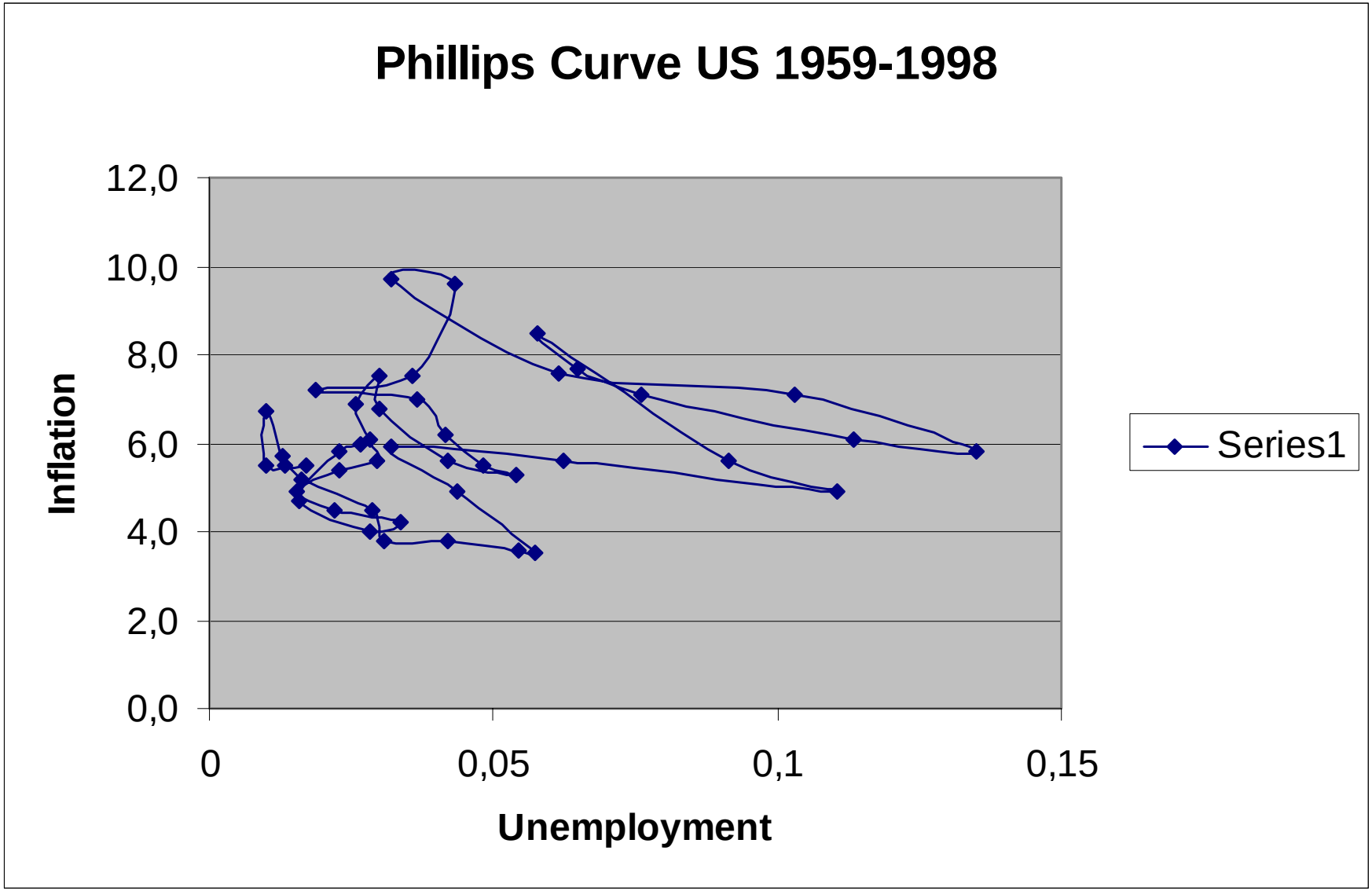
# HWI Results

- Total Possible Points: 16
- Total Points Counted: 15
- Maximum Points Acheived: 15 (2 people)
- Minimum: 3.5
- Distribution
  - 20th%: 9
  - 40th%: 10,5
  - 60th%: 12,5
  - 80th%: 13,5

