Technology shocks and Monetary Policy: Assessing the Fed’s performance
(J. Gali et al., JME 2003)

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We only know three chairmans of the Fed
Introduction: Three famous chairmans of the Fed

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  - Very famous economist
  - TV star during the financial crisis
- Alan Greenspan (1987 - 2006)
  - The "Maestro" of the economy
  - The Age of Turbulence
- Paul A. Volcker (1979 - 1987)
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Introduction: Main Question

Main question of the paper

⇒ *How well* does the Fed do its job?
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What is the Fed’s job?

The Federal Reserve Act says “…to promote maximum sustainable output and employment and to promote stable prices”
To answer *how well* the Fed does its job, the paper identifies technology shock as the only source of the unit root in labor productivity. It characterizes the Fed's systematic response to technology shocks and its implications for U.S. output, hours, and inflation based on a structural VAR model. The model compares the empirical responses to the simulated ones from three simple monetary policies in the context of a standard business cycle model with sticky prices.
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To answer *how well* the Fed does its job, the paper

- identifies technology shock as the only source of the unit root in labor productivity
- characterizes the Fed’s systematic response to technology shocks and its implications for U.S. output, hours and inflation based on a structural VAR model
To answer *how well* the Fed does its job, the paper identifies technology shock as the only source of the unit root in labor productivity. It characterizes the Fed’s systematic response to technology shocks and its implications for U.S. output, hours and inflation based on a structural VAR model. It compares the empirical responses to the simulated ones from three simple monetary policies in the context of a standard business cycle model with sticky prices:

- **optimal policy**: one that fully stabilizes prices
- simple Taylor rule
- monetary targeting rule
Baseline model: A New Keynesian model

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- Key feature of New Keynesian model: Nominal rigidities
- Representative household, continuum of firms \((i \in [0, 1])\), monetary policy
- Two key features of the baseline model
  1. Imperfect competition: differentiated goods, i.e. firms set their prices
  2. Sticky prices: only a fraction of firms can reset their prices in any given period
Baseline model: Household

- Infinitely lived representative household solving

\[
\max E_0 \sum_{t=0}^{\infty} \beta^t \left( \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right)
\]

subject to

\[
\int_0^1 P_t(i) C_t(i) di + Q_t B_t \leq B_{t-1} + W_t N_t
\]

\[
\lim_{T \to \infty} E_T B_T \geq 0
\]

where \( C_t \equiv \left( \int_0^1 C_t(i)^{1-\frac{1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}} \)
Baseline model: Household

- $P_t(i)$: price of good $i$ at $t$
- $P_t \equiv (\int_0^1 P_t(i)^{1-\epsilon} \, di)^{\frac{1}{1-\epsilon}}$: aggregate price index at $t$
- $C_t(i)$: amount consumed of good $i$ at $t$
- $C_t$: aggregate consumption index as previously defined
- $B_t$: quantity of 1 period risk-free discount bonds purchased at $t$
- $Q_t$: its price at $t$
- $W_t$: nominal wage (per hour) at $t$
- $N_t$: hours worked at $t$
Solving the problem and taking the log, we get the labor supply schedule

\[ w_t - p_t = \sigma c_t + \varphi n_t \]
Baseline model: Household optimization

- Solving the problem and taking the log, we get the labor supply schedule

\[ w_t - p_t = \sigma c_t + \varphi n_t \]

- Letting \( r_t \equiv -\log Q_t \), \( rr \equiv -\log \beta \) and taking the first-order Taylor expansion, we also get the log-linearized Euler equation

\[ c_t = -\frac{1}{\sigma} (r_t - E_t \pi_{t+1} - rr) + E_t c_{t+1} \]
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\[ c_t = -\frac{1}{\sigma} (r_t - E_t \pi_{t+1} - rr) + E_t c_{t+1} \]

and from the clearing of each market \( i \) (\( Y_t(i) = C_t(i) \), so \( Y_t = C_t \)), we get

\[ y_t = -\frac{1}{\sigma} (r_t - E_t \pi_{t+1} - rr) + E_t y_{t+1} \]
Baseline model: Firm

- Continuum of firms each producing a differentiated good with technology

\[ Y_t(i) = A_t N_t(i), \quad i \in [0, 1] \]

with \( a = \log A_t \) following

\[ \Delta a_t = \rho \Delta a_{t-1} + \epsilon_t \]

where \( \rho \in [0, 1) \)
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  \[ \Delta a_t = \rho \Delta a_{t-1} + \epsilon_t \]
  where \( \rho \in [0, 1) \)

