The Impact of Oil Demand and Oil Supply Shocks on the Real Price of Oil and on the Economy

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Part I:

The Role of Inventories and Speculative Trading in the Global Market for Crude Oil

What is Speculative Trading?

There are forward-looking elements in the spot price of oil that cannot be captured by past data on oil prices, world oil production, or global real activity.

Examples: New oil discoveries (Brazilian off-shore oil fields)

Anticipation of a War in the Middle East

Anticipation of a major global recession

Increased Uncertainty about Oil Supply Shortfalls

A rational response is to trade on this information by buying or selling stocks of oil. In economic terms, this constitutes speculation.

● Speculation in storable commodities may occur in two forms:

1. Buy oil, keep it in storage and sell it at a higher price later.
2. Lock in the expected higher price by buying an oil futures contract.

Economically, these strategies are equivalent.

● Arbitrage ensures that speculative demand shocks simultaneously affect the spot price (via inventory demand) and the futures price, creating a tight link between these markets.

As long as arbitrage works, the spot and futures prices are jointly determined and respond to the same economic determinants (Alquist and Kilian JAE 2010).

● Modeling speculative trading in oil markets requires a model of stock demand or inventory demand in addition to flow demand.

Key Contributions of Kilian and Murphy (2009):

1. We propose the first empirical model of the global market for crude oil that nests the stock demand and flow demand explanations of the determination of the real price of oil.
2. Using a new approach to identification, we show how the forward-looking element of the real price of oil can be identified with the help of data on crude oil inventories.
3. This allows us to shed light on the extent of speculation in oil markets since the late 1970s.
4. We provide for the first time a properly identified estimate of the short-run price elasticity of oil demand.

Structural Model of the Global Crude Oil Market

- Monthly VAR(24) model for 1973.2-2010.6:
  1. Percent change in global crude oil production
  2. Index of global real activity (in deviations from trend)
  3. Real price of oil
  4. Change in above-ground global crude oil inventories

- This model allows for the existence of oil futures markets, but does not require such markets to exist.

- Oil futures spread has no added predictive power, consistent with economic theory (see Giannone and Reichlin, JEEA 2006).

Four Structural Shocks

1. Shock to the flow of crude oil production ("flow supply shock")
2. Shock to the demand for crude oil associated with the global business cycle ("flow demand shock")
3. Shock to the demand for above-ground oil inventories arising from forward-looking behavior ("speculative demand shock")
4. Residual oil demand shock that captures all structural shocks not otherwise accounted for and has no direct economic interpretation (e.g., weather shocks, shocks to inventory technology or preferences, idiosyncratic shocks to SPR).

1. Identifying Assumptions on Sign of Impact Responses

	Flow Supply Shock	Flow Demand Shock	Speculative Demand Shock
Oil Production	-	+	+
Real Activity	-	+	-
Real Oil Price	+	+	+
Inventories			+

2. Bound on Impact Price Elasticity of Supply

- Consensus: The impact price elasticity of oil supply is near zero.
- Oil supply elasticity bound:

$$\eta^{Oil\ Supply} \leq 0.025 \quad \text{(baseline)}$$

Our main results are robust to using a bound as high as 0.1.

3. Bound on Impact Price Elasticity of Demand

- Standard demand elasticity measures equate the production of oil with the consumption of oil and ignore the role of inventory changes.

- We restrict the impact ***price elasticity of oil demand in use***:

