Empirical Evidence
Walsh Chapter 1
1 Correlations

1.1 Long-run relationships – average rates over long periods across countries

- Almost unitary correlation between money growth and inflation
- No correlation between either money growth or inflation and the growth rate of real output
  - Literature has some exceptions with positive and negative relationships
  - Permanent monetary shocks have no long-run output effects
• No long-run trade-off between inflation and unemployment (output)

• Fisher relation between real and nominal interest

\[ 1 + i_t = (1 + r_t) \frac{P_{t+1}}{P_t} \]

– Inflation and money growth are highly correlated with nominal interest rates

1.2 **Short-run relationships with real output– correlations at leads and lags**

• All series detrended
• Monetary aggregates (M0, M1, M2)
  – Lead real output (positive correlation between lagged money and output)
  – In later period, M2 no longer leads

• Interest rates
  – Low interest rates lead real output (negative correlation between lagged interest and current output)
  – Rise in output is followed by high interest rates (positive correlation between current output and future interest rates)
  – Less pronounced later
• Prices
  
  – Are low when output is high (negative contemporaneous correlations)

  – Increases in output are followed by price increases (positive correlation between current output and future prices)

• Interest rates move together except during recent financial crisis
Does money cause output?

2.1 Early empirical evidence

- Friedman and Schwartz
  - 100 years of data
  - Money growth rate changes lead growth in real output

- St. Louis equation
  - Regress nominal output on monetary aggregates and other possible determinants including fiscal policy
Money is important, but becomes less important when add an interest rate.

Causality

- Regressions do not imply causality
- Anticipations that output would rise could endogenously increase money supply
- Granger causality (Sims) – a variable m Granger causes a variable y, if coefficients on lagged m are significant
Lucas critique: coefficients on money depend on the policy rule

- Estimated equation

\[ y_t = y_0 + a_0 m_t + a_1 m_{t-1} + c_1 z_t + c_2 z_{t-1} + u_t \]

* Assume: we believe that this is the true relationship between money and output

* Choose money to min \( E_t (y_t - y_0)^2 \) to yield

\[ m_t = -\frac{a_1}{a_0} m_{t-1} - \frac{c_2}{a_0} z_{t-1} + \nu_t \]

where \( E_t z_t = E_t u_t = 0 \), and \( \nu_t \) is a monetary policy mistake.

* Substitute for \( m_t \) in the original equation to yield

\[ y_t = y_0 + c_1 z_t + u_t + a_0 \nu_t, \]
· money disappears

· showing that only the only part of monetary policy which affects output is the mistake \((v_t)\)

– Alternative: only monetary surprises \((v_t)\) affect output (Sargent)

\[
y_t = y_0 + d_0 v_t + d_1 z_t + d_2 d_{t-1} + u_t
\]

* Substitute for monetary surprises from above

\[
y_t = y_0 + d_0 \left( a_1 m_{t-1} + \frac{c_2}{a_0} z_{t-1} + m_t \right) + d_1 z_t + d_2 d_{t-1} + u_t,
\]

· which is observationally equivalent to equation in which money (not its surprise) affects output

· coefficients are functions of parameters in policy rule
• Need theory to determine which parameters change with policy change
3  VAR Approach

3.1  Statement of the problem

\[
\begin{bmatrix}
  y_t \\
  x_t \\
\end{bmatrix} = A (L) \begin{bmatrix}
  y_{t-1} \\
  x_{t-1} \\
\end{bmatrix} + \begin{bmatrix}
  u_yt \\
  u_xt \\
\end{bmatrix},
\]

where \( y \) is the log of real output, \( x \) is the monetary policy variable, \( u_s \) are innovations to output and policy. Regression identifies the elements of \( A (L) \) and residuals. However, the residuals are a linear combination of the fundamental errors, \( e_s \), according to:

\[
\begin{bmatrix}
  u_yt \\
  u_xt \\
\end{bmatrix} = \begin{bmatrix}
  e_yt + \theta e_xt \\
  \phi e_yt + e_xt \\
\end{bmatrix} = \begin{bmatrix}
  1 & \theta \\
  \phi & 1 \\
\end{bmatrix} \begin{bmatrix}
  e_yt \\
  e_xt \\
\end{bmatrix} = B \begin{bmatrix}
  e_yt \\
  e_xt \\
\end{bmatrix}
\]
The ones’ are normalizations. Need $\theta$ and $\phi$ to identify fundamental shocks, es.

