Lecture 6

Analyzing the New Keynesian DSGE Model (continued)

Maarten De Ridder

London School of Economics

EC417

This term

Part I: Shocking theory of the business cycle (weeks 1-6)

- Introduction to business cycles ✓
- Real Business Cycle (RBC) Model ✓
- New Keynesian DSGE Models $\Leftarrow$

Part II: Perspectives on business cycles and steady states (weeks 7-10)

- Persistent effects of recessions
- Aggregate shocks? Firm-heterogeneity and the business cycle
- Interesting steady states: firms, productivity, market power

New Keynesian DSGE lectures

- Lecture 1: Introduction to nominal rigidity, set up NK-DSGE $\checkmark$
- Lecture 2: Solve model with sticky prices, determinacy conditions $\checkmark$
- Lecture 3: Analyse the model, mechanisms, critiques $\Leftarrow$
- Next lecture: Inequality and heterogeneity in business cycle models

Reference

Gali (2008) *Monetary Policy, Inflation, and the Business Cycle*, Chapter 3

Overview

- Summary of the canonical New Keynesian DSGE model
- Calibration of the model, solution in Dynare
- Mechanisms and comparison with RBC model
- Productivity shocks in the NK-DSGE model
- Critiques

The model

- Dynamic IS Equation

$$\tilde{y}_t = -\frac{1}{\sigma}\left(i_t - \mathbb{E}_t(\pi_{t+1}) - r_t^n\right) + \mathbb{E}_t\left(\tilde{y_{t+1}}\right)$$

- New Keynesian Phillips Curve

$$\pi_t = \beta \mathbb{E}_t\left(\pi_{t+1}\right) + \kappa \tilde{y}_t$$

- Monetary policy rule:

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \tilde{y}_t + v_t$$

Dynamic IS curve

$$\tilde{y}_t = -\frac{1}{\sigma}\left(i_t - \mathbb{E}_t(\pi_{t+1}) - r_t^n\right) + \mathbb{E}_t\left(\tilde{y}_{t+1}\right)$$

- Comes from households' **intertemporal** optimization of consumption
- Role: relationship between **consumption** and **real interest rate**
- Intuition:
  - Demand is lower when real interest rate is higher
  - Central bank sets nominal rate; output gap depends on response π

New Keynesian Phillips Curve

$$\pi_t = \beta \mathbb{E}_t \left(\pi_{t+1} \right) + \kappa \tilde{y}_t$$

- Comes from optimal price setting by **firms** under **Calvo** pricing
- Intuition:
  - Innovation is **forward looking:** firms anticipate future price changes
  - Output gap $\rightarrow$ need more employees $\rightarrow$ wages higher + lower MPL
- Parameter κ is known as the **slope** of the Phillips Curve
  - Steeper slope? Stronger inflation response to output gap
  - High slope? Positive output gap $\rightarrow$ strong inflation response $\rightarrow$ nominal interest rate up (given Taylor principle) $\rightarrow$ output gap down
  - High κ means output gap is smaller

Interest rate policy rule

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \tilde{y}_t + v_t$$

- This is assumed to 'close' the model. Often called **Taylor** rule
- Intuition:
  - Innovation is **forward looking:** firms anticipate future price changes
  - Output gap $\rightarrow$ need more employees $\rightarrow$ wages higher + lower MPL
- Parameter κ is known as the *slope* of the Phillips Curve
  - Steeper slope? Stronger inflation response to output gap
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Parameters

- Dynamic IS Equation

$$\tilde{y}_t = -\frac{1}{\sigma}\left(i_t - \mathbb{E}_t(\pi_{t+1}) - r_t^n\right) + \mathbb{E}_t\left(\tilde{y_{t+1}}\right)$$