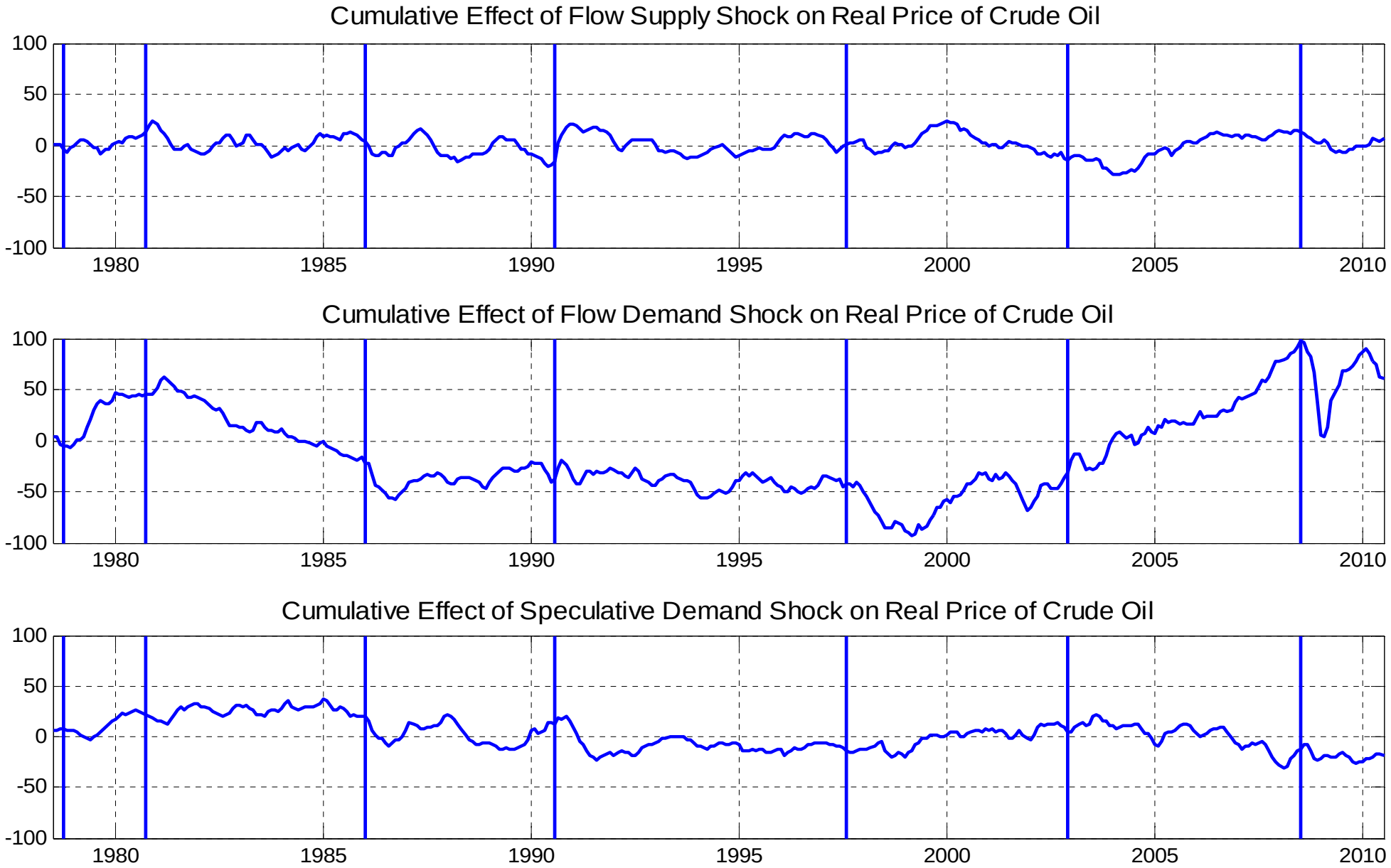
$$-0.8 \leq \eta^{Oil\ Use} \leq 0$$

4. Dynamic Sign Restrictions

- An unexpected flow supply disruption is associated with a positive response of the real price of oil and a negative response of oil production and global real activity for the first year.

This assumption helps rule out models that are inconsistent with conventional views of the effects of flow supply shocks.

Historical Decompositions for 1978.6-2010.6



What Explains the 2003-08 Oil Price Shock?

- No evidence that speculation by oil traders was responsible (so the point is moot whether speculation is desirable or not).
- No evidence that OPEC was behind the oil price increase.
- No evidence that "peak oil" has been the cause.
- Strong evidence that a booming world economy was the cause.

Related evidence in Kilian and Hicks (JForec. 2012):

$\Rightarrow$ Systematic errors by professional forecasters

$\Rightarrow$ Key role for emerging Asia

Three Policy Implications

1. Increased regulation of oil traders will not keep the real price of oil down.

2. Increased domestic oil production in the U.S. will not lower the real price of oil materially.

3. Efforts to revive the world economy will cause the real price of oil to recover, creating a policy dilemma.

Speculation without a Change in Oil Inventories?

Hamilton (BPEA 2009): If the short-run price elasticity of gasoline demand is zero, speculation may drive up the real price of oil ***without*** affecting crude oil inventories.

Consensus view from reduced form:

$$\eta^{Oil} \approx -0.06$$

Problems:

1. Estimate biased toward zero.
2. Estimate incorrectly equates oil production and oil consumption.

Estimates from structural VAR model:

Under empirically plausible assumptions, in the short run:

$$\eta^{Oil\ Use} \approx \eta^{Gasoline}$$

⇨ Our estimate is $\eta^{Gasoline} \approx -0.26$

⇨ With over 80% probability $\eta^{Gasoline} < -0.1$

Real-Time Out-of-Sample Forecast Accuracy

Baumeister and Kilian (JBES 2011):

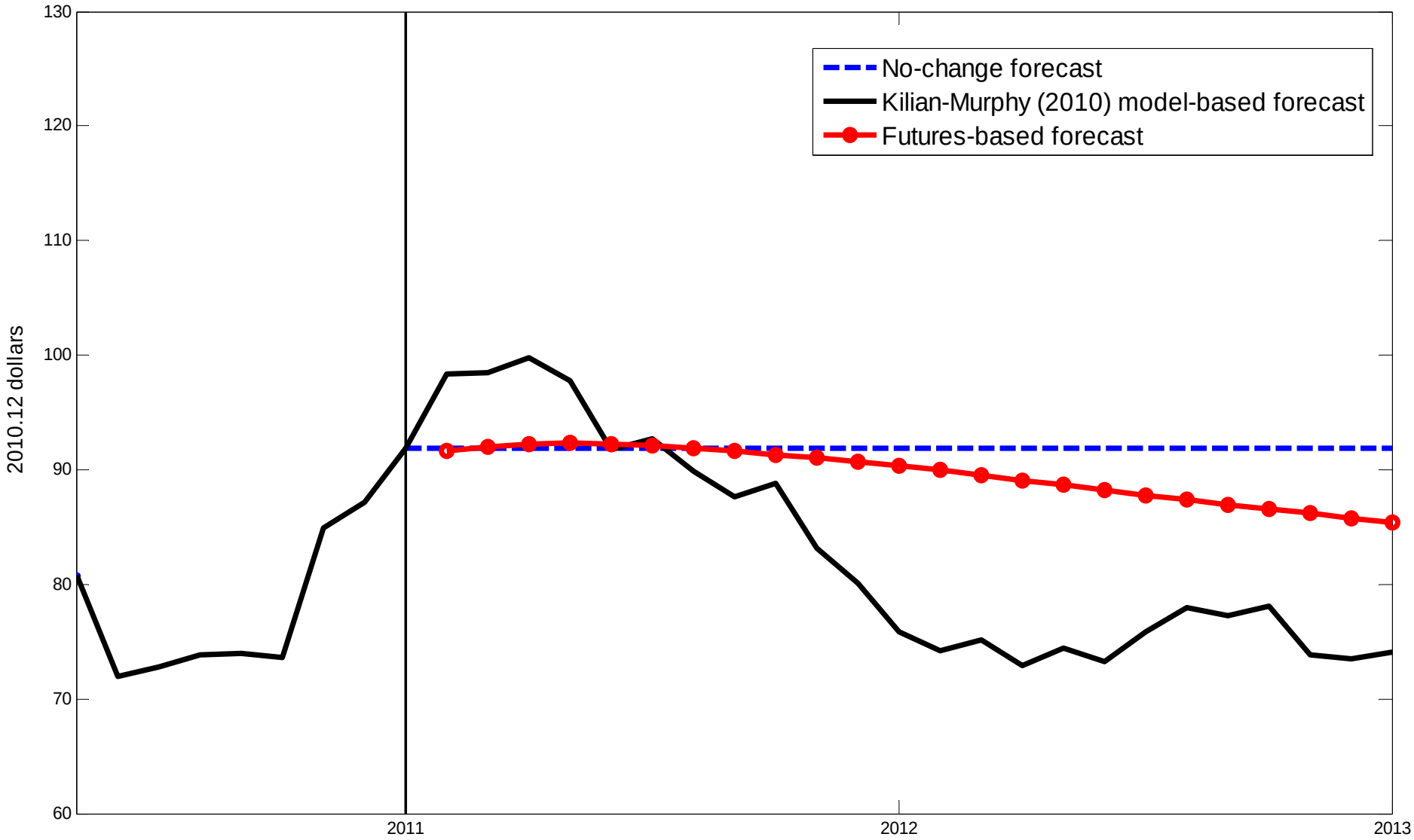
- Large out-of-sample MSPE reductions relative to no-change forecast up to six months (up to 25% in real time); smaller reductions up to one year.

