The Stategic Petroleum Reserve and Oil Prices

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Introduction

Question: Does the SPR affect crude oil prices?

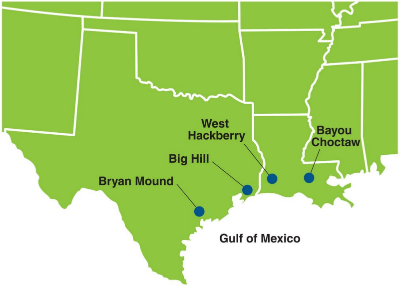
Answer: Yes, but not as intended.

	Assumption	Data
Crude Oil Release	Oil Price $\downarrow$	Oil Price —
Crude Oil Purchase	Oil Price —	Oil Price $\uparrow$

Introduction

Introduction: What is the SPR?

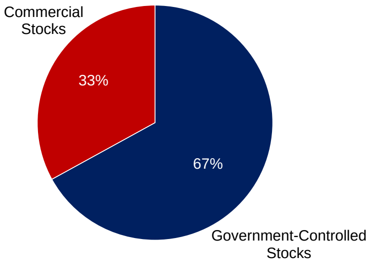
- 730 million barrels of crude oil
- Response to Arab Oil Embargo
- "To reduce the adverse economic impact of a major petroleum supply disruption"
- Controlled by the President



SPR Storage Locations

Introduction: How big is the SPR?

- 67% of total domestic crude stocks
- The equivalent of 148 days of net imports
- Cost $100 billion to date

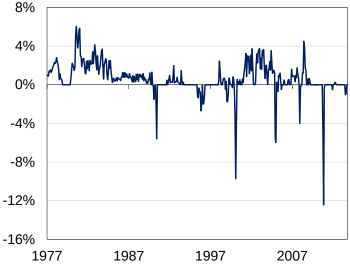


Total Crude Oil Stocks: 1.1 billion barrels

Introduction: When is it used?

SPR Releases

- International supply disruptions
- Domestic supply disruptions
- Non-emergency



SPR Purchases/Releases as a Share of US Oil Production

Introduction: Why would we care?

> *Every recession (with one exception) was preceded by an increase in oil prices, and every oil market disruption (with one exception) was followed by an economic recession.*

–Hamilton (2011)

If the SPR can decrease oil prices, it would be very valuable

Introduction: Why would we care?

Over half of global crude oil stocks in government-controlled reserves

- 26 IEA and 27 EU member countries must hold strategic reserves
- Russia, China, Japan also have large strategic reserves

Global Strategic Reserves

Introduction: Literature

Answers the question: How should the SPR be managed?

1980s

- US SPR: Teisberg (1981); Chao and Manne (1982)

2000s

- China's SPR: Wei et al. (2008); Han et al. (2014)

Little empirical work on the effect of the SPR on Oil prices

- Considine (2006)

Introduction: Literature

Why don't we know the SPR price effect?

- Spurious correlation
- Causal direction unclear
- Mutual dependence on a common cause
- Policy process difficult to model

Introduction: Literature

Killian (2009) monthly global oil market SVAR model:

$$A_0 Y_t = \alpha + \sum_{i=1}^{24} A_i Y_{t-i} + \varepsilon_t$$

where

$$Y_t = \begin{bmatrix} \text{Oil Supply}_t \\ \text{Oil Demand}_t \\ \text{Oil Price}_t \end{bmatrix}$$

SVAR: Model

Add SPR Policy variables to weekly US oil market model:

$$A_0 Y_t = \alpha + \sum_{i=1}^{40} A_i Y_{t-i} + \varepsilon_t$$

where

$$Y_t = \begin{bmatrix} \text{Oil Supply}_t \\ \text{Oil Demand}_t \\ \text{SPR Purchase}_t \\ \text{SPR Release}_t \\ \text{Oil Price}_t \end{bmatrix}$$

SVAR: Model

In this model,

$$A_0 Y_t = \alpha + \sum_{i=1}^{40} A_i Y_{t-i} + \varepsilon_t$$

The causal effect of SPR policy on crude oil prices is:

$$\frac{\partial \; Price_{t+h}}{\partial \varepsilon_t^{SPR}}, \; h = 1, 2, 3, ...$$

SVAR: Model

But we only estimate the reduced form:

$$Y_t = \beta + \sum_{i=1}^{40} B_i Y_{t-i} + e_t$$

where

$$e_t = A_0^{-1} \varepsilon_t$$

Useful forecasts but no causal interpretation

SVAR: Identifying Assumptions

To identify the causal effect, assume a temporal ordering of variables (exclusion restriction).

