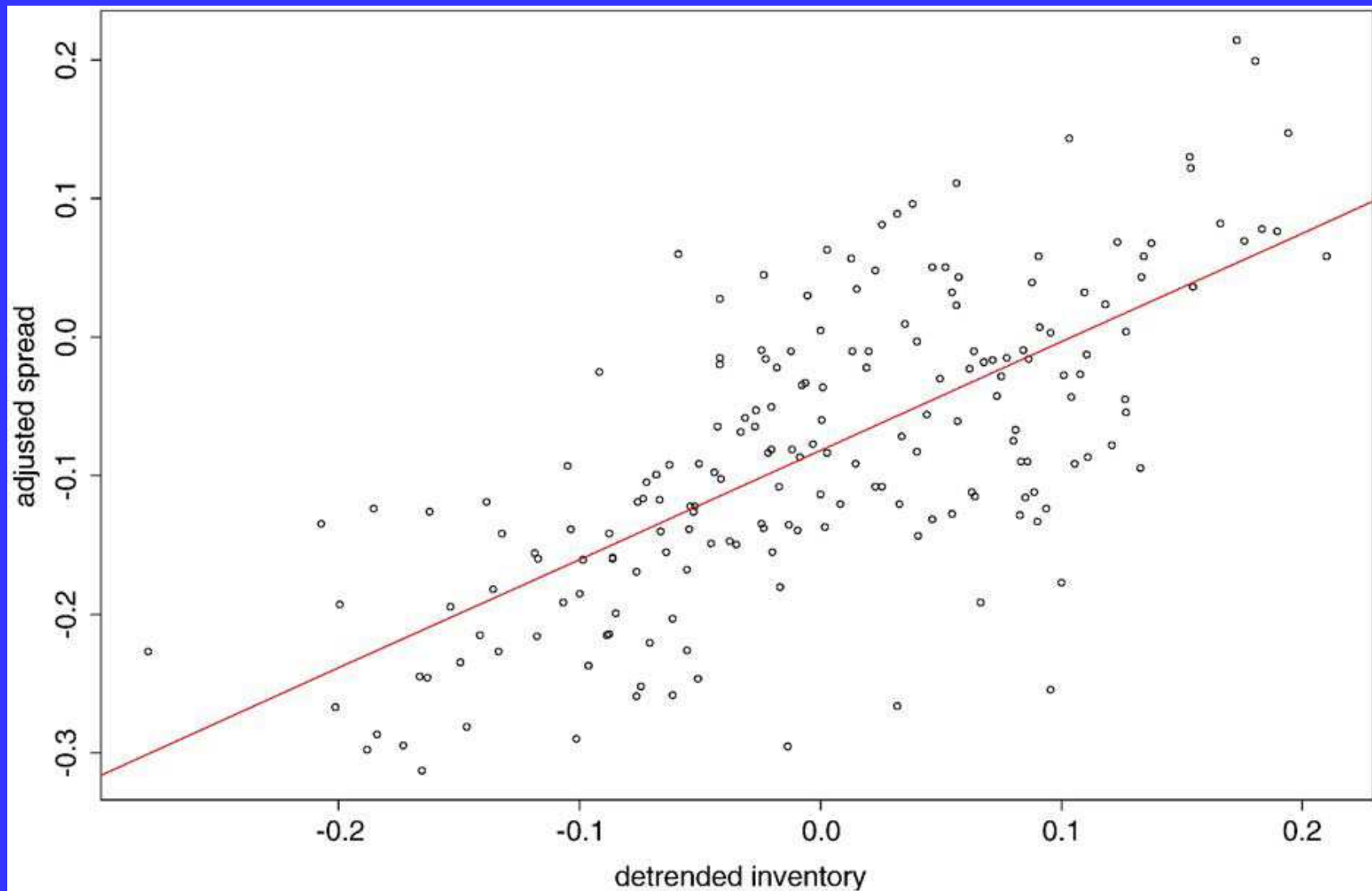
$$\text{Rel-spread} = 0.046 - 0.691 \text{ Inv}$$