- High and statistically significant real-time directional accuracy for horizons up to one year (as high as to 65%).

- Model works especially well during financial crisis.

- Model allows construction of forecast scenarios (Baumeister and Kilian, mimeo 2011).

Real-Time Forecast of Real U.S. RAC for Crude Oil Imports



Part II:

How the Transmission of Oil Price Shocks Depends on the Composition of the Underlying Oil Demand and Oil Supply Shocks

The Response of U.S. Real GDP to Real Oil Price Shocks

Standard approach:

VAR in real price of oil and real GDP. Real oil price innovation is predetermined with respect to real GDP.

Kilian (JEL 2008, AER 2009):

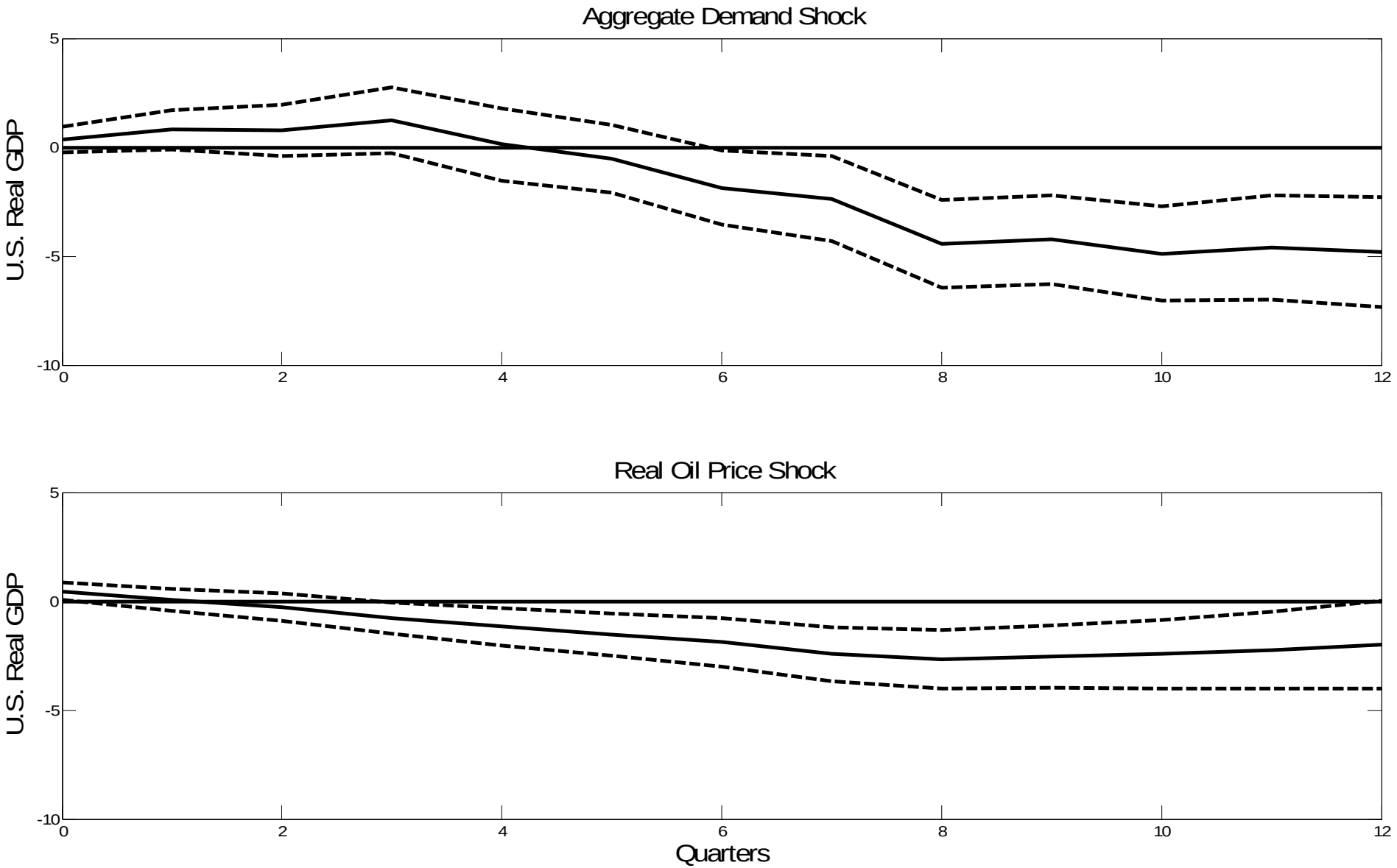
Real oil price innovation can be expressed as a linear combination of oil demand and oil supply shocks, each of which is predetermined with respect to U.S. macroeconomic aggregates.

Implications:

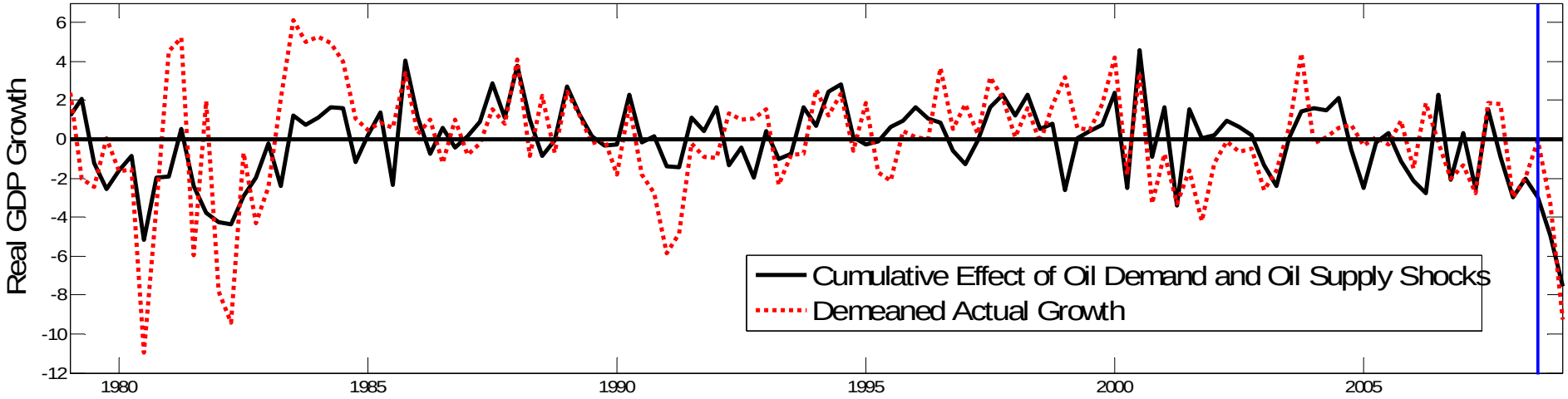
1. Standard VAR responses to oil price shocks do not quantify the effect of innovations to the price of oil, while holding everything else constant, but rather that of an average linear combination of the demand and supply shocks that drive the price of oil (and other economic variables).