- Assumptions
  1. variations in aggregate productivity are the only sources of fluctuations
  2. no capital accumulation (most results and implications not affected)
Firms put markup on marginal cost to maximize profits

- \( MC_t = \) real marginal cost at \( t = \) real wage/marginal product = \( \frac{W_t}{P_t A_t} \)
Baseline model: Firm’s profit maximization
under flexible prices

Firms put markup on marginal cost to maximize profits

- \( MC_t = \text{real marginal cost at } t = \frac{W_t}{P_tA_t} \)
- combined with labor supply and good market clearings
  \( \rightarrow \) the common marginal cost for all firms

\[
mc_t = (\sigma + \varphi)y_t - (1 + \varphi)a_t
\]
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\[
mc_t = (\sigma + \varphi)y_t - (1 + \varphi)a_t
\]

- same CRS technology, same isoelastic demand, same real marginal cost across all firms

\[
Y_t(i) = A_t N_t(i), \quad C_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} C_t
\]
Baseline model: Firm’s profit maximization under flexible prices

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- same CRS technology, same isoelastic demand, same real marginal cost across all firms

$$Y_t(i) = A_t N_t(i), \quad C_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} C_t$$

- under flexible prices, the markup is common across all firms, given by $\epsilon/(\epsilon - 1)$ and $mc_t = -\log \epsilon/(\epsilon - 1) = mc$ (not depending on $t$)
Baseline model: Equilibrium under flexible prices

- Call the equilibrium processes under flexible prices *Natural* levels
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- Natural level of output
  \[ y_t^* = \gamma + \psi a_t \]
  where \( \psi \equiv (1 + \varphi)/(\sigma + \varphi) \), \( \gamma \equiv mc/(\sigma + \varphi) \)
Baseline model: Equilibrium under flexible prices

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- Natural level of employment
  \[ n_t^* = \gamma + (\psi - 1)a_t \]
Call the equilibrium processes under flexible prices *Natural* levels

**Natural level of output**

\[ y_t^* = \gamma + \psi a_t \]

where \( \psi \equiv (1 + \varphi)/(\sigma + \varphi), \) \( \gamma \equiv mc/(\sigma + \varphi) \)

**Natural level of employment**

\[ n_t^* = \gamma + (\psi - 1)a_t \]

**Natural rate of real interest rate**

\[ rr_t^* = rr + \sigma \rho \psi \Delta a_t \]

where \( rr_t \): real interest rate at \( t \)
Baseline model: under sticky prices

- Assumption: $Pr_{i,t}(\text{reset its price in this period}) = 1-\theta$
Baseline model: under sticky prices

- Assumption: $Pr_{i,t}(\text{reset its price in this period}) = 1-\theta$
- the markup and the real marginal cost will no longer be constant and output gap ($x_t \equiv y_t - y^*_t$) may emerge

$$\pi_t = \beta E_t \pi_{t+1} + k x_t, \quad k \equiv (1-\theta)(1-\beta \theta)(\sigma + \phi)$$
Assumption: Pr_{i,t}(reset its price in this period) = 1-\theta

the markup and the real marginal cost will no longer be constant and output gap (x_t \equiv y_t - y^*_t) may emerge

Then we can derive the new Phillips curve

$$\pi_t = \beta E_t \pi_{t+1} + k x_t, \ k \equiv \frac{(1-\theta)(1-\beta\theta)(\sigma + \varphi)}{\theta}$$
Baseline model: under sticky prices

- Assumption: $Pr_{i,t}(\text{reset its price in this period}) = 1-\theta$
- the markup and the real marginal cost will no longer be constant and output gap ($x_t \equiv y_t - y_t^*$) may emerge
- Then we can derive the new Phillips curve

\[ \pi_t = \beta E_t \pi_{t+1} + kx_t, \quad k \equiv \frac{(1 - \theta)(1 - \beta \theta)(\sigma + \varphi)}{\theta} \]

and $y_t = -\frac{1}{\sigma}(r_t - E_t \pi_{t+1} - rr) + E_t y_{t+1}$ can be rewritten as

\[ x_t = -\frac{1}{\sigma}(r_t - E_t \pi_{t+1} - rr_t^*) + E_t x_{t+1} \]
The Basic New Keynesian Model