This is equivalent to restricting A_0^{-1} in

$$e_t = A_0^{-1} \varepsilon_t$$

SVAR: Identifying Assumptions

Exclusion Restriction

$$p_t = \alpha_1 q_t + \alpha_1 q_{t-1} + ... + \alpha_k p_{t-1} + ...$$

$$q_t = \beta_1 p_t + \beta_1 p_{t-1} + ... + \beta_k q_{t-1} + ...$$

SVAR: Identifying Assumptions

Exclusion Restriction

$$p_t = \cancel{\alpha_1 q_t} + \alpha_1 q_{t-1} + ... + \alpha_k p_{t-1} + ...$$

$$q_t = \beta_1 p_t + \beta_1 p_{t-1} + ... + \beta_k q_{t-1} + ...$$

SVAR: Identifying Assumptions

Partition Y_t into slow-moving, policy, and fast-moving variables:

- Slow-moving: Oil supply & oil demand
- Policy Variables: SPR purchases & SPR releases
- Fast-moving Variable: Oil Price

SVAR: Identifying Assumptions

Assumption 1:

> Oil supply shocks are exogenous and do not respond contemporaneously to other structural shocks

Motivation

- Production schedule changes costly
- Import transit time $>$ 1 week
- Uncertainty

SVAR: Identifying Assumptions

Assumption 2:

> Oil demand immediately responds to oil supply shocks, but not to SPR policy or oil price shocks

Motivation

- Economic production changes costly
- Uncertainty

SVAR: Identifying Assumptions

Assumption 3:

SPR policy can respond immediately to oil supply and demand shocks, but does not respond immediately to oil price shocks

Motivation

- Meeting-filled policy process

SVAR: Identifying Assumptions

Assumption 4:

> Oil prices can respond immediately to all other structural shocks

Motivation

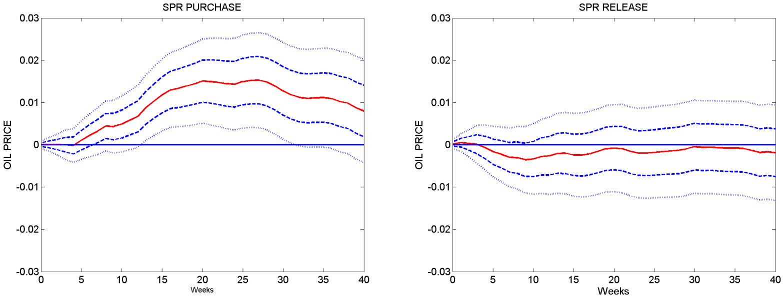
- Prices move quickly

SVAR: Data

Weekly Data: June 10, 1983 - October 3, 2014

- Oil Supply: Domestic Crude Production and Imports
- Oil Demand: ADS Business Conditions Index
- SPR Policy: Published by DOE
- Oil Price: West Texas Intermediate Spot Price (Real)

SVAR: Results



SPR Impulse Response Functions

SVAR: Results

	1983-1989	1990-2000	2000-2007	2007-2014
Release	-0.02	0.04	0.03	-0.02
Purchase	-0.03	-0.03	0.76	0.01

Average Structural Residuals for Subperiods

SVAR: Criticisms

SVAR Criticisms (Rudebusch, 1998)

- Timing assumptions not credible (simultaneniety)
- Policy reaction functions are naive (omitted variables)
- Estimated structural shocks do not always match futures markets shocks

Instrument

"Natural experiment" or "Narrative" approach

Romer and Romer (1989, 2004); Ramey and Shapiro (1998); Stock and Watson (2010)

Identify the effect of a policy (without exclusion restrictions) with an instrument that is

- Correlated with unexpected policy changes
- Uncorrelated with all other structural shocks

Instrument: Data

I construct the **SPR purchase schedule** as an instrument, Z_t, for actual purchases.