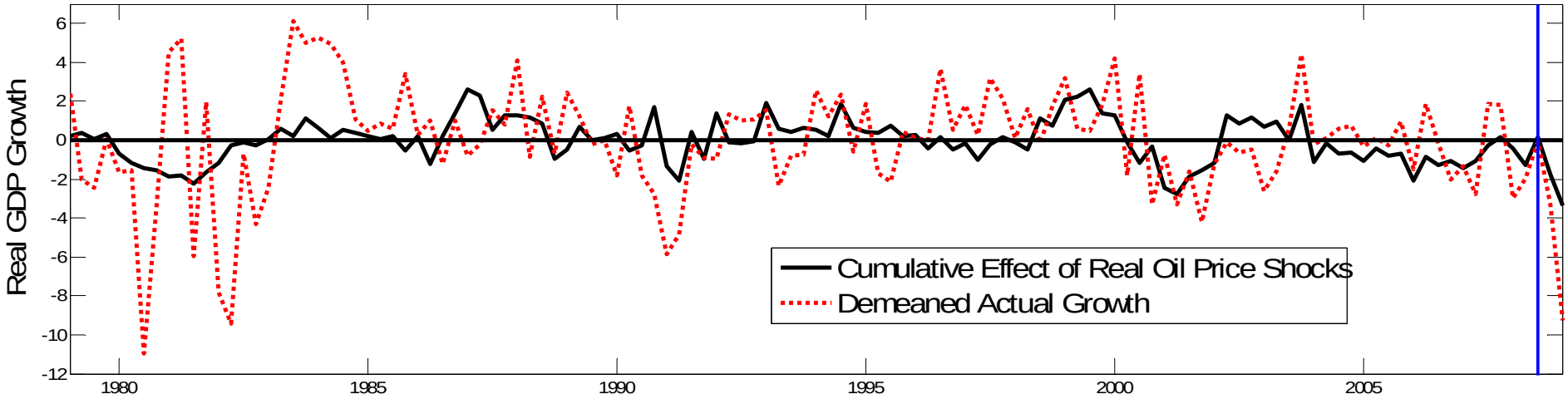
2. Each demand and supply shock triggers distinct dynamic responses. VAR responses to oil price shocks reflect the average composition of demand and supply shocks and hence may be misleading when it comes to interpreting specific historical episodes.

Responses of U.S. Real GDP to Oil Market Shocks (with 1-Std. Error Bands)



Explanatory Power of all Oil Demand and Oil Supply Shocks Combined and of Real Oil Price Shocks: 1979-2008





Part III:

Monetary Policy Responses to Oil Price Fluctuations: Lessons from the 1970s

What Happened in the 1970s?

Explanation 1 (Barsky and Kilian, NBER Macro Annual 2002):
Worldwide *shifts in monetary policy regimes* not related to the oil market played a major role in causing both the subsequent oil price increases and stagflation in many economies.

Explanation 2 (Bernanke, Gertler and Watson, BPEA 1997):
The oil price shocks of the 1970s arose exogenously with respect to global macroeconomic conditions, but were propagated by the *reaction of monetary policy makers*.

The Fed created a sharp recession by raising the interest rate in an only partially successful attempt to contain the inflationary pressures triggered by the oil price shock.

Why did stagflation never occur again after the 1970s?

Explanation 1 (Barky and Kilian 2002):

- Given the absence of major shifts in monetary policy regimes since the 1980s, there is no reason to expect stagflation to occur.

  To the extent that the public views the central bank's commitment to price stability as credible, the pass-through from oil price shocks to the domestic price level is not associated with sustained inflation.

- Why then the surge in the real price of oil in 2003-mid 2008?

  Structural shifts in demand associated with the transformation of emerging Asia rather than shifts in monetary policy regimes.

Explanation 2 (Blanchard and Gali 2010):

• Improved monetary policy responses to oil price shocks:

The central bank – by completely quenching inflationary pressures from unexpectedly high oil prices – prevents stagflation from arising at the cost of a sharp recession.

Problem: No sharp recession in the data.

• Alternative: Oil price shocks are not as inflationary as they used to be, allowing a less aggressive monetary policy response.

Blanchard and Galí (2010): Reduced real wage rigidities.

1. The Monetary Policy Regime Shifts Hypothesis (BK)

• Great Moderation debate misses that 1990s were not so different from 1960s. Really, the 1970s were the aberration. Why?

• The beginning of this decade coincided with a shift towards a less restrictive monetary policy regime. The breakdown of Bretton Woods loosened the remaining constraints on monetary policy.

• As the world entered uncharted territory in the early 1970s, policy making entered a stage of experimentation and learning.

• Central bankers felt the responsibility to stimulate employment by loosening monetary constraints, even if that perhaps meant some moderate inflation.

Step 1: Consequences of Excess Liquidity

• Data show a dramatic increase in worldwide liquidity in the early (and late) 1970s.

If inflation is sluggish (as would be the case if the public is slow to catch on to the shift in monetary policy regime), an unexpected monetary expansion will cause a temporary boom in output.

Inflation will rise slowly initially, but will continue to rise even after output has peaked, resulting in stagflation. As inflation peaks, the economy goes into recession.

In practice, the recession may be deepened by the decision of the central bank to raise interest rates to combat the inflationary pressures it had itself unwittingly created.

Step 2: Why policy makers were slow to realize their mistake

- One reason is that the acceleration of inflation coincided with the oil price shock of 1973/74, which seemed to provide a natural explanation of the inflationary pressures at the time.

- As a result, central bankers initiated a second expansionary cycle in the mid-1970s, causing another output boom in the late 1970s.