- New Keynesian Phillips Curve

$$\pi_t = \beta\mathbb{E}_t\left(\pi_{t+1}\right) + \kappa\tilde{y}_t$$

$$\kappa = (1-\beta\theta)\left(\frac{1-\theta}{\theta}\right)\left(\frac{(1-\alpha)}{1-\alpha+\alpha\epsilon}\right)\left(\sigma + \frac{\varphi+\alpha}{1-\alpha}\right)$$

- Monetary policy rule and monetary policy shock:

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \tilde{y}_t + v_t$$

Calibration

Parameter	Calibration	Source
θ	2/3	Avg. price duration of 1 year
ϵ	6.00	Markup of 20%
β	0.99	Approx. 4% real rate annually
σ	1.00	Balanced growth preferences: log-utility
φ	1.00	Unit elasticity of labor supply
α	1/3	Standard (derived from labor share)
ϕ_π	1.5	Taylor (1999)
ϕ_π	1/8	Taylor (1999)

Quarterly calibration $\Rightarrow$ matters for discount factor and price rigidity

Source of business cycles

Initially, only shocks in the model come from **monetary policy**:

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \tilde{y}_t + v_t$$

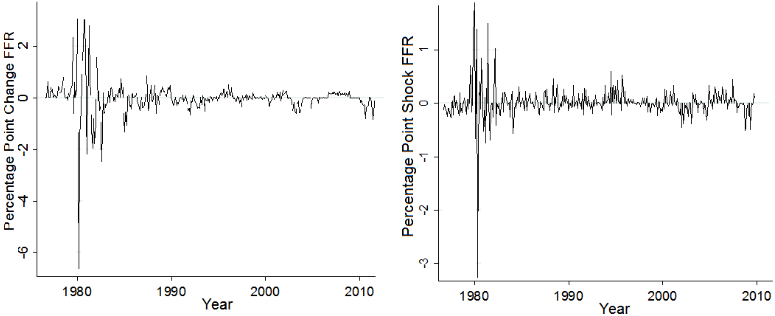
- Assume shock v_t is a stationary auto-regressive process:

$$v_t = \rho_v v_{t-1} + \chi_t$$

- χ_t is i.i.d with mean 0 and variance σ_χ^2
- Our calibration: $\rho_v = 0.5$ (moderately persistent)

Shocks in the data

Figure: Changes and Shocks in Federal Funds Rates (FFR)



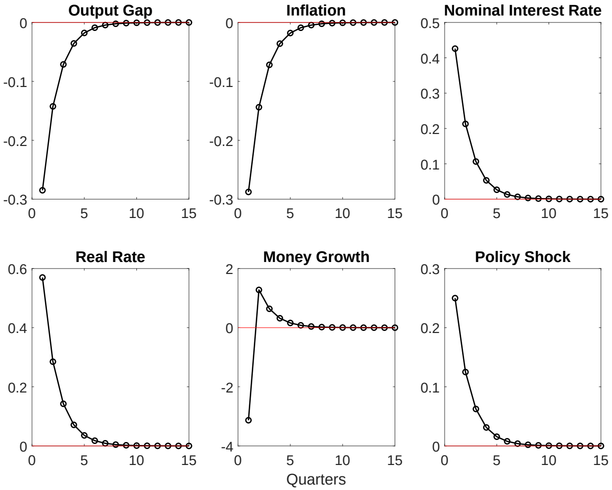
Dynare: see baseline_NKDSGE_model.mod on Moodle

```
var y pi i v r m pi_an ;
varexo e;
parameters theta beta alpha sigma phi epsilon phi_pi phi_y kappa autocor eta;
theta = 2/3 ;
beta = 0.99;
alpha = 1/3 ;
sigma = 1.00;
phi = 1.00;
epsilon = 6.00;
phi_pi = 1.5 ;
phi_y = 0.5/4;
kappa = (1-beta*theta)*(1/theta-1)*(1-alpha)/(1-alpha+alpha*epsilon)*(sigma+(phi+alpha)/(1-alpha));
autocor = 0.5 ;


model;
y = -1/sigma*(i - pi(+1) + log(beta)) + y(+1) ;
pi = beta*pi(+1) + kappa*y;
i = -log(beta) + phi_pi * pi + phi_y * y + v ;
v = v(-1)*autocor + e ;
r = i-pi(+1) ;
end;

shocks;
var e = 0.25^2 ;
end;
stoch_simul(irf=15,order=1,irf_plot_threshold=0) y pi i r v ;
```

Impulse responses



Impulse responses to 25 basis point contractionary monetary policy shock

Baseline calibration, inflation, money growth, interest rates multiplied by 4.

