

The Role of Time-Varying Price Elasticities in Accounting for Volatility Changes in the Crude Oil Market

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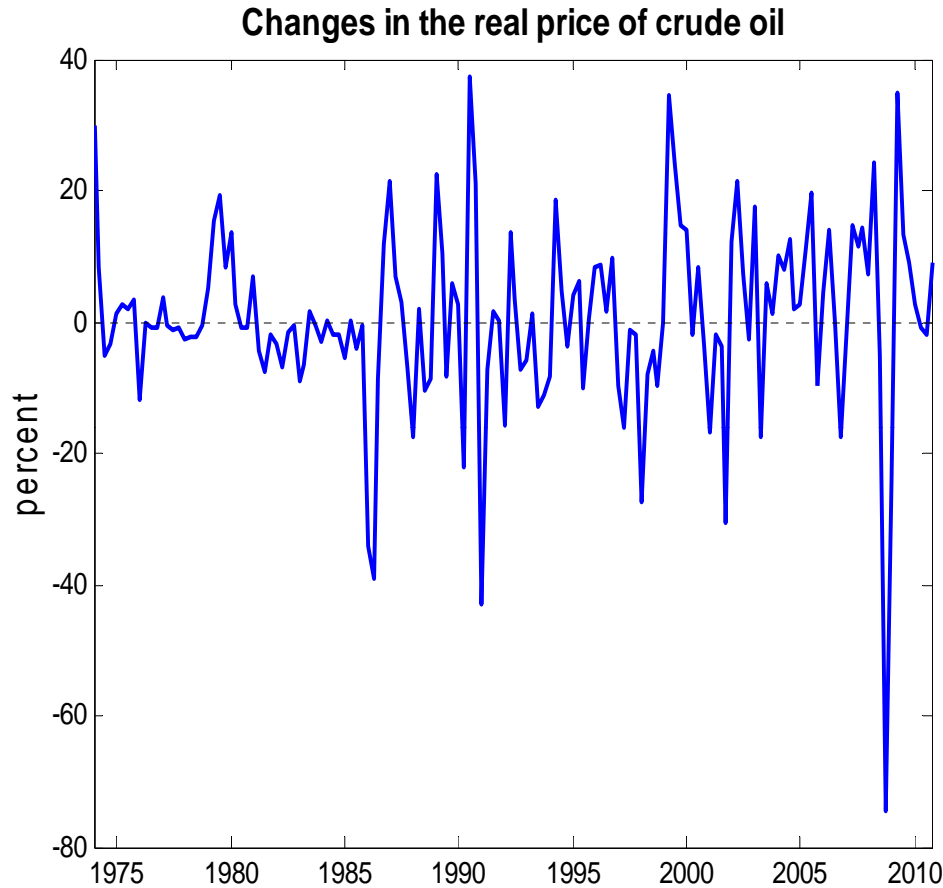
Gert Peersman

Ghent University

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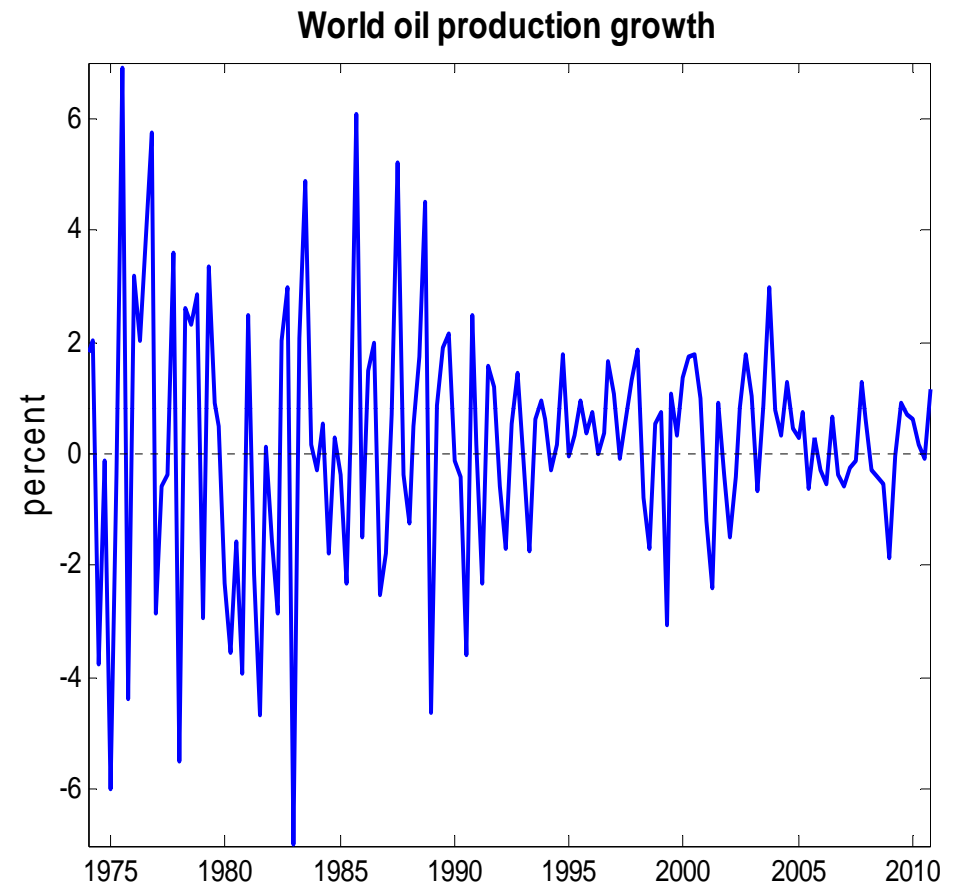
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Oil price volatility