As the public increasingly caught up to the change in regime, however, stimulative polices became less effective and inflation a growing concern.

Step 3: How the cycle was broken

• Only when Paul Volcker stepped in and insisted on the primacy of the inflation objective, this go-stop monetary cycle was broken.

As in the case of the initial regime shift, the public was slow to accept that a regime shift had taken place, and inflation was slow to come down, even as the economy entered a steep recession in the early 1980s.

The same model that explains the early 1970s also applies to the early 1980s, except run in reverse.

• Given that central bankers have accepted the primacy of the inflation objective, it is not surprising that there have been no more outbreaks of stagflation.

The Effect of Fluctuations in Real Activity on the Price of Oil

• The fact that both major global economic expansions in the 1970s coincided with major increases in the real price of oil (and other industrial commodities) is no coincidence.

• An unexpected increase in global real activity causes increased demand for oil. Such demand shifts may occur for multiple reasons:

- One is a shift in monetary policy regime: Occurs rarely and takes concerted action by many countries to exert enough demand pressure to drive global commodity prices.
- Others include unexpected productivity gains in oil-importing economies and unexpectedly fast oil-intensive economic development of emerging Asia, as in recent years.

2. The Monetary Policy Reaction Hypothesis (BGW, BG)

- Consider an exogenous oil price shock.
- Two main channels of transmission:
  - Increased cost of domestic production (adverse AS shock)
  - Reduced purchasing power (adverse AD shock), amplified by increased precautionary savings and increased operating cost of energy using durables.
- Supply channel is weak. The literature shows that the demand channel dominates.
  - If AD curve shifts, the shock is recessionary and deflationary.
  - If both AD and AS curves shift to the left, the net effect on the price level will be small.

⇨ There is little or no need for central banker to intervene.

Bernanke, Gertler and Watson (BPEA 1997):

- Take the stand that the AS shock interpretation is dominant.
- Assert that this shock triggers strong inflationary pressures, while the recessionary impact is weak ("weak form of stagflation"). Fear of wage-price spirals?
- A hawkish central banker will fight inflationary pressure by raising the interest rate, deepening the recession.
- If the central banker only partially succeeds at suppressing inflation, stagflation will arise ("strong form of stagflation").

Why this interpretation?

1. Standard models cannot explain the recessions in the data. Alternative models are not very plausible.

2. BGW's premise is that there must be a causal link from oil price shocks to large recessions. The policy reaction serves as a more plausible amplifier.

BGW Problem 1: No Rationale for a Monetary Tightening

1. Are exogenous oil price shocks inflationary?

AS shock: $Y \downarrow, P \uparrow$ versus AD shock: $Y \downarrow, P \downarrow$

2. What happened to the dual objective of the Fed?

3. Inflation hawks in the 1970s?

4. Oil price shocks reflect deeper demand and supply shocks, each if which may necessitate a different response by the Fed. A policy reaction to oil price shocks makes no sense in a world of endogenous oil price shocks (see Kilian, AER 2009; Nakov and Pecatori, JMCB 2010)

BGW Problem 2: Questionable Identification

BGW's evidence rests squarely on the 1979 oil price shock episode.

Key Issue: Did Volcker raise interest rates in 1979 to fight domestic inflation unrelated to oil prices or in response to the 1979 oil price shock?

A legitimate test of this proposition is to evaluate the BGW hypothesis on data not yet available to BGW, namely 1987.8-2008.6.

Rationale:

- Greenspan and Bernanke are both inflation hawks.
- Fairly long sample and arguably homogenous data.
- There is a sufficient number of oil price shocks in that sample period to allow identification.

BGW Problem 3: Specification of the Econometric Model

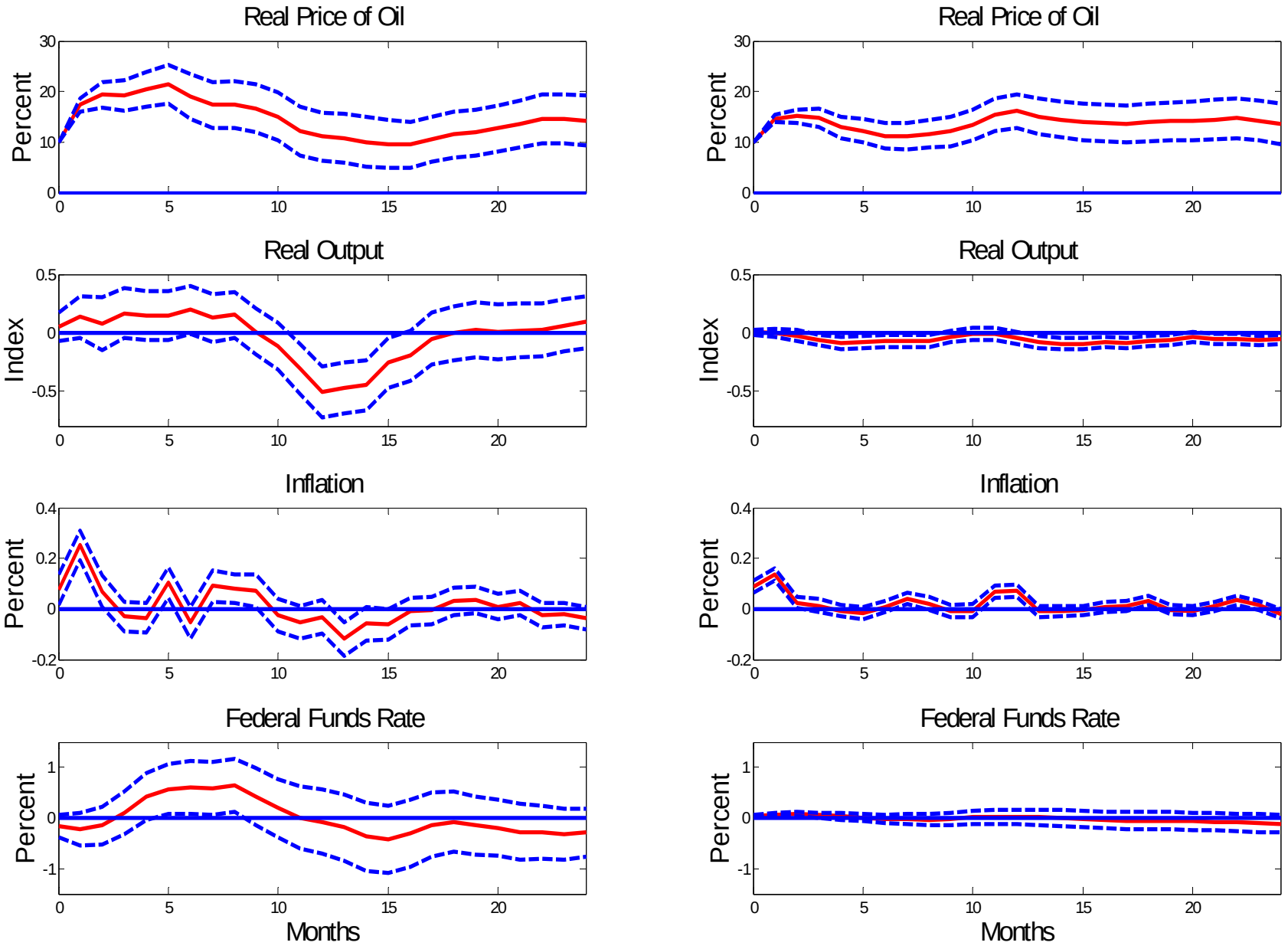
- VAR evidence based on censored oil price changes: Estimates are inconsistent because the structural model cannot be represented as a vector autoregression and because the nonlinear IRFs were computed incorrectly (see Kilian and Vigfusson QE 2011, MD 2011).

