THE SIMPLE ECONOMICS OF COMMODITY PRICE SPECULATION

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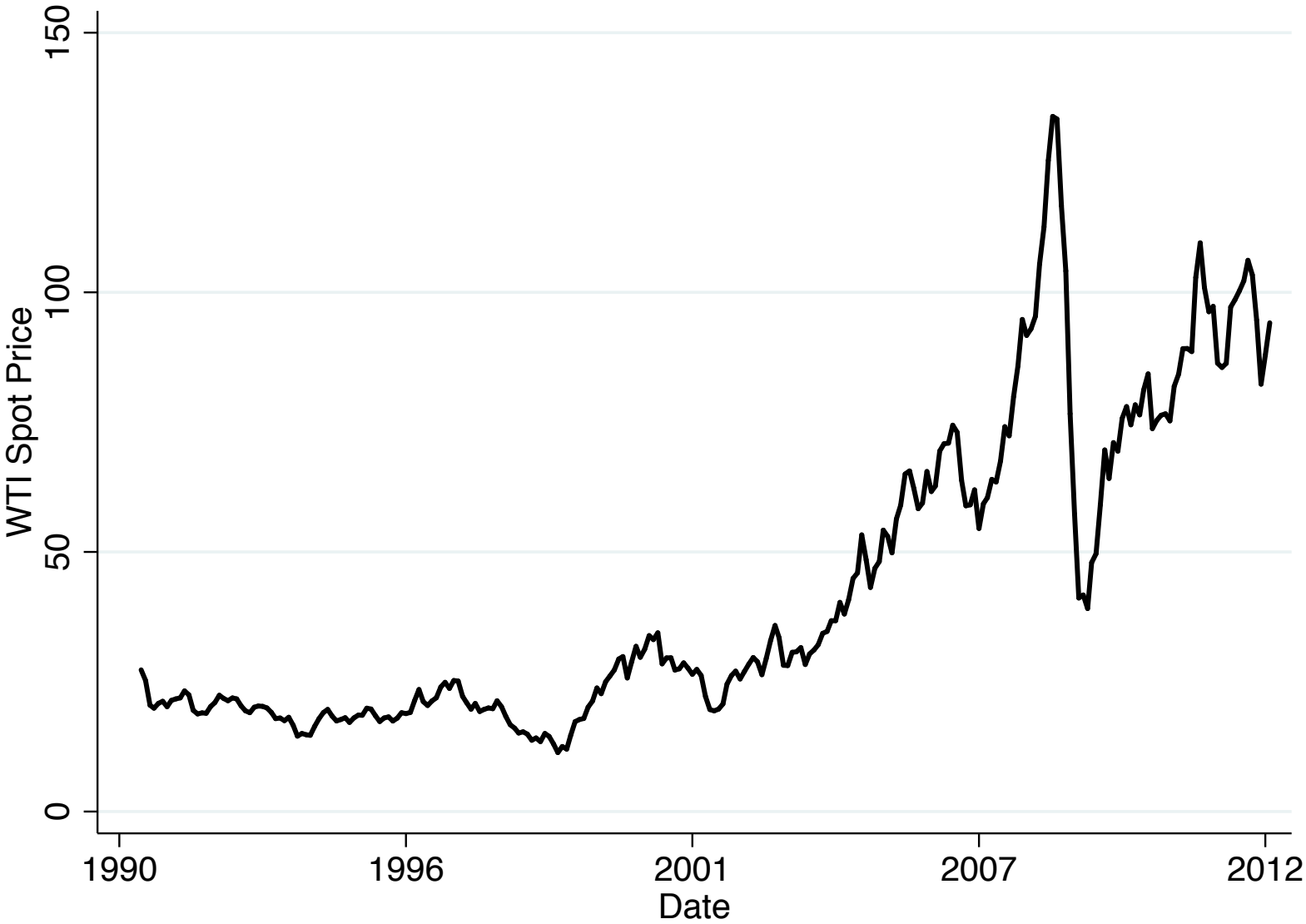
Introduction

- *"Commodities have become an investment class: declines in their prices may simply reflect the whims of speculators."*
  The Economist, June 23, 2012.
- *"Federal legislation should bar pure oil speculators entirely from commodity exchanges in the United States."*
  Joseph Kennedy II, *N.Y. Times*, April, 10, 2012.
- Sharp increases in oil prices:
  - \$40 per barrel in 2004 to \$70 in 2006 to \$140 in July 2008.
  - Fell to \$38 in early 2009, then increased to \$110 in 2011.
- Are "speculators" to blame? Should futures trading be limited?
- Confusion over commodity price speculation and how it works.
- We try to clarify the potential and actual effects of speculators on commodity prices.
- Focus on crude oil because it has received the most attention.

WTI Crude Oil Price



Outline

- What is meant by "oil-price speculation?" How does it relates to investment in oil reserves, inventories, or derivatives?
- How can one speculate on oil prices? (There must be 50 ways.)
- How will different forms of speculation affect the spot price?
- We focus on futures contracts as vehicle for speculation.
  - How does greater demand for futures affect spot prices?
  - How would other variables (e.g., inventories) be affected?
  - *Did* buying of futures drive up spot prices?
- We show that although we cannot rule out that speculation had *any* effect on oil prices, we can indeed rule out speculation as an explanation for sharp price changes since 2004.

Related Research

- Others have also investigated causes of oil price changes and role of speculation.
  - Kilian and Murphy show ...
  - Juvenal and Petrella (2011) show ...
  - Hamilton (2009) provides overview of possible causes of oil price changes and concludes that speculation played some role in the price increase during summer 2008.
  - Smith (2009) finds no evidence that speculation increased prices between 2004 and 2008. Notes that inventories fell and non-OPEC producers did not reduce output.
- We use a simple model of supply and demand in the cash and storage markets. Lets us determine whether speculation as driver of price changes is consistent with data on production, consumption, inventory changes, and spot and futures prices.

What Is "Oil Price Speculation?"

- We define oil price speculation as *purchase (or sale) of oil-related asset with expectation that price of the asset will rise (or fall) to create opportunity for a capital gain*.
- A variety of assets are available: futures, shares of oil companies, and reserves of oil are examples.
- How to distinguish speculation from an oil-related *investment*, which we define as purchase or sale of an asset such that expected NPV is positive? For example:
  - Purchase or sale of oil futures (or other derivatives), not to "beat the market," but to hedge against price fluctuations that could lead to bankruptcy.
  - Purchase of oil-related financial assets, e.g., futures or oil company shares, to diversify a portfolio.

Speculation vs. Investment

- Difficult or impossible to differentiate between speculative activity and investment.
- What we call an "investment" and what we call "speculation" are likely to be the same thing, or at best ambiguous.
- What oil price speculation is *not*: a shift in fundamentals, e.g., shift in consumption demand or supply (e.g., strike or hurricane that shuts down some output).
- Want to distinguish that from a price change caused by speculators or investors betting on a change in price not already accounted for by expected shifts in demand and supply.

How to Speculate on Oil Prices

- Buy Stocks of Oil Companies. This is most common way to speculate (or invest) in oil.
- If speculators become "bullish" and buy oil company stocks, driving up stock prices, what would it do to price of oil?
  - In the short run, would have no effect on oil production or consumption, and thus no effect on price of oil.
  - In longer run, stock prices of oil companies will be higher than otherwise, lowering companies' cost of capital.
  - Would encourage investment in exploration and development, and eventually lead to more oil production and *lower prices*.

How to Speculate on Oil Prices

- Hold Physical Oil in situ. Can "speculate" on higher prices by keeping the oil in the ground rather than producing it.
- Something oil companies can do, but not hedge funds.
- Depends on whether reserves are *undeveloped* or *developed*.
  - *Undeveloped reserves* have been discovered, but production requires large sunk cost investments in development. To "bet" on price increase, oil company could delay development.
  - What would happen? Lower production and higher prices — but only after one or two years.
  - Evidence? Normally rising oil prices increase the return from development, and lead to rising rig rental rates and rig utilization. Were rig rates and utilization instead falling?
  - *Developed reserves* have production wells, etc. needed to produce oil. But once reserve is developed and production begins, rate of production cannot be easily varied.
  - So this is not an economical way to speculate.