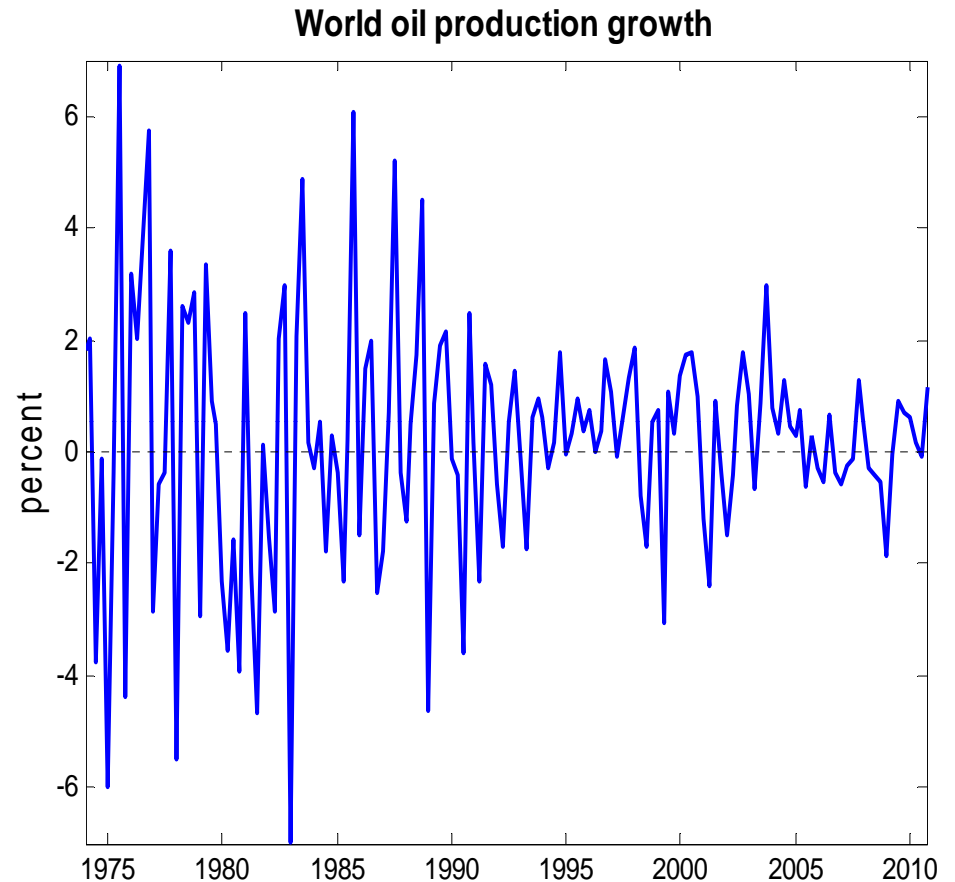
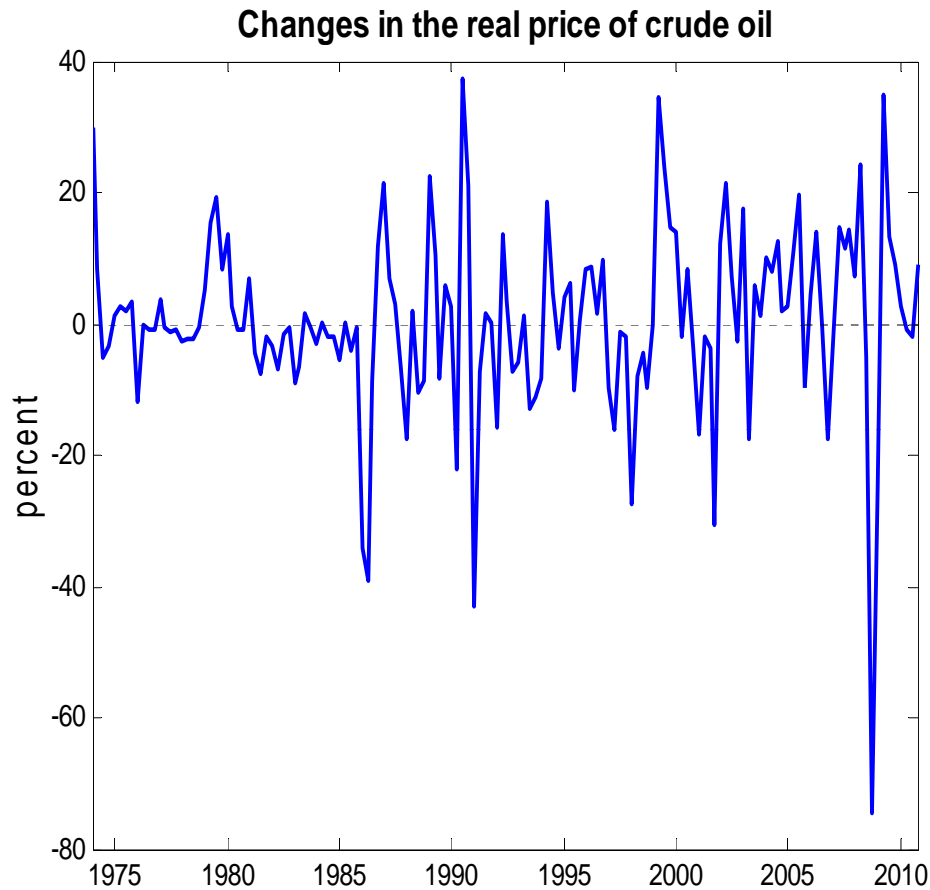
- Dramatic rise in oil price volatility after 1986 price collapse

Oil production volatility



- Gradual fall in oil production volatility

Changes in volatility



- Important structural transformations in crude oil market
- Causes of inverse evolution of oil price and oil production volatility

A stylized model of the crude oil market

- Oil demand: $Q_t^D = -d_t P_t^* + \varepsilon_t^d$
- Oil supply: $Q_t^S = s_t P_t^* + \varepsilon_t^s$
- Price adjustment: $P_t = \lambda_t P_t^* + (1 - \lambda_t) P_{t-1}$
- Equilibrium:
$$P_t = \frac{\lambda_t \varepsilon_t^d}{s_t + d_t} - \frac{\lambda_t \varepsilon_t^s}{s_t + d_t}$$
$$Q_t = \frac{[s_t + (1 - \lambda_t) d_t] \varepsilon_t^d}{s_t + d_t} + \frac{\lambda_t d_t \varepsilon_t^s}{s_t + d_t}$$
- Oil demand and supply shocks: $E[\varepsilon_t^d] = E[\varepsilon_t^s] = 0$
 $E[\varepsilon_t^d]^2 = \sigma_{d,t}^2 \quad E[\varepsilon_t^s]^2 = \sigma_{s,t}^2 \quad E[\varepsilon_t^d, \varepsilon_t^s] = 0$