# Random (Abnormally Distributed) Notes

- Efficiency Wages and Unemployment Vs. Full Employment
- Critiques of a Model: Assumptions, Conclusions, and Organization
  - What makes one theory different from another
- Making Your Own Models
- Show work when solving problems… dont just state the answer

# Phillips Curve Revisited:



# Lucas Critique I

Estimate Phillips Curve:

$$U_t = \alpha + \beta \pi_t + \varepsilon_t$$

$$U_t = \text{unemployment in year t,}$$

$$\pi_t = \text{inflation in year } t$$

Using Swedish Data from 1980-1996:

$$\hat{\beta} = -.5$$

# Lucas Critique II:

- When is this a valid estimator:
  - (1.) Lack of endogeneity:

$$\text{cov}(\pi_t, \varepsilon_t) = 0$$

Otherwise:

$$\hat{\beta} = \frac{\text{cov}(\alpha + \beta\pi_t + \varepsilon_t, \pi_t)}{\text{var}(\pi_t)} = \beta \frac{\text{cov}(\pi_t, \pi_t)}{\text{var}(\pi_t)} + \frac{\text{cov}(\pi_t, \varepsilon_t)}{\text{var}(\pi_t)} = \beta + \frac{\text{cov}(\pi_t, \varepsilon_t)}{\text{var}(\pi_t)}$$

  - (2.) Causal Interpetation (Akerlof Beer and Windsurfing example)

# Lucas Critique III:

- Consider a two system model with endogenous policy:

$$Y_{t+1} = F\left(Y_t, X_t, \theta, \mu_t\right)$$
$$X_t = G\left(Y_t, g, \varepsilon_t\right)$$

$Y_t = \text{Economic Variable}$

$X_t = \text{Government Policy}$

$\theta = \text{Behavioral Parameters}$

$\text{g} = \text{Policy Parameters}$

$\varepsilon_t, \mu_t = \text{Random Shocks}$

- What are the sources of endogeneity?

# Lucas Critique IV:

- Standard, before Lucas, is that g can be correlated with X.
- New, from Lucas, is that changes in g can lead to or be correlated with changes in $\theta$.
- Examples of standard critique:
  - Shifts along a stable Phillips Curve
- Examples of Lucas critique:
  - Shifts of a Phillips Curve: Stablity

# Lucas Critique V:

- Suppose prices follow a random walk:

$$P_{t+1} = P_t + \varepsilon_t$$

- Where $\varepsilon_t$ is distributed : $N\left(\pi, \sigma^2\right)$

- Take the Lucas Supply Curve:

- Then we have: $y_t = \theta\left(p_t - p_{t-1}\right) - \theta\pi + y_{pt} + v_t$

# Lucas Critique VI:

- What does Lucas suggest?
- Estimate Structural Models: Estimate

$$Y_{t+1} = F\left(Y_t, X_t, \theta, \mu_t\right)$$
$$X_t = G\left(Y_t, g, \varepsilon_t\right)$$

- Problems with Lucas Critique?

# Lucas Critique VIII:

- Problems with Lucas Critique?
  - Estimates only Meaningful if Model is the True Model.
  - Inseparability of testing rational expectations and a specfic model's functional forms…. so, model can never really be truly tested.

# VARs I:

- Sims (1980) takes a different approach: estimate reduced forms rather than structural models. These serve two purposes:
  - (1.) Establish covariances that you want to explain
  - (2.) Test models using reduced forms

# VARS II

- Example: Three variables (output, money, interest rates) and two lags (t-1, t-2):

$$y_t = \sum_{i=1}^{2} \left( \alpha_{1i} y_{t-i} + \beta_{1i} m_{t-i} + \gamma_{1i} r_{t-i} \right) + \varepsilon_{1t}$$

$$m_t = \sum_{i=1}^{2} \left( \alpha_{2i} y_{t-i} + \beta_{2i} m_{t-i} + \gamma_{2i} r_{t-i} \right) + \varepsilon_{2t}$$

$$r_t = \sum_{i=1}^{2} \left( \alpha_{3i} y_{t-i} + \beta_{3i} m_{t-i} + \gamma_{3i} r_{t-i} \right) + \varepsilon_{3t}$$

