ECON 5322

Macroeconomic Theory for Applications

Topic 3: Information Frictions and Nominal Rigidities

Today's topic:

Lucas' Imperfect Information Model

- Policy implications: Sargent-Wallace, Barro

A VERY QUICK Brief History of Macro:

- Neoclassical Synthesis
- The Breakdown of the Consensus + Rational Expectations Revolution
- Main approaches to modeling Aggregate Supply in the 80s & 90s
- The RBC model: the frictionless case (Topic 2)
- Market frictions: monopolistic power and nominal rigidities
- This part of the course: towards "New" Neoclassical Synthesis /DSGE
- Post-2008: Financial Friction, "Unconventional" Monetary Policy...etc.

Results of the Rational Expectation (RE) revolution

Pre-DSGE (after the 70's and up to 90's)**:**

- Focus on structural modeling of the economy (micro-foundation based on first principles)
- Taking **expectations** seriously, especially in policy design

  focus on developing on-going strategy & long-term rules, not one-time changes

Four Main Approaches followed in the 1970s-90s:

- Classical
- New Classical
- Nominal rigidity
- Real rigidity

+ Financial friction; credit channel of monetary transmission

Main questions for us now:

- What determines (the slope of the) aggregate supply?
- Does money affect output? (if so what is the mechanism?)

Emphasis: micro-foundation + RE (more generally: expectations and **information**)

Neo-Classical Real Business Cycle Theory (RBC)

- prices adjust instantaneously to clear markets
- Agents optimize, are forward-looking and form Rational Expectations
- cause of fluctuations: random shocks to technology (real shock)
- key mechanism: intertemporal substitution in consumption (savings) and leisure generated as a response to these shocks

↳ Euler Eq.

↳ Intratemporal tradeoff

Influence:

- methodological contribution is most emphasized
- useful for assessing how close reality is to the frictionless "benchmark" and understanding importance of market imperfections

The New Keynesians

- general equilibrium analysis when markets do not clear
- sticky prices and wages (nominal rigidities)
- rational expectations + no market clearing => *systematic monetary policy can stabilize the economy*
- **why** don't wages and prices clear the markets?
  - menu costs
  - efficiency wages
  - wage and price setters aren't perfectly rational
  - market power (monopolies): wedge between privately and socially optimal price adjustment

Four Main Approaches to Aggregate Supply (80-90s)

	Do Markets Clear?	
	Yes	**No**
Is Money Neutral? **Yes**	**1. Classical/RBC** Kydland & Prescott Minnesota	**3.Real Rigidity** e.g. Efficiency wage theory Akerlof, Yellen
No	**2. Imperfect Information** Friedman Lucas '77	**4.Nominal Rigidity** Nominal contracts, menu costs: Fischer, Taylor, Calvo …

NKDSGE

Dynamic Stochastic General Equilibrium (DSGE) models

D: some things don't make sense in static models (savings, investment)

- Intertemporal decision-making (agents care about tomorrow and form expectations)

S shocks hit the economy and force it off the balanced growth path (BGP)

- Fluctuations do not mean dis-equilibrium; it is the reaction of the economy to outside (exogenous) shocks

G E

- perfectly or monopolistically competitive markets
- optimizing agents and micro-foundation
- expectation: rational or otherwise
- transition towards market EQUILIBRIUM

Key: Money is not neutral,
Markets clear (Prices, wages adjust)

The Imperfect Information Model

1. The Lucas Model

   a. Only unanticipated money matters (monetary surprises) $\approx m_t - E_{t-1} m_t$

   b. Signal extraction with joint-normally distributed variables

   → Agents get aggregate info that includes both a signal and noise.

2. Policy Implications: Sargent-Wallace on Policy Irrelevance

3. Time Series Tests $\boxed{\text{(HW)}}$

   a. Sargent on **Observational Equivalence**

   b. Barro on Unanticipated Money

4. Extensions and critiques of the Imperfect Information Theory

Imperfect Information Model (Lucas Island Model '77)

Basic question: **How to model "why money can affect output" in a RE setup?**

- In Classical framework: when M increases, P and W go up, but Y stays fixed.

Don't want to rely on $\bar{P}$ (Sticky, Rigid) for having money to affect GDP.

- The goal of **New** Classical approach is to
  - preserve the **frictionless market assumption** of the Classical view,
  - But still show, in a Rational Expectation framework, how money can affect output, as empirically, it does seem to.

    (e.g. Friedman-Schwartz, "A Monetary History of the US, 1867-1960")

- Tool: Imperfect Information and Signal Extraction

Lucas Island Model:

- J consumer/producers, each lives on own island, and each produces a different good, indexed by j

$j = 1, 2, 3, \ldots, J$

- Supply of good j at each time t depends on its **relative price**

$$y_{j,t} = \gamma\big[\underbrace{p_{j,t}}_{\text{Product } j\text{'s price}} - E\big(\underbrace{P_t}_{\text{Aggregate Price level (for all J goods)}} \big| I_{j,t}\big)\big] \qquad \text{(again, all variables in logs)}$$

- What is the **information set $I_{j,t}$?** At time t, producer j observes:
    - $\underline{p_{j,t}}$ AND all of its history (lags)
    - Not P_t (the overall price level at t) but only its history (lags)
    - As such, j forms expectation $\underbrace{E\big(P_t \big| I_{j,t}\big)}_{\text{best guess of producer } j}$

Firm j knows at t:

$P_{t-1}, P_{t-2}, \ldots$

$p_{jt}, p_{jt-1}, p_{jt-2}, \ldots$

- **2 Types of Shocks that affect p_j**

The price of each good j is determined by two sources of shocks:

1) General monetary shock:

$$P_t \sim N(\mu_t, \sigma^2)$$

Related to Monetary policy (aggregate shock: the same for all islands)

2) Sector-specific shock:

$$z_{j,t} \sim N(0, \tau^2)$$

And

$$p_{j,t} = P_t + z_{j,t}$$

Relative price is $p_{j,t} - P_t = z_{j,t}$

- J is large: there are many producers, so individually, they don't affect the aggregate variable P

Q: given observed $p_{j,t}$ at t, how to choose production y_{jt}?

Need to know $E[P_t \,|I_{\cancel{t-1}}]$ ~~(same expectation as before, since $p_{j,t}$ on its own doesn't affect aggregate price from which only observations up to t-1 is known)~~

Conceptually, how would you form expectations if you have historical data on p_j and P, say, from 1960 up to time t-1?

You have time series data of: $(p_{j,0}, p_{j,1}, \dots, p_{j,t-1},\ p_{j,t})$ $(P_{,0}, P_{,1}, \dots, P_{t-1})$

Then you find the statistical relation between p_j, and P, e.g., in a regression:

Fit $P_t = \alpha + \beta\, p_{j,t} + \epsilon_t$ using data up to t-1, then used observed $p_{j,t}$ and estimated $\hat{\alpha}, \hat{\beta}$ to predict $E\left(P_t \middle| I_{j,t}\right) = \widehat{P_t} = \hat{\alpha} + \hat{\beta}\, p_{j,t}$

In general (for any variables x, y): $\hat{\beta} = \dfrac{Cov(x,y)}{Var(x)}$, also assume $\hat{\alpha} = 0$

$$\text{Then: } \hat{\beta} = \frac{Cov(\overbrace{p_j}^{z+P},P)}{Var(\underbrace{p_j}_{z+P})} = \frac{\underbrace{Cov(z,P)}_{=0\ (z \text{ is iid, i.e., uncorrelated shock})}+\overbrace{Var(P)}^{Cov(P,P)}}{Var(z+P)} = \frac{\sigma^2}{\sigma^2+\tau^2}$$

The Signal Extraction Process

With that value of $\hat{\beta}$:

$$E(P_t|I_{jt}) = \frac{\sigma^2}{\sigma^2+\tau^2}\cdot p_{jt}$$

$$y_{j,t} = \gamma\left(p_{j,t} - \underbrace{E\left(P_t \middle| I_{j,t}\right)}\right) = \gamma\left(\frac{\tau^2}{\tau^2+\sigma^2}\right)p_{j,t}$$

Note:

1. $\left(\frac{\tau^2}{\tau^2+\sigma^2}\right) < 1$ in general: "signal extraction" (τ: sector specific, σ: inflation shock)

2. If $\sigma^2 \to \infty$, $y_j \to 0$. (i.e., all p_j movements are due to general inflation and should not adjust output)

3. If $\tau^2 \to \infty$, y_j moves 1-to-1 with p_j

Then: $\tilde{z}_j$: sector's signal, $\tilde{P}$: noise

Signal-to-noise ratio: $\frac{\tau^2}{\sigma^2}$ $\longrightarrow$ (0: all noise, high: $y_{i,t}$ reacts)

Aggregate

(what we did holds for one firm j, now consider the sum of all)

$$y_{jt} = \gamma \cdot \frac{\tau^2}{\tau^2+\sigma^2}\, p_{jt}$$

$$Y = \int_j y_j d_j = \gamma\left(\frac{\tau^2}{\tau^2+\sigma^2}\right)\underbrace{\int_j p_j d_j}_{\propto P}$$

AS curve:

$Y \;=\; \theta P$ (i.e., AS: $P = \frac{1}{\theta}Y$)

- Can also use the following property of normal distributions to derive the same result for any general μ_t:

$P \sim N(\mu_t, \sigma^2)$ and $p_j = P + z_j$

$z_{j,t} \sim N(0, \tau^2)$

Note: if $$\begin{bmatrix} \overset{P_t}{x_1} \\ \underset{p_{jt}}{x_2} \end{bmatrix} \sim N\left[\begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix}, \begin{bmatrix} \overset{\sigma^2}{\sigma_{11}} & \overbrace{\sigma_{12}}^{\text{Covariance}} \\ \sigma_{21} & \underset{\tau^2}{\sigma_{22}} \end{bmatrix}\right],$$

$$\underbrace{E(x_1|x_2)}_{E[P_t|p_{jt}]} = \mu_1 + \frac{\sigma_{12}}{\sigma_{22}}(x_2 - \mu_2)$$

Aggregate individual producers to get the economy-wide supply:

$$Y_t = \int y_{j,t} dj, \qquad P_t = \int p_{j,t} dj$$

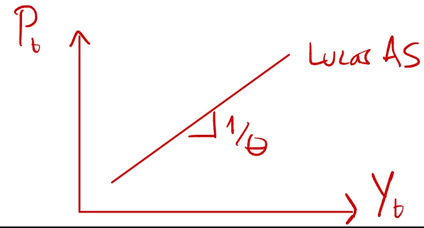
Extra credit: Derive the Lucas Aggregate Supply curve using joint normal distribution formula, i.e., fill in the steps to show:

$$Y_t = \gamma\left(\frac{\tau^2}{\tau^2 + \sigma^2}\right)[P_t - \underbrace{E_{t-1}P_t}]$$

\+ Hint: use $x_1 = P_t, x_2 = p_{j,t}$, and $\underbrace{\mu_t = E_{t-1}[P_t]}$

· First do it assuming $\mu_t = 0$

↳ Then, can work out complete case w/ $\mu_t \neq 0$



$$Y_t = \gamma\overbrace{\left(\frac{\tau^2}{\tau^2+\sigma^2}\right)}^{\Theta}[P_t - E_{t-1}P_t] \qquad \text{(Lucas Aggregate Supply)}$$