Hypotheses

- Variability of crude oil prices and oil production

$$E[P_t]^2 = \frac{\lambda_t^2 (\sigma_{d,t}^2 + \sigma_{s,t}^2)}{(s_t + d_t)^2} \quad E[Q_t]^2 = \frac{[s_t + (1 - \lambda_t)d_t]^2 \sigma_{d,t}^2 + \lambda_t^2 d_t^2 \sigma_{s,t}^2}{(s_t + d_t)^2}$$

1. Changes in the variance of oil market shocks

$$\frac{\partial E[P_t]^2}{\partial \sigma_{s,t}^2} > 0$$

$$\frac{\partial E[Q_t]^2}{\partial \sigma_{s,t}^2} > 0$$

- 1970s: major production disruptions (Hamilton 2009)

$$\frac{\partial E[P_t]^2}{\partial \sigma_{d,t}^2} > 0$$

$$\frac{\partial E[Q_t]^2}{\partial \sigma_{d,t}^2} > 0$$

- 1980s: shift in pricing regime (Hubbard 1986, Mabro 2005)
- mid-1980s: Great Moderation (Herrera and Pesavento 2009)

Hypotheses

2. Changes in price elasticities of oil demand and oil supply

$$\frac{\partial E[P_t]^2}{\partial d_t} < 0$$

$$\frac{\partial E[Q_t]^2}{\partial d_t} > 0$$

- 1980s: changes in demand behavior
(Baumeister and Peersman 2008)

$$\frac{\partial E[P_t]^2}{\partial s_t} < 0$$

$$\frac{\partial E[Q_t]^2}{\partial s_t} > 0$$

- mid-1980s: little spare capacity
Kilian (2008)

3. Changes in the speed of oil price adjustment to shocks

$$\frac{\partial E[P_t]^2}{\partial \lambda_t} > 0$$

$$\frac{\partial E[Q_t]^2}{\partial \lambda_t} = \frac{2d_t}{(s_t + d_t)^2} \{ -[s_t + (1 - \lambda_t)d_t] \sigma_{d,t}^2 + \lambda_t d_t \sigma_{s,t}^2 \} < 0$$

- mid-1980s: collapse of OPEC cartel and increased spot trading

Empirical model

- VAR with global oil production, real price of crude oil and world industrial production
- Time-varying parameters
- Stochastic volatilities in the innovation process

Cogley and Sargent (2002, 2005), Primiceri (2005), Benati and Mumtaz (2007)

$$y_t = c_t + B_{1,t} y_{t-1} + \dots + B_{p,t} y_{t-p} + u_t \equiv X_t' \theta_t + u_t$$

- First differences, 4 lags
- 1947Q1-2010Q4 (first 25 years as a training sample)

Empirical model

- Drifting coefficients capture time variation in propagation

$$\theta_t = \theta_{t-1} + v_t \quad v_t \sim N(0, Q)$$

- Time-varying covariance matrix

- Heteroscedasticity of the shocks: changes in magnitude of shocks
- Time variation in simultaneous relationships between variables

$$u_t \sim N(0, \Omega_t)$$

$$\Omega_t = A_t^{-1} H_t (A_t^{-1})'$$

$$A_t = \begin{bmatrix} 1 & 0 & 0 \\ \alpha_{21,t} & 1 & 0 \\ \alpha_{31,t} & \alpha_{32,t} & 1 \end{bmatrix} \quad H_t = \begin{bmatrix} h_{1,t} & 0 & 0 \\ 0 & h_{2,t} & 0 \\ 0 & 0 & h_{3,t} \end{bmatrix}$$

- Error terms of transition equations are independent of each other and of the innovations of the observation equation

Identification

- Sign restrictions implied by stylized supply and demand model of the crude oil market

	Q_{oil}	P_{oil}	Y_{world}
Oil supply shock	-	+	≤ 0

- Oil **supply** shocks move oil prices and oil production in **opposite** direction

Identification

- Sign restrictions implied by stylized supply and demand model of the crude oil market

	Q_{oil}	P_{oil}	Y_{world}
Oil supply shock	-	+	≤ 0
Other oil demand shock	+	+	
Aggregate demand shock	+	+	

- Oil supply shocks move oil prices and oil production in opposite direction
- Oil **demand** shocks move oil prices and oil production in the **same** direction

Identification

- Sign restrictions implied by stylized supply and demand model of the crude oil market

	Q_{oil}	P_{oil}	Y_{world}
Oil supply shock	–	+	≤ 0
Other oil demand shock	+	+	≤ 0
Aggregate demand shock	+	+	> 0