# VARS III

- Recursive VAR

$$m_t = \sum_{i=1}^{2} \beta_{1i} m_{t-i} + \varepsilon_{1t}$$

$$r_t = \sum_{i=1}^{2} \left( \beta_{2i} m_{t-i} + \gamma_{2i} r_{t-i} \right) + \varepsilon_{2t}$$

$$y_t = \sum_{i=1}^{2} \left( \alpha_{3i} y_{t-i} + \beta_{3i} m_{t-i} + \gamma_{3i} r_{t-i} \right) + \varepsilon_{3t}$$

# VARS IV

- Structural VARS=Use institutional detail to label certain variables exogenous and others endogenous.

$$u_t = \sum_{i=1}^{2} \left( \alpha_{1i} u_{t-i} + \beta_{1i} \pi_{t-i} + \gamma_{1i} r_{t-i} \right) + \varepsilon_{1t}$$

$$\pi_t = \sum_{i=1}^{2} \left( \alpha_{2i} u_{t-i} + \beta_{2i} \pi_{t-i} + \gamma_{2i} r_{t-i} \right) + \varepsilon_{2t}$$

$$r_t = r^* + 1.5\left( \pi_t - \bar{\pi} \right) - 1.25\left( u_t - \bar{u} \right) + \varepsilon_{3t}$$

- The last equation is just a Taylor Rule... It can be either adaptive or forward looking depending on calculation of targets.

# VARS V

- Impulse Responses
- Time path of shock to a given variable
- Involves movement in the whole system
- Example:First Estimate the VAR
- Then consider a shock to money supply:

$$(0,1,0)\ldots \varepsilon_{02},\ \varepsilon_{01} = \varepsilon_{03} = 0$$

- Calculate first period realizations:

$$u_0, r_0, \pi_0$$

- Then calculate other period values recursively:

$$u_t, r_t, \pi_t$$

# VARS VI:Root Mean Squared Error Comparisons of 100 Basis Point Shocks to r

| | Pi RW | Pi AR | Pi VA | U RW | U AR | U VA | R RW | R AR | R VA |
|---|---|---|---|---|---|---|---|---|---|
| 2 Q | .82 | .7 | .68 | .34 | .28 | .29 | .79 | .77 | .68 |
| 4 Q | .73 | .65 | .63 | .62 | .52 | .53 | 1.36 | 1.25 | 1.07 |
| 8 Q | .75 | .75 | .75 | 1.12 | .95 | .78 | 2.18 | 1.92 | 1.7 |

# VARS VII:
# General Theory

- General Theory

$$Z_t = B_1 Z_{t-1} + ... B_q Z_{t-q} + \varepsilon_t$$

$$E\varepsilon_t \varepsilon_t^{'} = V$$

- But shocks not orthogonal to eachother... so:

$$A_0 \varepsilon_t = \mu_t$$

- Then, we get:

$$A_0 Z_t = A_0 B_1 Z_{t-1} + ... A_0 B_q Z_{t-q} + A_0 \varepsilon_t$$

$$A_0 Z_t = A_1 Z_{t-1} + ... A_q Z_{t-q} + \mu_t$$

# VARS VIII:
# General Theory

- Look at impulse responses from the vector $u_t$
- B coefficients easy to estimate just by OLS
- A coefficents are harder... non-linear set of equations. Can't just run $u_t$ on $\varepsilon_t$ because we dont observe $u_t$.
- Suggestions as to what to do?

# VARS IX:
# General Theory

- Assume that D= $Eu_t u_t'$ is diagonal. Then $V = A_0^{-1} D\left(A_0^{-1}\right)'$

- Remember that $\text{cov}(u_t, u_{t-1}) = \text{cov}(u_{t-1}, u_t)$ . So, a variance-covariance matrix with k columns and rows will have k+(k-1)+... 1= $\frac{k(k+1)}{2}$

- Problem: in general, we more unkowns than equations... thus many solutions... need to come up with restrictions. Standard Var assumes $A_0 = 1$

# VARS X:
# General Theory

- Modern Theory Asks:

What kinds of restrictions can be imposed?

- One other problem: $V = A_0^{-1}\left(A_0^{-1}\right)'$ is non-linear. We can have multiple solutions. Some are local solutions... one is a global solution.

# Granger Causality I

- Even if we can identify patterns of correlation, how can we identify causation?
- ”Does Money Growth Cause Changes in GNP”? (Freidman and Schwartz)… answer: yes.
- Tobin Critique: phase lead and correlation may not imply causation… possibility of reverse causation. Akerlof windsurfing example.