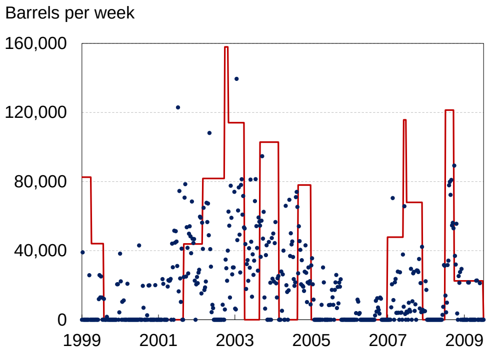
Purchase schedules set months before actual purchases and not publicly announced

- $E(Z_t \varepsilon_t^i) = 0, \ i \neq Purchase$

DOE reluctant to give purchase schedule exemptions

- $E(Z_t u_t^{Purchase}) \neq 0$

Instrument: Data



SPR Purchase Schedule (Red) and Actual Deliveries (Blue)

Instrument: Model

Partition Y_t into the SPR purchase variable ($P_{1\times1}$) and all other variables ($X_{4\times1}$).

$$e_t = \begin{pmatrix} e_t^X \\ \\ e_t^P \end{pmatrix}, \varepsilon_t = \begin{pmatrix} \varepsilon_t^x \\ \\ \varepsilon_t^P \end{pmatrix} A_0 = \begin{pmatrix} A_{11} & A_{12} \\ \\ A_{21} & A_{22} \end{pmatrix}$$

Now, $A_0 e_t = \varepsilon_t$ becomes:

$$A_{11}e_t^X + A_{12}e_t^P = \varepsilon_t^X$$

$$A_{21}e_t^X + A_{22}e_t^P = \varepsilon_t^P$$

Instrument: Model

Which simplifies to,

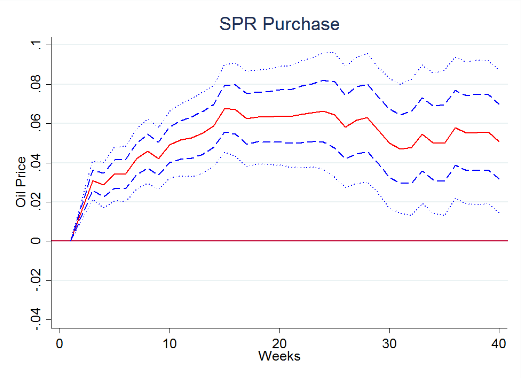
$$e_t^X = -A_{11}^{-1} A_{12} e_t^P + A_{11}^{-1} \varepsilon_t^X \qquad (1)$$

$$e_t^P = -A_{22}^{-1} A_{21} e_t^X + A_{22}^{-1} \varepsilon_t^P \qquad (2)$$

To estimate ε_t^P

1. Use Z_t as instrument for e_t^P in (1) and estimate $-A_{11}^{-1} A_{12}$
2. Estimate $\tilde{\varepsilon}_t^X = A_{11}^{-1} \varepsilon_t^X$, as $e_t^X + \widehat{A_{11}^{-1} A_{12}} e_t^P$
3. Use $\tilde{\varepsilon}_t^X$ as an instrument for e_t^X in (2) to estimate $-A_{22}^{-1} A_{21}$
4. Finally, estimate $\tilde{\varepsilon}_t^P = e_t^P + \widehat{A_{22}^{-1} A_{21}} e_t^X$
5. $\tilde{\varepsilon}_t^P$ give us ε_t^P to scale, $\frac{\partial Oil\ Price_t}{\partial \varepsilon_{t+h}^P}$, $h = 1, 2, ...$

Instrument: Results



Impulse Response Function (Purchase Instrument)

Event Study

Cochrane and Piazzesi (2002); Bernanke and Kuttner (2005)

Directly estimate structural policy shock ($\varepsilon_t^{release}$) from daily futures market data

If you are right, you are done

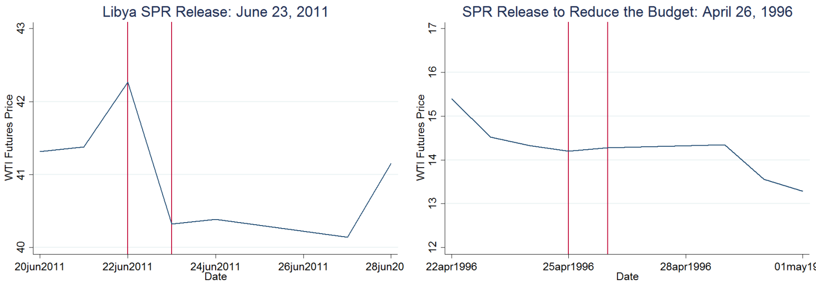
$$\frac{\partial \text{Oil Price}_{t+h}}{\partial \varepsilon_t^{\text{SPR}}}, \quad h = 1, 2, 3, \ldots$$

Event Study

Assumptions:

- The change in crude futures price $(P_t - P_{t-1})$ captures the unexpected component of the SPR announcement
- The change in crude futures price is driven only by SPR announcement