- The null of symmetric response functions cannot be rejected.

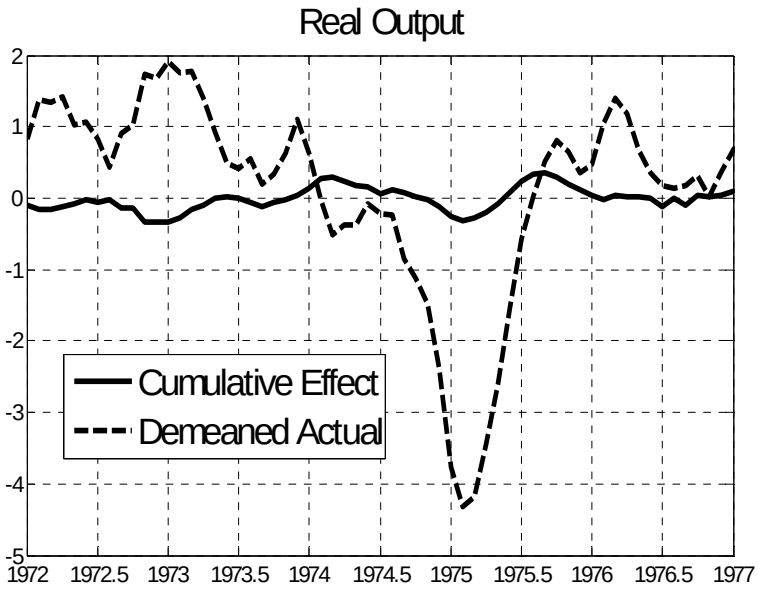
- We re-estimate this model using monthly data including the percent change in the real price of oil and the CFNAI measure of deviations of U.S. real output from trend (see Kilian and Lewis EJ 2011).

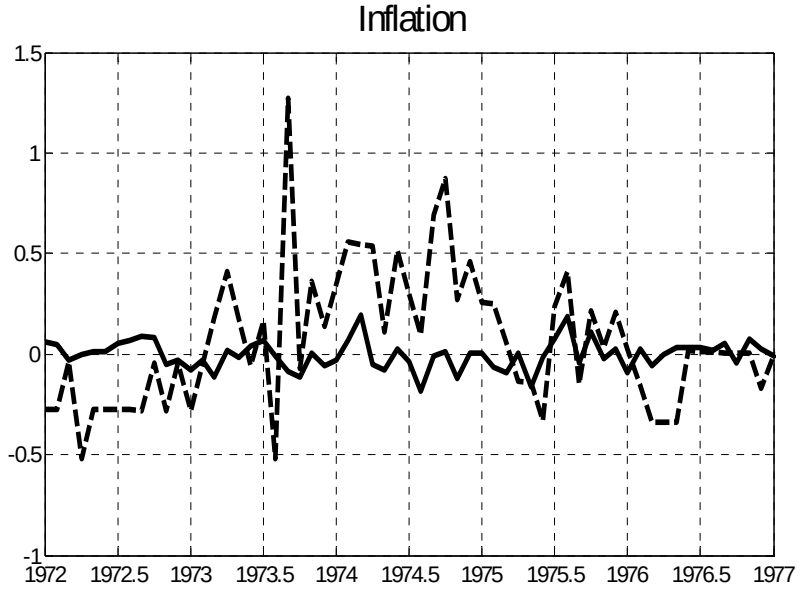
U.S. Responses to Real Oil Price Shocks (with One-Standard Error Bands)

