COVID Models

using

Cambridge Macro

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This Class

- Faculty COVID Research.
- Basic COVID Shocks (Intertemporal).
- Shapiro-Stiglitz Model (Labour)
- Optimal COVID Contractions (Monetary)
- Asset Approach to Exchange Rates (International)

COVID Research at the Faculty

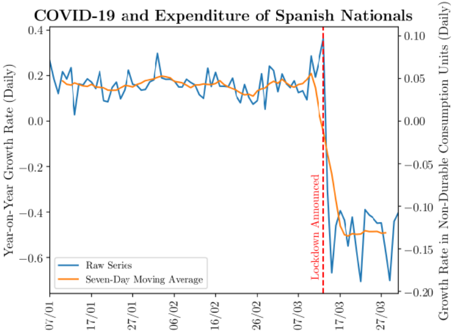
COVID Research at the Faculty

- Before starting, worthwhile pointing out a number of pieces of useful faculty work.
- Economists have been quick to react. In some sense this shock is truly **exogenous**
- High-Resolution Transaction Data. (Macroeconomics).
- Costs of Social Distancing. (Macroeconomics).
- Equilibrium Social Distancing (Microeconomics).
- Predicting peak outcomes . (Econometrics).

Through the Lens of 1.4 Billion Transactions

- Using real-time transactions data from BBVA.
- Show lockdown reduced nominal expenditure by 50%, while stockpiling boosted expenditure by 20% beforehand.

Spanish Lockdown Impact



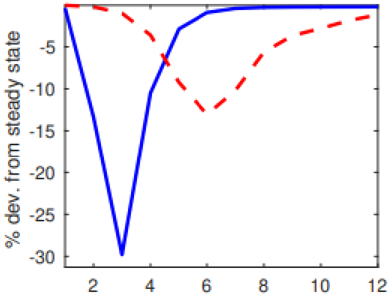
Source: Carvalho et al. (2020).

Social Distancing and Supply Disruptions in a Pandemic

- Lockdowns can reduce loss of life without overly costly effects.

- Two-sector model suggests better outcomes when social distancing falls away from core industries (producing inputs).

Total Output Losses

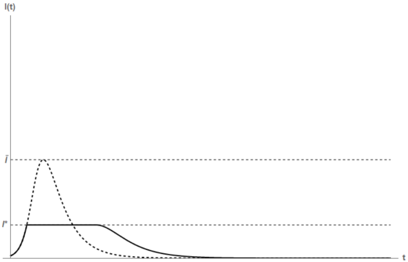


Source and Notes: Bodenstein et al. (2020). Blue solid line denotes do nothing while red dashed line denotes social distancing.

Equilibrium Social Distancing

- Susceptible individuals engage in costly social distancing.
- Equilibrium social distancing arises endogenously around the peak of the epidemic, determined by preferences.
- Uncoordinated social distancing "flattens the curve" by reducing peak prevalence.

Paths of infected Individuals

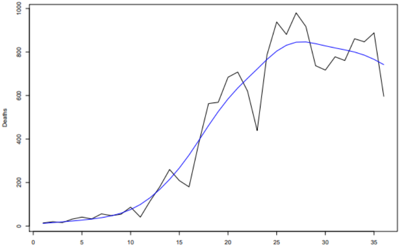


Source and Notes: Toxvaerd (2020). Dashed line shows epidemiological model; solid line shows economic model.

Predictions for the UK COVID Turning Points

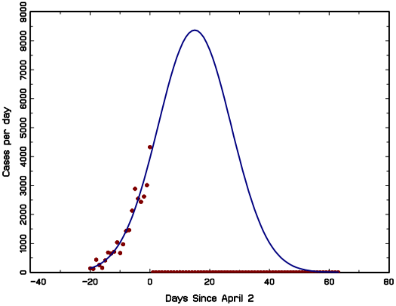
- Two different approaches, both highly accurate!

Kalman Filter Approach



Source: Ashby (2020).