with

- ♦ Residual standard error = 0.092
- ♦ $R^2 = 26\%$



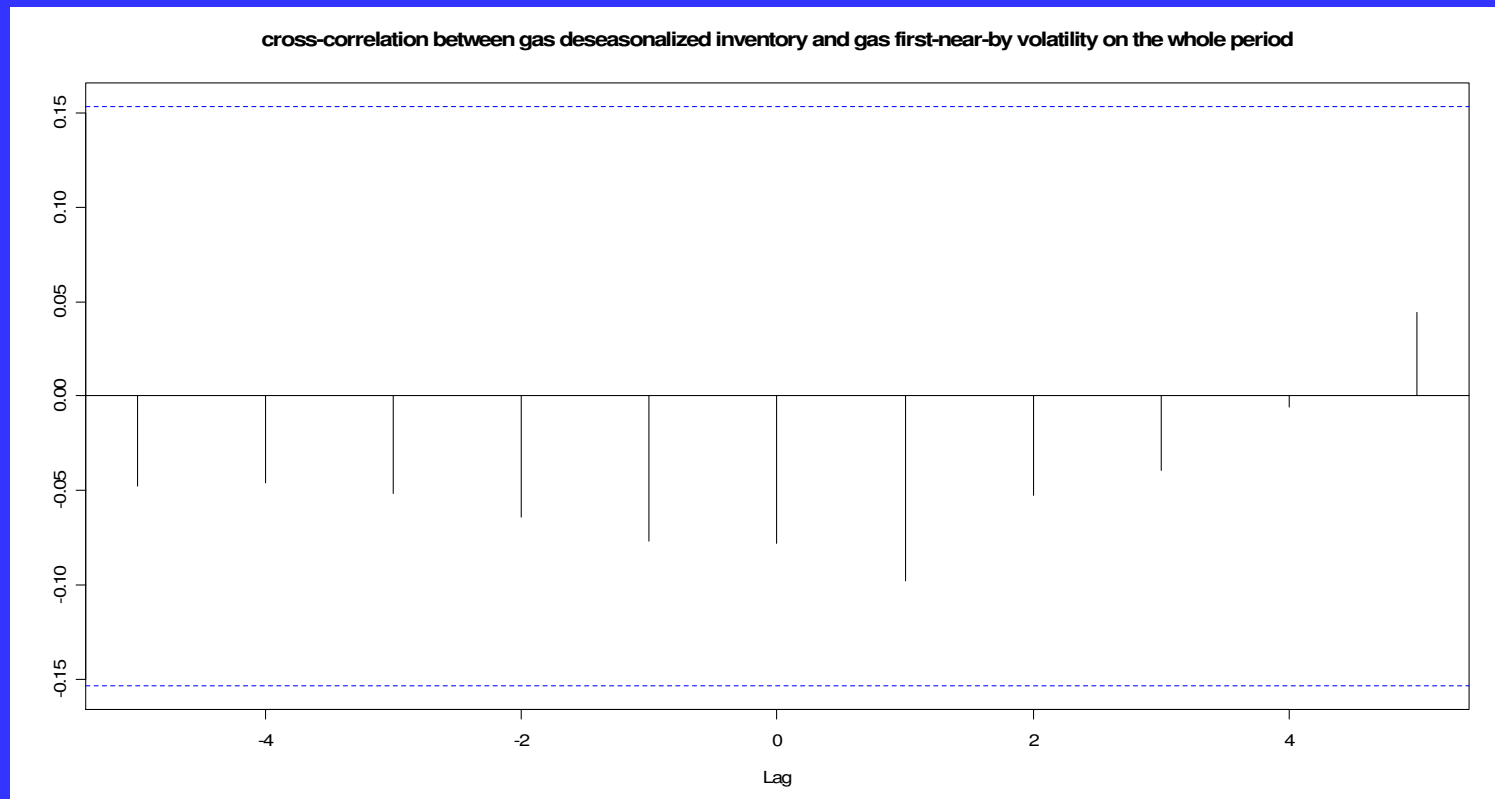
Crude Oil Adjusted Spread vs Detrended Inventory