To analyze policy implications, add Aggregate Demand

$$\text{AS:}\quad Y_t = \Theta[P_t - E_{t-1}P_t]$$

$$\text{AD:}\quad \tilde{m}_t + \tilde{v}_t = P_t + Y_t$$

To solve: Express endogenous variables as functions of exogenous ones.

$$\Rightarrow E_{t-1}P_t = E_{t-1}[m_t + v_t - Y_t] \quad (*)$$

↳ Plug P_t & $E_{t-1}P_t$ (from $*$) in AS: $\quad Y_t = \frac{\Theta}{1+\Theta}[\underbrace{(m_t - E_{t-1}m_t)}_{\text{Policy Surprise}} + (v_t - E_{t-1}v_t)]$

=> **<u>Sargent-Wallace on Policy Irrelevance:</u>**

output changes due to: unexpected change in monetary policy or demand

Policy Implication: Consider the Fed setting M_t **systematically**

↳ Not random

Assume at time t, the Fed observes all information up to time t-1

(Note: no information advantage in terms of timing over public)

Let $\mathbf{Q_{t-1}}$ be a vector of observed variables that the Fed cares about

rather than taking m_t as a shock, we could model it:

$$m_t = \delta \underbrace{Q_{t-1}} + \varepsilon_t$$

$$Q_{t-1} = \begin{bmatrix} \pi_{t-1} \\ \text{Unemply} \\ k_{t-1} \\ \vdots \end{bmatrix}$$

$$m_t = \delta_1 \pi_{t-1} + \delta_2 \text{Unempl} + \delta_3 k_{t-1} + \dots + \varepsilon_t$$

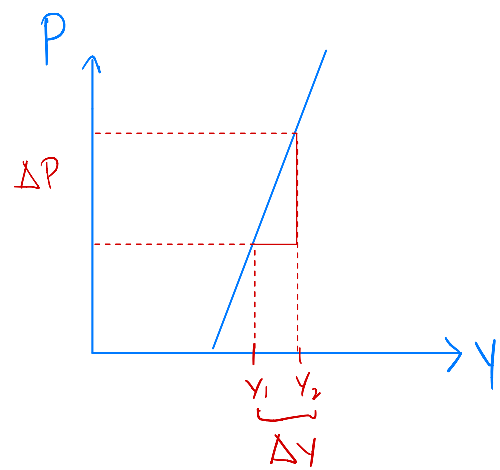
Plug in in AS:

$$Y_t = \frac{\theta}{1+\theta}\Big[\underbrace{\varepsilon_t}_{\text{Policy Surprise}} + (V_t - E_{t-1} V_t)\Big]$$

=> Systematic policy have no effect on output; Fed can affect output only by being erratic

Empirical test: (for both results of the above)

1) **Lucas cross regime test:**
2) **Sargent-Wallace & Observational Equivalence (HW)**



Lucas cross regime test:

<u>Model-Implied Hypothesis</u>:

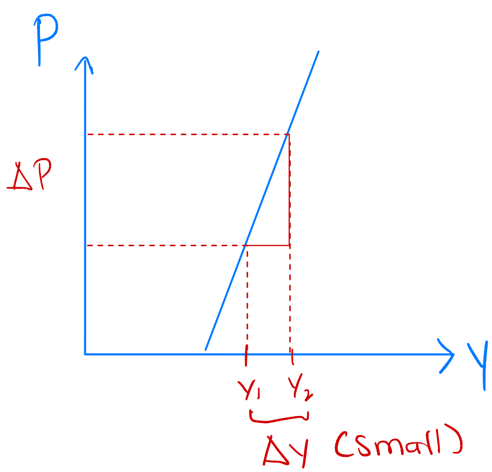
Countries with more volatile monetary policy or AD shocks $\sigma^2_{\Delta x}$ have steeper AS curve, so output react less and prices react more, given the same AD shock.

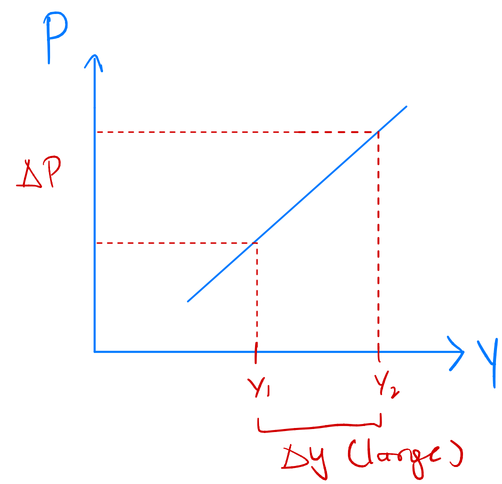
Nominal GDP $x = p + y = m + v$ $\rightarrow$ uses Δx as a proxy for AD shock

Lucas cross regime test:

Test empirically how EACH of their real output reacts to AD shocks (18 countries)

$$\Delta y = \alpha + \underbrace{\beta \Delta x}_{\Delta \text{ agg demand}} + \cdots$$





<u>Finding:</u> countries with large $\sigma^2_{\Delta x}$ tend to have smaller $\hat{\beta}$ (steeper AS), as predicted

Critiques:

1) Correlation ≠ Causation

Above only showed correlation between high $\sigma^2_{\Delta x}$ and β, but has not proven causation

Δreal GDP $\longleftrightarrow$ $\Delta \sigma_x$

Changes in Prices

2) Can't rule out alternative mechanisms:

e.g. high $\sigma^2_{\Delta x}$ countries tend to have high or volatile inflation rate π

Given high π, output response to Δx can be small because:

a) People are less likely to sign long-term nominal contracts when prices are volatile (or when there is high inflation) => less nominal rigidity

Based on the mechanism described in the contracting models, we would also see steeper AS, i.e. to Δx has a smaller effect on y

b) Menu cost story: when π is high, firms would be willing to incur small menu cost to change prices => less nominal rigidity as well

Unclear from test whether imperfect info is the cause of the high $\sigma^2_{\Delta x}$ and small β (steep AS)

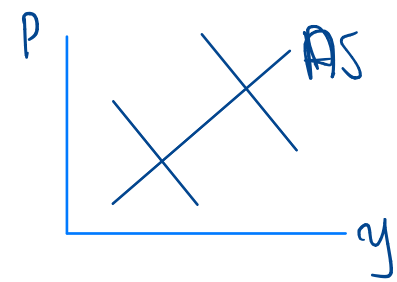
or Is there something else causing $\sigma^2_{\Delta x}$?

e.g. Nominal rigidities

Other critiques of the Imperfect Information Theory

- Is the info asymmetry plausible/efficient/consistent with optimizing agents?

Know about P_j but not about P ?



- Large supply elasticity is implied => not plausible

CPI-announced monthly, and the changes are typically very small, less than half a %. For small price change to generate the observed output fluctuations, need **huge** elasticity.

↳ ΔP is small & Δy is large?

- Cost of announced-disinflation: e.g. late-70s, high inflation. According to RE, fully credible announced changes in monetary policy slow down should not cause output to react.

But, Volker did announce contraction of money supply (credibly), and the interest increase (money contraction) ended up killing inflation via a deep recession.

↳ $\downarrow \pi$ ($\downarrow P$)

↳ $\Delta y < 0$

Nominal Rigidities:

Alternative view: Nominal Rigidities create a role for monetary policy
[P does not adjust fast enough so money has a temporary real effect in the economy]

Overview of the Contracting Model:

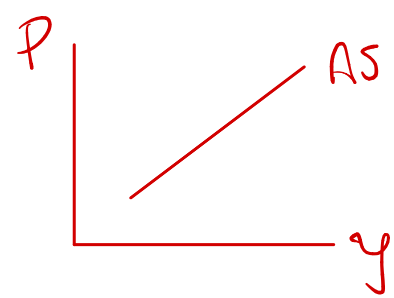
Lucas ('72, '73), Sargent+Wallace ('75) made the point that if:

1) the economy gravitates around a natural rate of output
2) expectations are rational
3) monetary authority follows a rule based on lagged variables

Money is not neutral

⇒ Money matters, but Systematic Monetary policy is irrelevant. Systematic counter-cyclical MP is not only impossible, but also undesirable

⇒ An economy where expected money is neutral could nevertheless generate an observed sloped AS curve.



Contracting models of Fischer (1977) /Taylor (1980):

Show that above assumption is NECESSARY but not SUFFICIENT:

Rational Expectation does NOT imply policy irrelevance (but continuous market clearing via flexible prices).

Claim: **If (wage) contracts are "long enough"**, a deterministic (w/o surprises) monetary rule CAN still affect GDP & employment even w/ rational expectations

Cant volatility in an economy

Specifically, MP is useful and can serve a **"stabilization"** purpose.
(a Keynesian model with RE that has Keynesian conclusion)

Crucial Assumption: Agents write nominal contracts that last longer than the time it takes the monetary authority to react to changing economic environment.

(From your HW1):

(I) A Simple Contract Model (NOT Fischer yet)

1) $w_t = E_{t-1}p_t$ (wage-setting rule: 1-period stickiness)

2) $y_t = -(w_t - p_t)$ (AS)

3) $y_t + p_t = m_t + v_t$ (AD)

$$v_t = D(L)v_{t-1} + \eta_t$$
$$= D_1 v_{t-1} + D_2 v_{t-2} + \cdots \eta_t,$$

Result from HW1:

$y_t = \frac{1}{2}\eta_t$

$\eta_t \sim N(0, \sigma^2)$ is an iid shock (AD shock)

4) $m_t = b(L)v_{t-1}$ (monetary policy rule)

$$= b_1 v_{t-1} + b_2 v_{t-2} + \cdots$$

Note: b_1, b_2, … are policy choice parameters (in the deterministic rule)

[Detour: Methodological Note on Lag Operator]

The "lag operator" L and "lag polynomial" $A(L)$

- Define L, so that $L(x_t) = Lx_t = x_{t-1}$

  $L^8 x_{t-1} = x_{t-9}$

  e.g. $L^2x_t = ?$ $\rightarrow L(L(x_t)) = L x_{t-1} = x_{t-2}$

- Define a general lag polynomial: $A(L) = a_0 + a_1L + a_2L^2 + a_3L^3 + \ldots.$

  e.g. $B(L) = b_1 + b_2L + b_3L^2$ (a 2nd degree polynomial)

  then $B(L)x_{t-1} = ?$ $\rightarrow b_1 x_{t-1} + b_2 x_{t-2} + b_3 x_{t-3}$

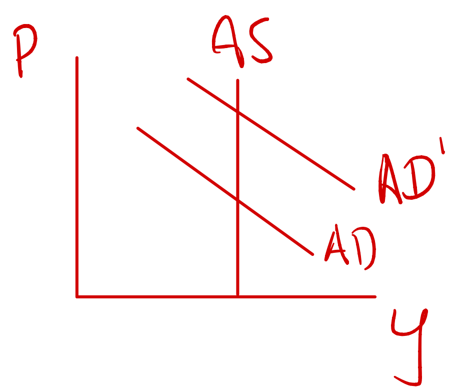
Note that if there is **no "nominal friction" or "wage-rigidity"** (here in the form of having to set wages a period in advance),

