

# MA Advanced Macroeconomics

## 3. Examples of VAR Studies

Karl Whelan

School of Economics, UCD

Spring 2016

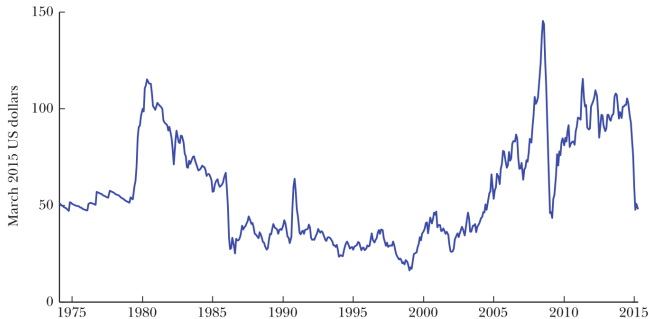
# Examples of VAR Studies

We will look at four different examples of studies that use recursive VARs:

- 1 Lutz Killian (2009): Not All Oil Price Shocks are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market. *American Economic Review* and Christiane Baumeister and Lutz Killian (2016): Forty Years of Oil Price Fluctuations: Why the Price of Oil May Still Surprise Us, *Journal of Economic Perspectives*.
- 2 Olivier Blanchard and Roberto Perotti (2002): An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output. *Quarterly Journal of Economics*.
- 3 James Stock and Mark Watson (2001): Vector Autoregressions, *Journal of Economic Perspectives*. This paper examines the effect of monetary policy shocks.
- 4 Glenn Rudebusch (1998). "Do Measures of Monetary Policy in a Var Make Sense?" *International Economic Review* and a reply by Chris Sims.

# The Price of Oil

## Inflation-Adjusted WTI Price of Crude Oil, 1974.1–2015.3



Source: US Energy Information Administration.

Note: The West Texas Intermediate (WTI) oil price series has been deflated with the seasonally adjusted US consumer price index for all urban consumers.

# Paper 1: Killian on Oil Shocks

- Oil shocks—large run-ups and subsequent declines in the price of oil—regularly receive a lot of attention.
- Many recessions have been preceded by an increase in the price of oil. Why exactly this has occurred is not obvious: Oil usage is actually a relatively small input compared to GDP.
- Previous empirical work has generally asked the question “what are the effects of an oil price shock?”
- Killian asks “what is an oil price shock and are there different kinds of oil price shocks?”
- He uses VAR analysis to distinguish between shocks to oil prices due to global demand, shocks due to oil supply, and shocks due to speculation in the oil price market.
- Let’s see how he does it.

# Killian's Model

- Three variable monthly VAR in the growth rate of oil production, real global economic activity, and the real price of oil:  $z_t = (\Delta prod_t, rea_t, rpo_t)'$ .
- VAR structure is

$$A_0 z_t = \alpha + \sum_{i=1}^{24} A_i z_{t-i} + \epsilon_t$$

where  $\epsilon_t$  are the structural shocks, and  $A_0$  is lower-rectangular

$$A_0 = \begin{pmatrix} a & 0 & 0 \\ b & c & 0 \\ d & e & f \end{pmatrix}$$

- Identifying assumptions:
  - 1 Oil production does not respond within the month to world demand and oil prices
  - 2 World demand is affected within the month by oil production, but not by oil prices.
  - 3 Oil prices respond immediately to oil production and world demand.

# Interpreting the Structural Shocks

- If  $A_0$  is lower-triangular, then so is  $A_0^{-1}$ .
- Reduced-form model is

$$z_t = A_0^{-1}\alpha + \sum_{i=1}^{24} A_0^{-1}A_i z_{t-i} + A_0^{-1}\epsilon_t$$

- Reduced-form shocks  $e_t$  related to structural shocks as  $e_t = A_0^{-1}\epsilon_t$ :

$$\begin{pmatrix} e_t^{\Delta prod} \\ e_t^{rea} \\ e_t^{rpo} \end{pmatrix} = \begin{pmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} \epsilon_t^{\Delta prod} \\ \epsilon_t^{rea} \\ \epsilon_t^{rpo} \end{pmatrix}$$

- The oil production reduced-form shock is a structural shock; the reduced-form economic activity shock combines the structural oil shock and the structural activity shock; the reduced-form oil price shock combines all three structural shocks.

# Checking the Identification Restrictions

Relative to the general model

$$AY_t = BY_{t-1} + C\epsilon_t$$

where are our  $2n^2 = 18$  identifying restrictions?

- 1 We set  $C = I$  instead assuming contemporaneous interactions between variables: 9 restrictions.
- 2 Lower-diagonal assumption on  $A_0$ : 3 zero restrictions.
- 3 Unit coefficient normalization on diagonal of  $A_0$ : 3 restrictions.
- 4 Orthogonal structural shocks: 3 off-diagonal elements of  $\Sigma$  are zero.