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Mechanism

Monetary policy shock: central bank raises **nominal** interest rate

- Ceteris paribus, this raises the **real** interest rate
- The higher interest rate raises incentive to **save**, lower consumption
- Lower output $\rightarrow$ less demand for labor $\rightarrow$ lower nominal wage
- Flexible prices:
  - Lower wage $\rightarrow$ lower prices today $\rightarrow$ **higher** inflation tomorrow
  - This means that the ex-ante **real** interest rate **falls again**
  - This offsets the initial rise in the nominal interest rate
- Sticky prices:
  - Lower wage $\rightarrow$ constant(ish) prices today $\rightarrow$ flat inflation tomorrow
  - Hence the central bank's nominal intervention affects **output**

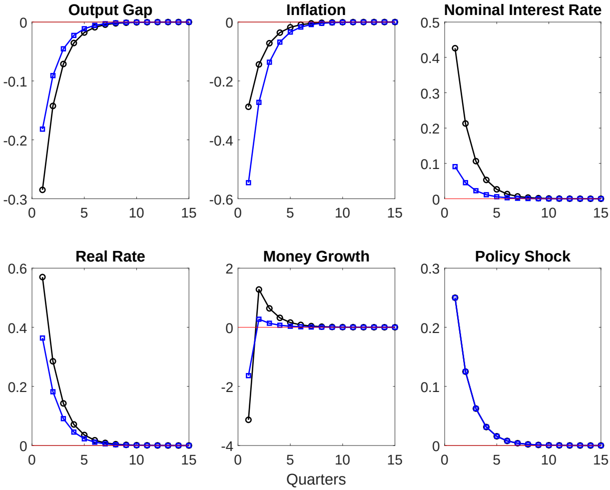
Non-neutrality in the NK-DSGE

Key: under flexible prices, central bank can set **nominal interest rate**, not real rate

$$\tilde{y}_t = -\frac{1}{\sigma}\left(i_t - \mathbb{E}_t(\pi_{t+1}) - \rho\right) + \mathbb{E}_t\left(\tilde{y_{t+1}}\right)$$

- Price rigidities ($\theta > 0$ and $\kappa < \infty$) change this
- They reduce responsiveness of inflation to changes in nominal rates
- $\Rightarrow$ monetary policy has an effect on real interest rates

Comparative dynamics: lower price rigidity



Impulse responses to 25 basis point contractionary monetary policy shock

Blue-squared lines: $\theta = 1/3$. Black-circled lines: $\theta = 2/3$ (baseline).

Flexible prices in our model

What happens as price stickiness $\theta \to 0$?

$$
\begin{aligned}
\pi_t &= \beta \mathbb{E}_t(\pi_{t+1}) + \kappa \tilde{y}_t \\
\kappa &= (1-\beta\theta)\left(\frac{1-\theta}{\theta}\right)\left(\frac{(1-\alpha)}{1-\alpha+\alpha\epsilon}\right)\left(\sigma + \frac{\varphi+\alpha}{1-\alpha}\right) \\
\lim_{\theta\to 0} \kappa &= \infty.
\end{aligned}
$$

See what happens with output gap in the dynamic IS equation:

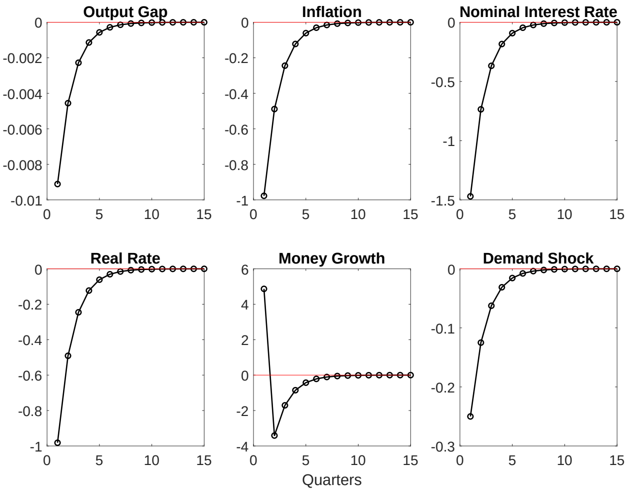
$$
\begin{aligned}
\tilde{y}_t &= -\frac{1}{\sigma}\left(i_t - \mathbb{E}_t(\pi_{t+1}) - \rho\right) + \mathbb{E}_t(\tilde{y}_{t+1}) \\
&= -\frac{1}{\sigma}\left(i_t - (\pi_t - \kappa\tilde{y}_t)\beta^{-1} - \rho\right) + \mathbb{E}_t(\tilde{y}_{t+1}) \\
&= -\left(\frac{1}{1+\kappa\beta^{-1}}\right)\left[\frac{1}{\sigma}\left(i_t - \pi_t\beta^{-1} - \rho\right) - \mathbb{E}_t\left(\tilde{y_{t+1}}\right)\right] \to \lim_{\theta\to 0}\left(\partial\tilde{y}_t/\partial i_t\right) = 0
\end{aligned}
$$

Demand shock

$$\tilde{y}_t = -\frac{1}{\sigma}\left(i_t - \mathbb{E}_t(\pi_{t+1}) - r_t^n\right) + \mathbb{E}_t\left(\tilde{y_{t+1}}\right) - \vartheta_{it}$$

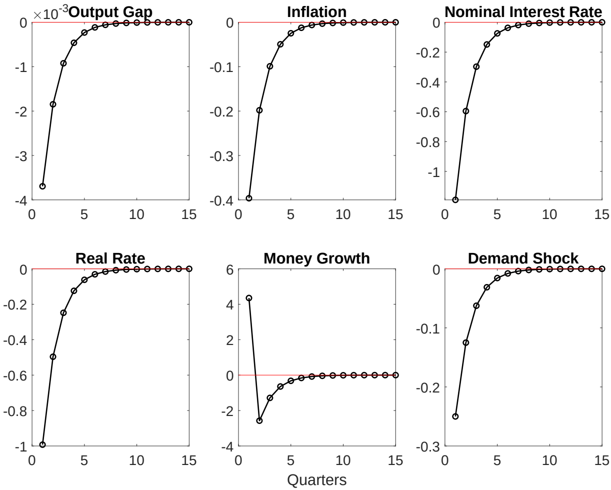
- E.g. for given real interest rate, reduction in current consumption
- This is again a **nominal shock**
  - There is no change in economy's **productive capacity**
- But it has **real effects** under **sticky prices**
  - Less demand $\rightarrow$ less labor $\rightarrow$ lower prices (if flexible)
  - Today's inflation down, but **tomorrow's** inflation up $\rightarrow$ real int. down
  - Sticky price? No price response $\rightarrow$ real interest rate **too high**
  - But the central bank can help!

Comparative dynamics: demand shock



Impulse responses to 25 basis point contractionary monetary policy shock

Demand shock with aggressive central bank



Impulse responses to 25 basis point contractionary monetary policy shock

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Household spending falls sharply as cost of living crisis grips Britain

By Tom Rees
8 February 2022 • 6:00am

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Former Treasury minister Lord O'Neill has hit out at the Bank of England's record of low interest rates and said central bankers should have seen the current wave of inflation coming.