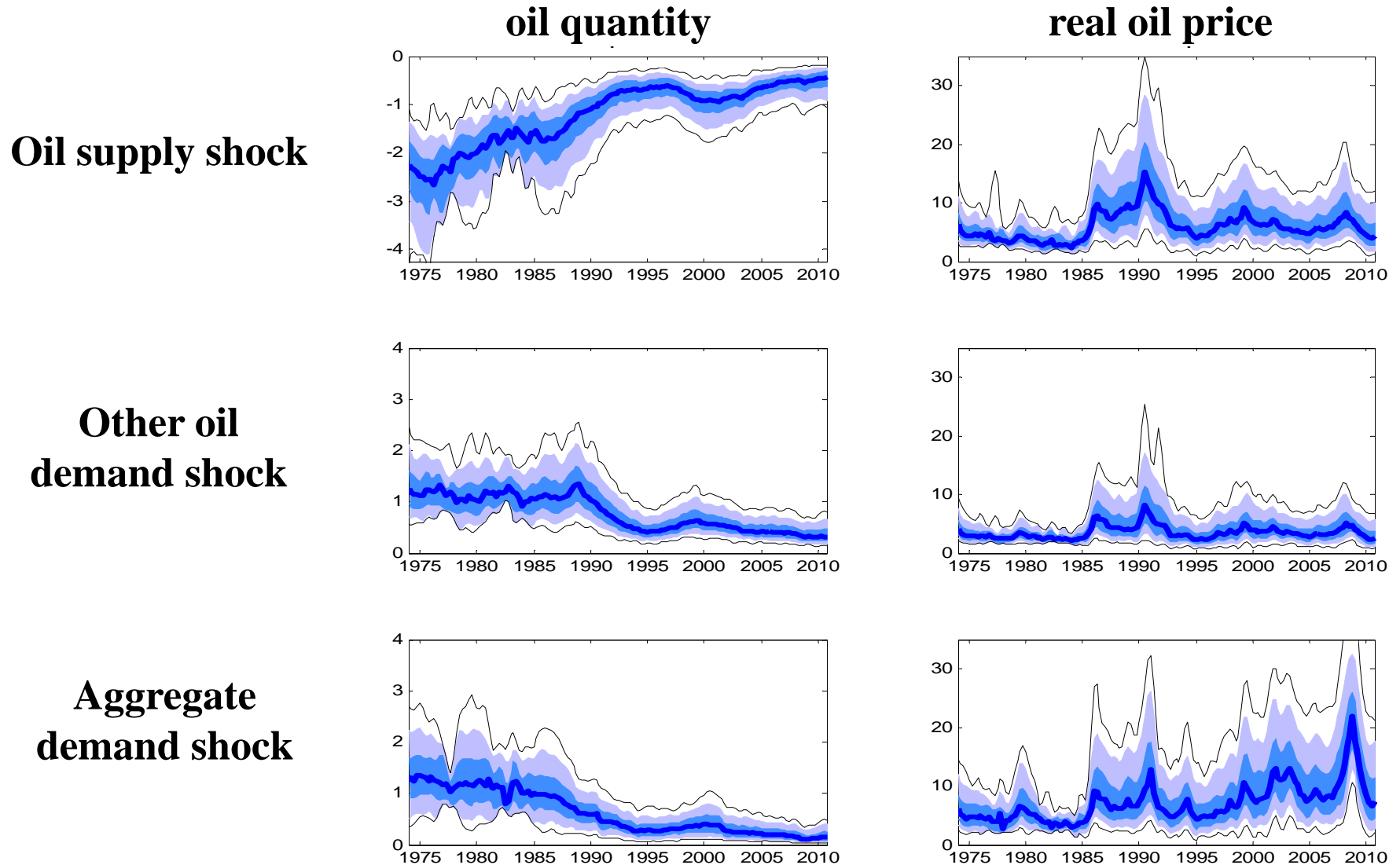
- Oil supply shocks move oil prices and oil production in opposite direction
- Oil demand shocks move oil prices and oil production in the same direction
 - **Other oil** demand shocks: **non-positive** effect on global economic activity
 - **Aggregate** demand shocks: **positive** effect on global economic activity

Identification

- Sign restrictions imposed only on impact
- Kilian and Murphy (2011): sign restrictions alone are too weak
- Augment identification strategy by boundary restrictions on impact price elasticities:
 - **Oil demand elasticity**: lower bound of **-0.8** which corresponds to long-run oil demand elasticity (Hausmann and Newey 1995)
 - **Oil supply elasticity**: upper bound of **0.6**

Results

- Impulse responses after typical (one standard deviation) oil market shocks



Results

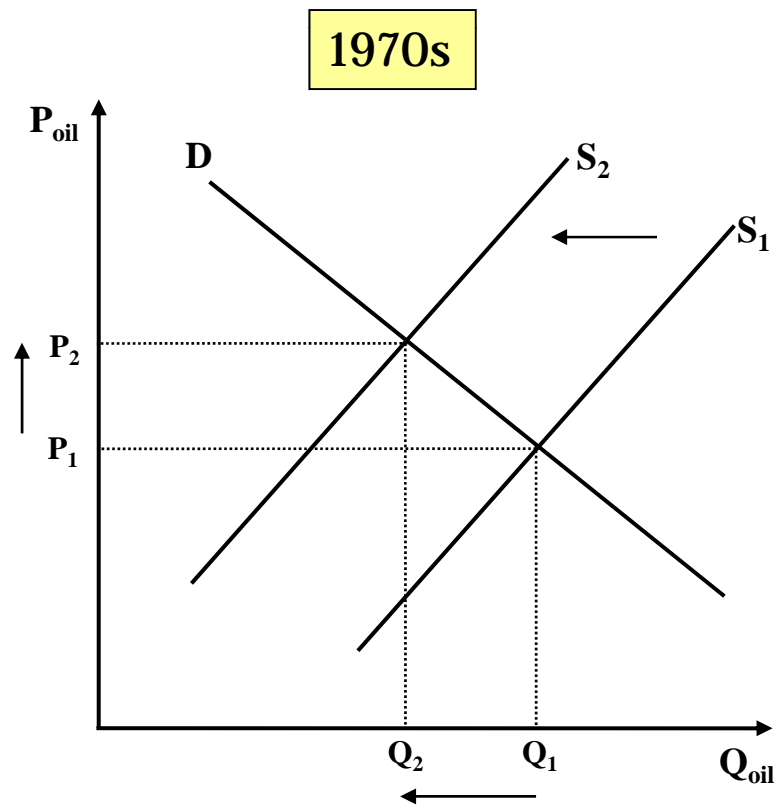
- Declining effect of oil market shocks on oil production
→ implies: *smaller* quantity movements

Results

- Declining effect of oil market shocks on oil production
 - implies: *smaller* quantity movements
- Stronger effect of oil market shocks on oil prices
 - implies: *larger* price movements