How to Speculate on Oil Prices

- Hold Physical Oil Above Ground. Oil producers and consumers normally hold inventories, e.g., to facilitate production and delivery scheduling and avoid stockouts.
- In principle, inventories could be held to speculate: Buy oil and store it in tanks, oil tankers, etc.
- Not something hedge funds or mutual funds can do.
- Were oil companies (or industrial consumers of oil) accumulating "excess" inventories during periods of suspected speculation?
- Can test for this using futures price data.
- Hold Oil Futures. The easiest, lowest cost, and most common way to speculate on oil prices.
  - very low transaction costs, even for individual investor.
  - Important means of investment for hedge funds, some ETFs, mutual funds, and also individuals.
  - Most common means for oil price speculation.

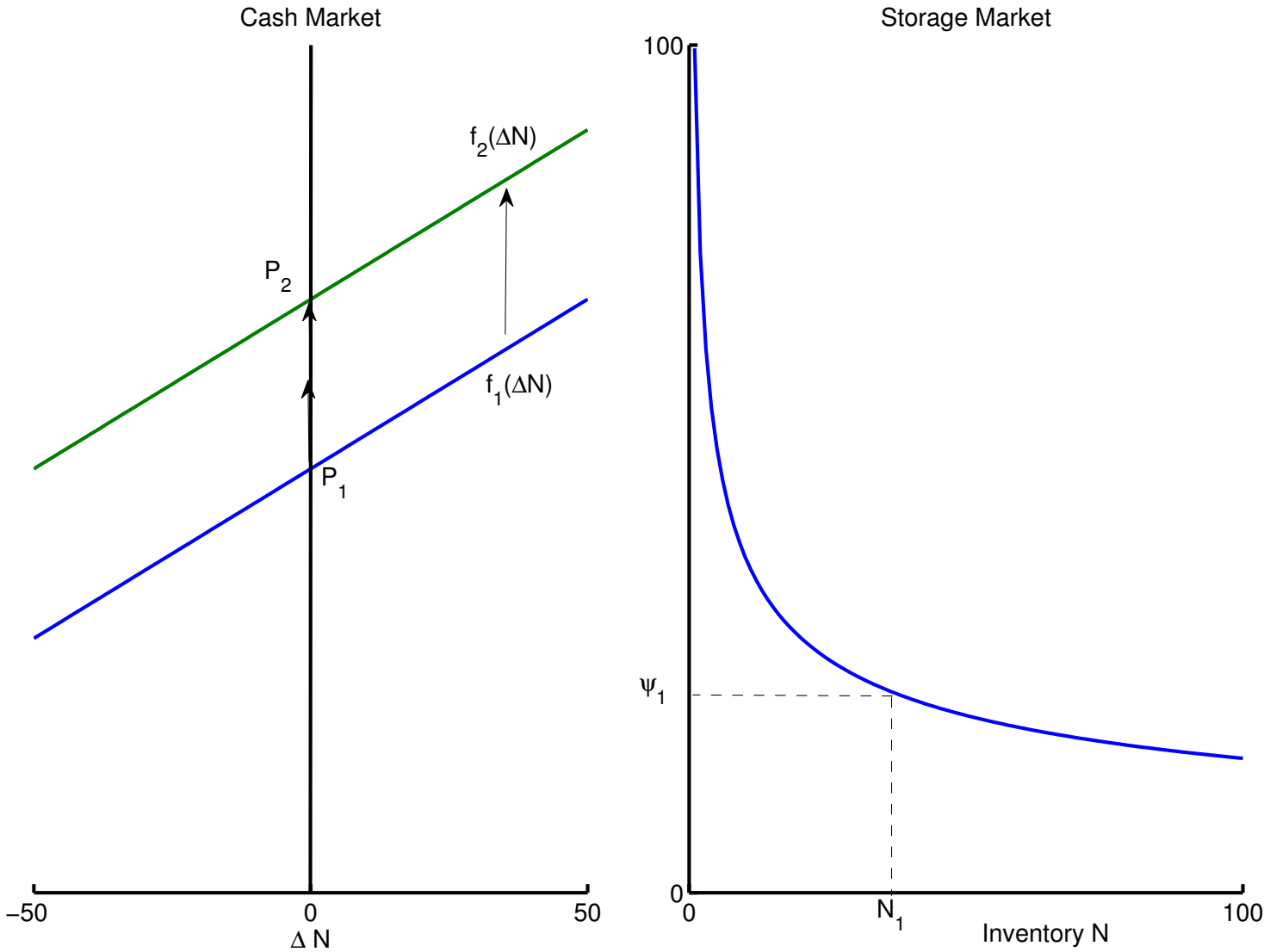
Framework

- Two interrelated markets for a commodity:
  - *Cash market* for immediate, or "spot," purchase and sale.
  - *Storage market* for inventories of the commodity.
  - Although price of storage is not directly observed, it can be determined from futures-spot spread.
  - Price of storage equals marginal value of storage, i.e., the flow of benefits to inventory holders from marginal unit of inventory. Called *marginal convenience yield*.
- Cash Market. Purchases and sales for immediate delivery occur at "spot price" P.
  - Demand: $Q = Q(P; z_1, \epsilon_1)$, where z_1 is vector of demand-shifting variables, ϵ_1 is random shock.
  - Supply: $X = X(P; z_2, \epsilon_2)$, where z_2 is a vector of supply-shifting variables, ϵ_2 is random shock.
  - Change in inventories: $\Delta N_t = X(P_t; z_{2t}, \epsilon_{2t}) - Q(P_t; z_{1t}, \epsilon_{1t})$

Framework (Con't)

- ΔN_t is *net demand*. So cash market is in equilibrium when net demand equals net supply. Can write this using *inverse net demand function*: $P_t = f(\Delta N_t; z_{1t}, z_{2t}, \epsilon_t)$.
- Market clearing in the cash market is therefore a relationship between spot price and change in inventories.
- In figure, $f_1(\Delta N)$ is inverse net demand function for initial z_1 and z_2, and $f_2(\Delta N)$ is inverse net demand function following increase in z_1 or decrease in in z_2.
- Storage Market. Supply of storage is total quantity of inventories held by producers, consumers, or third parties, N_t.
- Price of storage (*marginal convenience yield*), ψ_t, equals value of flow of services from holding marginal unit of inventory.
- Right-hand part of figure. Can write the inverse demand function as $\psi = g(N; z_3, \epsilon_3)$

Permanent Increase in Demand



Spot Price, Futures Price, Convenience Yield

- To avoid arbitrage, $\psi_{t,T}$ must satisfy:

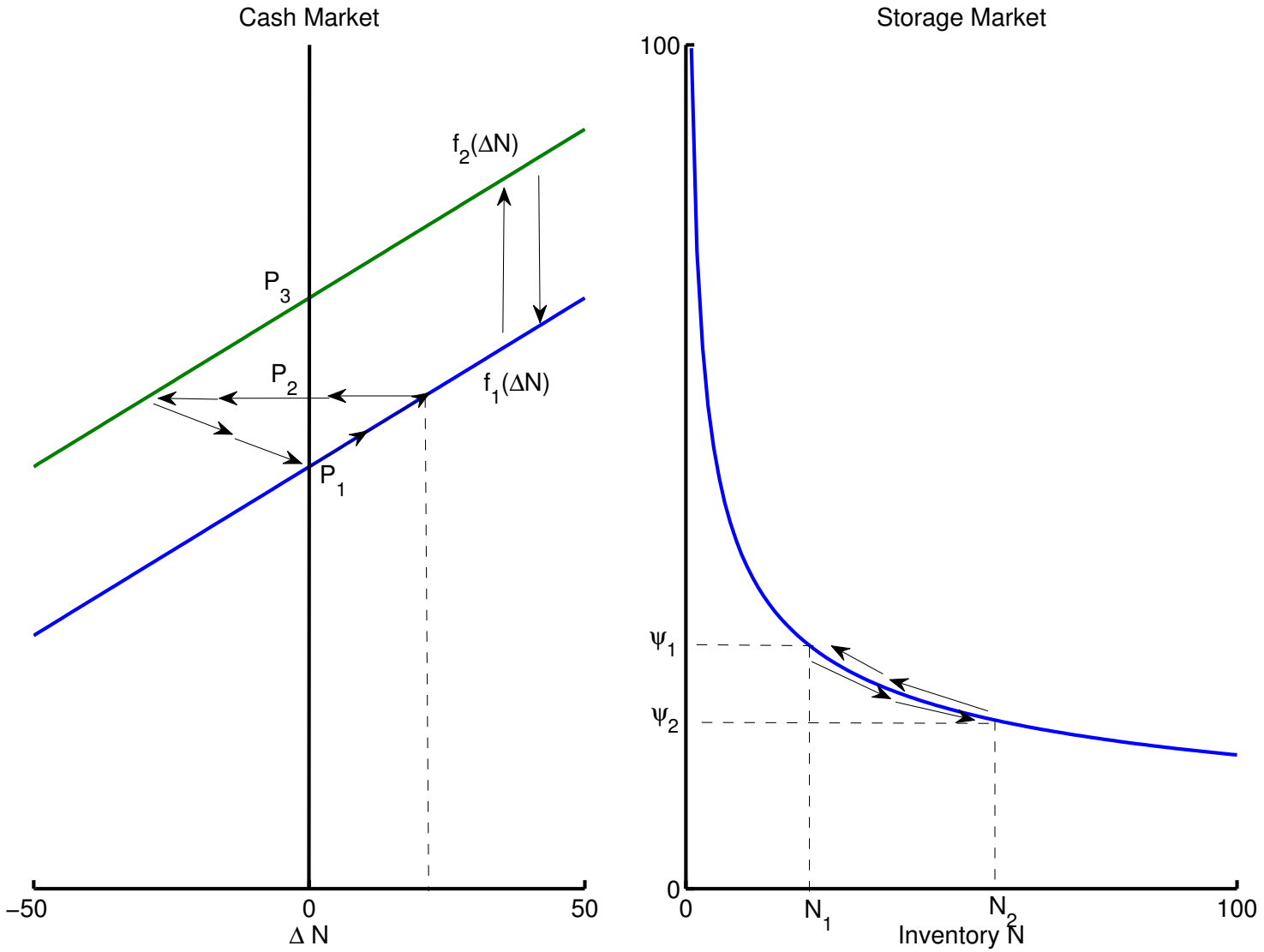
$$\psi_{t,T} = (1 + r_T)P_t - F_{t,T} + k_T$$

  $F_{t,T}$ is futures price for delivery at $t + T$, r_T is risk-free T-period interest rate, and k_T is T-period storage cost.
- Want to see how changes in futures price affect spot price, so rewrite with P_t on LHS:

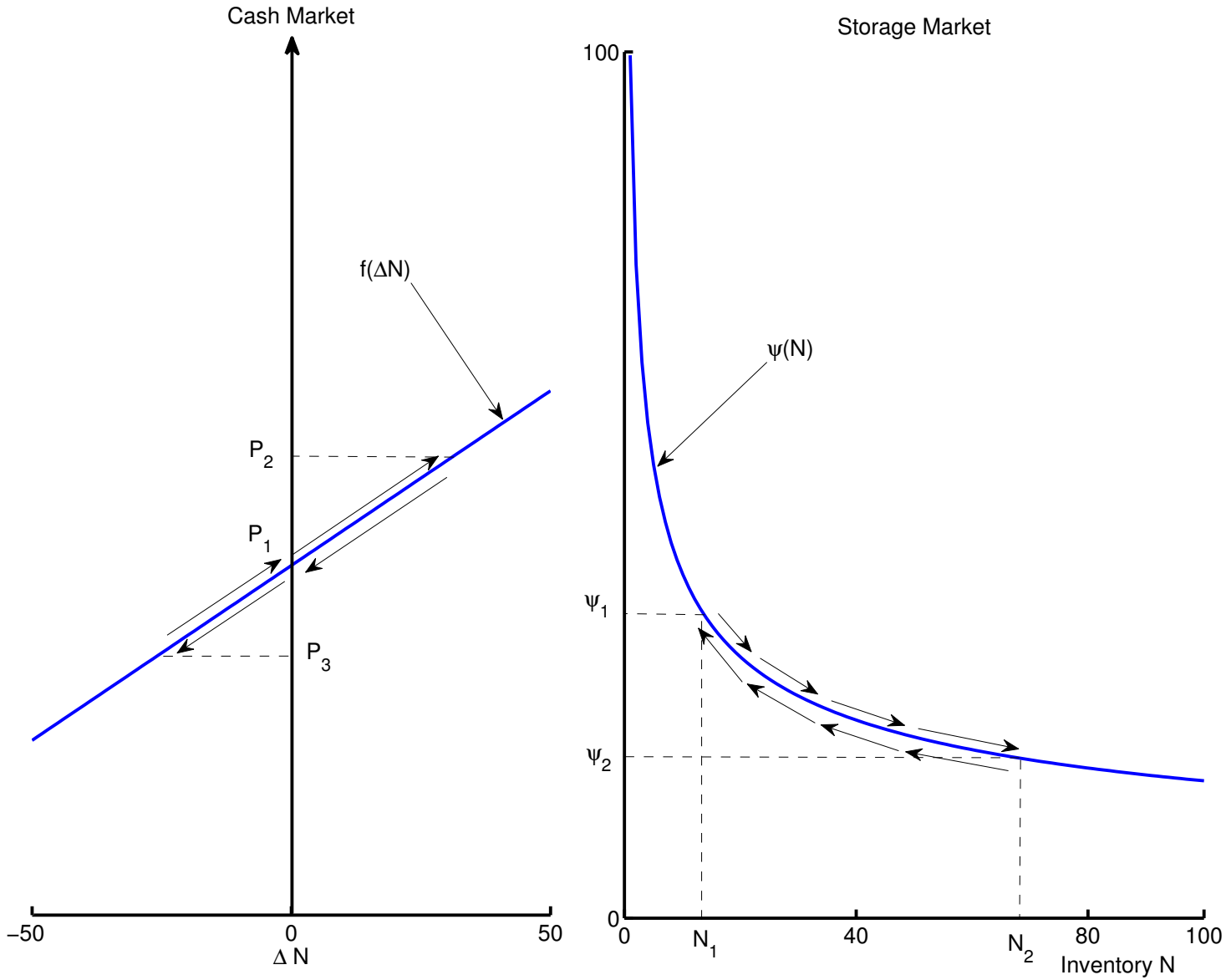
$$P_t = \frac{1}{1 + r_T}[F_{t,T} + \psi_{t,T} - k_T] \ .$$

- So increase in $F_{t,T}$ leads to increase in P_t—unless there is a equivalent decrease in $\psi_{t,T}$ and/or increase in k_T.
  - Drop in $\psi_{t,T}$ could occur if N_t increases.
  - What if N_t can't increase because no more storage capacity?
  - Then k_T will increase sharply, limiting impact of $F_{t,T}$ on P_t.
- Key: impact of increase in $F_{t,T}$ on P_t limited by storage market.

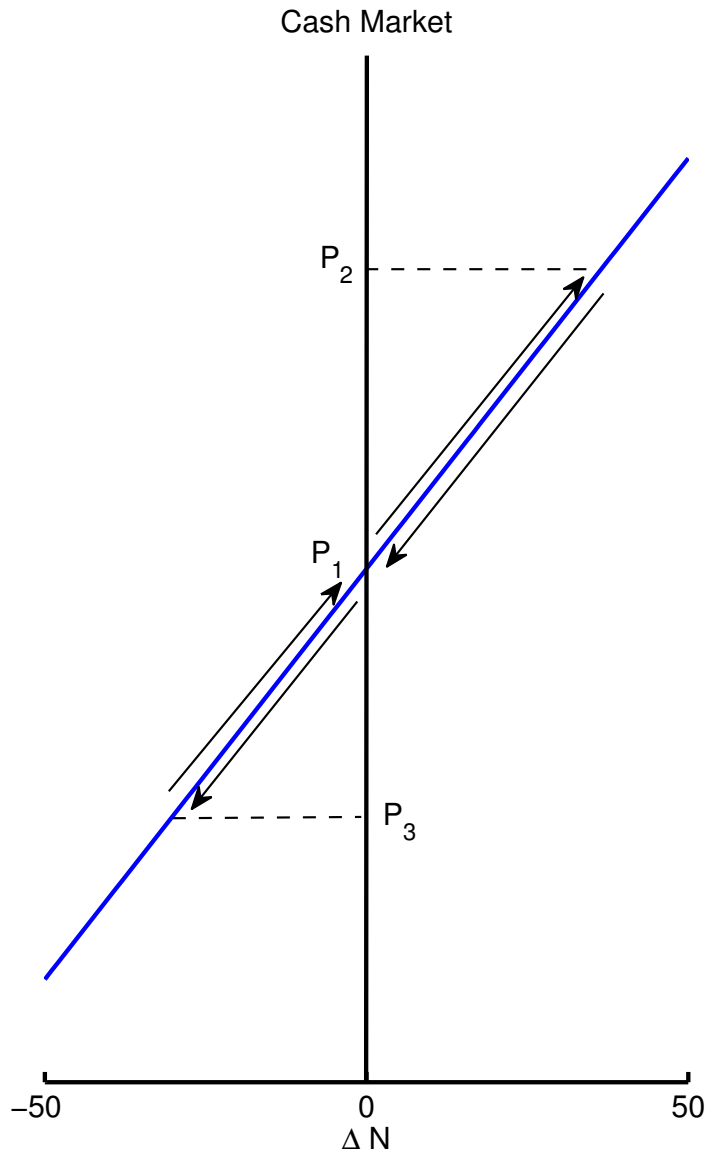
Seasonal (and Anticipated) Change in Demand