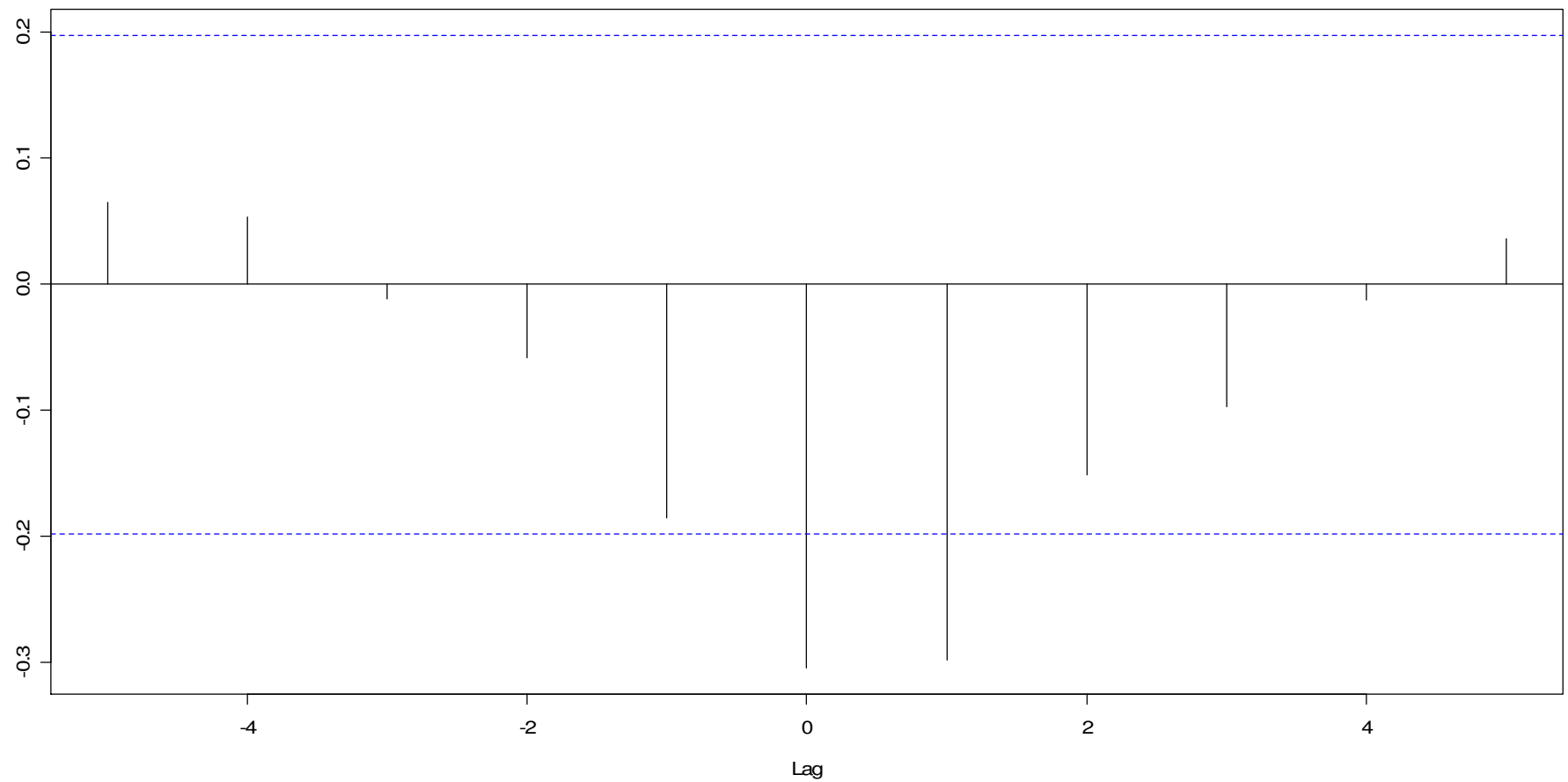
The Relations between Inventory and Volatility