Quadratic Function Approach



Source: Linton (2020).

Find Out More (Hyperlinks)

- Cambridge faculty COIVID webpage.
- CEPR policy blog, VoxEu.
- Newspapers, e.g. FT.
- Online economics seminars, e.g. VMACS.

Intertemporal Macroeconomics

Supply Side

- Recall output:

$$Y_t = A_t F(K_t, L_t),$$

  where A_t is productivity and captures everything infulencing production apart from K_t and L_t.

- Could this capture COVID-19?
  - Potentially $A_t \downarrow$ due to absenteeism / sickness.
  - Potentially $A_t \downarrow$ due to government shutdowns.
  - Potentially $A_t \downarrow$ due to working from home.

- What about A_{t+1}?
  - Potentially falls, though maybe less that A_t.

Demand Side

- Recall period utility:

$$U_t = \alpha \ln C_t + (1-\alpha) \ln \ell_t,$$

  where C_t denotes consumption, ℓ_t leisure and α is the consumption weight.

- Could this capture COVID-19?
  - Potentially $\alpha \downarrow$ due to preference for staying (safe) at home.
  - Potentially $\alpha \downarrow$ since told to stay home (can't consume).

Household's Problem

- Consider a price-taking representative agent who faces the following optimisation problem:

$$\max_{C_1, C_2, B_2, \ell_1, \ell_2} \alpha \ln C_1 + (1-\alpha) \ln \ell_1 + \beta(\alpha \ln C_2 + (1-\alpha) \ln \ell_2),$$

subject to:

$$\begin{aligned} B_2 + C_1 &= W_1(1-\ell_1) - T_1, \\ C_2 &= W_2(1-\ell_2) - T_2 + B_2(1+r_2), \end{aligned}$$

where B_t denotes savings, T_t lump-sum taxes, W_t the real wage, r_t the real interest rate, and β the intertemporal discount factor $(0 < \beta < 1)$. Subscript denote time periods.

Optimality Conditions

- Recall, household optimality conditions take the form:

$$\frac{1}{C_1} = \frac{\beta(1+r_2)}{C_2},$$
$$\frac{\alpha}{C_1} = \frac{1-\alpha}{W_1\ell_1},$$
$$\frac{\alpha}{C_2} = \frac{1-\alpha}{W_2\ell_2},$$
$$C_1 + \frac{C_2}{1+r_2} = W_1(1-\ell_1) - T_1 + \frac{W_2(1-\ell_2) - T_2}{1+r_2}.$$

- Solve the system by writing household consumption function:

$$C_1 = \frac{1}{1+\beta}\left[W_1(1-\ell_1) - T_1 + \frac{W_2(1-\ell_2) - T_2}{1+r_2}\right],$$
$$C_1 = \frac{\alpha}{1+\beta}\left[W_1 - T_1 + \frac{W_2 - T_2}{1+r_2}\right],$$

  where second equation uses the ℓ_1 and ℓ_2 conditions above.

Firm's Problem

- Assume production is linear in labour:

$$Y_t = A_t(1 - \ell_t).$$

- Firms maximise profits subject to production constraint:

$$\max_{1-\ell_t} A_t(1 - \ell_t) - W_t(1 - \ell_t).$$

- Under prefect competition:

$$A_t = W_t.$$

- Then ℓ_t is solely determined by household supply.

Moving to General Equilibrium

- Assuming a closed economy, with no capital stock, saving market equilibrium implies:

$$0 = B_2 = W_1(1 - \ell_1) - T_1 - C_1.$$

- Using the consumption function this infers:

$$0 = W_1 - T_1 - \frac{1}{1+\beta}\left[W_1 - T_1 + \frac{W_2 - T_2}{1 + r_2}\right],$$

$$1 + r_2 = \frac{1}{\beta}\frac{W_2 - T_2}{W_1 - T_1}.$$

- Government spending satisfies:

$$G_t = T_t.$$

- Finally, output is:

$$Y_t = C_t + G_t.$$

Equilibrium Conditions

- Household:

$$
\begin{aligned}
C_1 &= \alpha(A_1 - G_1),\\
C_2 &= \alpha(A_2 - G_2),\\
\ell_1 &= (1-\alpha)(A_1 - G_1)/A_1,\\
\ell_2 &= (1-\alpha)(A_2 - G_2)/A_2.
\end{aligned}
$$