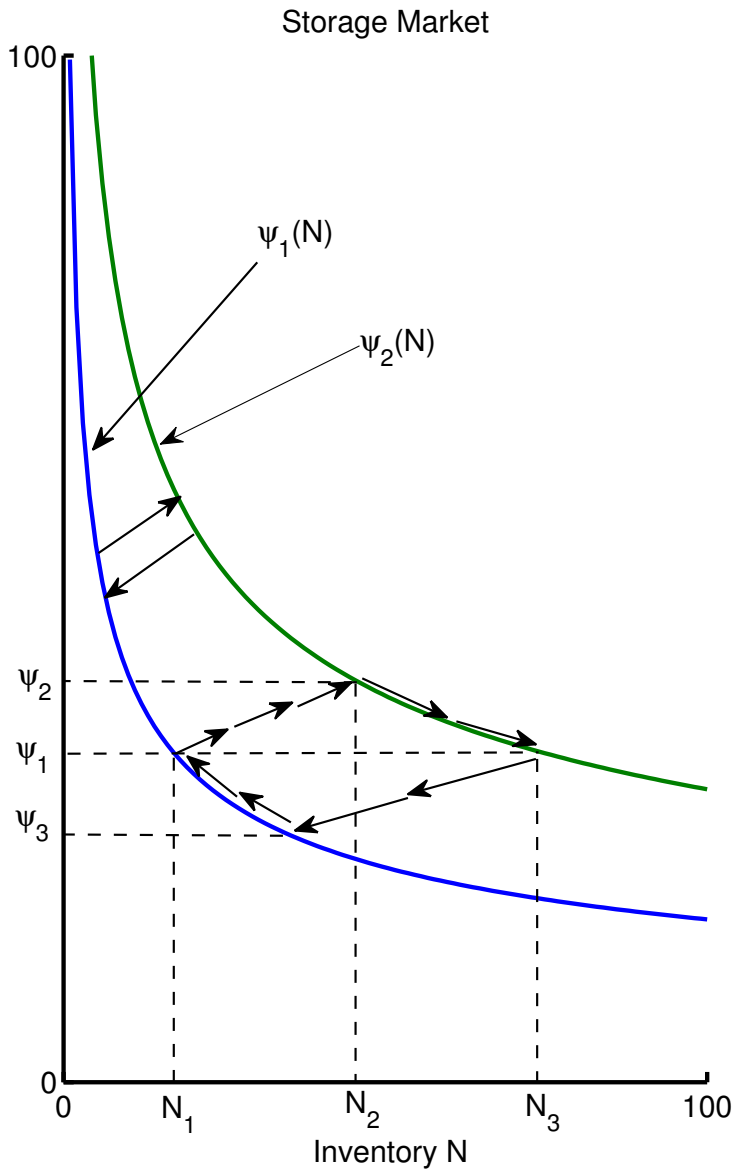


Impact of Speculation



Speculation via Inventory Accumulation





Limits to Speculative Effects

- From 2007 to 2008, WTI price went from about \$60 to \$130. Could this have been due solely to speculation?
- To answer this—using data only on cash market—calculate necessary change in inventories.
  - Supply: $X = k_S P^{\eta_S}$.
  - Demand: $Q = k_D P^{\eta_D}$.
  - Then change in inventories is $\Delta N_t = k_S P_t^{\eta_S} - k_D P_t^{\eta_D}$.
  - Calibrate to US monthly consump. of 540 MB and $P = \$60$.
  - Elasticities: $\eta_S = 0.2$ and $\eta_D = -0.2$.
  - Implies $k_S = 238.1$ and $k_D = 1224.7$.
- At price of \$130, supply would rise to 630.3 MB/month, and demand would fall to 426.1 MB/month.
  - Means inventories would have to increase at a rate of 168 million barrels *per month*!
  - Note *total* commercial inventories was 286 MB in 2007, and SPR held 700 MB.

Evaluating Impact of Speculation

- Recall $\Delta N_t = k_S P_t^{\eta_S} - k_D P_t^{\eta_D}$. Divide both sides by Q_t, rearrange and take logs:

$$(\eta_S - \eta_D) \log P_t = \log k_D - \log k_S + \log \left(\frac{\Delta N_t}{Q_t} + 1 \right)$$

- If no change in fundamentals, k_S and k_D are constant, so:

$$(\eta_S - \eta_D) \Delta \log P_t = \Delta \log \left(\frac{\Delta N_t}{Q_t} + 1 \right) \quad .$$

- Since $\Delta N_t = X_t - Q_t$, this is equivalent to:

$$(\eta_S - \eta_D) \Delta \log P_t = \Delta \log (X_t / Q_t)$$

- This ΔP_t is result of speculation or investment, not a change in fundamentals. Use this to test for speculation in three ways:

Evaluating Impact of Speculation (Con't)

- Price Behavior. Beginning with $\eta_S - \eta_D$, decompose price changes into fundamental and speculative components: $\Delta \log(P_T) = \Delta \log(P_S) + \Delta \log(P_F)$.
- Inventory Behavior. If price change is entirely due to speculation:

$$\frac{\Delta N_t}{Q_t} + 1 = \left(\frac{\Delta N_0}{Q_0} + 1\right)\left(\frac{P_t}{P_0}\right)^{\eta_S - \eta_D} .$$

- If speculation was substantial cause of price change, this ΔN_t should be close to actual ΔN_t.
- Elasticities. Given ΔP_t and ΔN_t, determine sum of elasticities needed to reconcile with pure speculation:

$$\eta_S - \eta_D = \frac{\log(\Delta N_t / Q_t + 1) - \log(\Delta N_0 / Q_0 + 1)}{\log P_t - \log P_0} .$$

- These tests all based on cash market. Speculation via inventory accumulation will manifest itself in market for storage.

Speculative Inventory Holdings

- Write (inverse) demand for storage curve as:

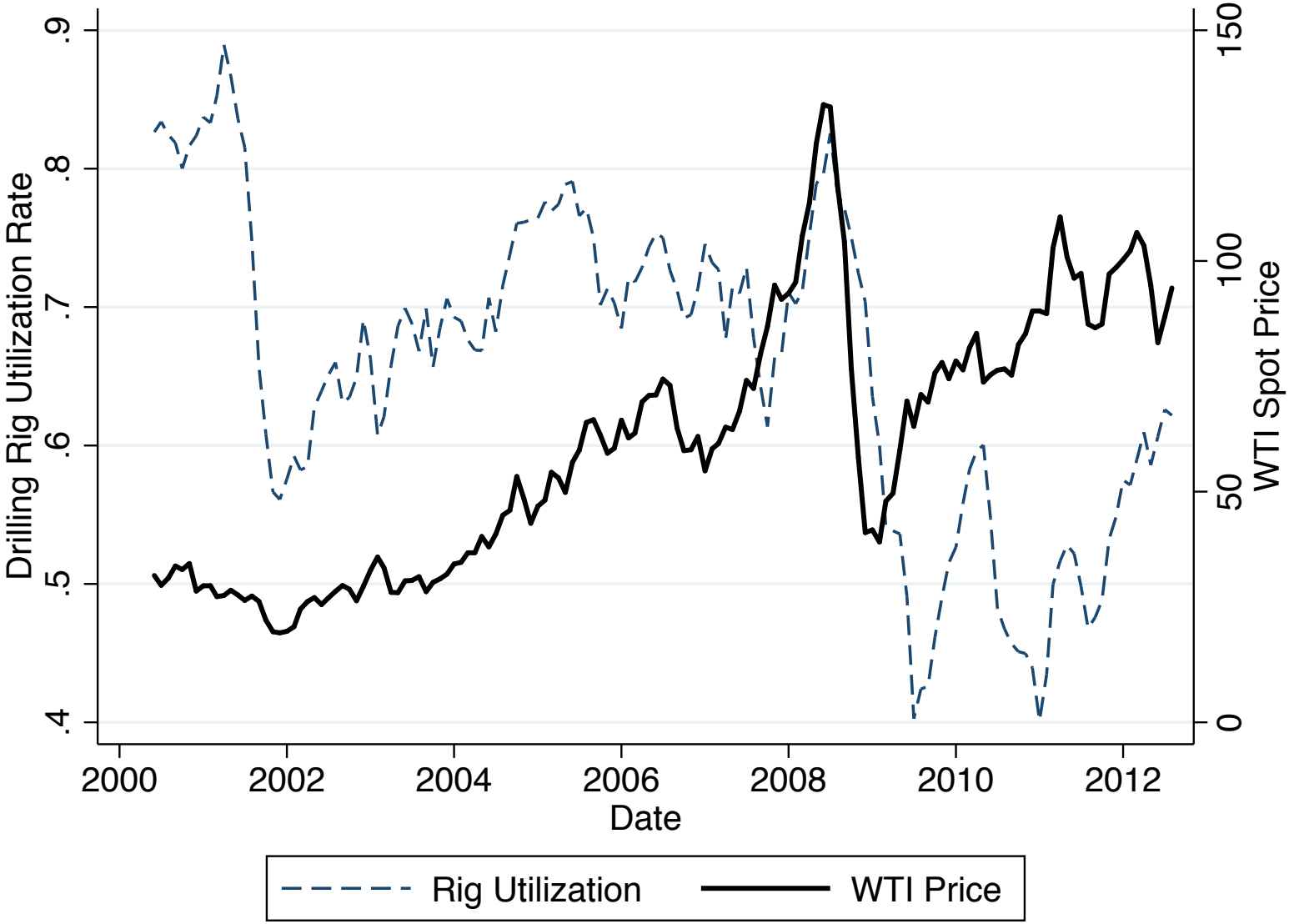
$$\psi(N_t) = P_t g(N_t) = k_N P_t N_t^{-1/\eta_N}$$

  where $\eta_N > 0$ is price elasticity of demand for storage.
- We estimated this, found $\eta_N \approx 1$, consistent with other studies.
- k_N captures other factors affecting demand for storage:
  - *Fundamentals*: increased volatility or threat of war increases k_N.
  - *Speculation*: will also increase k_N.
- Take logs and first differences of eqn. for $\psi(N_t)$:

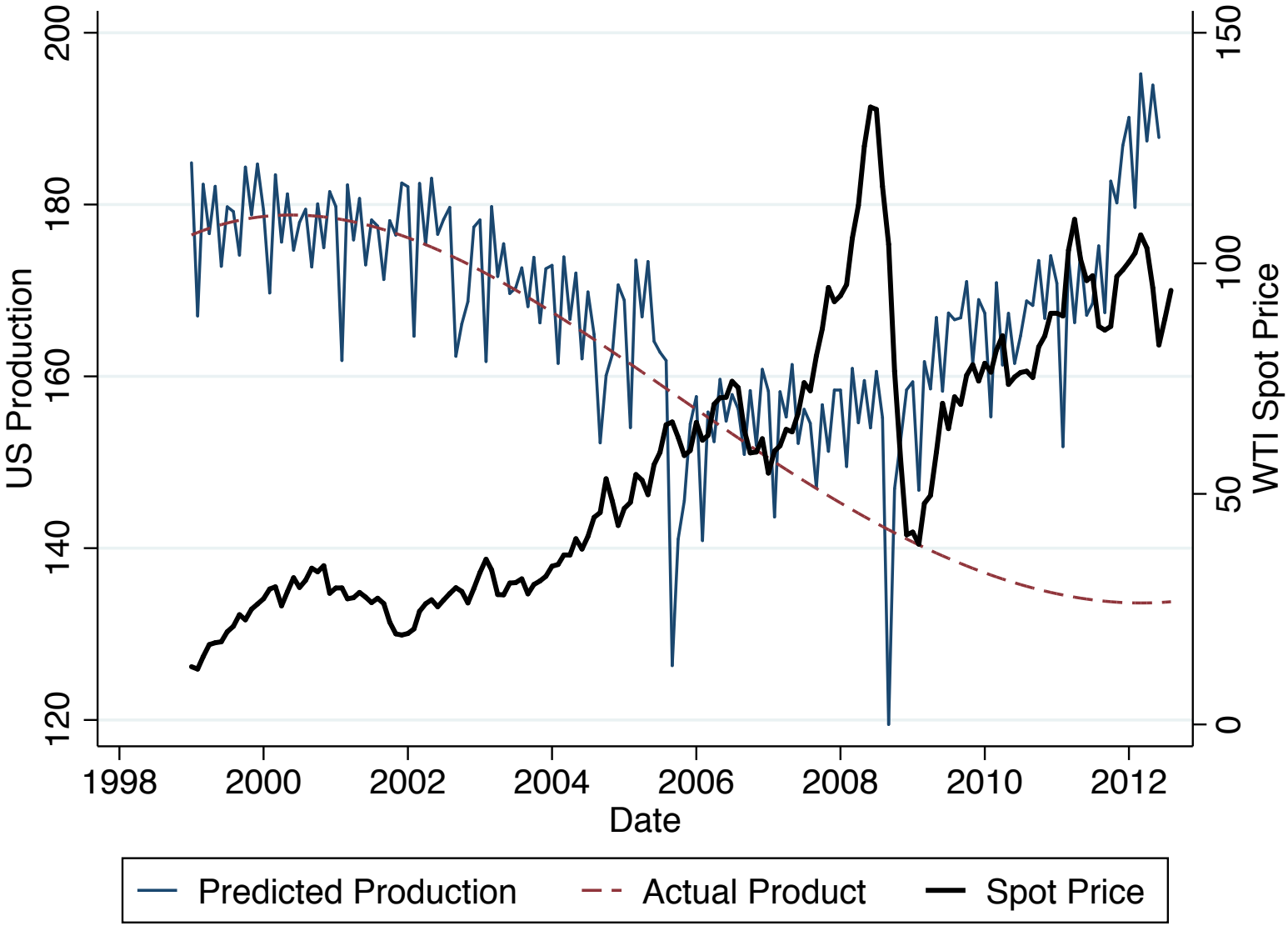
$$\Delta \log \psi_t = \Delta \log P_t - (1/\eta_N)\Delta \log N_t + \Delta \log k_N \ .$$

- Assume no change in volatility or threat of war, so last term reflects shift in demand for storage due to speculation. Use this to compare actual ψ_t to ψ_t with no speculation.