- New Keynesian Phillips curve
  \[ \pi_t = \beta E_t\{\pi_{t+1}\} + \kappa x_t \]

- Dynamic IS Equation
  \[ x_t = -\left(\frac{1}{\sigma}\right)(r_t - E_t\{\pi_{t+1}\} - rr^*) + E_t\{x_{t+1}\} \]

- Monetary Policy Rule
Dynamics effects of technology shocks

Alternative specifications of the systematic component of monetary policy that will try to lead us to the optimal allocation:

- A simple Taylor rule
- Constant money growth

How the nature of the monetary policy affects the equilibrium responses of different variables to a permanent shock to technology?
Aim of monetary policy: to replicate the allocation associated with the flexible price equilibrium.

The optimal policy requires that $x_t = \pi_t = 0$, for all $t$.

Flexible price equilibrium replicated with the following interest rule:

$$r_t = r^* + \sigma \rho \psi \Delta a_t + \phi_\pi \pi_t$$

for any $\phi_\pi > 1$

The equilibrium response of output and unemployment will match that of their natural levels.
Optimal monetary policy

- The sign of the response of employment depends on the size of $\sigma$ ($1/\sigma$: intertemporal elasticity of substitution between consumption in 2 periods)

$$E_0 \sum \beta^t \left( \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right)$$
Optimal monetary policy

\[ \sigma < 1 \]

\[ \sigma c_1 + \phi n \]
\[ \sigma c_0 + \phi n \]
\[ a_1 - \alpha n + \log(1-\alpha) \]
\[ a_0 - \alpha n + \log(1-\alpha) \]
\[ w \]
\[ w_1 \]
\[ w_0 \]
\[ n_0 \]
\[ n_1 \]
\[ n \]

\[ \sigma > 1 \]

\[ \sigma c_1 + \phi n \]
\[ \sigma c_0 + \phi n \]
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\[ a_0 - \alpha n + \log(1-\alpha) \]
\[ w \]
\[ w_1 \]
\[ w_0 \]
\[ n_1 \]
\[ n_0 \]
\[ n \]
A simple Taylor rule

- The central bank follows the rule:
  \[ r_t = rr + \phi_\pi \pi_t + \phi_x x_t \]
- Calibration
  \[ \phi_\pi = 1.5 \quad \phi_x = 0 \]
  \[ \sigma = 1 \quad \beta = 0.99 \quad \varphi = 1 \quad \rho = 0.2 \quad \theta = 0.75 \]
A monetary targeting rule

- \( m_t - m_{t-1} = \Lambda_m \)
- Without loss of generality assume \( \Lambda_m = 0 \), which is consistent with zero inflation in the steady state.
- The demand for money is assumed to be \( m_t - p_t = y_t - \eta r_t \)
- Letting \( m_t^* \equiv m_t - p_t - \psi a_t \)
  \[ m_t^* = x_t - \eta r_t \]
  \[ m_{t-1}^{*} = m_t^* + \pi_t + \psi \Delta a_t \]
- \( r_t = rr + (\frac{\sigma-1}{1+\eta}) \sum (\frac{\eta}{1+\eta})^{k-1} E_t \{ \Delta y_{t+k} \} \)
Optimal vs Money Rule

- Productivity vs Nominal Rate
- GDP vs Real Rate
- Labor vs Inflation

△ Optimal □ Money Rule
Evidence on the Fed’s systematic response to technology shocks and its implications for U.S. output, hours and inflation.

Are those responses consistent with any of the rules considered in the previous section?


The empirical effects of technology shocks are determined through the estimation of a structural VAR.
The Fed’s response to technology shocks: evidence
Pre-Volcker vs Volcker-Greenspan Era

Clarida, Galí and Gertler, QJE 2000


- Results
  - Differences in estimated rule across across periods
  - The Volcker-Greenspan rule is stabilizing over the equilibrium properties of inflation and output
We are considering a structural VAR(4) with four variables.