Simplify original model to

$$
\begin{bmatrix}
  y_t \\
x_t
\end{bmatrix} =
\begin{bmatrix}
  a_1 & a_2 \\
  0 & 0
\end{bmatrix}
\begin{bmatrix}
  y_{t-1} \\
x_{t-1}
\end{bmatrix} +
\begin{bmatrix}
  u_{yt} \\
u_{xt}
\end{bmatrix}
\quad a_1 < 1,
$$

such that

$$x_t = u_{xt}$$

$$y_t = a_1 y_{t-1} + a_2 x_{t-1} + u_{yt}.$$ 

Solving the second yields

$$y_t (1 - a_1 L) = a_2 x_{t-1} + u_{yt}$$

$$y_t = \frac{1}{(1 - a_1 L)} (a_2 x_{t-1} + u_{yt})$$
where \( \frac{1}{(1-a_1L)} = 1 + a_1L + (a_1L)^2 + (a_1L)^3 + \ldots \)

\[ y_t = a_2 \sum_{i=0}^{\infty} a_1^i u_{xt-i-1} + \sum_{i=0}^{\infty} a_1^i u_{yt-i}. \]

This gives impulse response for effects of shocks to \( u_x \) on \( y \). Really want effects of \( e_x \) on \( y \). Substituting for \( u_x \) and \( u_y \)

\[ y_t = a_2 \sum_{i=0}^{\infty} a_1^i (e_{yt-i-1} + \theta e_{xt-i-1}) + \sum_{i=0}^{\infty} a_1^i (\phi e_{yt-i} + e_{xt-i}). \]

We need to know \( \theta \) to know the effect of a monetary disturbance on \( y \).
3.2 Possible solutions

3.2.1 Short-run restrictions

if know either $\phi$ or $\theta$, can recover the other in regressions
• Set $\phi = 0$, reflecting assumption that a monetary policy shock cannot react to a contemporaneous output shock

  – System becomes

  $$x_t = ext$$

  $$y_t = a_1 y_{t-1} + a_2 x_{t-1} + \theta e_{xt} + u_{yt}$$

• – View monetary policy shock as exogenous and order this equation first. Estimate second using estimate of monetary policy shock from first.
Set $\theta = 0$, reflecting assumption that current output does not react to a monetary policy shock

- System becomes

$$y_t = a_1 y_{t-1} + a_2 x_{t-1} + e_y t$$

$$x_t = \phi e_y t + e_x t$$

- View output shock as exogenous and order this equation first. Estimate the money shock after accounting for the output shock from the first equation.
3.2.2 Long-run restrictions

- No long-run effect of a permanent money shock \( e_{xt} \) on output

\[
\theta + \sum_{i=0}^{\infty} a_i (a_1 \theta + a_2) = 0
\]

\[
\theta + \frac{(a_1 \theta + a_2)}{1 - a_1} = 0
\]

\[
\theta = -a_2.
\]
3.3 Empirical Results

- Sims (1992)
  - Industrial production, CPI, short-term interest rate as a measure of monetary policy, money supply, exchange rate index, index of commodity prices
  - orders interest rate first
  - decrease in interest rate produces hump-shaped pattern for output
• Eichenbaum (1992)

  – price, output, fed funds rate, M1

  – alternatively lets M1 and Fed funds rate be policy variable ordered first

  – M1 up followed by interest up and output down – puzzling if M1 is policy variable – literature searching for liquidity effect of money on interest rate

  – interest rate up followed by output down but price up – price puzzle

    * monetary policy is reacting to forecast of inflation which it is not strong enough to reverse

    * interest rate represents a cost shock
• How much output forecast error variance is due to monetary policy shocks?
  
  – Sensitive to way monetary policy is measured
  
  – Do small numbers imply effective policy (few mistakes leading to low variance) or ineffective policy (monetary policy has small effects).
3.4 Criticism

- Do puzzling results represent misspecification?

- Residual from VAR regressions bear little resemblance to standard interpretations of the historical record of past policy actions.

- VAR’s are based on revised data while the Fed’s reaction function is based on real time data.

- Most monetary policy is a stabilization effort, not an attempt to create unanticipated shocks.
4 Other Approaches

- Large Keynesian models with adaptive expectations
  - Ended by the Lucas critique

- Structural DSGE models which embed rational expectations

- Narrative approaches

- Case studies for specific events
  - Sargent and the end of hyperinflations
  - Recovery from the Great Depression and abandoning the gold standard
5 Consensus

- Money growth and inflation have almost a unitary correlation coefficient.

- Money growth and output growth are basically uncorrelated.
  - possibly slight positive correlation at low inflation
  - slight negative correlation at high inflation

- Monetary policy shocks produce a hump-shaped response of output.