Then $w_t = p_t$

$\Rightarrow \; y_t = 0$ (output at trend at all times – no cycles/wiggles)

This is the **flexible price/wage equilibrium**. Interpretation:

- AS is vertical
- AD shocks do NOT cause fluctuations in this equilibrium with no wage rigidity



Solution method: express endogenous variables in terms of exogenous ones

i) Eliminate all but 1 endogenous variable, e.g. P

ii)	**Technique: Law of Iterated Expectations:**			
	$E_{t-i}E_{t-j}X_t =$	$E_{t-i}X_t$	if $i > j$	(don't expect to change one's mind)
		$E_{t-j}X_t$	if $i < j$	(past expectation is known)

Follow what you did in HW1:

Sub (1) into (2): $y_t =$ (5)

Sub (5) into (3):

$p_t =$ (6)

Take E_{t-1} of (6): $E_{t-1}\, p_t = E_{t-1}$ {exogenous variables} (7)

Plug (7), (6) into (5) to solve for y_t

$\Rightarrow$ $\boxed{y_t = \tfrac{1}{2}\eta_t}$ $\to$ $y_t = (P_t - E_{t-1} P_t) = \overset{\text{HW1 steps}}{\ldots} = \frac{1}{2}\eta_t$

$m_t, v_t \ldots$

Interpretations/Observations: $\boxed{y_t = \frac{1}{2}\eta_t}$

Systematic

1) In this **one-period** sticky wage contract setup, monetary policy is irrelevant: all coefficients of b(L) drop out

Get Sargent-Wallace result in a Keynesian model with nominal rigidity

(with short lived contracts)

2) Even though **AD shock v_t is persistent**, final output is still I.I.D.

Random as η_t

Reason: When (rational) agents set wages at time t-1, they already observe v_{t-1} so can predict v_t and p_t based on it, leaving η_t as the only source of uncertainty

(essentially *undoing the serial correlation*)

(agents already have info needed for setting policy informed wages at t-1, thus can only be surprised through shocks)

Fischer's 2-period staggered contracts

- ½ the population sets wages in odd periods, t = 1, 3, 5…

  even periods, t = 2, 4, 6…

- each wage contract lasts for 2 periods

Then w_t is given by $\underbrace{\mathbb{E}_{t-2} p_t}_{\text{New}}$ and $\mathbb{E}_{t-1} p_t$

1) (Wage-setting)

$$w_t^i = E_{t-i} p_t \qquad i = \{1, 2\}$$

2) (AS)

$$y_t = -\frac{1}{2}(w_t^1 - p_t) - \frac{1}{2}(w_t^2 - p_t)$$

3) (AD) $y_t + p_t = m_t + v_t$ with $v_t = D(L)\, v_{t-1} + \eta_t$

4) (MP) $m_t = \underbrace{b(L)}_{\text{Policy coefficients}} v_{t-1}$

To Solve it:

Wage setting AS

- Sub 1) into 2) leading to (5)
- Subs (5) into (3) leading to (6) (equation for p_t)
- Take E_{t-1} and E_{t-2} to get $E_{t-1}\,p_t$ and $E_{t-2}\,p_t$ then solve for p_t (long algebra and involved)
- Plug into (AS) for y_t

Previous result w/o staggered contracts

Result:

$$y_t = \frac{\eta}{2} + \frac{1}{3}(m_t - E_{t-2}m_t) + \frac{1}{3}(E_{t-1}v_t - E_{t-2}v_t)$$

$$y_t = \frac{\eta}{2} + \frac{1}{3}(m_t - E_{t-2}m_t) + \frac{1}{3}d_1\eta_{t-1}$$

[Algebra steps (detour)]

(5) into (3) and solving for p_t: $p_t = \frac{1}{2}m_t + \frac{1}{2}v_t + \frac{1}{4}E_{t-1}p_t + \frac{1}{4}E_{t-2}p_t$

Taking expectations:

$$E_{t-1}p_t = \frac{2}{3}E_{t-1}m_t + \frac{2}{3}E_{t-1}v_t + \frac{1}{3}E_{t-2}p_t$$
$$E_{t-2}p_t = E_{t-2}m_t + E_{t-2}v_t$$

Subs $E_{t-2}p_t$ in the expression for $E_{t-1}p_t$:

$$E_{t-1}p_t = \frac{2}{3}E_{t-1}m_t + \frac{1}{3}E_{t-2}m_t + \frac{2}{3}E_{t-1}v_t + \frac{1}{3}E_{t-2}v_t$$

Replace these two expectations in the equation for p_t:

$$p_t = \frac{1}{2}m_t + \frac{1}{6}E_{t-1}m_t + \frac{1}{3}E_{t-2}m_t + \frac{1}{2}v_t + \frac{1}{6}E_{t-1}v_t + \frac{1}{3}E_{t-2}v_t$$

Finally, find expressions for $E_{t-1}p_t - p_t$ and $E_{t-2}p_t - p_t$ and replace in AS:

$$E_{t-1}p_t - p_t = -\frac{1}{2}\eta_t; \;\; E_{t-2}p_t - p_t = \frac{2}{3}E_{t-2}m_t + \frac{2}{3}E_{t-2}v_t - \frac{4}{6}m_t - \frac{4}{6}E_{t-1}v_t - \frac{1}{2}\eta_t$$

In AS:

$$y_t = \frac{\eta}{2} + \frac{1}{3}(m_t - E_{t-2}m_t) + \frac{1}{3}(E_{t-1}v_t - E_{t-2}v_t)$$

Finally, use that

$$E_{t-1}v_t - E_{t-2}v_t = E_{t-1}(d_1 v_{t-1} + d_2 v_{t-2} + \cdots) - E_{t-2}(d_1 v_{t-1} + d_2 v_{t-2} + \cdots) = E_{t-2}d_1 v_{t-1} + d_1\eta_{t-1} - E_{t-2}d_1 v_{t-1} = d_1\eta_{t-1}$$

And simplify to arrive to: $y_t = \frac{\eta}{2} + \frac{1}{3}\boxed{(m_t -} E_{t-2}m_t) + \frac{1}{3}d_1\eta_{t-1}$

$m_t = \bar{m}$ $\quad y_t = \frac{\eta}{2} + \frac{1}{3}(0-0) + \frac{1}{3}d_1\eta_{t-1} = \frac{\eta}{2} + \frac{1}{3}d_1\eta_{t-1}$

$m_t = -d_1\eta_{t-1}$ $\quad y_t = \frac{\eta}{2} + \frac{1}{3}(-d_1\eta_{t-1} + d_1 \cancelto{0}{E_{t-2}\eta_{t-1}}) + \frac{1}{3}d_1\eta_{t-1} = \frac{\eta}{2}$

Fischer's question: **how should we set Monetary Policy?**

- Since model embodies natural rate hypothesis, MP cannot raise <u>average Y</u>, but CAN affect the variance of Y => M.P. can play a stabilization role.

$Corr(\eta_t, \eta_{t-1}) = 0$

$Var(\eta_t) = \sigma^2$

e.g. compare 2 simple MP rules:

1) $m_t = \bar{m} = 0$

$\Rightarrow \; y_t = \frac{1}{2}\eta_t + \frac{1}{3}D_1\eta_{t-1}$ $\qquad \Rightarrow \sigma_y^2 = \left(\frac{1}{4} + \frac{1}{9}\underbrace{D_1^2}_{\neq 0}\right)\sigma^2$ higher volatility of output

2) $m_t = -D_1\eta_{t-1}$

$\Rightarrow y_t = \frac{1}{2}\eta_t$ $\qquad \Rightarrow \sigma_y^2 = \frac{1}{4}\sigma^2$ lower volatility of output

<u>(2) is the optimal rule:</u>

Variance left comes from shocks neither policymaker nor the agents can predict

$\Rightarrow$ MP CAN help stabilize output

For this non-trivial policy relevance result in a RE framework, note 3 conditions:

1) Policymaker has a **larger information set** than private. ("Information advantage") The timing of action matters here. MP knows η_{t-1} at the time of setting policy, but it is not known to half of agents when setting wages.

2) Sharing this info with the economy doesn't help, since contracts are pre-formed already. Central bank "transparency" is not the issue. (Contrary to Lucas model where Fed announcing the info, what P is, would clear mis-perception)

3) Extra info of policymaker must be relevant, i.e. here, $d_1 \neq 0$. Otherwise, knowing η_{t-1} wouldn't help predict V_t, (hence wouldn't help conduct counter-cyclical M.P.)

Indexation

Q: Why do agents set nominal wage contract when they know only real wage matters? Why not index wages to the price level?

In practice, we often see both nominal shocks AND real shocks. And for:

1) nominal shocks => want to keep real wage fixed and thus full indexation is optimal;

but with …

2) real shocks => want real wage to adjust to the new marginal product of labor, hence do not want full indexation

So in the presence of both nominal and real shocks, the optimal indexation may be somewhere in the middle, i.e. some degree of nominal rigidity is reasonable (so the Fischer mechanism can be justified)

Some critiques/discussions on this literature:

1) Are these contracts rational? (would people sign Fischer contracts?)

Claim: NO; these are stupid both ex ante and ex post.

Ex ante: contracts will make them worse off compared to spot labor market (take current wages), no benefits to lock into longer contract

Ex post: once agreed on contract, should try to re-negotiate too, as both firms and labor are stuck in inefficient situation and can both gain from negotiating.

Implicitly saying both firms and workers are not optimizing even WITH information on η_t

Fischer's Response:

Can't explain why agents write them, but they do! We see contracts length often as long as 3 years.

Can view contracts as a convenient way for installment payment, not actual spot WAGE for the work.

Under same contract, workload can be allocated differently from month to month.

Plus, re-negotiation is costly in real life, so perhaps contracts are the optimal solution reflecting long term relationship.

So, the contracted real wage might not really affect firms hiring decision from period to period

but then it's unclear how they play a role in economic fluctuations

+ ~~3~~ 2) Empirical Real Wage:

In the Fischer model, real wage is counter-cyclical.

e.g. given a positive AD shock,

$P\uparrow, \bar{w} \Rightarrow$ real wage $\downarrow$

$\Rightarrow$ firms hire more workers $(L\uparrow) \Rightarrow Y\uparrow$

Problem: data shows that RW is basically acyclical or slightly pro-cyclical (Topic 1)

$\uparrow Y$ $\qquad \dfrac{\uparrow W}{\uparrow P}$

Q: How do we generate pro-cyclical real wage in models??