Only interested in exogenous variations in technology.

\[
Y_t = \begin{pmatrix}
Productivity_t \\
\pi_t \\
hours_t \\
real \ interest \ rate_t
\end{pmatrix}
\]

\[Y_t = F_1 Y_{t-1} + F_2 Y_{t-2} + F_3 Y_{t-3} + F_4 Y_{t-4} + E_t\]

Identification restriction: Only technology shocks may have a permanent effect on the level of labor productivity (Gali AER 1999)

\[Productivity_t = z_t + \zeta_t(K_t, L_t, Z_t, U_t, N_t)\]
Table 1
Estimated VAR model: summary statistics

<table>
<thead>
<tr>
<th>Equation</th>
<th>Pre-Volcker</th>
<th>Volcker–Greenspan</th>
<th>Own lags</th>
<th>Other lags</th>
<th>$R^2$</th>
<th>DW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor productivity</td>
<td></td>
<td></td>
<td>0.02</td>
<td>0.00</td>
<td>0.49</td>
<td>1.97</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.20</td>
<td>0.15</td>
<td>0.43</td>
<td>1.92</td>
</tr>
<tr>
<td>Hours</td>
<td></td>
<td></td>
<td>0.00</td>
<td>0.20</td>
<td>0.94</td>
<td>1.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
<td>0.01</td>
<td>0.96</td>
<td>1.95</td>
</tr>
<tr>
<td>Real interest rate</td>
<td></td>
<td></td>
<td>0.30</td>
<td>0.20</td>
<td>0.60</td>
<td>1.96</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
<td>0.03</td>
<td>0.89</td>
<td>1.96</td>
</tr>
<tr>
<td>Inflation</td>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.95</td>
<td>1.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
<td>0.60</td>
<td>0.90</td>
<td>1.95</td>
</tr>
</tbody>
</table>

Note: Values in the third and fourth columns are $p$-values for the $F$ tests. The Pre-Volcker period corresponds to 1954:2-1979:3; and the Volcker–Greenspan period corresponds to 1982:4-1998:4.
The Fed’s response to technology shocks: evidence


- Estimated response to a positive technological shock \((sd = 1)\) vs Impulse response under optimal policy.

**Optimal Policy:**
- \(x_t = \pi_t = 0\)
- \(\rho = 0\), \(\Delta a_t = \rho \Delta a_{t-1} + \epsilon_t\), \(y_t^* = \gamma + \left(\frac{1+\varphi}{\sigma+\varphi}\right) a_t\)
- \(n_t^* = \gamma + \left(\frac{1+\varphi}{\sigma+\varphi} - 1\right) a_t\), \(rr_t^* = rr + \sigma \rho \left(\frac{1+\varphi}{\sigma+\varphi}\right) \Delta a_t\)
The Fed’s response to technology shocks: evidence
The Fed’s response to technology shocks: evidence

- Both hours and inflation response functions are not significant

- Volcker-Greenspan period consistent with the optimal policy
The Fed’s response to technology shocks: evidence

The Pre-Volcker Period (1954:I-1979:II)

- Estimated response to a positive technological shock \((sd = 1)\) vs Impulse response under optimal policy.

Optimal Policy: \(x_t = \pi_t = 0\)

- \(\rho = 0.7\), \(\Delta a_t = \rho \Delta a_{t-1} + \epsilon_t\), \(y^*_t = \gamma + \left(\frac{1+\phi}{\sigma+\phi}\right) a_t\)
- \(n^*_t = \gamma + \left(\frac{1+\phi}{\sigma+\phi} - 1\right) a_t\), \(rr^*_t = rr + \sigma \rho \left(\frac{1+\phi}{\sigma+\phi}\right) \Delta a_t\)
The Fed’s response to technology shocks: evidence

The Pre-Volcker Period (1954:I-1979:II)
The Fed’s response to technology shocks: evidence

The Pre-Volcker Period (1954:I-1979:II)

- Both hours and inflation response functions deviate from optimal path

- Pre-Volcker period is not consistent with the optimal policy
The Fed’s response to technology shocks: evidence
The Pre-Volcker Period vs Monetary Targeting Rule

![Graphs showing the response of M1 and M2 to technology shocks. The graphs illustrate the growth rate and level of monetary aggregates over time.](image)
Conclusions

- Analysis of the Fed’s response to technology shocks and its implications for U.S. output, hours and inflation.
- Consistency of the Fed’s (Volcker-Greenspan period) response to a technology shock with a rule that seeks to stabilize prices and the output gap.
- The Fed’s policy in Pre-Volcker period tended to overstabilize output thus generating excess volatility in inflation.