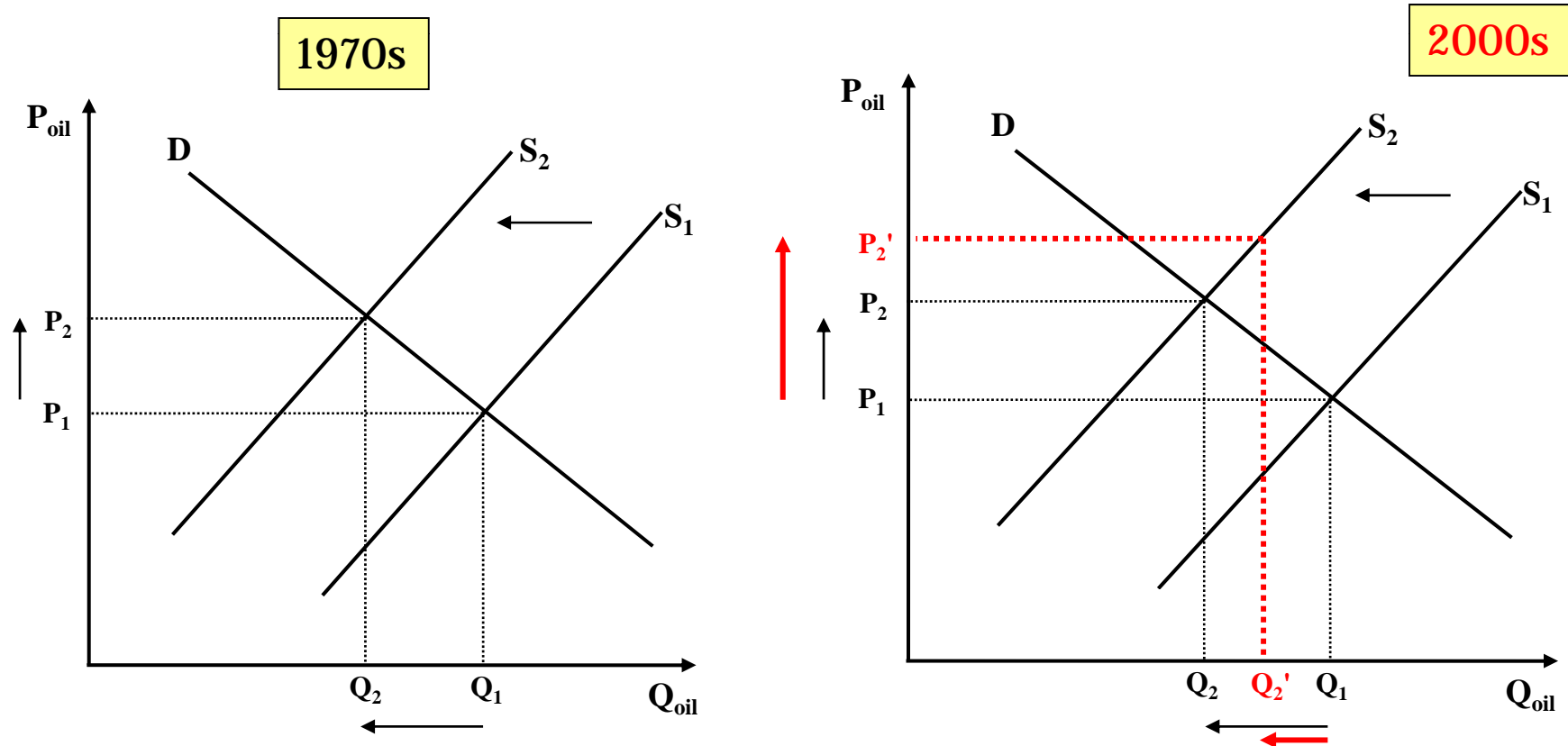
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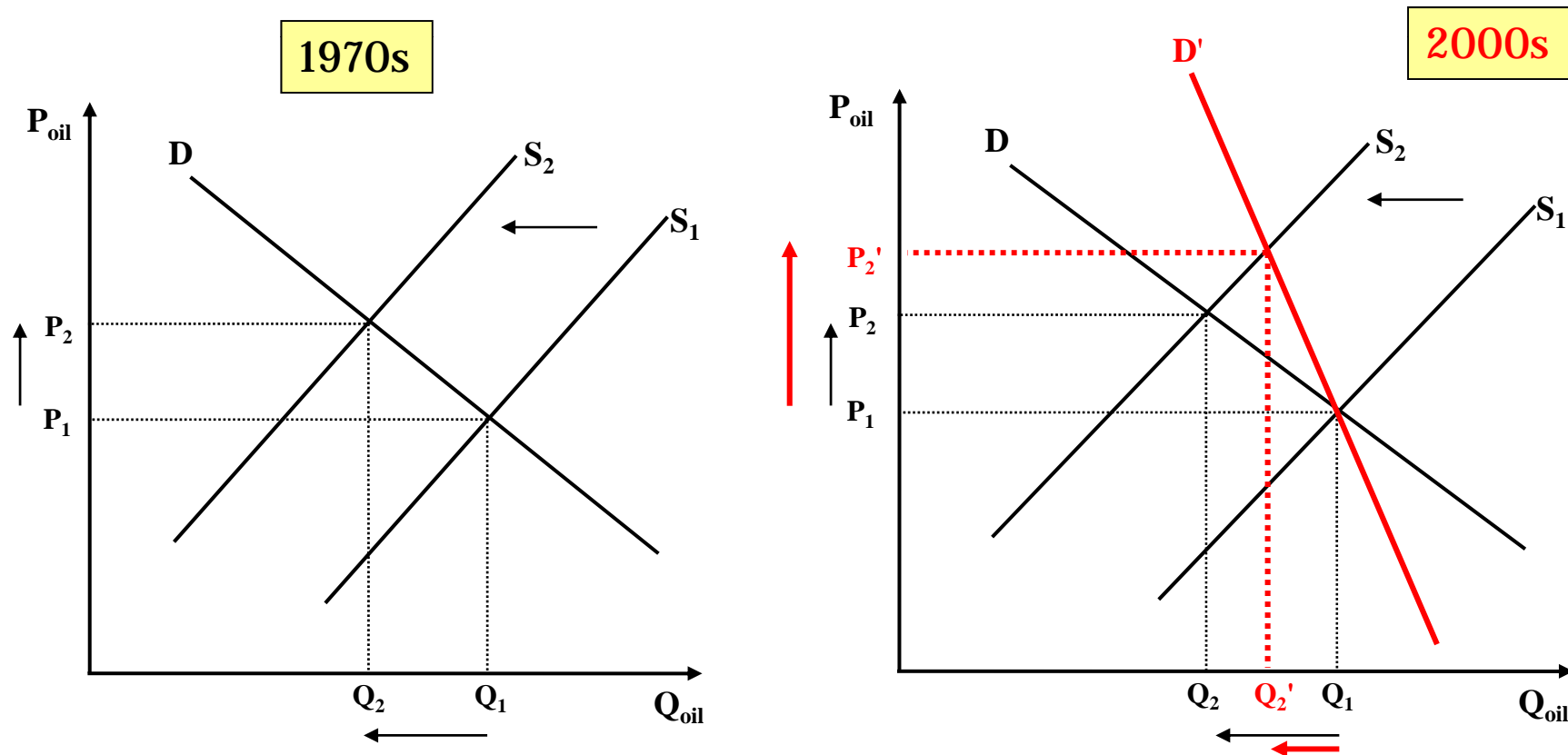
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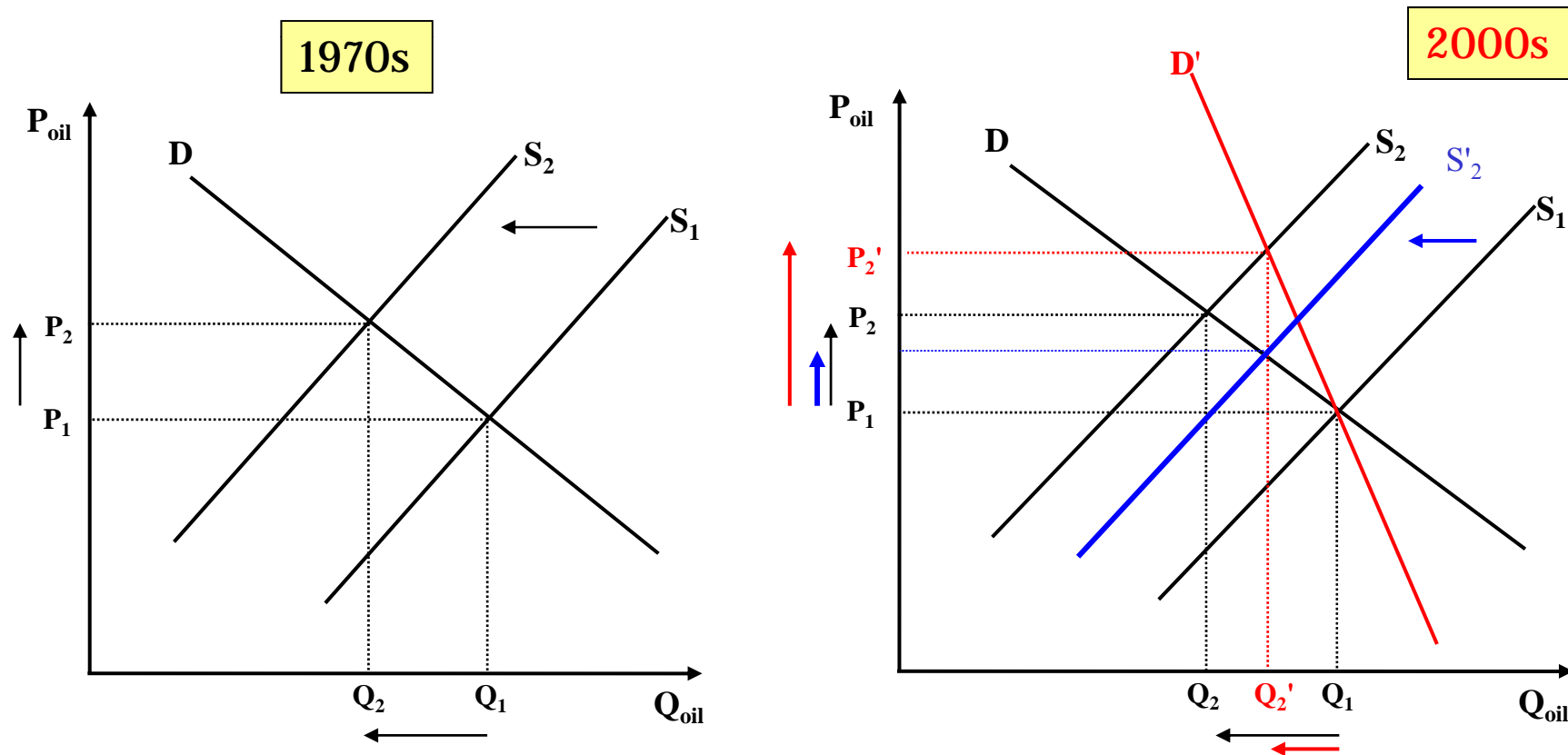
Results