# Decomposing the Variables

- In addition to the standard impulse response analysis, Killian shows how the real price of oil can be decomposed into components related to these three shocks. How did he do this?
- Recall the VMA representation:

$$Y_t = \epsilon_t + A\epsilon_{t-1} + A^2\epsilon_{t-2} + A^3\epsilon_{t-3} + \dots + A^t\epsilon_0$$

- One can do this calculation three times, each time with only one type of shock “turned on” and the other set to zero. Adding these up, one will get the realized values of  $Y_t$ .
- Alternatively, one can do a dynamic simulation of the model

$$Y_t = AY_{t-1} + \epsilon_t$$

in each case letting the  $\epsilon_t$  represent one of the realized historical shocks with the others set to zero.



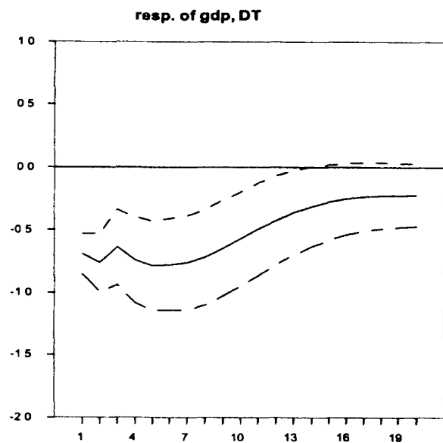
# Some of Killian's Findings

- 1 Despite getting a lot of attention, shocks to oil supply have limited effects on oil prices and have been of negligible importance in driving oil prices over time.
- 2 Both global demand and speculative oil price shocks can have significant effects on oil prices, but speculative oil price shocks have limited effects on global economic activity.
- 3 Speculative oil-market shocks have accounted for most of the month-to-month movements in oil prices.
- 4 But the steady increase in oil prices from 2000 onwards was almost solely due to strong global demand.
- 5 Main Lesson: How the economy reacts to an “oil price shock” will depend on the origins of that shock.
- 6 Helps to explain why the world economy survived a long period of increasing oil prices in the 2000s without going into recession. (And when it did go into recession, it had little to do with oil prices.)

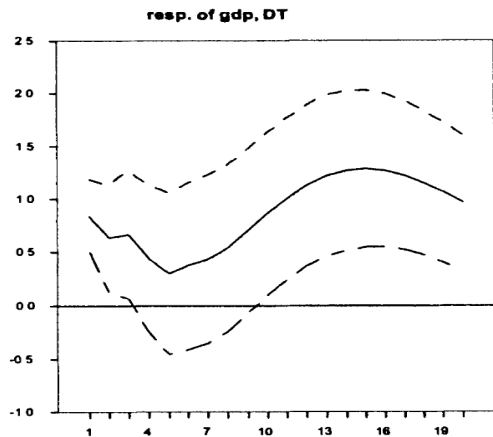
## Paper 2: A Fiscal Policy VAR

- Blanchard and Perotti (2002) examined a three-variable quarterly VAR using US data: Federal tax revenues, federal government spending and GDP.
- As with previous studies, they use prior information to set three different contemporaneous effect coefficients:
  - ① They assume no within-quarter effect of GDP on government spending. They note “Direct evidence on the conduct of fiscal policy suggests that it takes policymakers ... more than a quarter to learn about a GDP shock, decide what fiscal measures, if any, to take in response, pass these measures through the legislature, and actually implement them.”
  - ② They use separate information on tax elasticities to set a specific positive value for the contemporaneous effect of GDP on tax revenues.
  - ③ They then swap between setting the contemporaneous effect of taxes on spending equal to zero and setting the contemporaneous effect of spending on taxes equal to zero, and report that results are similar when either is used.
- BP assume that taxes and spending can both affect GDP within the same quarter, i.e. they place GDP last in the ordering as we describe it.

# BP's Estimate of GDP Response to Higher Taxes



# BP's Estimate of GDP Response to Higher Spending



## Paper 3: A Monetary Policy VAR

- Stock and Watson's 2001 *JEP* paper is a very useful introduction to VAR methods.
- The paper contains an important application: What are the effects of monetary policy shocks?
- You can think of these VARs as useful in two ways:
  - ① From a scientific perspective: Monetary policy co-moves with lots of other macro variables. Only by identifying the structural or exogenous shocks to policy can we discover its true effects.
  - ② From a policy perspective, helps to answer the question “if I choose to raise interest rates by an extra quarter point today, what is likely to happen over the next year to inflation and output relative to the case where I keep rates unchanged?” Essentially, this is a question about impulse responses.