Not very easy,

e.g. under a competitive economy: P = MC (marginal cost)

$$MC = \frac{w}{MPL}$$

$$\Rightarrow \frac{w}{p} = MPL \quad \text{(marginal product of labor)}$$

From diminishing returns under Neoclassical Production function:

$\uparrow$ Y$\uparrow$ (L$\uparrow$) => MPL$\downarrow$ $\rightarrow$ $\downarrow \frac{w}{p}$

=> counter-cyclical real wage

Possible Fixes: some approaches to generate pro-cyclical real wage
[need to add or drop some assumptions of previous models]

a) Real Business Cycle (RBC) literature: productivity shocks cause business cycle fluctuation, e.g. shifting up both MPL and Y during expansion

[Add output augmenting technology shock]

We go from $Y = f(L)$ to $Y = \tilde{A} f(L)$

$$\left.\begin{matrix} \uparrow \tilde{A} \longrightarrow \uparrow Y \\ \vdots \\ \uparrow MPL \end{matrix}\right\} \oplus \text{ Comovement}$$

$$\frac{\partial Y}{\partial L} = \tilde{A} f'(L) = MPL$$

b) Imperfect Competition: [drop Perfect Competition assumption]

Now Firms have price Setting Power (monopolistic power)

- Instead of P = MC, P = μ MC where μ = mark-up and ≥ 1

So $$\frac{w}{p} = \frac{MPL}{\mu}$$

↑ y ↓ MPL Compatible with ↑ Real Wage

$\boxed{\downarrow \mu}$

(Countercyc in the data)

- Mark-up μ is countercyclical (so real wage is pro-cyclical), e.g.

  - more firms enter in booms => goods market more competitive, μ ↓
  - booms induce price wars, better time for Cartel members to cheat and gain large market shares when there are lots of customers (game theory argument)
  - During booms, people are more picky about prices with larger selections

=> focus on "**monopolistic competition**" setup (Tech session 2 and later lecture)

<u>Another empirical issue with the contracting models:</u>

- **In the data, monetary policy has persistent effect <u>beyond</u> the length of contracts**

- whereas in the Fischer staggered contract model, MP is effective only during the length of the contract. (Please make sure you see this point)

How to **generate long-lasting effect of MP**? Taylor/Calvo pre-fixed contracts with:

  - Staggered **pre-fixed price**

  - "Strategic complementarity"

Working towards NK Phillips curve:
- Prices are sticky
  - Monetary Policy affects the economy
- Why firms would not want to adjust prices?

Terminology (Romer Ch. 7.2 - 7.3)

Pre-determined prices/wages vs. Pre-fixed prices/wages

Fischer

- Prices set in advance but they can differ within contract period

e.g. for 2-period contracts:

At time t, set w_{t+1} and w_{t+2} based on E_tP_{t+1} and E_tP_{t+2}

(Can have $w_{t+1} \neq w_{t+2}$)

Taylor/Calvo HW4

- Within contract length, P or w are fixed (the same)

At time t, set $w_{t+1} = w_{t+2}$ based on E_tP_{t+1} and E_tP_{t+2}

(Adds that $w_{t+1} = w_{t+2}$)

With fixed-length "pre-fixed" contracts, the **staggered mechanism** + **strategic complementarity** can help provide a channel for shocks to propagate beyond the length of the contracts (Taylor)

Taylor Model of Pre-Fixed Prices

Motivation: Reconcile time-contingent price adjustment, with empirical observation that monetary policy has longer effects beyond contract length

(A) Basic Setup (#1): Staggered pre-fixed price only (not yet Taylor)

- uniformly distributed firms on the unit interval [0, 1], indexed by i

Year 3

$P_{1/2} = \begin{cases} P_{1/2,2} & \text{until June 30} \\ P_{1/2,3} & \text{after June 30} \end{cases}$

$P_{1/2,3}$

$P_{0.8,3}$

1. (AD) $P_t + Y_t = M_t$

2. (Price-setting): Optimal price for each firm i at t: $p^*_{i,t} = M_t$

3. (Price rigidity): each i can adjust price p_i once a year with **pre-fixed** pricing that lasts a year, i.e. need to choose the same price for the year

4. All the firms take turn ("staggered") to set their price over the year

↳ $\text{Firm}_{0.5}$: Changes prices at the half point of the year

When it's firm i's turn to set its price:

choose the average of the expected optimal price over the next year:

$$\underbrace{p_{i,t}}_{\text{Individual (firm) price decision}} = \int_0^1 E_t p^*_{i,t+s}\, ds = \int_0^1 E_t M_{t+s}\, ds$$

So what is the effect of a Monetary policy change, say **a 10% drop in M_t** ?

Aggregate (over firms and time):

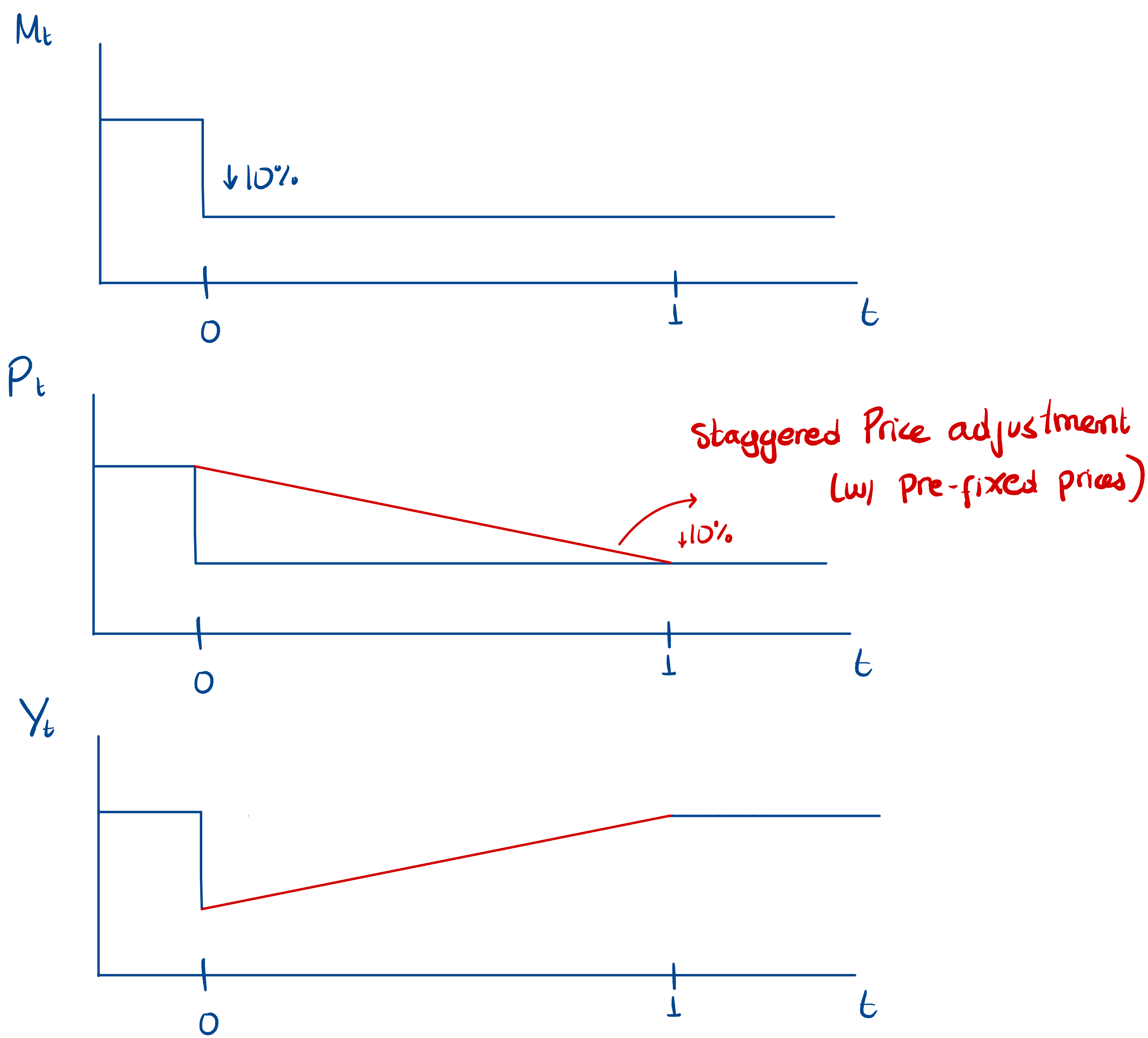
$$\underbrace{P_t}_{\text{Price index}} = \int_0^1 p_{i,t}\, di = \int_0^1 \overbrace{\int_0^1 E_t M_{t+s}\, ds}\, di$$

aggregate through all firms

So aggregate price P depends on expected future money M_{t+s}

(as well as previously expected M_t….etc.)

Consider a 10% M_t drop at time t:



What does this mean?

- Under staggered pre-fixed price rigidity (only) here, the effect of a decline of M on Y still ends with the length of the contract (blue line), once all firms have adjusted their prices to the unexpected M drop

- To generate longer-lasting response in Y (red line), we need each firms in the above example to adjust price by less than 10%

=> add **strategic complementarity**

Setup #2: **Taylor Model**

- fixed-length, pre-fixed staggered contracts with **strategic complementarity** in price-setting decision
- **Strategic complementarity:** optimal strategy or action of an agent depends positively upon the strategies of other agents

Motivation: show time-contingent price adjustment can deliver the empirical observation that monetary policy has longer effects beyond contract length

Here: assume firms care about their relative price as well

(why? e.g. Blanchard-Kiyotaki aggregate demand externality, next topic)

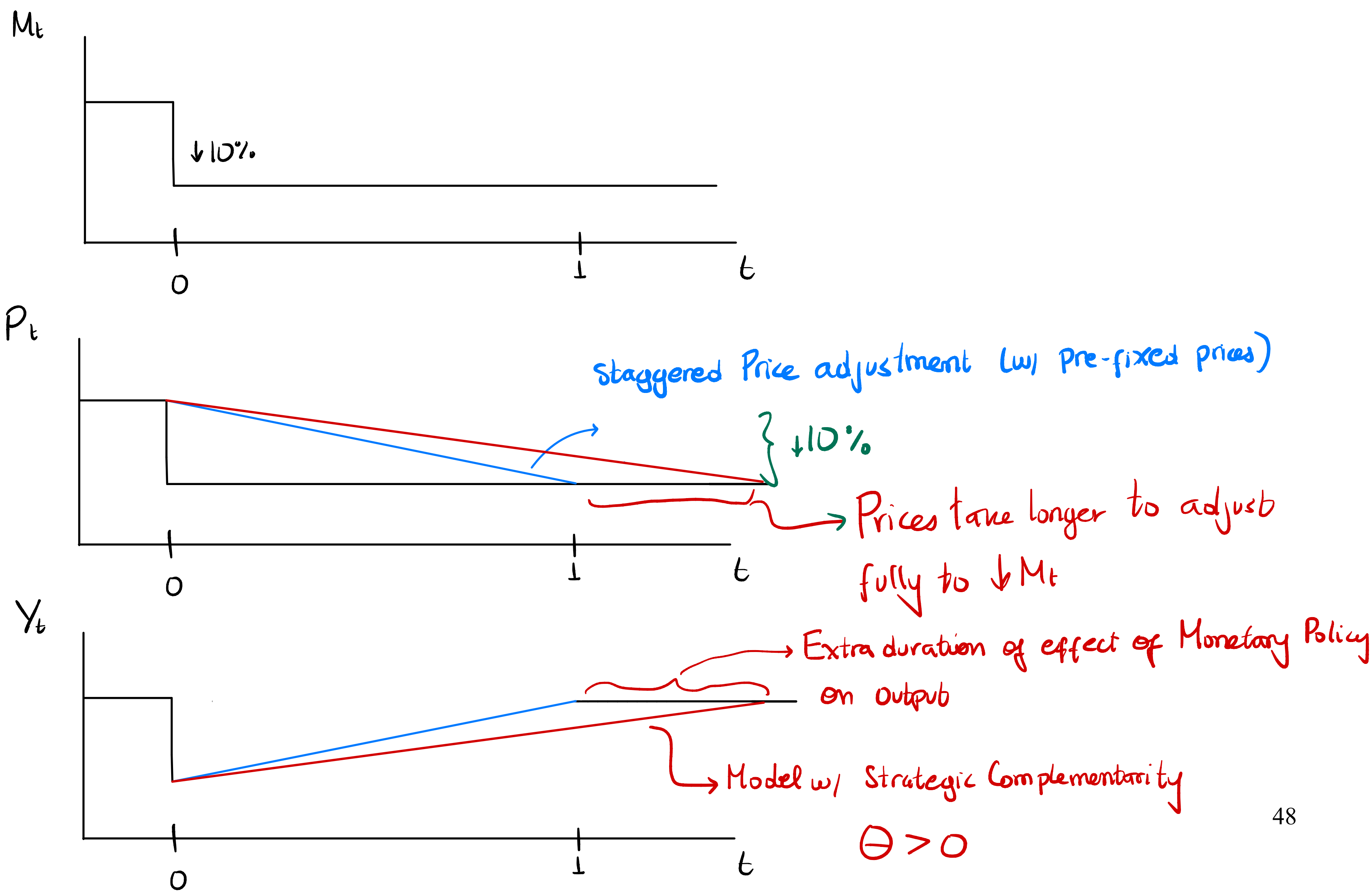
$$p_{i,t}^{*} = \theta M_t + (1-\theta)P_t$$