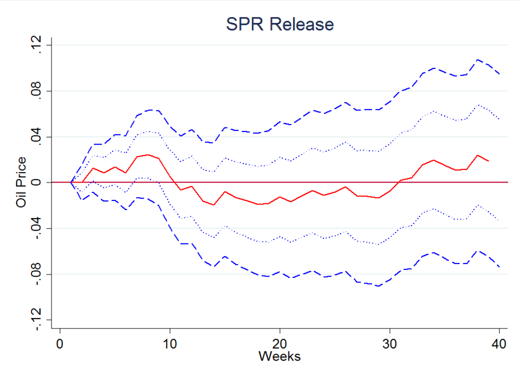
Event Study



Event Study Examples

Event Study: Results

The SPR and Oil Prices



Impulse Response Function (Release Event Study)

Model: Event Study

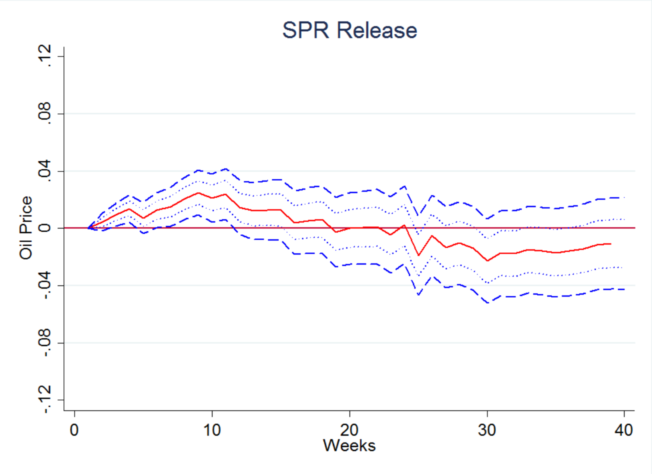
Problematic assumption:

- The change in crude futures price is driven only by SPR announcement

To make this assumption more plausible, use an alternate financial instrument

- WTI-Canadian crude oil futures spread

Event Study: Results



Impulse Response Function (Release Event Study)

Question: Does the SPR affect crude oil prices?

Answer: Yes, but not as intended.

	Assumption	Data
Crude Oil Release	Oil Price $\downarrow$	Oil Price —
Crude Oil Purchase	Oil Price —	Oil Price $\uparrow$

Uncertainty Model

Uncertainty interacted SVAR (Towbin and Weber, 2013)

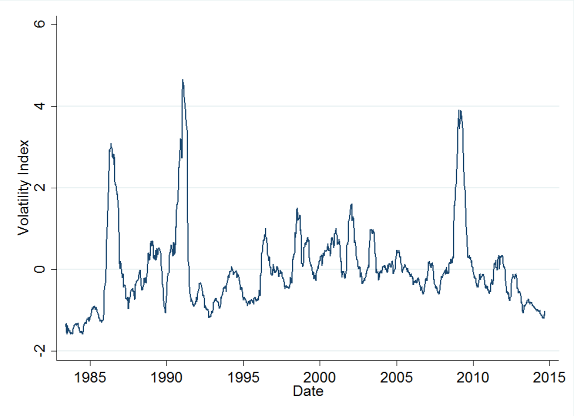
Add uncertainty (V_t) and uncertainty-SPR policy interaction terms to the price equation

$$Y_t = B_0 + \sum_{i=1}^{40}(B_i Y_{t-i} + C_i Y_{t-i} V_t) + D V_t + e_t$$

where,

$$V_t = \text{WTI Spot Price Volatility (90-day)}$$

Uncertainty Model: Data



Oil Market Uncertainty Index

Uncertainty Model

Use the $V^{high} =$ 90th percentile volatility to estimate,

$$Y_t^{high} = \widehat{F}^{high} + \sum_{i=1}^{40} \widehat{G_i}^{high} Y_{t-i} + \widehat{e}_t$$

where,

$$\widehat{F}^{high} = \widehat{B_0} + \widehat{D} V^{high}$$

$$\widehat{G_i}^{high} = \widehat{B_i} + \widehat{C_i} V^{high}$$

Uncertainty Model

Use the V^{low} = 10th percentile volatility to estimate,

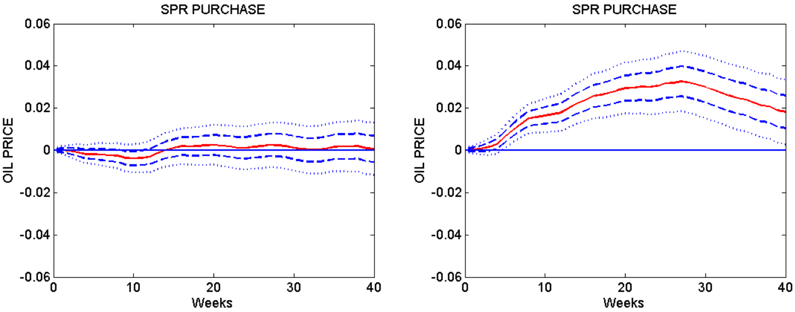
$$Y_t^{low} = \widehat{F}^{low} + \sum_{i=1}^{40} \widehat{G_i}^{low} Y_{t-i} + \widehat{e}_t$$