- Combination of *larger* price response and *smaller* quantity reaction
- Oil demand curve must have become steeper (less elastic) over time



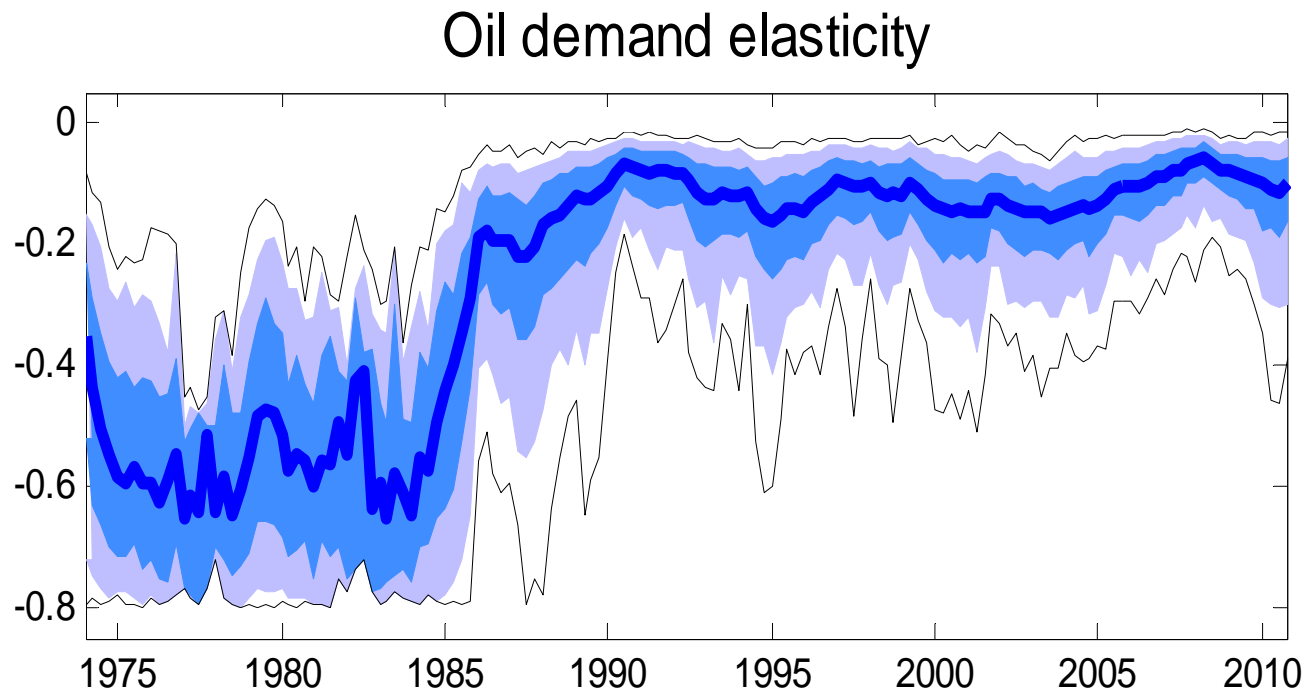
Results

- Combination of greater price response and smaller quantity reaction
- Oil demand curve must have become steeper (less elastic) over time → same reasoning applies for oil supply curve