- Firms:

$$
\begin{aligned}
W_1 &= A_1,\\
W_2 &= A_2.
\end{aligned}
$$

- General Equilibrium:

$$
\begin{aligned}
1 + r_2 &= \frac{1}{\beta}\frac{A_2 - G_2}{A_1 - G_1},\\
T_t &= G_t,\\
Y_t &= C_t + G_t.
\end{aligned}
$$

Response to COVID Shocks

- **Prices**. When A_1 falls by more than A_2, real wages fall more in period 1, and the real interest rate increases.
- **Allocations**. Shocks to both productivity (via A_t) and preferences (via α) influence consumption and labour supply.
- Must **calibrate** relative size of demand and supply shocks:
  - Lower A_t decreases leisure, while lower α increases leisure.
  - Let's assume these are scaled to leave leisure hours broadly unchanged. I seem to spend just as much of my **time** "at work", even though I'm at home and less productive...
  - Turns out this depends critically upon size of G_t. By inspection if $G_t = 0$ then no move in α required.

Calibration

- In **baseline** case, assuming $G_t = 0$, then ℓ_t unchanged (by construction), while C_t falls.

- Assuming $G_t > 0$ but small, then $\alpha \downarrow$ a touch to leave ℓ_t unchanged. C_t falls by more than in first case.

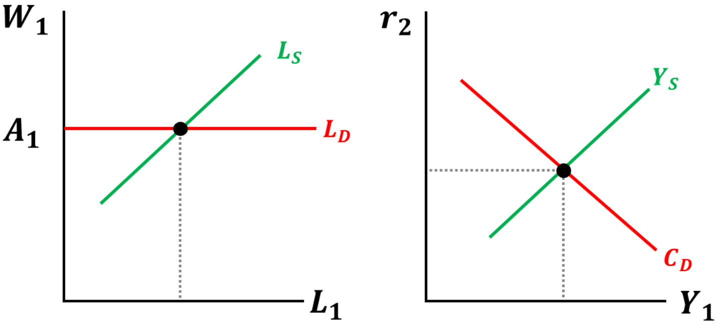
- Of course no reason to suspect this is a reasonable assumption, could calibrate with stronger effects either way...

- Clear role for changes in government spending to offset these impacts!

Graphically I

- Now let's analyse what happened graphically.
- Starting equilibrium in the labour and goods markets.

Labour and Goods Market

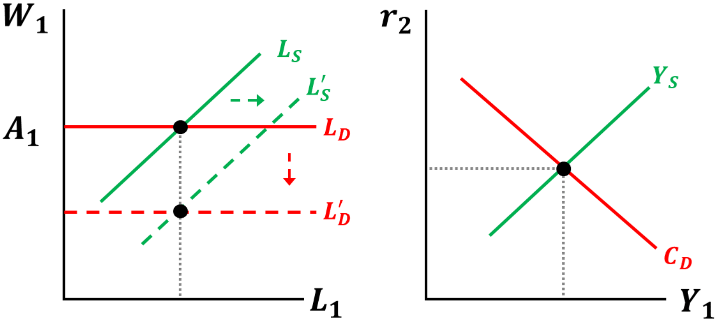


Graphically II

- Perfectly elastic labour demand falls as productivity is cut.
- Supply shifts right as $W_2 \downarrow$ and $r_2 \uparrow$ (intertemporal effects) dominate leftward shift $\alpha \downarrow$ (greater leisure preference).