Overview

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- Critiques

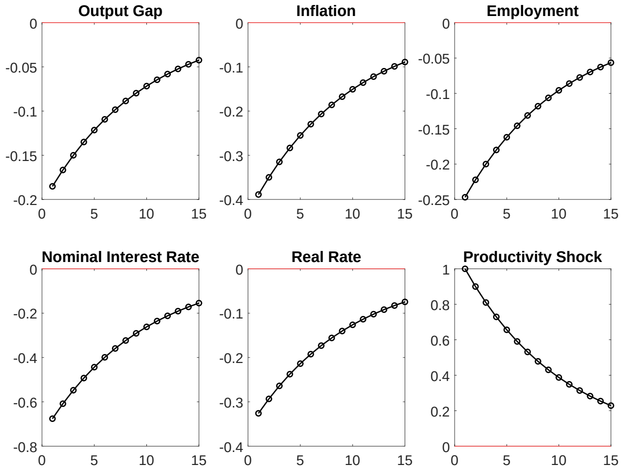
Adding productivity shocks

So far, we didn't consider shocks to productivity:

$$a_t = \rho_a a_{t-1} + \chi_t^a \quad \text{with} \quad 0 < \rho_a < 1$$

- This **raises** productive capacity of the economy (real shock)
- Remember, our output gap $\tilde{y}_t$ is versus the **flexible-price** output
- Counter-intuitive result: positive shock creates **negative** $\tilde{y}_t$

Impulse responses: productivity



Impulse responses to a productivity shock with 0.5 AR.

Productivity shock: mechanism

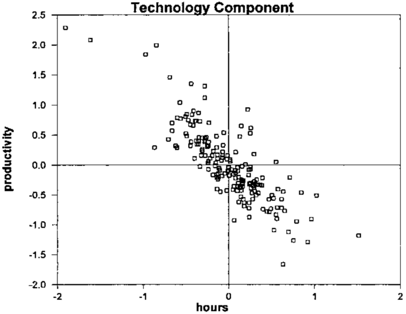
Positive productivity shock: **natural real interest rate** falls

$$\tilde{y}_t = -\frac{1}{\sigma}\left(i_t - \mathbb{E}_t(\pi_{t+1}) - r_t^n\right) + \mathbb{E}_t\left(\tilde{y_{t+1}}\right)$$

- Today's consumption is relatively high: incentive to **save**
- But bonds are in zero net supply: **interest decreases** to offset this
- Sticky price model: ceterus paribus, interest rate is **high**
- This causes output gap to **fall**, inflation to **fall**

Employment declines

- Productivity increases production capacity
- But sticky prices: demand doesn't increase sufficiently
- Lower demand for labor



Correlation between growth rate in hours and growth rate in productivity

Source: Gali (1999), Figure 1

Note: output gap

We've defined output gap as: $\tilde{y}_t = y_t - y_t^n$

- y_t^n is log output in the flexible price equilibrium

$$y_t^n = a_t + l_t^n(1-\alpha)$$

- Alternative, data-consistent definition of the output gap :

$$\widehat{y}_t = y_t - y^n$$

Labor supply and demand in flexible price eq:

$$\begin{aligned} l_t^n &= \varphi^{-1}(w_t - p_t - \sigma y_t) \\ w_t - p_t &= y_t - l_t - \mu + \log\,(1-\alpha) \end{aligned}$$

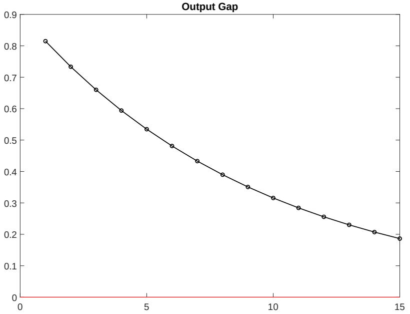
Combined:

$$\begin{aligned} y_t^n &= y^n + a_t(1+\varphi)(\sigma(1-\alpha)+\varphi+\alpha)^{-1} \\ \widehat{y}_t &= \tilde{y}_t + a_t(1+\varphi)(\sigma(1-\alpha)+\varphi+\alpha)^{-1} \end{aligned}$$

- Note: Gali (2015) specifies the monetary policy rule in terms of $\widehat{y}_t$

Note: output gap

Data-consistent gap $\widehat{y}_t$ **positive** after **positive** productivity shock



Impulse responses to a 1% productivity shock with 0.9 AR.