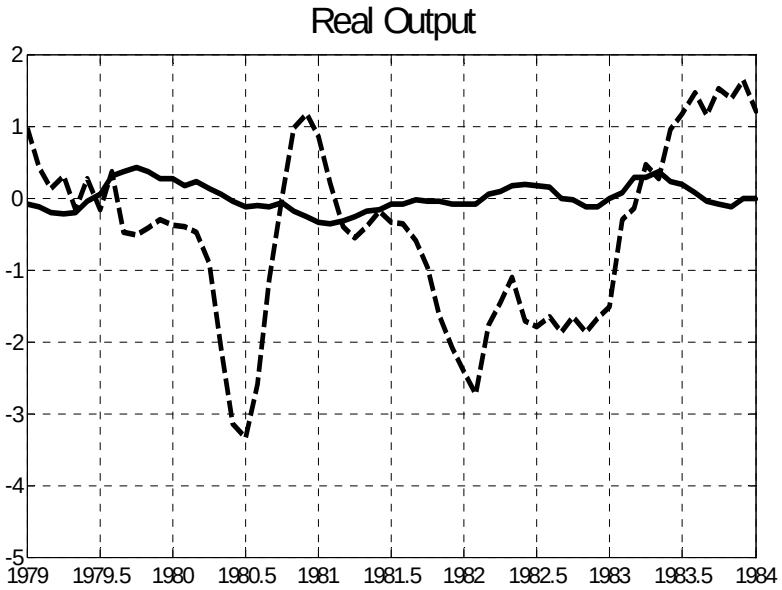
1967.5-1987.7 | **1987.8-2008.6**

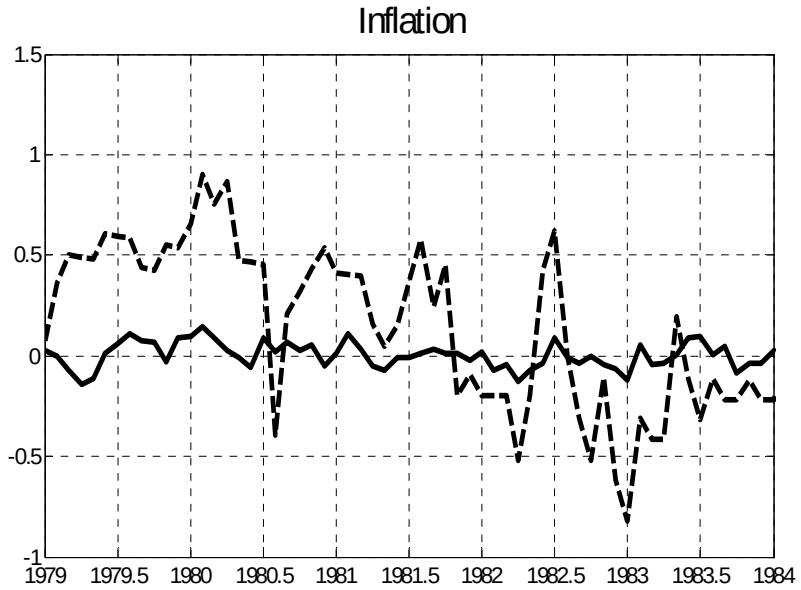


Cumulative Effect of Real Oil Price Shocks: Selected Episodes



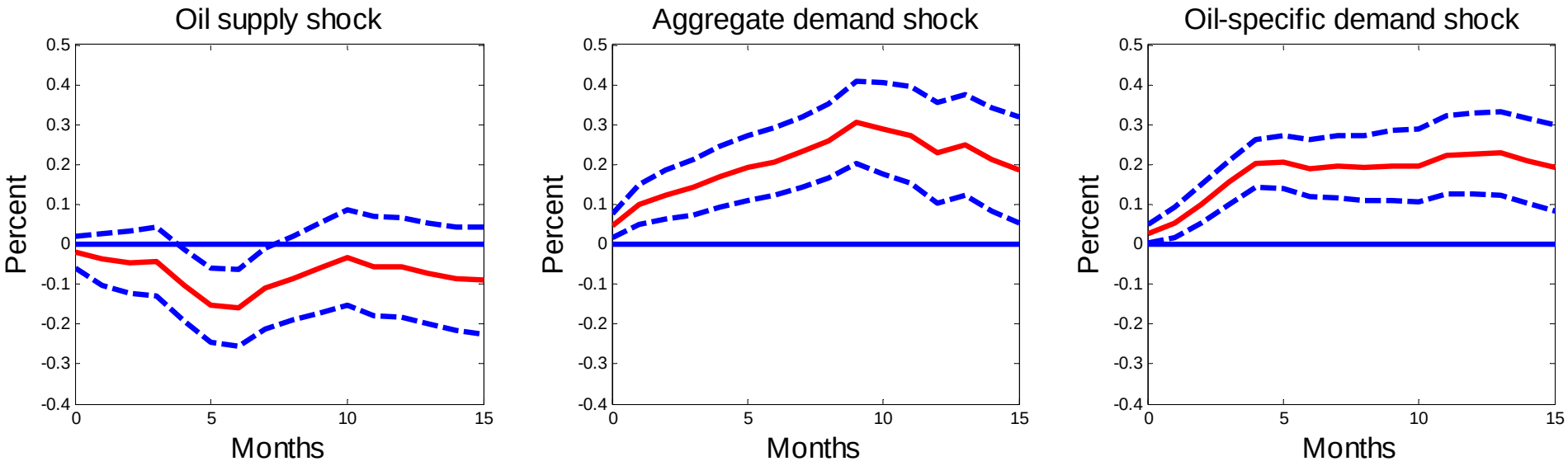






Why the Fed Deserves More Credit than BGW's Model Gives

Estimated Response of the Effective Federal Funds Rate to Oil Demand and Oil Supply Shocks



Are oil price shocks not as inflationary as they used to be?

Possible rationales:

1. Changes in the composition of oil demand and oil supply shocks (Kilian, AER 2009).

2. Lower energy share in the economy? (Edelstein and Kilian, JME 2009).

3. Reduced real wage rigidities? (Blanchard and Gali 2010)

Do Reduced Real-Wage Rigidities Rescue the BGW Model?

- VARs show that U.S. real wages decline in response to oil price shocks. No evidence that response of real wage to oil price shock has increased in magnitude since the 1970s.

- BG (2010): The same required decline in the real wage in response to the exogenous oil price shock is achieved with a smaller increase in unemployment, consistent with reduced U.S. real wage rigidities.

Problem: The smaller response of unemployment is also explained by changes in the composition of oil demand and oil supply shocks without appealing to structural change.

- This does not preclude that U.S. real wages have become more flexible, but it invalidates the evidence presented by BG (2010).

Did the Fed Contribute to the 2003-08 Oil Price Surge?

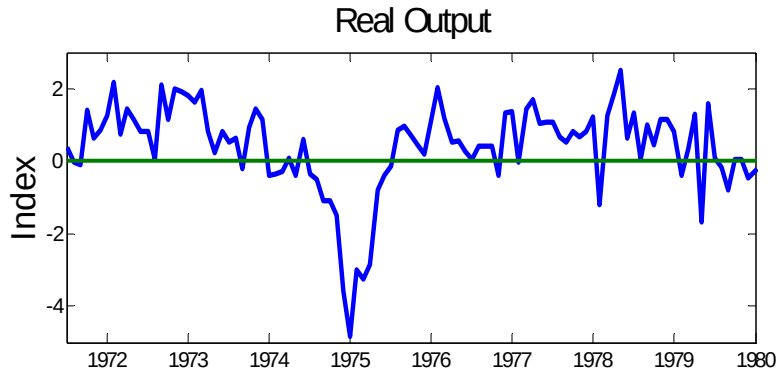
• Greenspan has been blamed with the benefit of hindsight for being too lenient in dealing with asset markets.