=> can see effects of monetary shocks lasting longer than adjustment period

Staggered pre-fixed price (blue) vs. **Taylor with strategic complementarity** (red)

$$p^*_{i,t} = M_t \qquad \text{vs.} \qquad p^*_{i,t} = \theta M_t + (1 - \theta) P_t$$

Drop in M by 10%:



- Without strategic complementarity, effect of M drop on Y ends with length of the contract (blue line) once all firms adjust prices to the unexpected M drop.

- To generate longer-lasting response in Y (red line), we need each firm to adjust price by less than 10% (in the above example)

- Taylor model adds "**real rigidity/indexation**" in price setting decision:

$$p^*_{i,t} = \theta M_t + \underline{(1 - \theta) P_t} \qquad \theta > 0$$

i.e. firms now care about relative price as well as monetary aggregate M

=> can see effects of monetary shocks lasting longer than adjustment period

Empirics of Nominal Rigidities

Nature and Behavior of Nominal Rigidity: Booming Empirical Literature

- Heterogeneity/skewness in stickiness across sectors
  - 80 months (laundry machines) vs. 0.5 months (gasoline)
  - mean frequency: 4.7 months., median: 11.5 months
- Many sales/temporary price changes
- Distribution of price changes matters:
  - Large average size of price changes
  - Large dispersion in size of price changes

Next: Why don't prices change/clear markets instantaneously?

But before: Detour to Tech Slides 2: CES functions

Key Questions (EC):

- How does real wage co-move with output in the Fischer model?
- What are the two the main empirical failings of the Fischer staggered wage contract model?
- What elements or mechanisms can help address them and help generate model outcomes consistent with the data?

(check Tech Slides 2: CES and Constrained Optimization refresher)

Why don't prices change/clear markets instantaneously?

Concept: Menu Cost, "z":

- decision making cost
- menu pricing cost
- near-rationality (Akerlof & Yellen): "satisficing" (close enough)

We will look at 2 stories of how the presence of menu cost may lead to monetary non-neutrality:

A) Partial Equilibrium Analysis (Mankiw)

- small (2nd order) adjustment cost at the individual level may induce large (1st order) aggregate social inefficiency

B) General Equilibrium with **Aggregate Demand externalities** (Blanchard-Kiyotaki)

Modeling the decision to change prices and its aggregate implication: rely on <u>imperfect competition</u> & <u>**externalities**</u>

A) P.Eq story: Setup:

$i = 1,..N$ producers each has some monopoly power ("**Monopolistic Competition**")

Why?

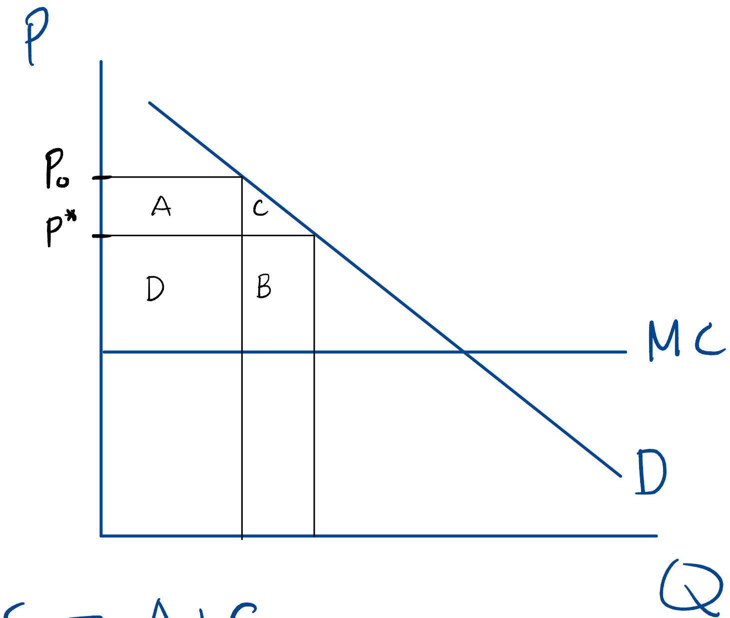
so firms can set their own prices (and face a downward-sloping demand curve for its product)

Story: At time $t = 0$, a firm sets $P = P^0$

However, it had over-estimated M (or: $M^S\downarrow$, Demand $\downarrow$ unexpectedly), so the optimal P is actually $P^* < P^0$ (P^0 is close to P^*)

The firm needs to decide whether to incur the **menu cost z** to change the price or not.

Graphically, for intuition:



$\Delta CS = A + C$

(Consumer surplus)

Firm's decision:

$\Delta\pi = \pi(p^*) - \pi(p_0) = (D+B) - (A+D)$

Profits $\qquad = B - A$

Changing price or not depends on $B - A \gtreqless z$

Δ Social Surplus $= B + C$

$\Rightarrow$ If $B + C > z > B - A \Rightarrow$ Firms will Not change Price (Socially Inefficient)

i.e., firms look at their own surplus to decide whether to adjust prices. If they don't want to adjust when society would like to adjust a social inefficiency arises

(remember the efficiency of RBC models: social planner yields the same result than private markets? … it would not happen here)

Large

Claim: Decision to change price has 1st order effect on social welfare but only 2nd
2nd order effect on firms' profits, i.e., socially inefficient outcome is likely to happen

Small

(due to externality on consumer surplus)

$\pi(p)$ (Profits) ; Social Welfare function $SW(p) = \pi(p) + CS(p)$

Approximate functions via Taylor Expansion of $\pi(P_0)$ around P^*

$$\pi(P_0) = \pi(P^*) + \underbrace{\pi'(P^*)}_{=0 \text{ (From FOC of Profit Maximization)}}(P_0 - P^*) + \frac{1}{2}\pi''(P^*)(P_0 - P)^2 + \dots$$

Same w/ $SW(P_0)$

Similar But $SW'(P^*)$ is not 0

$$SW(P_0) = SW(P^*) + SW'(P^*)(P_0 - P^*) + SW''(P^*)(P_0 - P^*)^2 + \dots$$

$\Delta\pi = \pi(P_0) - \pi(P^*) \propto (P_0 - P^*)^2$ (Smaller if $P_0 - P^*$ is small)

$\Delta SW = SW(P_0) - SW(P^*) \propto (P_0 - P^*)$ (Larger)

Given menu cost z, a small M^S shock is likely to result in fixed P, implying output adjustment and non-neutrality of money

↳ firms unwilling to adjust prices

[Tech Session #2 example]

B) **Blanchard and Kiyotaki (AER 1987)**

- Use Dixit-Stiglitz (AER '77) setup with Differentiated goods (CES)
- Emphasis: Firms exert aggregate demand externality on one another

Dixit-Stiglitz (AER '77) setup:

1) Differentiated goods (Chamberlin '33)

   ↳ CES functions for aggregating varieties of goods

2) Price setting power (monopolistic competition)

   $P > MC$ or $P = \mu \cdot MC$ ($\mu > 1$: Mark-up)

3) N firms (N large); each firm is small relative to the whole market

   Δp_i has almost no impact on P

4) Free entry & exit

   N fixed, $\pi_i \to 0$ (Long run); Short run $\pi_i \neq 0$

Monopolistic Competition & Differentiated goods

- Gives price-setting decision to the firms
- Justifies **demand-determined output**, e.g. shocks to AD can affect output
- Firms willing to sell more because P > MC; quantity constrained by demand
- Monopolists set high prices and constrain output below social optimal: Justifies policy interventions (private equilibrium no longer efficient)
- Firms have monopoly power and set prices above the competitive level.
- Implicitly assuming that labor market is not competitive either (firms' output level determines how many workers are employed)

AD Externality:

When a firm considers whether to lower its price,

1) it would increase its own demand (<u>along</u> its own demand curve)

$\downarrow P_i \rightarrow \uparrow D_i$ (Private / individual effect)

2) it would help lower overall price level, thereby raise AD

$\downarrow P \rightarrow \uparrow AD$ (Social benefit / effect)

3) Since most of the extra AD would fall on other firms, individual firm ignores #2 in making its price decision => ignoring the social benefit of lowering price

4) With menu cost, it's possible that firms do not lower prices to the socially efficient level => overall P too high, and aggregate output too low

Blanchard and Kiyotaki (AER 1987) Setup:

Continuum of HH-producers on [0, 1] indexed by i

1) $$\text{Max } U\left(C_i, \frac{M_i}{P}, L_i\right) = \left(\frac{C_i}{\alpha}\right)^{\alpha}\left(\frac{M_i/P}{1-\alpha}\right)^{1-\alpha} - \frac{L_i^{\beta}}{\beta}$$

$$C_i = \left[\int_0^1 C_{ij}^{\frac{\sigma-1}{\sigma}} dj\right]^{\frac{\sigma}{\sigma-1}}$$

i : Consumer

j : Varieties

σ = Elast. of substitution

2) Production: $Y_i = L_i$

3) i's budget constraint: $P_i Y_i = \int_0^1 P_j C_{ij} dj + M_i$

=> Solve for equilibrium (see Tech Session 2) $\{Y_i, P_i\}$ s.t. $\begin{cases} S_i = D_i \ \forall i \in [0,1] \\ \Pi_i \text{ is maximized} \end{cases}$

$$P = \left[\int_0^1 P_j^{1-\sigma} dj\right]^{\frac{1}{1-\sigma}}$$

$$y_i = D\left(\overset{(-)}{\frac{P_i}{P}}, \overset{(+)}{y}\right) = D\left(\frac{P_i}{P}, \frac{M}{P}\right)$$