Results: Development Activity



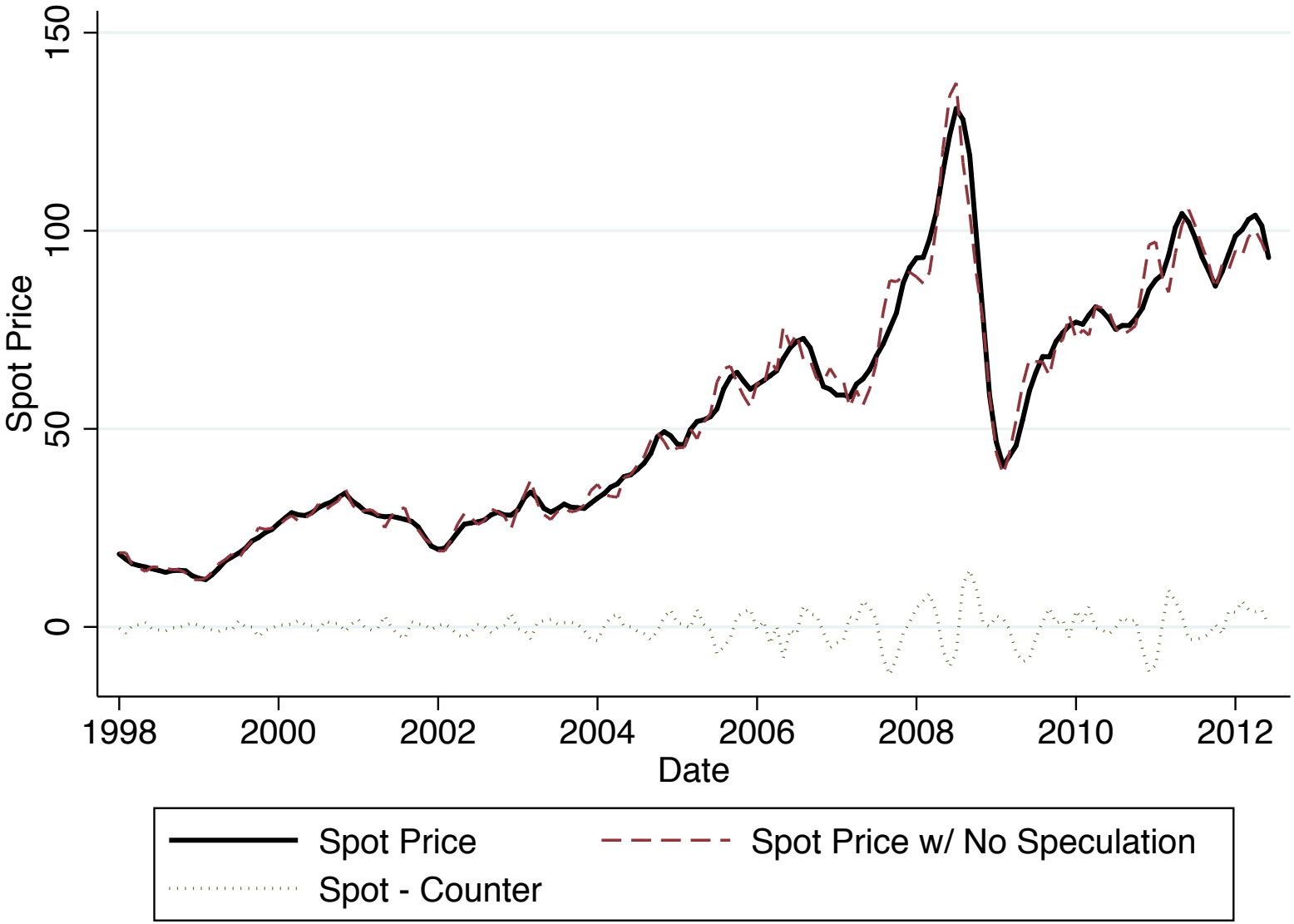
Results: Production Activity



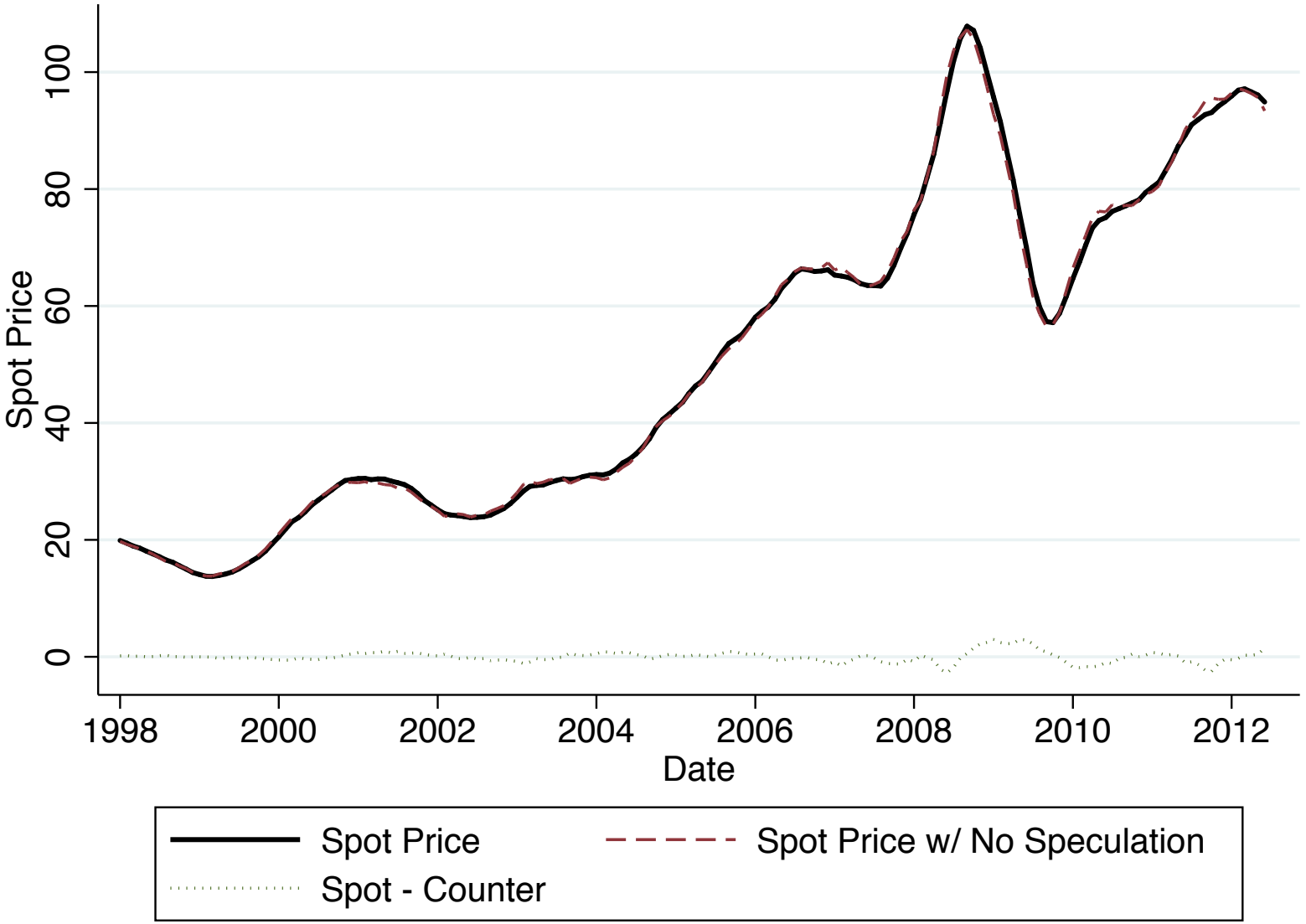
Speculation via Futures Market

- Examine price and inventory changes for non-overlapping 3-month and 12-month intervals.
  - Each price and inventory change calculated on moving month-to-month basis.
  - For each interval, calculate consumption-weighted P, average consumption, average N, and change in N over the interval.
  - We de-seasonalize inventories.
- Generate counterfactual (no speculation) prices for each interval.
- For 3-month interval, $\eta_S - \eta_D = 0.2$. For 12-month, 0.4.
- Calculate 3-month convenience yield, $\psi_{t,3}$:
  - Use 3-month T-bill rate and 3-month futures price.
  - Need net $\psi_{t,3}$, so use $k = \$1.50/\text{barrel}/\text{month}$.
  - Truncate $\psi_{t,3}$ at \$1.50 (5 of 162 months).
- Generate counterfactual $\psi_{t,3}$ using $\eta_N = 1$.