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Critiques

Three critiques of the model that we have just covered:

- Key micro foundation: **intertemporal substitution**
  - Does consumption really depend so much on real interest rate?
  - More about this in the next lecture
- There is still no involuntary unemployment!
  - Add an additional nominal stickiness: sticky **wages**
  - Maybe more about this in the next lecture (maybe not)
- Implausible transmission mechanism: **profits**
  - More on this now.

Mechanism: profits and output

We had the following new New Keynesian Phillips Curve:

$$\pi_t = \kappa \tilde{y}_t + \beta \mathbb{E}_t (\pi_{t+1})$$

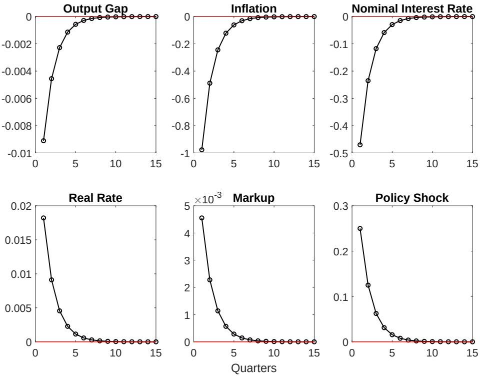
Note that this is related to price markups:

$$\begin{aligned} w_t - p_t &= mpl_t - \mu_t \\ \tilde{\mu}_t &= \tilde{mpl}_t - (\tilde{w}_t - \tilde{p}_t) \\ &= -\frac{\alpha}{1-\alpha} \tilde{y}_t \end{aligned}$$

The New Keynesian Phillips Curve in terms of markups:

$$\pi_t = \beta \mathbb{E}_t (\pi_{t+1}) - \Lambda \tilde{\mu}_t$$

Mechanism: profits and output

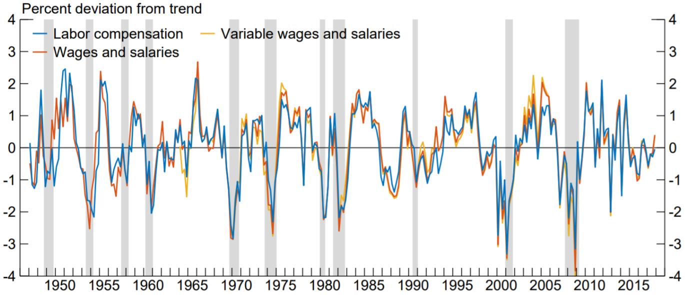


- Shock reduces preference for goods but price doesn't adjust: lower output
- But the firm faces lower costs:
  - Less output: lower average costs due to returns to scale ($\alpha > 0$)
  - Wage declines

Mechanism: profits and output

Hence: **negative** correlation between output gap and profits/markups

What does the data say?