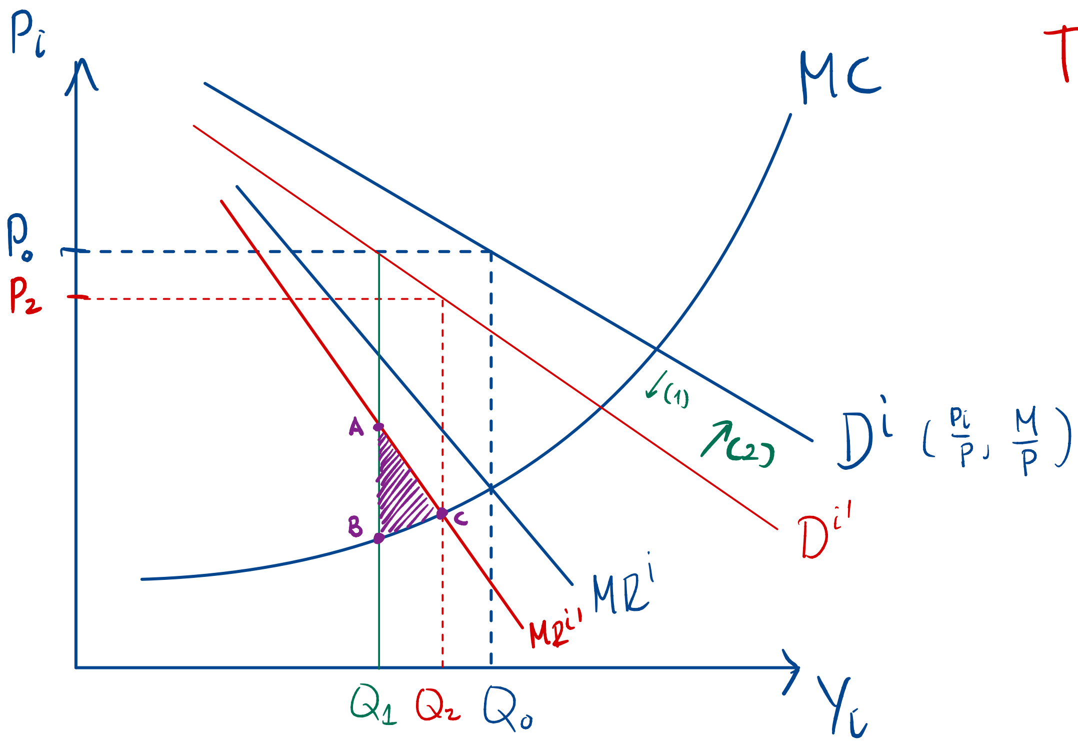
Consider a negative money shock: $M^s\downarrow$:

Start @ (P_0, Q_0)

Then $\downarrow M^S$ and firms decide between:

(1) Stay at (P_0, Q_1)

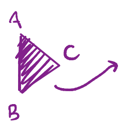
(2) Change price and move to (P_2, Q_2)



W/O Menu Costs → Choose (2)

↳ ⇒ every P_i lowers (symmetric equilibrium assumption)

⇒ D^i shifts back



↑ in profits from resetting the price to new optimal level*

Without menu cost:

- MR > MC at Q_1, so $Q_i\uparrow$ => $p_i\downarrow$ (to p_2)
- Since firms are identical => overall $P\downarrow$
- M^s/P goes back up => $D_i\uparrow$ => $Q_i\uparrow = Y\uparrow$ (output recovers)

* (This assumes P_0 & P_2 are not too different so the extra marginal revenue is well approximated by the triangle)

2) Add in Menu Cost

If shock is small, profit loss from staying at p_0 may be smaller than Menu Cost of price adjustment

What if there is a menu cost z s.t.

$$z > \triangle abc$$

Menu Cost > Profit gain from changing price

- Firms do not adjust prices in response to M shock (staying at p_0), so real money balance and aggregate demand will drop $\rightarrow \downarrow \frac{M}{P}$

- Output drops further below socially optimal output ($Q_0\downarrow\downarrow$ to Q_1)

In the **presence of menu cost**, when a firm considers whether to lower its price,

1) it would increase its own demand (along its own demand curve)

2) **externality:** it would help lower overall price level => raise/shift AD

↳ ($\downarrow P_i \rightarrow \downarrow P$)

3) individual firm ignores #2 in making its price-changing decision,

4) With menu cost, firms **may not lower prices** to the socially efficient amount: overall P too high, and aggregate output is too low.

This gives us:

1) Monetary non-neutrality

2) Pro-cyclical real wage

3) Potential justification for small monetary expansion as it could raise output towards socially optimal level.

4) Large shocks: always socially costly, as it would force firms to pay menu costs.

Q: How do we think about the dynamic adjustment process under the assumed (nominal) rigidity in a microfounded setup?

Dynamics of Price Adjustment:

Time-Contingent Price Adjustment:

- Calvo (1983): Microfoundation of Fischer, Taylor ideas

State-contingent price adjustment:

- Rotemberg (1982): Microfoundation of menu cost ideas

Examples of others: Caplin and Spulberg (1997), Golosov and Lucas (2003)

Remember the need to reconcile microeconomic evidence of price changing frequency with the high persistence of the effect of monetary policy in macro data

(HW4)

Calvo (1983) and Yun (1996):

Context: "micro-foundation" for the New-Keynesian Phillips curve

- Firms adjust prices at random intervals in a staggered fashion
- Price stickiness is costly as it causes inefficient allocation of production
- Many elements we have seen from earlier models (e.g. pre-fixed pricing)
- Opportunity to adjust price arrives as an exogenous Poisson process:

constant probability $1-\theta$ of getting to change price at each t

θ: Nominal Rigidity parameter

Notice: this setup is Time-contingent with exogenous probability of price change

- See handout for a step-by-step derivation of the Phillips curve (also HW)
- (optional) See Romer 7.4 and Walsh Ch.6 pp249 for discussion
- focus on minimizing expected **quadratic loss**

Some comments on key elements:

- 1-θ probability for changing prices @ each t

Expected duration = ? (remember $E[t] \; = \; \sum_{t=1}^{\infty} t \; Pr(x \; \leq \; t)$)

$$E[t] = 1-\theta + 2\theta(1-\theta) + 3\theta^2(1-\theta) + \dots$$

$$= (1-\theta)(1+2\theta+3\theta^2+4\theta^3+5\theta^4+\dots)$$

$$= (1+\cancel{2}\theta+\cancel{3}\theta^2+\cancel{4}\theta^3+\cancel{5}\theta^4+\dots) + (-\cancel{\theta}-\cancel{2\theta^2}-\cancel{3\theta^3}-\cancel{4\theta^4}-\dots)$$

$$= (1+\theta+\theta^2+\theta^3+\theta^4+\theta^5+\dots) \qquad \left(\sum_{s=0}^{\infty} \alpha^s = \frac{1}{1-\alpha}, \quad 0<\alpha<1 \right)$$

$$= \frac{1}{1-\theta}$$

Given a change of price at t=0, What is the probability of the next price change?

$t=1$ $\quad 1-\theta$

$t=2$ $\quad \theta.(1-\theta)$

$t=3$ $\quad \theta^2(1-\theta)$

$\vdots$

$t=j$ $\quad \theta^{j-1}(1-\theta)$

Empirics/calibration:

θ : Prob. of not changing price (Price Stickyness)

e.g. $\theta = 0.75 \Rightarrow$ Exp. duration of price $= \frac{1}{1-0.75} = 4$

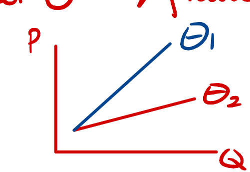
Estimates

Micro v.s. Macro

~1,2 quarters vs. 6 quarters

~3,4 months

(higher $\theta \longrightarrow$ flatter AS



$\theta_2 > \theta_1$)

- Per-period quadratic loss function:

$$L(x_t) = \frac{k}{2}(x_t - p_t^*)^2$$

↳ Price to set at firm level

- Minimize expected loss:

$$\min_{x_t} \sum_{j=0}^{\infty} (1-\theta)\,\theta^j \beta^j \frac{k}{2}\left(\mathbb{E}_t\, p_{t+j}^* - x_t\right)^2$$

- Solve for x_t (check intuition)

for each firm

- Aggregate & first differencing: $\pi_t = p_t - p_{t-1}$ (in logs)

$$\pi_t = \beta\, E_t[\pi_{t+1}] + \frac{(1-\beta\theta)(1-\theta)}{\theta}\,\phi\, y_t$$

=> New Keynesian Phillip's Curve (Micro-founded, expectation augmented AS)

NEW KEYNESIAN THEORY: MONOPOLY PRICING

supply side price setting and towards microfounded menu costs model

RELEVANT MARKET STRUCTURE(S)?

Real business cycle (RBC)/neoclassical theory

– All (goods) prices are determined in perfect competition
– In both consumption-leisure and consumption-savings dimensions
– Critical assumption: no firm is a price *setter* → no firm has any market power

New Keynesian theory

– Starting point: firms *do* wield (at least some) market power
– Critical assumption: firms *do* set their (nominal) prices
– Purposeful setting/re-setting of (nominal) prices may entail costs of some sort
  - "Menu costs," but soon interpret more broadly
  - Central issue in macro: how do "costs of adjusting prices" ("sticky prices") affect monetary policy insights and recommendations?

Upcoming analysis

Step 1: Develop theory in which firms are purposeful price setters, not price takers
Step 2: Superimpose on the theory some "costs" of setting/re-setting nominal prices

MONOPOLISTIC COMPETITION

Monopolistically-competitive view of goods markets the foundation of NK theory:

An intermediate market structure between pure perfect competition and pure monopoly

Framework

- Allows for purposeful price setting by firms
- Retains some competitive features of pure supply-and-demand theory
- Assumes that goods are imperfect substitutes
  - The foundation/essence of market power
  - In contrast to the perfect substitutability of goods in theory of perfect competition

Markup

- The ratio of a firm's unit sales price to its marginal cost of production
- A key concept in the theory of monopoly/monopolistic competition
- A key measurable (sort of…) empirical concept
- Perfect competition: markup = 1

MONOPOLISTIC COMPETITION

(Chugh 2015)

Graphical review of monopoly theory (general case)

Same as Blanchard - Kiyotaki plot/model from before

Simplify: assume fixed cost = 0 and marginal cost does not depend on quantity produced

Main result: p $\underline{>}$ mc → markup $\underline{>}$ 1

NK MODEL OVERVIEW

Monopolistic competition in goods markets the underlying market structure:

Operationalize by dividing goods markets into two "sectors"

Retail firms

Each sells a perfectly-substitutable "retail good" in a perfectly-competitive market

Purchase differentiated "wholesale goods" in monopolistically-competitive markets

Wholesale firms

An "infinite" number of them

Each produces a imperfectly substitutable "wholesale good"

Thus each firm is a monopolist of its own variety, but is affected by competition with varieties offered by other wholesale firms

Each wholesale firm is a price setter

"Wholesale goods" are sold to retail firms

Conceptual separation allows for separate consideration of:

Price setting at the microeconomic level

Determination of market outcomes at the macroeconomic level

RETAIL FIRMS

A representative retail firm

Operates a "production function" that "bundles together" wholesale goods into retail goods