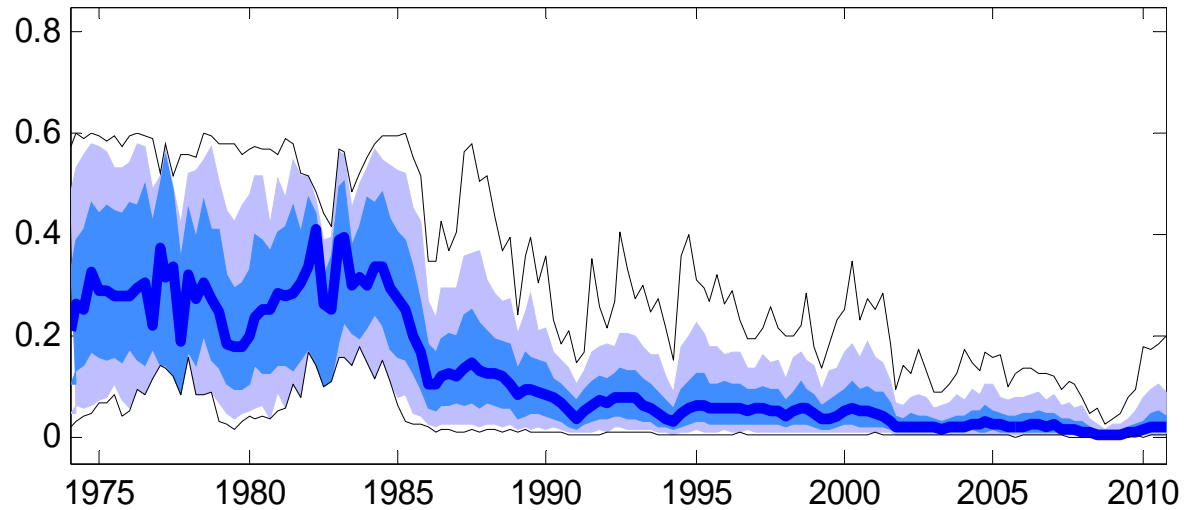
Evaluation of hypotheses

- Evolution of short-run price elasticities of oil supply and oil demand: considerable decrease in responsiveness of oil supply and oil demand to price changes over time