$$W_1(1 - L_1^S) = \frac{1-\alpha}{1+\beta}\left[W_1 - T_1 + \frac{W_2 - T_2}{1+r_2}\right],$$

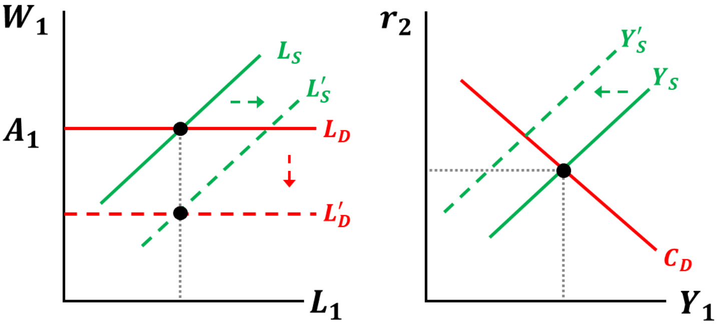
Labour and Goods Market



Graphically III

- Now turn to the goods market.
- The **direct** effect of lower productivity reduces supply.

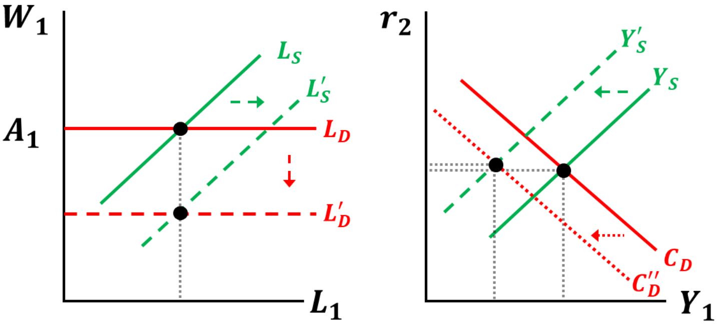
Labour and Goods Market



Graphically IV

- No **indirect** impact on supply, as L_1 unchanged.
- **Indirect** fall in demand as $PV(Y) \downarrow$ (intertemporal effect), further fall due to preference shift to leisure.

Labour and Goods Market



Labour Markets

Transitional Dynamics

- The flows of employed, E_t, and unemployed, U_t:

$$E_{t+1} = fU_t + (1-s)E_t$$
$$U_{t+1} = (1-f)U_t + sE_t,$$

- As in lectures, let's ignore non-participation so $E_t + U_t = 1$.
- Steady state unemployment rate given by:

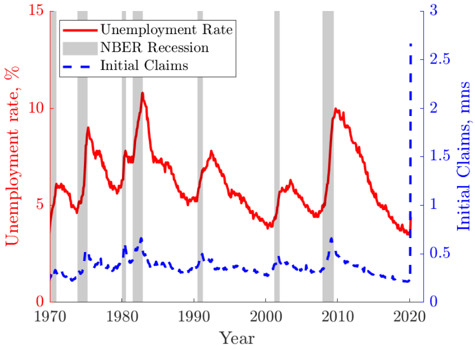
$$u_{SS} = \frac{s}{s+f} = \frac{1}{1+f/s}.$$

- Plausible that $s\uparrow$, as workers laid off when productivity fell.
- Plausible that $f\downarrow$, as firms reluctant to hire.
- Overall **highly likely** that $u_{SS}\uparrow$.

Turning to the Data

- Labour market has already responded.
- Far **more rapid** deterioration than 2006 recession.

US Labour Market

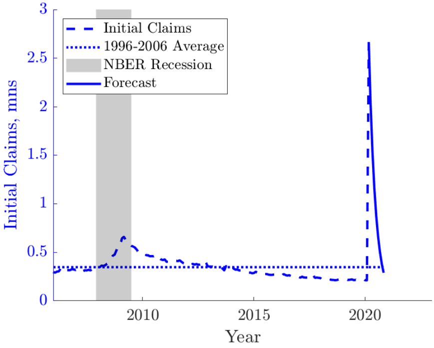


Source: FRED.