- Inputs: wholesale goods ONLY, no labor or other inputs required
- Example: a retail store that produces no goods of its own

Dixit-Stiglitz aggregator function/"production function"

$i \in [0, 1] \rightarrow$ input good ("wholesale") index

- Workhorse building block of NK theory

$$y_t = \left[\int_0^1 y_{it}^{1/\varepsilon} di \right]^{\varepsilon}$$

(Also a basic building block of theory of international trade)

Output of the retail good **An infinity (continuum) or differentiated wholesale goods**

- Parameter ε measures curvature
- Elasticity of substitution between any pair of differentiated wholesale goods is $\varepsilon/(\varepsilon-1)$
- ε also the critical determinant of profit-maximizing markup
- Restriction for NK model to make any sense: $\varepsilon > 1$
- Setting ε = _1_ recovers perfect competition (i.e., RBC, not NK)

$$ES = \frac{\varepsilon}{\varepsilon - 1}$$

See all this soon

RETAIL FIRMS

A continuous infinity of wholesale goods

- A metaphor for “many varieties of goods”
- Easier to deal with mathematically than discrete infinity (tools of calculus can be applied!)
- And normalize to continuum [0,1] (could also say, i.e., [0,2], etc…)

Schematic structure of goods markets

Representative retail firm’s profit function:

Nominal price of the retail good **Nominal price of wholesale good *i***

$$P_t y_t - \int_0^1 P_{it} y_{it} di$$

Max profits s.t. technology

$$y_t = \left[\int_0^1 y_{it}^{1/\varepsilon}\right]^{\varepsilon}$$

Substitute Dixit-Stiglitz production function

$$P_t \left[\int_0^1 y_{it}^{1/\varepsilon} di\right]^{\varepsilon} - \int_0^1 P_{it} y_{it} di$$

RETAIL FIRMS

Representative retail firm's profit-maximization problem:

$$\max_{\{y_{it}\}_{i=0..\infty}} P_t \left[\int_0^1 y_{it}^{1/\varepsilon} di \right]^{\varepsilon} - \int_0^1 P_{it} y_{it} di$$

Chooses profit-maximizing quantity of input of *each* wholesale good. Focus on any arbitrary wholesale good – call it y_{jt}.

FOC with respect to y_{jt} (for any j):

$$[y_{jt}] = \frac{\partial [\cdot]}{\partial y_{jt}} = 0$$

.

.

.

…after several rearrangements

$$y_{jt} = \left(\frac{P_{jt}}{P_t} \right)^{\frac{\varepsilon}{1-\varepsilon}} y_t$$

(Optimal) DEMAND FUNCTION FOR GOOD j

WHOLESALE FIRMS

- Focus on the activities of an arbitrary wholesale firm *j*
- Symmetry: assume that every wholesale firm makes decisions analogously
  - Consistent with the representative-agent approach
- So can speak of a “representative” wholesale firm

- Assume zero fixed costs of production

- Operates a constant-returns-to-scale (CRS) production technology in order to produce its unique, differentiated output
  - CRS: if all inputs are scaled up by a factor *x*, total output is scaled up by a factor *x*
  - Implementation of theory requires specifying neither the factors of production (i.e., labor, capital, etc) nor a production function (*f*(.))

Together, these imply a simple description of production

- Marginal cost of production
  - = average cost of production
  - is invariant to the quantity produced
    - i.e., mc is NOT a function mc(quantity)

WHOLESALE FIRMS

- Representative wholesale firm's profit-maximization problem

Total revenue depends on firm's production and its *own* product price.

mc is NOT a function of quantity produced – CRS assumption.

FC = 0 → *mc* = *ac*

$$\max_{P_{jt}} \underbrace{P_{jt} y_{jt}}_{\text{s.t. Optimal demand of } y_{jt}} - P_t mc_{jt} y_{jt}$$

Conversion of production costs into nominal terms requires factor P_t, NOT P_{jt}. Because costs are not denominated in the firm's *own* prices.

Substitute in demand function for wholesale good *j*.

The critical point of analysis of monopoly: the firm *understands* and *internalizes* the effect of *its* price on the quantity sold

Substitute it!

$$\max_{P_{jt}} P_{jt} \underbrace{\left(\frac{P_{jt}}{P_t}\right)^{\frac{\varepsilon}{1-\varepsilon}} y_t}_{y_{jt}} - P_t mc_{jt} \underbrace{\left(\frac{P_{jt}}{P_t}\right)^{\frac{\varepsilon}{1-\varepsilon}} y_t}_{y_{jt}}$$

- The sole choice object is P_{jt}
  - Compute FOC!

    → wrt P_{jt}

WHOLESALE FIRMS

- Representative wholesale firm's profit-maximization problem

$$\max_{P_{jt}} P_{jt}\left(\frac{P_{jt}}{P_t}\right)^{\frac{\varepsilon}{1-\varepsilon}} y_t - P_t mc_{jt}\left(\frac{P_{jt}}{P_t}\right)^{\frac{\varepsilon}{1-\varepsilon}} y_t$$

- FOC with respect to P_{jt} (lengthy algebra…)

$$\frac{1}{\cancel{1-\varepsilon}} P_{jt}^{\frac{\varepsilon}{1-\varepsilon}} P_t^{\frac{\varepsilon}{\varepsilon-1}} \cancel{y_t} - \frac{\varepsilon}{\cancel{1-\varepsilon}} P_{jt}^{\frac{2\varepsilon-1}{1-\varepsilon}} P_t^{\frac{2\varepsilon-1}{\varepsilon-1}} mc_t \cancel{y_t} = 0$$

.
.
.

…after several rearrangements:

$$\frac{P_{jt}}{P_t} = \varepsilon mc_{jt}$$

Optimal relative price of wholesale firm j is a markup ε over marginal cost of production.

KEY PRICING RESULT OF DIXIT-STIGLITZ THEORY.

- Define relative price as $p_{jt} = \dfrac{P_{jt}}{P_t}$

In which case can express pricing rule as → $p_{jt} = \varepsilon mc_{jt}$

>1 in monop. competition
(Mark up)

Or as optimal markup rule → $\mu_{jt} = p_{jt} / mc_{jt} = \varepsilon$

THE DIXIT-STIGLITZ FRAMEWORK

Key prediction of basic Dixit-Stiglitz theory

$$\mu_{jt} = \frac{p_{jt}}{mc_{jt}} = \varepsilon$$

- Firms aim to keep their prices at a constant markup over marginal cost

this changes once we assume menu costs (and nominal rigidities)

Empirical relevance of DS constant markup prediction?

- Not very in the short run…
- …but maybe in the long run

Markups generally observed to be countercyclical (with respect to GDP)

- During expansions, markups decline; during recessions, markups rise
- (detrended, business cycle frequencies)

DS framework has long been the main starting point for pricing theories; some applications:

- Customer switching effects
- Brand loyalty
- Search costs

NEXT: The Dixit-Stiglitz framework as the foundation of New Keynesian sticky-price models.

NEW KEYNESIAN THEORY:
THE MODERN STICKY-PRICE MODEL

Rotemberg – Menu Costs model

Relevant Market Structure(s)?

- Real business cycle (RBC)/neoclassical theory
  - All (goods) prices are determined in perfect competition
  - In both consumption-leisure and consumption-savings dimensions
  - Critical assumption: no firm is a price ***setter*** → no firm has any market power

- New Keynesian theory
  - Starting point: firms ***do*** wield (at least some) market power
  - Critical assumption: firms ***do*** set their (nominal) prices
  - Purposeful setting/re-setting of (nominal) prices may entail costs of some sort
    - "Menu costs," but soon interpret more broadly
    - Central issue in macro: how do "costs of adjusting prices" ("sticky prices") affect monetary policy insights and recommendations?

- Upcoming analysis
  - Step 1: Develop theory in which firms are purposeful price setters, not price takers
  - NOW → Step 2: Superimpose on the theory some "costs" of setting/re-setting nominal prices

MENU COSTS

Do firms incur "costs" in the very act of setting/re-setting nominal prices?

If so, what is the nature and prevalence of these costs? $\rightarrow$ A central issue in price theory

+

- Menu cost – any and all costs incurred directly due to the price (re-)setting process
  - Independent of any physical production costs – i.e., NOT a cost captured by standard "production functions"

- Two common views of nature of menu costs
  - Fixed menu cost: total menu cost is independent of the magnitude of the price change being considered
  - Example: cost of printing new prices on restaurant menus is probably independent of what the new prices are

  - Convex menu cost: total menu cost is convex and increasing in the magnitude of the price change being considered
  - Example: if "menu cost" includes "cost of angering customers," "managerial time," etc., convexity assumption may be more appropriate

Anderson and Simester; Zbracki et al papers

- Both fixed and convex are likely aspects of menu costs
- Formal theoretical NK model typically focuses only on convex menu costs

Modeling Convex Menu Costs

Introduce menu costs at level of wholesale firms

- Because they actually (re-)set prices!
- What does it mean for a firm that is not a price-setter to incur costs of setting prices?...

Wholesale firm j incurs real menu cost of nominal price adjustment

$$\frac{\psi}{2}\left(\frac{P_{jt}}{P_{jt-1}}-1\right)^2$$

- REAL cost of price adjustment – denominated in goods
- Parameter $\Psi > 0$ governs "importance" of menu costs
  - $\Psi = 0$ means no menu cost, which recovers basic Dixit-Stiglitz framework

Convex: the larger the percentage deviation of P_{jt} from P_{jt-1}, the larger the menu cost

- Implication: a disincentive to adjusting prices "too quickly"

Question: are downward adjustments just as costly as upward adjustments?

- Intuition: "no"   Anderson and Simester evidence: "maybe?..."

Retail Firms

Representative retail firm's profit-maximization problem

$$\max_{\{y_{it}\}_{i=0..\infty}} P_t \left[\int_0^1 y_{it}^{1/\varepsilon} di \right]^{\varepsilon} - \int_0^1 P_{it} y_{it} di$$

Chooses profit-maximizing quantity of input of *each* wholesale good. Focus on any arbitrary wholesale good – call it y_{jt}.

FOC with respect to y_{jt} (for any j)

.

.

.

…after several rearrangements:

$$y_{jt} = \left(\frac{P_{jt}}{P_t} \right)^{\frac{\varepsilon}{1-\varepsilon}} y_t$$

DEMAND FUNCTION FOR GOOD j

IDENTICAL TO BASIC (FLEXIBLE-PRICE) DIXIT-STIGLITZ FRAMEWORK!

WHOLESALE FIRMS

- Focus on the activities of an arbitrary wholesale firm *j*
- Symmetry: assume that every wholesale firm makes decisions analogously
  - Consistent with the representative-agent approach
- So can speak of "the" wholesale firm

- Assume zero fixed costs of production

- Operates a constant-returns-to-scale (CRS) production technology in order to produce its unique, differentiated output
  - CRS: if all inputs are scaled up by the factor *x*, total output is scaled up by the factor *x*
  - Implementation of theory requires specifying neither the factors of production (i.e., labor, capital, etc) nor a production function (*f*(.))