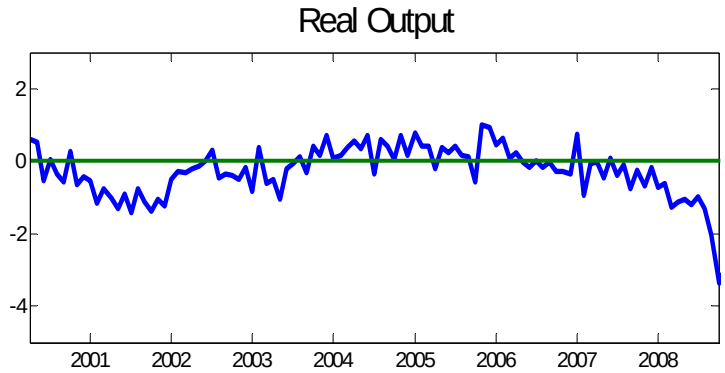
• Both Greenspan and Bernanke have been criticized for being overly concerned with the employment objective.

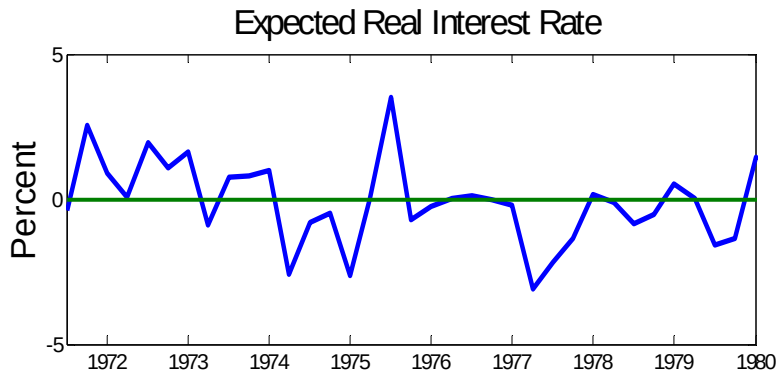
It is unlikely that U.S. monetary policy has been too stimulative after 2000, because:

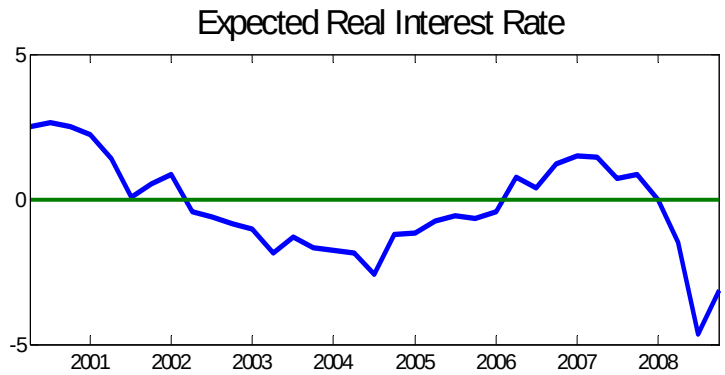
- Timing is off.
- No concerted action by OECD economies.
- U.S. economic environment is quite different than in 1970s.

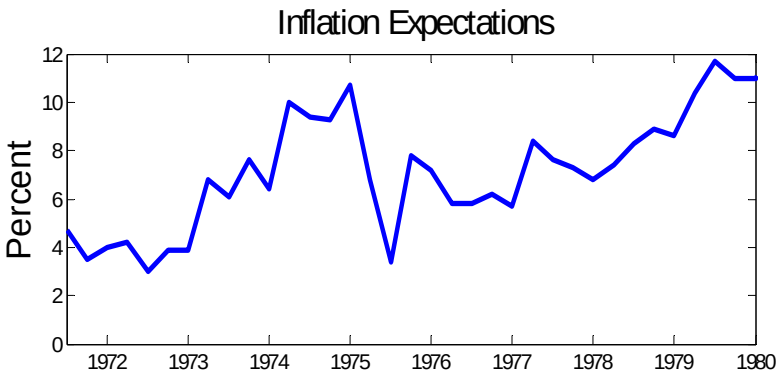
Indicators of the Stance of U.S. Monetary Policy: 1971.II-1979.IV vs 2000.I-2008.III











Other Explanations of the 2003-08 Oil Price Surge

1. Exogenous transformation of emerging Asia?
2. U.S. monetary policy eased too early and too fast, enabling export-based economies in Asia to thrive and fueling the commodity price boom?
3. Failure of U.S. regulatory policies rather than monetary policy?

How Should the Central Bank Respond to Oil Price Shocks?

- The appropriate policy response will depend on the composition of the underlying oil demand and oil supply shocks.

- This requires a different class of structural models than are customarily used by policy makers:

Recent advances in the DSGE modeling of endogenous oil prices are a step in the right direction (e.g., Nakov and Pescatori, JMCB 2010; Balke, Brown and Yücel, mimeo 2008; Bodenstein, Erceg and Guerrieri, JIE 2011; Bodenstein, Kilian and Guerrieri, mimeo 2012).

In addition, future models will have to incorporate in more detail the external transmission of oil demand and supply shocks as well as the nexus between crude oil and retail energy prices.

Example: Policy Responses to the 2003-08 Oil Price Shock

- The extent to which the price of oil responds to global demand pressures depends on how elastically oil is supplied. Recently, oil supply has been very inelastic, while demand shifts have been persistent.

- Since this oil price shock reflected a persistent shift in the real scarcity of resources, there is nothing a central bank could or should have done in response beyond making sure that inflation expectations remain anchored in the face of inflationary pressures arising from both oil and commodity prices.

Conclusions

• Central bankers are rightly proud that they have learned the lessons of the 1970s, but there is no reason for complacency.

• It is easy to forget that the central bankers of the 1970s had the best of intentions and were fully aware of the dangers of inflation.

<u>Ingredients of the 1970s crisis:</u>

- Major structural changes and need for experimentation.
- Multiple shocks and complexity of the economy make it difficult to sort out competing interpretations of the data in real time.
- Perceived need to stabilize employment.
- Urgency for action (infusion of liquidity).
- Inflation considered the lesser risk compared with unemployment.

Much like today?

Policy makers have not lost sight of the inflation objective, but:

- Determining the right timing for withdrawing excess liquidity is about as difficult as guessing when the stock market will recover. In both cases, the right timing depends on consumer and business confidence.

- There will be a tendency to downplay the risk of inflation relative to that of unemployment, all the more so, as confidence is fragile.

- Big unknown: What is potential output in a post-crisis world?

Hence, the real test of whether we have learned the lessons of the 1970s is yet to come.