How Much More Rapid?

- Already same excess claims (those above 1996-2006 average) as first 16 months of 2006 recession.
- If total **cumulative** impact today is the same (6 mn excess claims over $5\frac{1}{2}$ years), would only remain elevated for 6 months!

US Labour Market



Source: FRED.

Shapiro-Stiglitz Model

- No shirking condition (NSC):

$$w \geq b + \frac{\bar{e}}{\pi u}.$$

  where w is the real wage, b are unemployment benefits, $\bar{e}$ is the cost of effort, u is the unemployment rate and π is the probability of being caught shirking.

- Plausible that $\pi \downarrow$, as everyone works from home.

- FOC for labour demand:

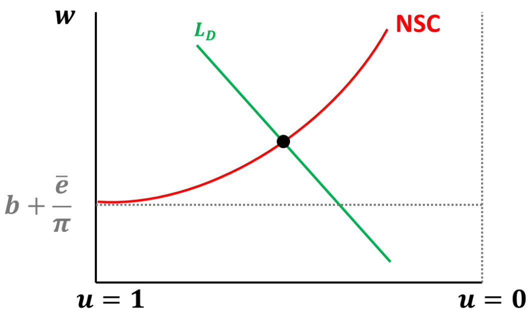
$$\bar{e}F'(\bar{e}L) = w.$$

- Plausible that $F'(\cdot) \downarrow$, as workers less productive.

Graphically I

- Recall initial equilibrium.
- Together NSC and labour demand determine efficiency wage and unemployment rate.

Labour Market

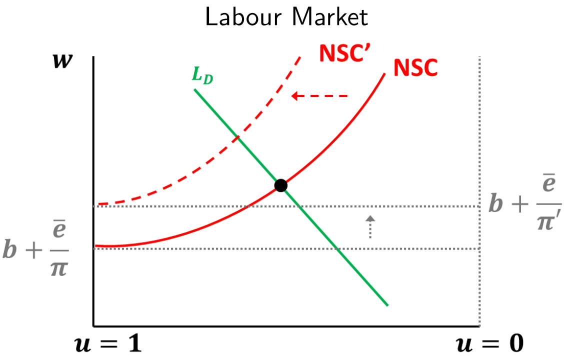


Graphically II

- Claimed that $\pi \downarrow$. Recall that since:

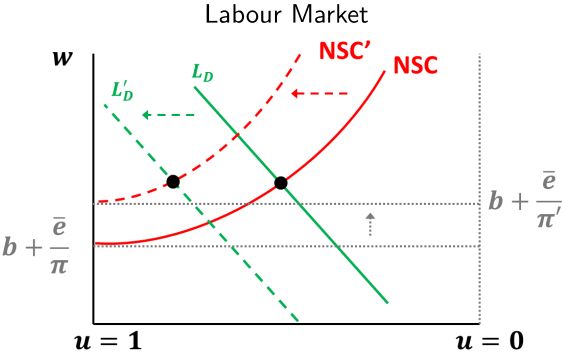
$$\frac{dw}{d\pi} = -\frac{\bar{e}}{\pi^2 u}.$$

high levels of u react **less** to the change in π.



Graphically III

- Claimed that $F'(\cdot)\downarrow$, such that labour demand shifts **inwards**.
- Overall, unemployment **increases**, the impact on wages is uncertain (drawn with no impact).



Final Thought

- In your lecture notes Pontus sets the probability of finding a job p to depend on the unemployment rate $p = 1 - u$.

- If this mapping were a bit more complicated, entirely plausible that NSC condition does not move.

- In this case, just the labour demand story (as in intertemporal case), which leads to lower wages and higher unemployment.

Optimal Policy

Inflation Bias Model

- Recall the inflation bias model from lectures.

- Policy makers face a loss from deviations of output and inflation from target:

$$L = Y^2 + \beta\pi^2.$$

- But operate subject to constraint on target comovement:

$$\pi = \pi^e + \alpha Y,$$

  under the Phillips curve.