Together, these imply a simple description of production

- Marginal cost of production
  - = average cost of production
  - is invariant to the quantity produced
    - i.e., mc is NOT a function mc(quantity)

- AND ALSO INCUR QUADRATIC MENU COSTS

$$\frac{\psi}{2}\left(\frac{P_{jt}}{P_{jt-1}}-1\right)^2$$

(:)

The basis for "sticky" or "sluggish" nominal price adjustment in this setup

Wholesale Firms

- Representative wholesale firm's period-t profit function

Total revenue depends on firm's production and its *own* product price

mc is NOT a function of quantity produced – CRS assumption.
FC = 0 → *mc* = *ac* OF PRODUCTION!

$$P_{jt}y_{jt} - P_t mc_{jt} y_{jt} - \underbrace{\frac{\psi}{2}\left(\frac{P_{jt}}{P_{jt-1}} - 1\right)^2 P_t}$$

Conversion of production costs into nominal terms requires factor P_t, NOT P_{jt}. Because costs are not denominated in the firm's *own* prices

Period-t menu costs, conversion of which into nominal terms requires factor P_t, NOT P_{jt}. Because costs are not denominated in the firm's *own* prices.

- Presence of menu cost makes wholesale firm's profit-maximization problem a DYNAMIC one
  - Because any nominal price chosen in a given period has consequences for profits in the subsequent period through menu costs
  - Firm pricing problem is forward-looking

- Dynamic (two-period) profit function

Discount factor requires inflation adjustment.
And background assumption: no agency problem.

Max P_{jt}

$$P_{jt}y_{jt} - P_t mc_{jt} y_{jt} - \frac{\psi}{2}\left(\frac{P_{jt}}{P_{jt-1}} - 1\right)^2 P_t + \frac{\beta}{1+\pi_{t+1}} \underbrace{\left[P_{jt+1}y_{jt+1} - P_{t+1}mc_{t+1}y_{jt+1} - \frac{\psi}{2}\left(\frac{P_{jt+1}}{P_{jt}} - 1\right)^2 P_{t+1}\right]}_{\text{Now future profits must be considered when setting } P_{jt}}$$

s.t $y_{jt} = \left(\frac{P_{jt}}{P_t}\right)^{\frac{\varepsilon}{1-\varepsilon}} y_t$

WHOLESALE FIRMS

Representative wholesale firm's profit-maximization problem:

$$\max_{P_{jt}} P_{jt} y_{jt} - P_t mc_{jt} y_{jt} - \frac{\psi}{2}\left(\frac{P_{jt}}{P_{jt-1}} - 1\right)^2 P_t + \frac{\beta}{1+\pi_{t+1}}\left[P_{jt+1} y_{jt+1} - P_{t+1} mc_{t+1} y_{jt+1} - \frac{\psi}{2}\left(\frac{P_{jt+1}}{P_{jt}} - 1\right)^2 P_{t+1}\right]$$

Substitute in demand function for wholesale good *j* in both period t and t+1 (and t+2, t+3, t+4, …)

The critical point of analysis of monopoly: the firm *understands* and *internalizes* the effect of *its* price on the quantity that it sells.

$$\max_{P_{jt}} P_{jt}\left(\frac{P_{jt}}{P_t}\right)^{\frac{\varepsilon}{1-\varepsilon}} y_t - P_t mc_{jt}\left(\frac{P_{jt}}{P_t}\right)^{\frac{\varepsilon}{1-\varepsilon}} y_t - \frac{\psi}{2}\left(\frac{P_{jt}}{P_{jt-1}} - 1\right)^2 P_t$$

$$+\frac{\beta}{1+\pi_{t+1}}\left[P_{jt+1}\left(\frac{P_{jt+1}}{P_{t+1}}\right)^{\frac{\varepsilon}{1-\varepsilon}} y_{t+1} - P_{t+1} mc_{t+1}\left(\frac{P_{jt+1}}{P_{t+1}}\right)^{\frac{\varepsilon}{1-\varepsilon}} y_{t+1} - \frac{\psi}{2}\left(\frac{P_{jt+1}}{P_{jt}} - 1\right)^2 P_{t+1}\right]$$

In period t, firm chooses P_{jt}.

So FOC with respect to P_{jt}…

WHOLESALE FIRMS

Representative wholesale firm's profit-maximization problem:

$$\max_{P_{jt}} P_{jt}\left(\frac{P_{jt}}{P_t}\right)^{\frac{\varepsilon}{1-\varepsilon}} y_t - P_t mc_{jt}\left(\frac{P_{jt}}{P_t}\right)^{\frac{\varepsilon}{1-\varepsilon}} y_t - \frac{\psi}{2}\left(\frac{P_{jt}}{P_{jt-1}}-1\right)^2 P_t$$

$$+\frac{\beta}{1+\pi_{t+1}}\left[P_{jt+1}\left(\frac{P_{jt+1}}{P_{t+1}}\right)^{\frac{\varepsilon}{1-\varepsilon}} y_{t+1} - P_{t+1}mc_{t+1}\left(\frac{P_{jt+1}}{P_{t+1}}\right)^{\frac{\varepsilon}{1-\varepsilon}} y_{t+1} - \frac{\psi}{2}\left(\frac{P_{jt+1}}{P_{jt}}-1\right)^2 P_{t+1}\right]$$

FOC with respect to P_{jt} :

$$\frac{1}{1-\varepsilon} P_{jt}^{\frac{\varepsilon}{1-\varepsilon}} P_t^{\frac{\varepsilon}{\varepsilon-1}} y_t - \frac{\varepsilon}{1-\varepsilon} P_{jt}^{\frac{2\varepsilon-1}{1-\varepsilon}} P_t^{\frac{2\varepsilon-1}{\varepsilon-1}} mc_t y_t - \psi\left(\frac{P_{jt}}{P_{jt-1}}-1\right)\frac{P_t}{P_{jt-1}} + \frac{\beta\psi}{1+\pi_{t+1}}\left(\frac{P_{jt+1}}{P_{jt}}-1\right)\frac{P_{t+1}}{P_{jt}}\frac{P_{jt+1}}{P_{jt}} = 0$$

If ψ = 0, collapses to : $$\frac{P_{jt}}{P_t} = \varepsilon mc_t$$

Exactly the flexible-price Dixit-Stiglitz pricing rule

Existence of menu costs (ψ > 0) complicates pricing rule

Symmetric Equilibrium

Now drop the distinction between “retail goods” and “wholesale goods”

– Suppose “goods” are all identical

A macro perspective

– The “representative good”….
– …since macro analysis is most concerned with aggregates

Impose symmetry by now dropping j indexes – i.e., now suppose $\boxed{P_{jt} = P_t}$

$$\frac{1}{1-\varepsilon}\underbrace{P_t^{\frac{\varepsilon}{1-\varepsilon}} P_t^{\frac{\varepsilon}{\varepsilon-1}}}_{=1} y_t - \frac{\varepsilon}{1-\varepsilon}\underbrace{P_t^{\frac{2\varepsilon-1}{1-\varepsilon}} P_t^{\frac{2\varepsilon-1}{\varepsilon-1}}}_{=1} mc_t y_t - \psi\left(\frac{P_t}{P_{t-1}}-1\right)\frac{P_t}{P_{t-1}} + \frac{\beta\psi}{1+\pi_{t+1}}\left(\frac{P_{t+1}}{P_t}-1\right)\frac{P_{t+1}}{P_t}\frac{P_{t+1}}{P_t} = 0$$

$$\cancel{\frac{P_t^{\frac{\varepsilon}{1-\varepsilon}}}{P_t^{\frac{\varepsilon}{1-\varepsilon}}}} = 1$$

Several terms combine…

$$\frac{1}{1-\varepsilon}\left[1-\varepsilon mc_t\right] y_t - \psi\left(\frac{P_t}{P_{t-1}}-1\right)\frac{P_t}{P_{t-1}} + \frac{\beta\psi}{1+\pi_{t+1}}\left(\frac{P_{t+1}}{P_t}-1\right)\frac{P_{t+1}}{P_t}\frac{P_{t+1}}{P_t} = 0$$

…and use definition of inflation $P_t/P_{t-1} = 1 + \pi_t$ $\left(P_{t+1}/P_t = 1+\pi_{t+1}\right)$

$$\frac{1}{1-\varepsilon}\left[1-\varepsilon mc_t\right] y_t - \psi\left(1+\pi_t-1\right)\left(1+\pi_t\right) + \frac{\beta\psi}{\cancel{1+\pi_{t+1}}}\left(1+\pi_{t+1}-1\right)\left(1+\pi_{t+1}\right)\cancel{\left(1+\pi_{t+1}\right)} = 0$$

NEW KEYNESIAN PHILLIPS CURVE

The New Keynesian Phillips Curve (NKPC):

$$\longrightarrow \qquad \frac{1}{1-\varepsilon}\left[1-\varepsilon mc_t\right] y_t - \psi\pi_t(1+\pi_t) + \beta\psi\pi_{t+1}(1+\pi_{t+1}) = 0$$

Links period-t inflation to period-t marginal costs of production and period-(t+1) inflation

"Classical" Phillips Curve

- A link between period-t inflation and one component of period-t marginal costs of production (employment)
- No "forward-looking" elements in it

Forward-looking pricing/inflation behavior the key idea articulated by NKPC

- Pricing decisions are inherently dynamic

NKPC is the cornerstone idea in New Keynesian theory

Here derived from Rotemberg framework…can derive off alternative theories (e.g., Calvo-Yun)

Is the Rotemberg framework NK Phillips Curve too different from the Calvo-Yun NKPC?

Not really, the Rotemberg NKPC looks more complicated, but is actually the same

Remember these models usually yield non-linear expressions unless simplified …

We take these expressions and log-linearize. For example, log-linearizing the expression above:

$$\frac{1}{1-\epsilon}\bar{y}\hat{y}_t - \frac{\epsilon}{1-\epsilon}\overline{mc}\bar{y}(\widehat{mc}_t + \hat{y}_t) - \psi\bar{\pi}\hat{\pi}_t - \psi\bar{\pi}^2 2\hat{\pi}_t + \beta\psi\bar{\pi}\hat{\pi}_{t+1} + \beta\psi\bar{\pi}^2 2\hat{\pi}_{t+1}$$

…

Rearrange and you get: $\hat{\pi}_t = \gamma_1\hat{y}_t - \gamma_2\widehat{mc}_t + \beta E_t[\hat{\pi}_{t+1}]$

(where we grouped the first two coefficients into γ_1, γ_2 and applied the expectation operator to future variables)

Now, simplify further and use that mc is proportional to the output: $\widehat{mc}_t \propto \hat{y}_t$

Then: $\hat{\pi}_t = \lambda\hat{y}_t + \beta E_t[\hat{\pi}_{t+1}]$

. . . this is analogous to Calvo NKPC! (Just in that case $\lambda = \left[\frac{(1-\theta)(1-\theta\beta)}{\theta}\right]$)

Wrapping up Aggregate Supply: What have we done?

- Neo Classical Synthesis
- Rational Expectation and Microfoundation

- How to model a sloped-AS?
    - New Classical
    - New Keynesian

- Emphasis on empirical support
- New Neoclassical Synthesis

- Are we done? Following building blocks of the model?

[Next: Consumption and Aggregate Demand]