HP-detrended markups based on various data sources (Nekarda and Ramey 2020)

Measuring profits

Don't write a PhD thesis about markup cyclicality

Measuring profits

In a model with perfect competition:

$$Y_t = r_t K_t + w_t L_t$$

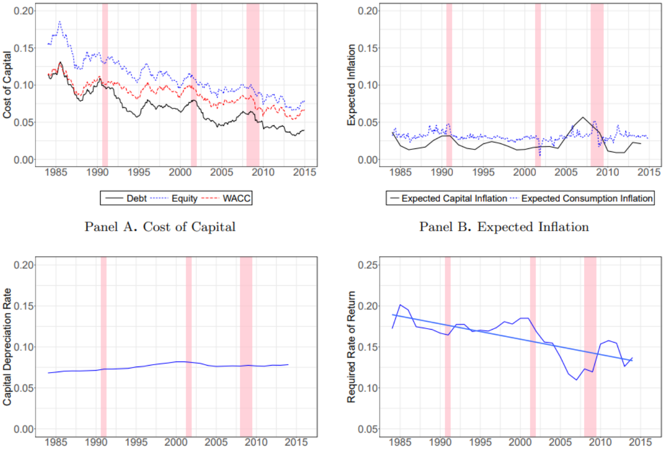
In a model with profits:

$$Y_t = r_t K_t + w_t L_t + \Pi_t$$

Hence profit share:

$$\frac{\Pi_t}{Y_t} = 1 - r_t \frac{K_t}{Y_t} - w_t \frac{L_t}{Y_t}$$

Measuring profits



Panel A. Cost of Capital

Panel B. Expected Inflation

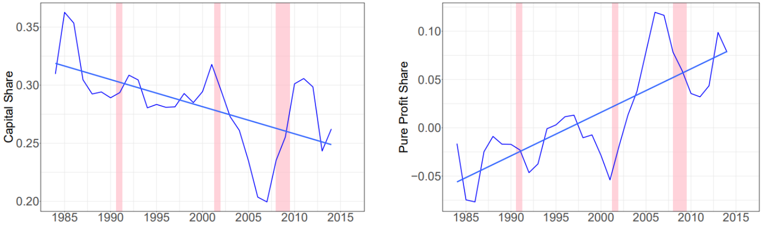
Panel C. Depreciation Rate

Panel D. Required Rate of Return

Inputs to calculate the required rate of return on capital.

Barkai (2017, published 2020).

Measuring profits



Panel A. Capital Share

Panel B. Pure Profit Share

Fraction of GDP not earned by labor or capital, using required rate of return on capital.

Barkai (2017, published 2020).

Mechanism: profits and output

Note that the labor supply equation is:

$$l_t = (w_t + p_t - \sigma c_t - log(\chi))$$

where $c_t = y_t = w_t l_t + profits_t$

- Profits have a negative income effect on labor
- Countercyclical markups: lower profits after expansionary shock
- Lower profits $\rightarrow$ more labor supply $\rightarrow$ more output
- Broer et al. (2020): this explains **most** of output response!

Do **workers** really receive **profit** income?

Use of NK-DSGE models

The model in this lecture is a **laboratory**

- Framework to analyze policies, mechanisms, counterfactual analysis
- Extended versions are used at major policy institutions, central banks
  - FRBNY-DSGE Model, European Commission Quest III model, Riksbank Ramses II model, Smets and Wouters model
  - Price frictions ($\checkmark$), labor market frictions), capital, financial sector, multi-sector (sometimes), input-output, fiscal policy, taxation, forward guidance, monetary policy at the ELB, open economy ...
  - More shocks: discount factor, price markup, wage markup, labor disutility, capital utilization, sectorial taste, etc.
- But have shortcomings (see rest of course) and **bad** at forecasting

Example of extension: financial frictions

Cash in advance constraint: need to pay factors in advance

$$\Psi_{it}\left(Y_{it}\right) = w_t \left(Y_{it}/A_t\right)^{1/(1-\alpha)}\left(1+\tilde{r}_t\right)$$

Imperfect **financial intermediation**: households save through banks

$$\tilde{r}_t = r_t + \zeta_t$$

Banks can default: need to maintain a minimum equity $\rightarrow$ need profits

- Hence they charge a premium $\zeta_t > 0$
- Shock to equity? Premium increases: ζ_t up; $\tilde{r}_t$ up; Y_{it} down
- See (e.g.) Gertler and Kiyotaki (2010), Gertler and Karadi (2011)

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