- In what follows we reinterpret this model.

COVID-19 Social Welfare Function

- Society faces welfare losses:

$$L = Y^2 + \beta D^2.$$

where Y represents the output gap, and D are excess deaths.

- Deaths evolve according to:

$$D = D_0 + \alpha Y, \tag{YD}$$

where D_0 are the minimum level of excess deaths introduced by COVID and αY captures the fact that greater economic activity increases deaths.

- Solution is then clearly:

$$\min_{Y,D} \quad Y^2 + \beta D^2 = \min_{Y} \quad Y^2 + \beta(D_0 + \alpha Y)^2,$$

with FOC $\quad 0 = Y^* + \alpha\beta D^*.$

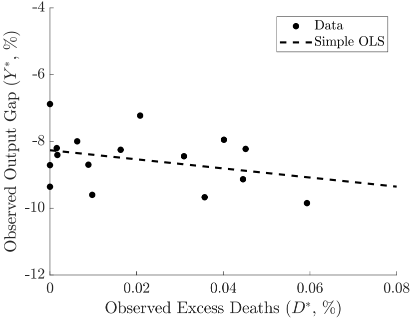
Turning to the Data

- Optimal response follows:

$$Y^* = -\alpha\beta D^*.$$

- Plot outcomes across countries, slope $\Rightarrow \alpha\beta = 13.6$.

Observed Outcomes



Sources: FT analysis of mortality data, IMF 2020 WEO and own calculations.

Optimal Response

- Calculate outcome variables, under optimal policy:

$$D^* = D_0 + \alpha\Big(-\alpha\beta D^*\Big),$$
$$D^* = \frac{1}{1+\alpha^2\beta} D_0, \quad \Rightarrow \quad Y^* = -\frac{\alpha\beta}{1+\alpha^2\beta} D_0.$$

- Imperial College COVID report said without shutdown $D_0 \approx 250,000$.

- Actual UK deaths $D^* \approx 27,000$.

- Implies $\frac{D^*}{D_0} \approx \frac{27}{250} \approx \frac{1}{1+\alpha^2\beta}$.

Recover the Parameters of Interest

- Combine slope estimate with $\frac{D^*}{D_0}$ ratio to estimate α:

$$\frac{27}{250} = \frac{1}{1+\alpha^2\beta} = \frac{1}{1+13.6\alpha},$$
$$\alpha = \frac{1}{13.6}\left(\frac{250}{27} - 1\right) \approx 0.6.$$

- A 1% reduction in output reduces excess deaths by c. 0.6% of population.

- Then use slope to back out β:

$$\Rightarrow \beta = \frac{13.6}{\alpha} \approx 22.5.$$

- Society values excess deaths 23× more than output losses.

Sensitivities

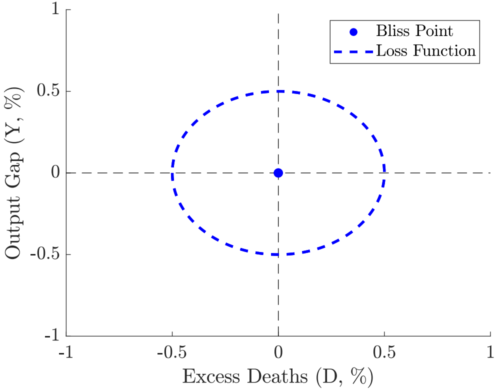
- Clearly analysis here is (too) simple.
- Parameters sensitive to slope and $\frac{D^*}{D_0}$ estimates.