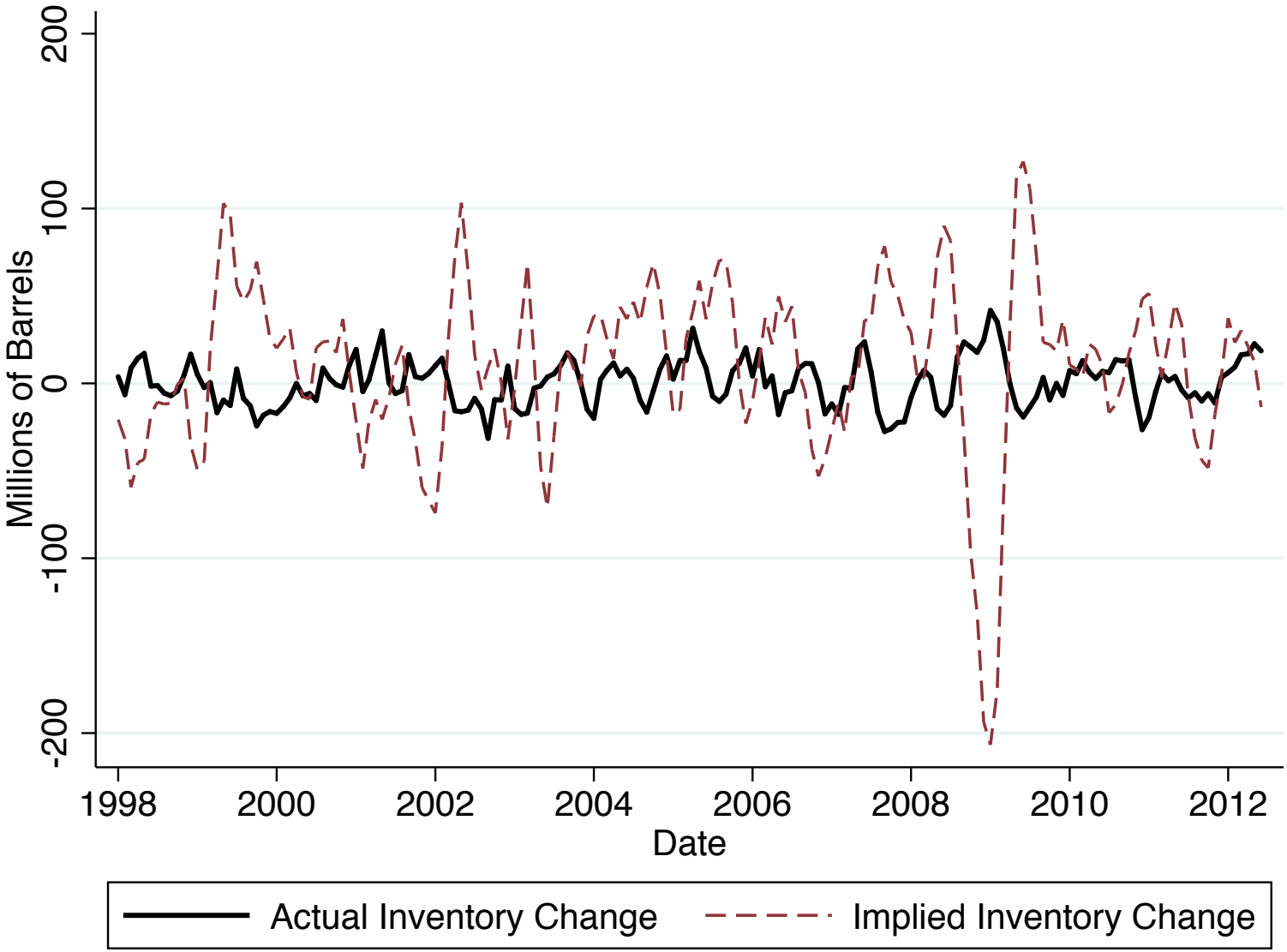
Results: Prices, 3-Month Intervals



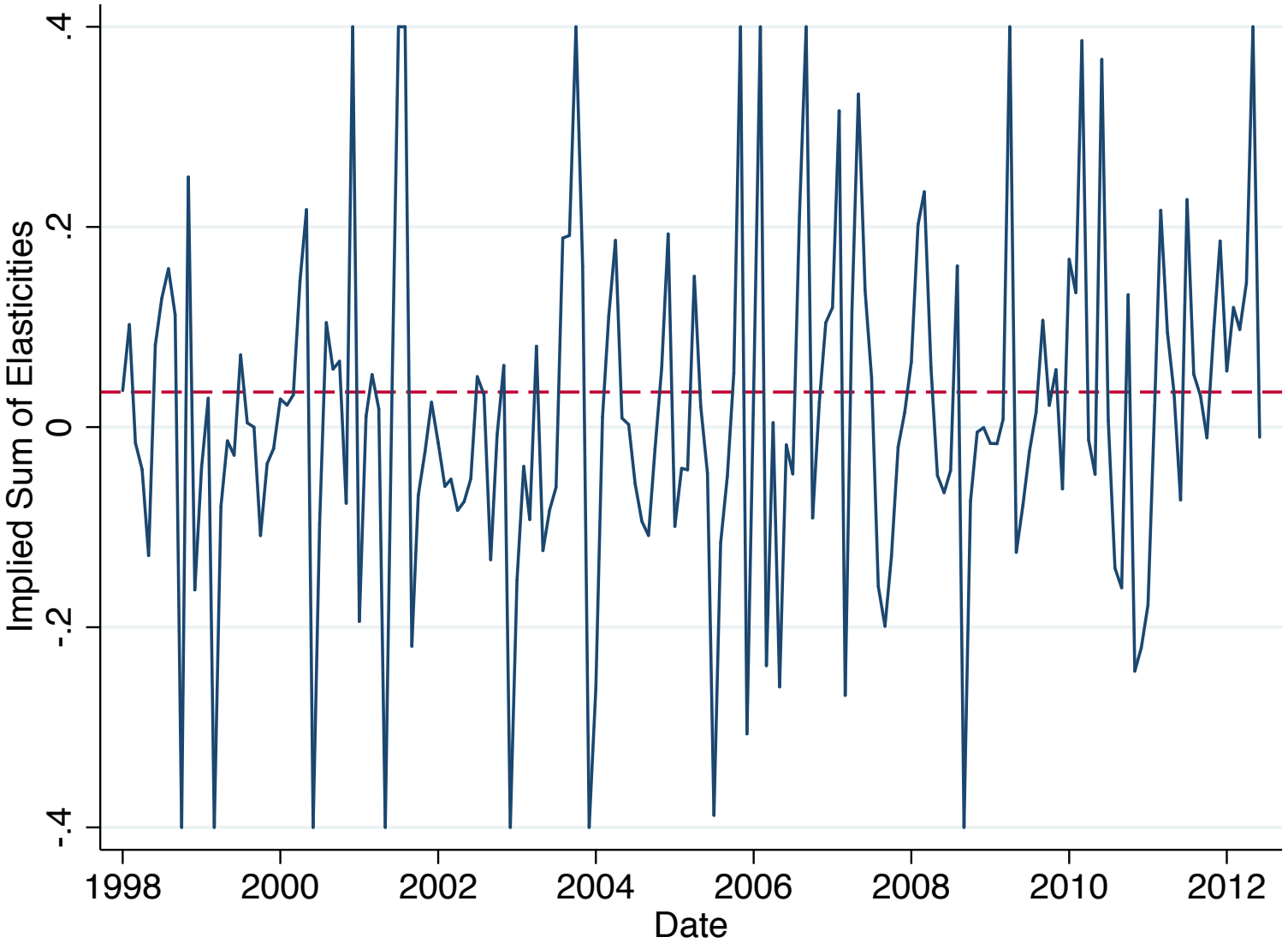
Results: Prices, 12-Month Intervals



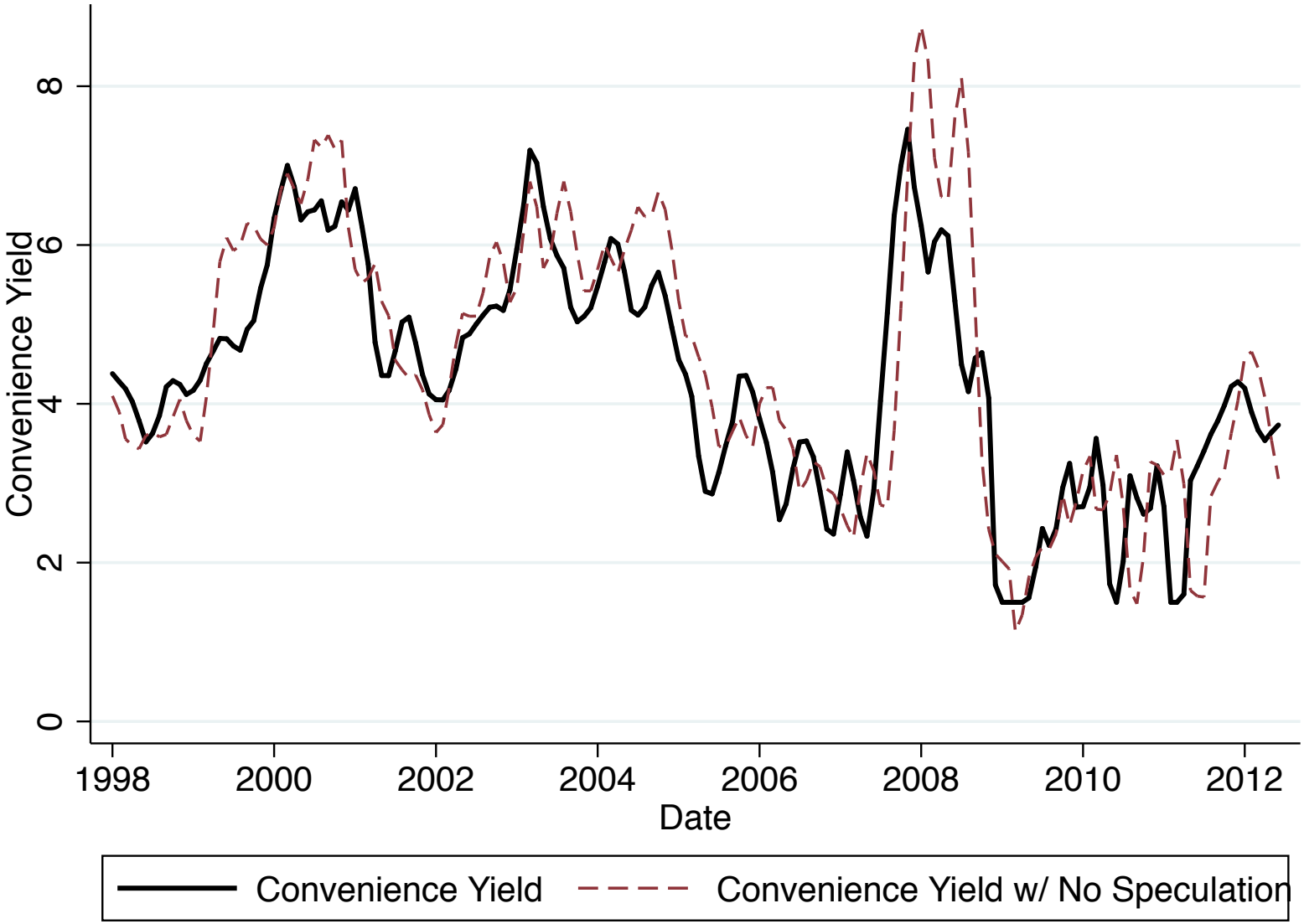
Results: Inventory Changes, 3-Month Intervals



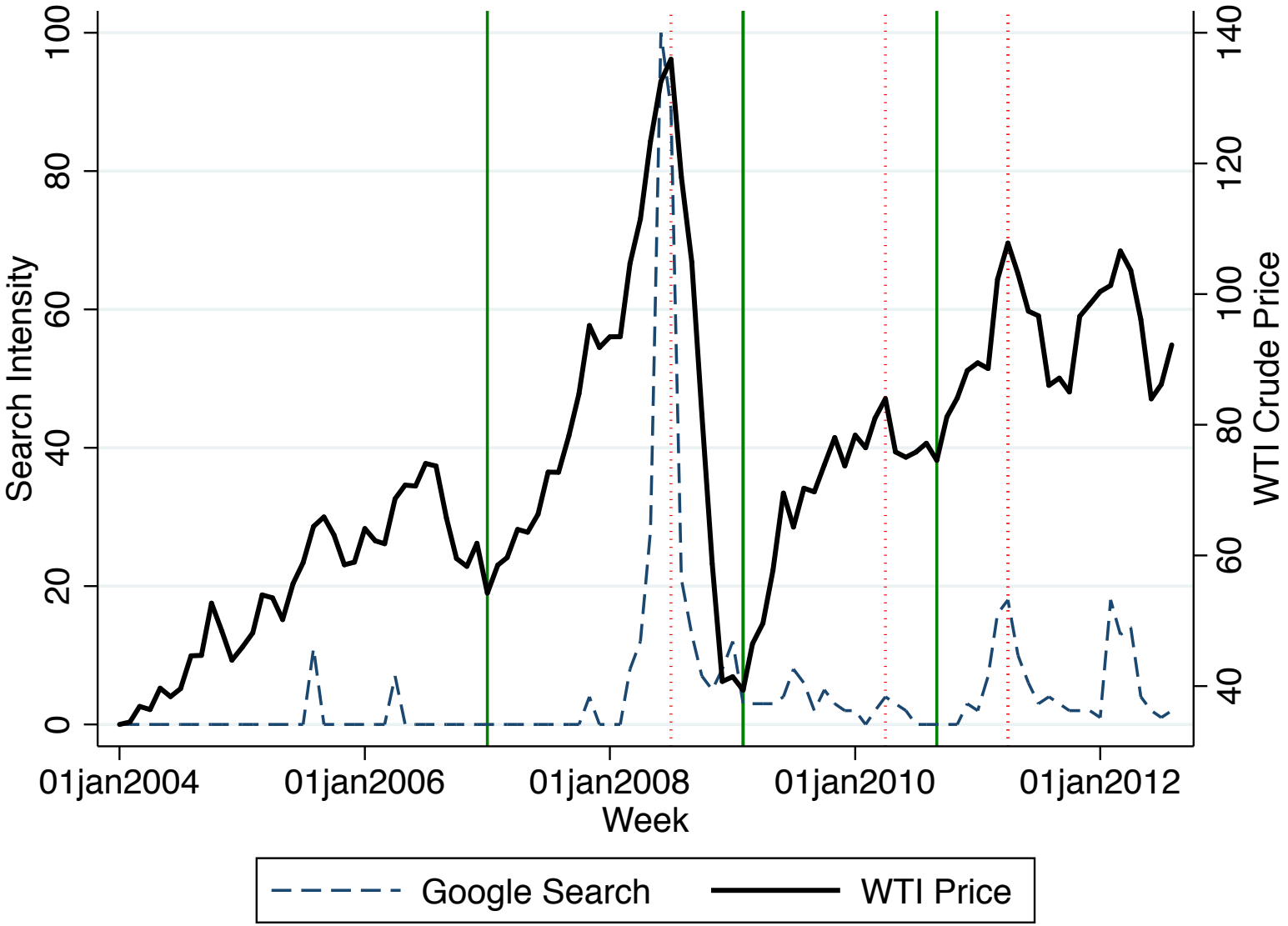
Results: Implied $\eta_S - \eta_D$, 3-Month Intervals



Results: Convenience Yields, 3-Month Intervals



WTI Price and Google Search Intensity



Results: Epoch Analysis

Epoch	1 1/07-7/08	2 2/09-4/11	3 2/09-4/10	4 9/10-4/11
Beginning Price	$ 54.51	$ 39.09	$ 39.09	$ 75.24
Ending Price	$ 133.37	$ 102.86	$ 81.20	$ 102.86
Fundamental-Only Price*	$ 140.99	$ 98.31	$ 77.67	$ 99.02
Ending Inventories (Millions of Barrels)	295.23	360.21	359.25	360.21
Actual Inventory Build up	-0.54	11.75	-0.54	11.75
Implied Inventory Build up, π=100%	261.47	121.16	183.46	74.47
Implied Inventory Build up, π=50%	125.71	61.26	88.63	37.92
Implied Inventory Build up, π=20%	55.18	28.00	38.03	17.06
Implied Inventory Build up, π=10%	33.30	17.34	22.13	10.28
Ending Convenience Yield	$ 2.39	$ 1.50	$ 2.17	$ 1.50
Actual Change in Convenience	$ 0.37	$ 0.00	$ 0.67	$ 0.00
Fundamental-Only Change in Convenience Yield	$ 5.42	$ 3.92	$ 3.10	$ 2.07

Conclusions

- Simple model of cash and storage markets can be used to assess speculation as driver of price changes.
- Can't rule out speculation had *any* effect on oil prices, but:
  - Can rule out speculation caused sharp price changes after 2004.
  - Unless one believes η_S and $\eta_D \approx 0$, inventories and futures-spot spreads inconsistent with speculation as significant driver of prices.
  - If anything, speculation had slight stabilizing effect on prices.
- Simplicity of our approach has limitations:
  - Yields results that are qualitative in nature.
  - Can't estimate specific fraction of a ΔP due to speculation. Instead, conclude any effects of speculation very small.
  - Why not use equations of our model to get precise estimates? Because model is too simple.
- Finally, can't distinguish "speculation" from "investment."