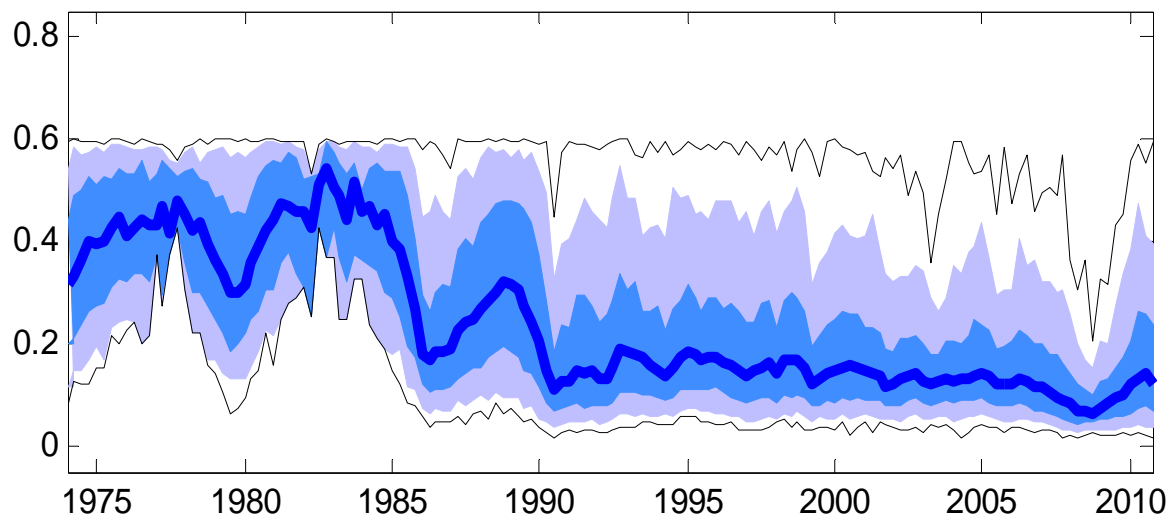


Evaluation of hypotheses

Oil supply elasticity with aggregate demand shock



Oil supply elasticity with other oil demand shock



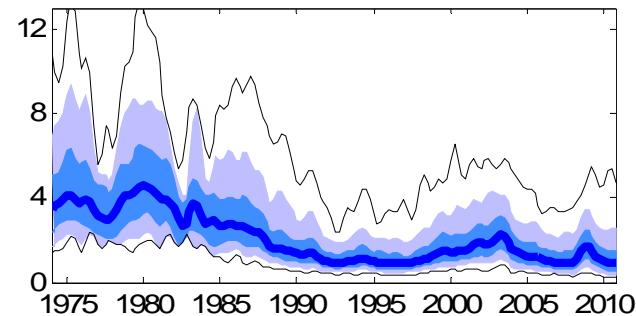
Evaluation of hypotheses

- Evolution of variances of shocks: smooth decline over time

Aggregate demand shock

- Great Moderation
- Oil intensity of production

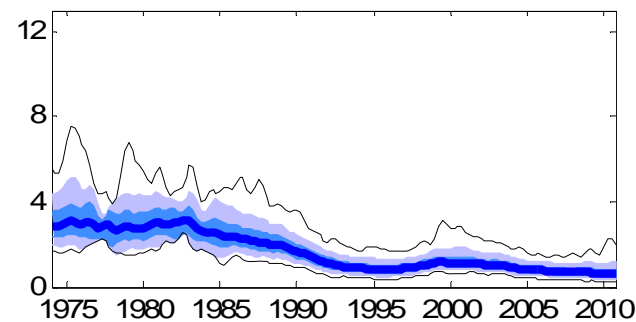
Aggregate demand shock



Other oil demand shock

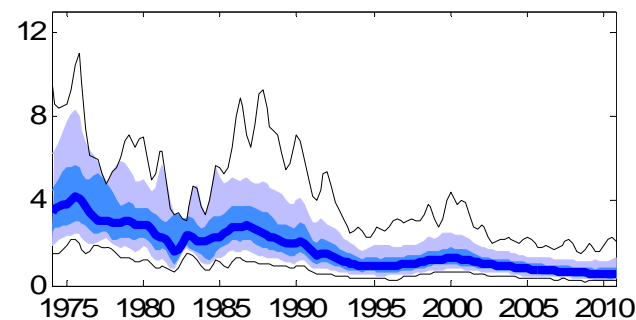
- Fears about future oil supplies
- Changes in inventory behavior
- Speculation

Other oil demand shock



Oil supply shock

Oil supply shock



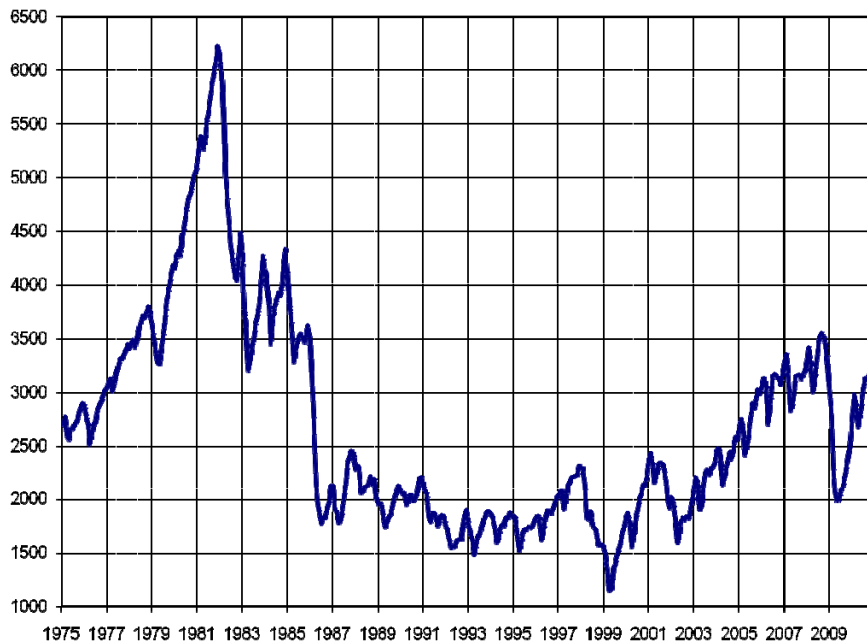
Reasons for decline in elasticities

- Oil futures markets
 - Hedging possibilities reduce exposure to price changes for oil consumers and producers: less sensitive to price fluctuations
 - Volume of trading on NYMEX expanded after 1985
- Demand side
 - High oil prices of 1970s caused industries to switch away from oil to other sources of energy
 - Higher share of developing countries in global oil demand
- Supply side
 - Decline in global spare oil production capacity
 - Lack of investment in oil sector

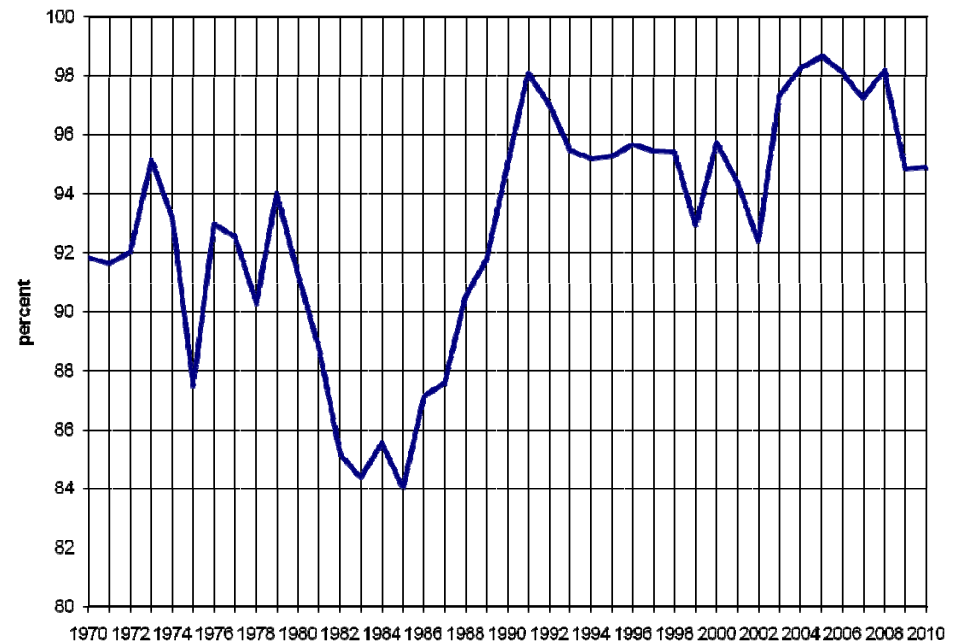
Reasons for decline in elasticities

- Demand-supply feedback loop
 - Tightness in the market affects demand behavior
 - Operation close to full capacity can lead to relative higher share of (less elastic) precautionary oil demand

Worldwide oil rig counts



Global capacity utilization rates



Conclusions

- Important volatility changes in crude oil market
- Potential sources
 - Changes in speed of adjustment of oil prices to shocks
 - Changes in volatility of structural shocks
 - Changes in short-run price elasticities of oil demand and supply
- Time-varying framework to assess hypotheses empirically
- Key findings
 - Steepening of oil supply and oil demand curves over time
 - Decrease in variances of structural shocks
- Driving forces behind decrease in elasticities
 - Development of oil futures markets
 - Lack of investment and spare capacity in oil sector