Parameter	Baseline	Double $\frac{D^*}{D_0}$	Double Slope
$\frac{D^*}{D_0}$	0.11	0.22	0.11
Slope	13.6	13.6	27.3
α	0.6	0.3	0.3
β	22.5	51.2	90.0

Graphically I

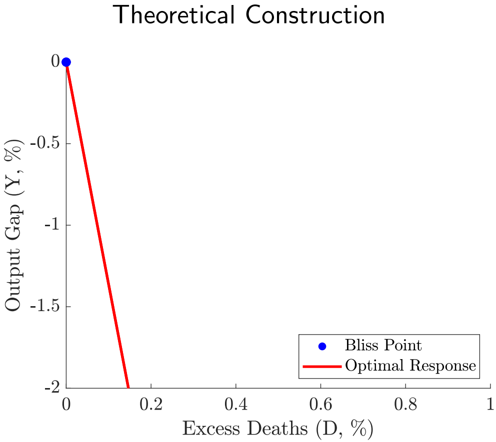
- First we identify the bliss point and circular loss function.
- Analysis will concentrate entirely on negative quadrant.

Theoretical Construction



Graphically II

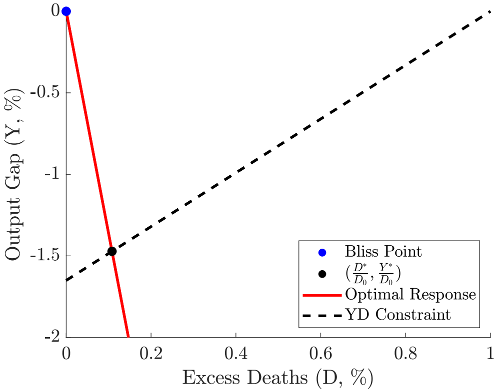
- Then use the FT/IMF data to plot ("optimal") responses.
- Very steep as deaths have been low percentage of populations.



Graphically III

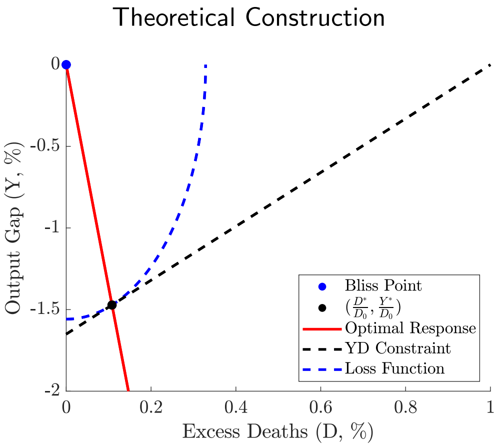
- Calibrate $\frac{D^*}{D_0}$, to observe $(\frac{D^*}{D_0}, \frac{Y^*}{D_0})$ for arbitrary shock, D_0.
- Knowing $(\frac{D_0}{D_0}, 0)$ and $(\frac{D^*}{D_0}, \frac{Y^*}{D_0})$ and back out YD slope.

Theoretical Construction



Graphically IV

- Loss function is tangent to YD constraint at $(\frac{D^*}{D_0}, \frac{Y^*}{D_0})$.
- Finally, back out β.



International

International

- Your course often considers the impact of **monetary** shocks.
- COVID-19 may be a good source of **exogenous** variation to consider such shocks.
- What do the data show?

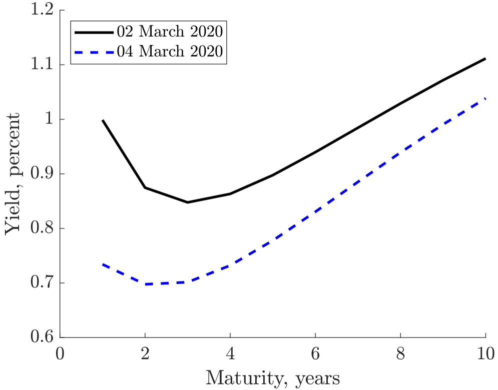
Key US Monetary Policy Events (Q1 2020)

February 25	March 3	March 15	March 17/18
Yield curve inverts	Unscheduled FOMC 0.5pp rate cut to [1%, 1.25%]	Unscheduled FOMC 1pp rate cut to [0%, 0.25%], and $700bn additional QE	Cancelled FOMC

Monetary Policy - 3 March 2020

- Substantial downwards shift after 3 March announcement.
- Larger falls for lower maturity.