# Stock and Watson's VAR

- Monthly data on inflation ( $\pi_t$ ), the unemployment rate ( $u_t$ ) and the federal funds rate ( $i_t$ ).
- Posits a lower-triangular causal chain of the form

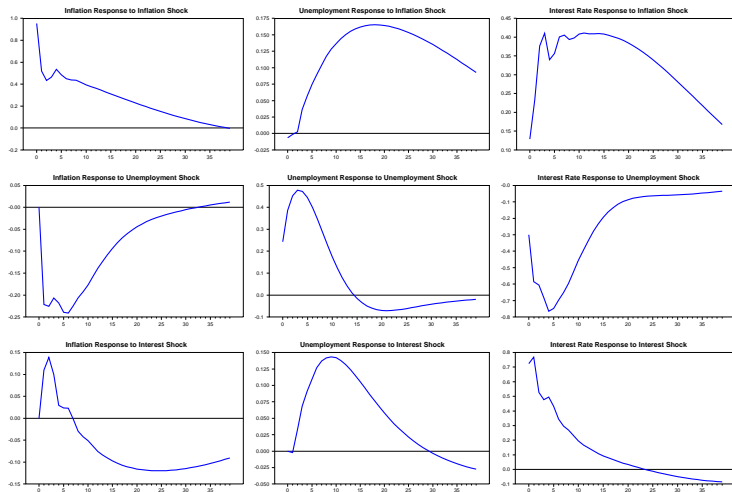
$$AZ_t = \begin{pmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} \pi_t \\ u_t \\ i_t \end{pmatrix} = BZ_{t-1} + \epsilon_t$$

- Identifying assumptions
  - 1 Inflation depends only on lagged values of the other variables (perhaps motivated by the idea of sticky prices.)
  - 2 Unemployment depends on contemporaneous inflation but not the funds rate.
  - 3 The funds rate depends on both contemporaneous inflation and unemployment. (Fed using its knowledge about the current state of the economy when it is setting interest rates).
- I have used quarterly data to re-do Stock and Watson's VAR analysis and have reported the Impulse Response Functions on the next page.

# IRFs From Recursive VAR, First Identification

**Figure 1: IRFs From Recursive VAR, First Identification**

*Order is Inflation, Unemployment, Interest Rate*



# A Puzzle?

- These results generally make sense.
- In particular, a positive interest rate shock raises the unemployment rate, and over time it reduces the inflation rate.
- The short-run response of the inflation rate, however, is a bit puzzling: The interest rate increase seems to raise the inflation rate for a few periods.
- This “price puzzle” result has been obtained in a number of VAR studies. It provides a good illustration of the potential limitations of VAR analysis.
- Some think the explanation is that the Fed is acting on information not captured in the VAR (for example, information about commodity prices) and that this information may provide signals of future inflationary pressures.
- Thus, interest rate increases can tend to occur just before an increase in inflation. The VAR may be capturing this pattern and confusing causation and correlation.
- Indeed, adding commodity prices to the VAR has often been found to eliminate the “price puzzle.” But is this improving the specification or is it data mining to find the result we want?



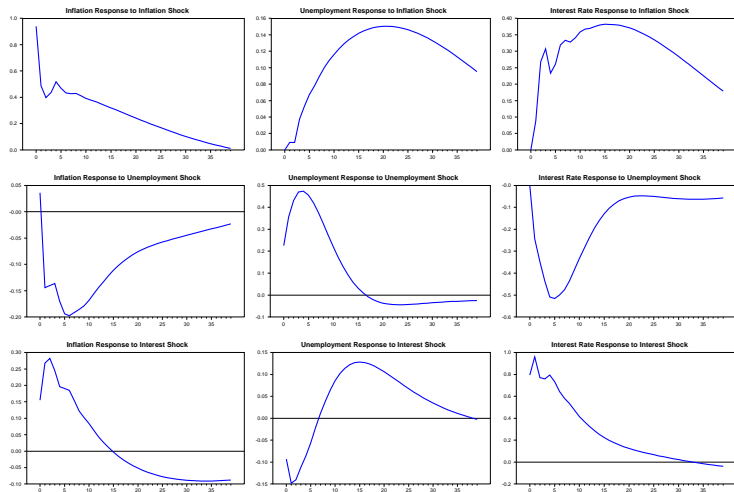
## A Second Identification

- The results from the Stock-Watson identification generally make sense but you could imagine other possible identifications.
- The next slide shows results from an alternative ordering with interest rates first, unemployment second, and inflation last.
- You could argue for this case on the grounds that the Fed can only respond to the economy with a lag because it takes a while to receive data about the current state of the economy (so they are reacting to lagged information) but that inflation should be able to respond immediately to economic events.
- This may sound reasonable enough but the results from this identification don't make as much sense: The interest rate shock raises inflation now for almost four years and unemployment drops for a while after the increase in interest rates.
- Which identification a researcher settles on may depend on how “sensible” they believe results are. This can cause problems.
- RATS code for both identifications are available on the website.