- We compute the annualized standard deviations of the returns of first nearby futures prices on a monthly basis
- We use the deseasonalized inventory for natural gas, the detrended inventory for oil
- For both energies, we observe absence of correlation between the two variables using the whole data

→ However, when the inventory is lower than its average value (situation of *scarcity*), there is a negative correlation between inventory and volatility



cross-correlation between crude detrended inventory and crude first-near-by volatility in periods of scarcity



Héllyette Geman

Héllyette GEMAN is a Professor of Finance at Birkbeck, University of London and ESCP Europe. She is a graduate of Ecole Normale Supérieure in mathematics, holds a Masters degree in theoretical physics and a PhD in mathematics from the University Pierre et Marie Curie and a PhD in Finance from the University Pantheon Sorbonne. Professor Geman has been a scientific advisor to a number of major energy companies for the last decade, covering the spectrum of oil, natural gas and electricity as well as agricultural commodities origination and trading. She was previously the head of Research and Development at Caisse des Depots.

She has published more than 100 papers in major finance journals including the Journal of Finance, Mathematical Finance, Journal of Financial Economics, Journal of Banking and Finance and Journal of Business. She has also written a book entitled *Insurance and Weather Derivatives* and is a Member of Honor of the French Society of Actuaries. Professor Geman's research includes asset price modelling using jump-diffusions and Lévy processes, commodity forward curve modelling and exotic option pricing for which she won the first prize of the Merrill Lynch Awards. She was named in 2004 in the Hall of Fame of Energy Risk. Her reference book *Commodities and Commodity Derivatives* was published by Wiley Finance in January 2005.

Professor Geman is a Member of the Board of the UBS-Bloomberg Commodity Index.

References

- A. Cartea, M. Figueroa and H.Geman (2009) “ Modeling Electricity Prices under Forward Looking Capacity Constraints”, *Applied Mathematical Finance*
- H Ohana (2009) "Inventory, Reserves and Price volatility in Oil and Natural Gas Markets", *Energy Economics*.
- H.Geman and Yfong Shi (2008) “ The CEV model for Commodity Prices”, *Journal of Alternative Investments*
- H. Geman and S. Kourouvakalis (2009) "A Lattice-Based Method for Pricing Electricity Derivatives under the Geman-Roncoroni Model", *Applied Mathematical Finance*
- S. Borovkova and H. Geman (2007) "Seasonal and Stochastic Effects in Commodity Forward Curves", *Review of Derivatives Research*
- H. Geman and A. Roncoroni (2006) "Understanding the Fine Structure of Electricity Prices", *Journal of Business*
- H. Geman (2005) "Energy Commodity Prices: Is Mean Reversion Dead", *Journal of Alternative Investment*
- H. Geman (2005) "Commodities and Commodity Prices: Pricing and Modelling for Agriculturals, Metals and Energy", *Wiley Finance*
- H. Geman and V. Nguyen (2005) "Soybean inventory and forward curves dynamics", 2005, *Management Science*
- H. Geman and M. Yor (1993) "An Exact Valuation for Asian Options", *Mathematical Finance*
- A. Eydeland and H. Geman (1999) "Fundamentals of Electricity options" in *Energy Price Modelling*, Risk Books
- H. Geman and O. Vasicek (2001) "Forwards and Futures on Non Storable Commodities", *RISK*
- H. Geman (2002) "Pure Jump Lévy Processes for Asset Price Modelling", *Journal of Banking and Finance*
- H. Geman (2003) "DCF versus Real Option for Pricing Energy Physical Assets" Conference of the International Energy Agency - Paris - March 2003

h.geman@bbk.ac.uk