US Yield Curve



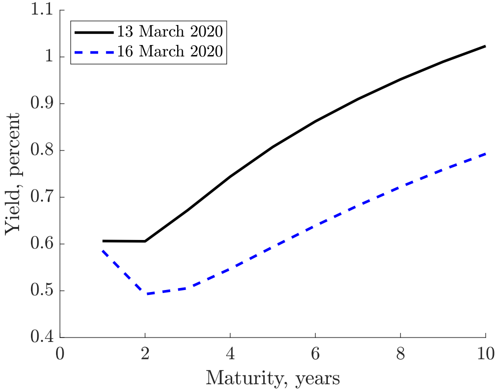
Source: Adrian, Crump, and Moench (2013).

Monetary Policy - 15 March 2020

- Further downwards shifts in intervening days.

- Shift after 15 March announcement mainly at "long end".

US Yield Curve

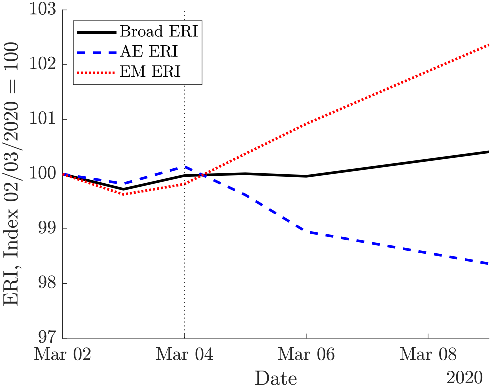


Source: Adrian, Crump, and Moench (2013).

Exchange Rate Movements

- Monetary policy announcements left ERI broadly unchanged.
- But compositional effects between AE and EM.

US Exchange Rate Index (ERI)

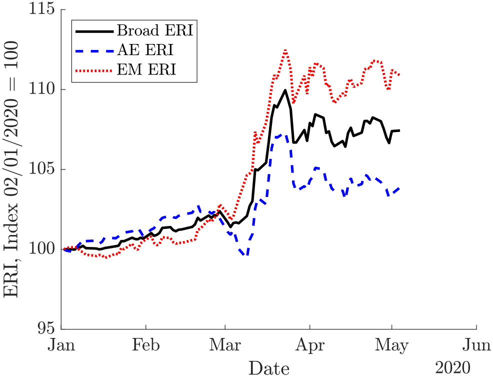


Source and Notes: Federal Reserve. Upwards indicates US dollar **appreciation**

Exchange Rate Movements - Longer Picture

- "Risk on" & "dollar cycle" effects clearer in longer time span.
- See Corsetti and Marin (2020).

US Exchange Rate Index (ERI)



Source and Notes: Federal Reserve. Upwards indicates US dollar **appreciation**

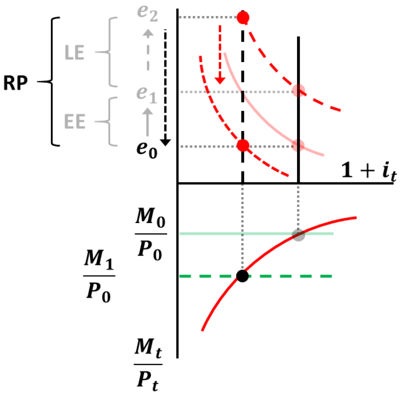
We've Seen This Before

- Unanticipated monetary policy stimulus.
- Causes interest rates to fall, and the exchange rate to **appreciate**.
- This is a version of Supervision 9, Question A3.

Recall Supervision 9, Question A3

- A large downwards Risk Premium (RP) shift could cause exchange rate to **appreciate**.

Money and FX Equilibrium



Next Class

Next Class

- Revision session discussing answers from mock exam.
- Will take place after econometrics project.