where,

$$\widehat{F}^{low} = \widehat{B_0} + \widehat{D}V^{low}$$

$$\widehat{G_i}^{low} = \widehat{B_i} + \widehat{C_i}V^{low}$$

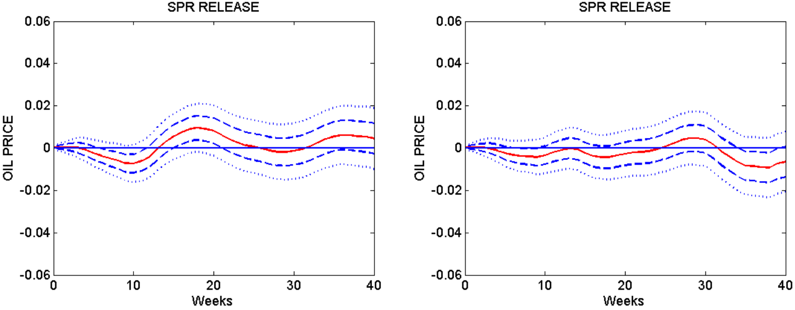
Uncertainty Model: Results



Low Volatility   High Volatility

SPR Purchase Impulse Response Functions

Uncertainty Model: Results



Low Volatility High Volatility

SPR Release Impulse Response Functions

Other mechanisms have been proposed in the literature (Considine, 2006):

- OPEC reduces production in response to SPR releases
- Gulf Coast commercial stocks absorb SPR releases

To find the effect of SPR policy on OPEC production and Gulf Coast crude oil stocks:

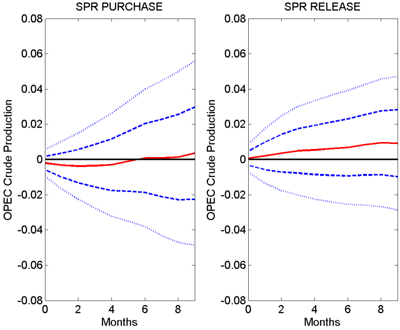
First, convert weekly structural shocks to monthly shocks,

$$\widehat{\varepsilon_t^m} = \frac{1}{4}\sum_{i=1}^{4}\widehat{\varepsilon_{it}}$$

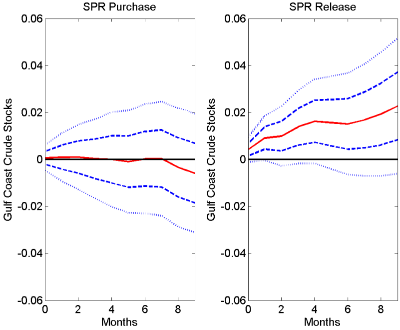
Then, regress OPEC production and regional stocks on monthly shocks,

$$OPEC_t = \alpha + \sum_{i=0}^{9}\widehat{\varepsilon_t^m} + u_t$$

$$Stocks_t = \alpha + \sum_{i=0}^{9}\widehat{\varepsilon_t^m} + u_t$$



SPR-OPEC Impulse Response Functions



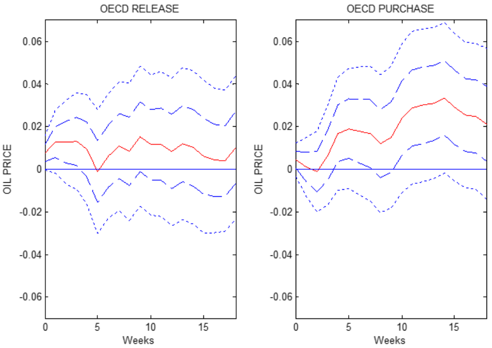
SPR-Gulf Coast Crude Stocks Impulse Response Functions

Policy Implications:

- Do not purchase oil for the SPR when oil market uncertainty is high
- If you want to lower oil prices, try another policy

Policy Implications:

- Coordinate strategic reserve purchases across countries



SPR-OECD Strategic Reserves Impulse Response Functions

Thank You