# IRFs From Recursive VAR, Second Identification

## Figure 2: IRFs From Recursive VAR, First Identification

*Order is Interest Rate, Unemployment, Inflation*



## Final Example: The Rudebusch-Sims Debate

- A lot of interesting material on monetary policy VARs can be found in a 1998 exchange between Glenn Rudebusch and Chris Sims.
- Rudebusch's paper contains a strong critique of VARs used to assess monetary policy. Among his points:
  - 1 The VARs ignore changes over time in the formulation of monetary policy.
  - 2 They use final published data instead of the preliminary estimates the Fed has available when it makes decisions.
  - 3 They greatly underestimate the information available to the Fed when it takes decisions.
  - 4 They incorporate long lags but he argues it is not credible that the Fed responds to information from over a year prior to taking a decision.
  - 5 The monetary policy shocks don't look anything like the surprise element of monetary policy decisions obtained from looking at financial contracts like fed funds futures.
  - 6 Models with very different monetary policy shocks report similar IRFs, suggesting that perhaps the models have been data-mined to give these answers.

## Final Example: The Rudebusch-Sims Debate

- Sims responded in detail to Rudebusch's critiques. Some of his points were as follows.
  - ① VAR models may differ in their shocks but agree on their effects. For example, one model may include more variables in a supply equation than another so its supply shocks are, by construction, smaller in size but both models could still capture roughly the same effect of a shock to supply.
  - ② Financial market "surprises" are not necessarily the best measures of the exogenous element of monetary policy. A Fed governor could give a speech the week before an FOMC meeting indicating that the Fed is going to raise rates (even if this isn't predicted by inflation or GDP or other standard VAR variables.) When this rate increase happens, we'd like to know what effect it has even though, on the day, it is not a surprise for financial markets.
  - ③ Issues like "time invariance, linearity, and variable selection are universal in macroeconomic modeling" and are not special to VARs.
- The exchange is well worth reading in full as it sheds light on a lot of the issues that economists need to think about when doing VAR analysis.

## An Alternative Identification: Romer and Romer (2004)

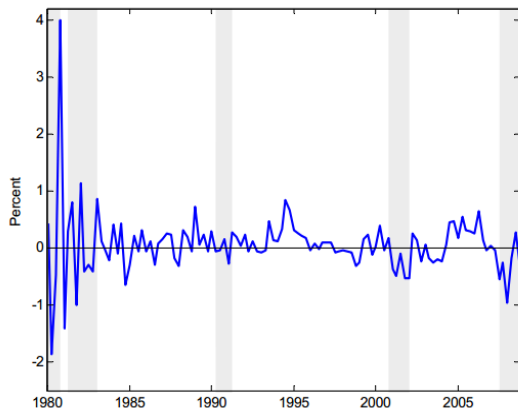
- There are other ways to try to get at “truly exogenous” movements in monetary policy.
- For example, Romer and Romer (2004) look at each FOMC meeting and attempt to get at a measure of monetary shocks that *“should be relatively free of both endogenous and anticipatory actions.”* They do this as follows.
  - 1 They use internal documentation to assess the Fed’s intended policy rate.
  - 2 They obtain the Fed’s internal forecasts of inflation and real activity.
  - 3 They regress the change in the intended funds rate around forecast dates on these forecasts. The residuals *“purge the intended funds rate of monetary policy actions taken in response to information about future economic developments.”*
- Romer and Romer find *“The response of industrial production to our measure of monetary shocks indicates a strong relationship ... The same regression run using the change in the actual funds rate as the measure of monetary policy indicates a considerably weaker correlation between monetary developments and real activity. The estimated impact of this broader measure is smaller, slower, and less significant than the impact of our new indicator.”*

# Updated Romer and Romer Shocks

- Coibon (2012) updates the Romer and Romer shocks and presents an analysis of why the estimated effects on output of the Romer shocks are so much larger than those from traditional VARs.
- Another paper co-authored by Coibon provides a graph of the updated shock measures. See the next page.
- The shocks from the recent recession raise a few issues about this methodology. They show large negative shocks, meaning the Fed cut rates by more than would have been justified by forecasts of output and inflation.
- But what if there was another factor that the Fed was worried about e.g. a financial crisis? And what if financial crises tend to be associated with particularly slow recoveries?
- One could look at this chart and conclude that the large monetary stimulus didn't actually help the economy much. But this large stimulus may have been in response to the potential for financial crises to have long-lasting effects and could have prevented an even deeper fall in output.
- Ultimately, no method is perfect and the world keeps changing in ways that require us to keep on our toes!

# Updated Romer and Romer Shocks

FIGURE 2: MONETARY POLICY SHOCKS



*Note:* The figure plots the quarterly sum of monetary policy shocks as identified in Romer and Romer (2004). See section 3.1 for details.