# Granger Causality II

- First try: regress y on lagged m :

$$y_T = \alpha + \sum_{t=0}^{\infty} \beta_{T-t} m_{T-t}$$

- But this is not robust to reverse causation: Akerlof windsurfing example. Ideally, want to randomize m and see what happens to y. This usually can not be done. Test for direction of causality: regress y on lagged y and lagged m:

$$y_T = \alpha + \sum_{t=0}^{\infty} \beta_{T-t} m_{T-t} + \sum_{t=1}^{\infty} \gamma_{T-t} y_{T-t}$$

# Granger Causality III

- F-Test the m variables jointly equal to zero
- If you can reject that the m are jointly equal to zero, we can say that m Granger causes y.
- Sims, (1972), ”Money, Income and Causality” found an equivalent formulation and ran y on past and future m:

$$y_T = \alpha + \sum_{t=-\infty}^{\infty} \beta_{T-t} m_{T-t}$$

# Granger Causality IV

- Sims found that money Granger caused output. People at the time interpreted this as monetary policy leads to changes in output. Do you agree that this is sufficient evidence?
- Why?  Why not?
- Sims (1980) Example

# Granger Causality V: % of Variation Explained by Shocks (Impulse Responses)

| Cause<br>Effect | M1 | Industrial Production | Wholesale Price Index |
|---|---|---|---|
| M1 | 97% | 2% | 1% |
| Industrial Production | 37% | 44% | 18% |
| Wholesale Price Index | 14% | 7% | 80% |

# Granger Causality VI: % of Variation Explained by Shocks (Impulse Responses)

| Cause<br>Effect | R | M1 | WP | IP |
|---|---|---|---|---|
| R | 50% | 19% | 4% | 28% |
| M1 | 56% | 42% | 1% | 1% |
| WP | 2% | 32% | 60% | 6% |
| IP | 30% | 4% | 14% | 52% |

# Granger Causality VII

- What do we learn from this example? Any pattern or lack of pattern of correlation between X and Y may be caused by an underlying pattern of correlation with an ommitted variable (Z)

- With three variables, Wholesale Prices seem to be exogenous; including the interest rate, however:
  - Money no longer causes industrial production but rather the interest rate and the interest rate industrial production
  - Money now affects Wholesale Prices
  - Money is now endogenous, affected by interest rate changes

- Trend is now not to test for Granger causality (i.e. yes or no) but to document feedback as in previous tables (i.e. decomposing variances of variables in a system).

# Calibration I

- First, build a theoretical dynamic, stochastic, infinite horizon, general equilibrium model of the economy. Usually there are shocks to technology as well as shocks to preferences over leisure.

- Historically, these were real models with representative agents (producer/consumers).

- First paper: ”Time to Build and Aggregate Fluctuations”, *Econometrica* (1982) by Finn Kydland and Edward Prescott.

# Calibration II

- Plugs in econometric estimates for some model parameters (i.e. intertemporal elasticity of substitution of labor, labor's share, intertemporal elasticity of substitution of consumption, etc.)
- Plugs in guesses for other parameters (discount factor, rate of depreciation of capital, technology shock serial correlation parameter, etc.)
- Solve the model for particular plugged in values and try to match empirical data on SDs of GNP, C, I, Inventories, Hours of Work, Capital Stock, Labor Productivity, Real Interest Rate, as well as correlations of GNP with above variables

# Calibration III

- Differences between Simulation and Calibration?
  - Simulation is used when models are not solvable; the goal is usually to numerically compute outcomes for a wide range of parameter values, substituting numerical solutions with proof.
  - Calibration is used to replicate stylized facts about the economy using econometric estimates where possible (i.e. aggregate intertemporal elasticity of substitution of labor) and specific parameter values where data is not available.

# Identification: Romer and Romer I

- Based on Milton Friedman and Anna Schwartz, ”A Monetary History of the United States”… 1000 page book which argues that all recessions can be accounted for as being induced by monetary policy.

- Friedman and Schwartz looked at historical records in order to document when shocks occurred. They defined a monetary shock as an unusual event given the real state of the economy.

# Identification: Romer and Romer II

- R&R ”Improvements” over Friedman and Schwartz:
  - R&R claim that Friedman and Schwartz have a definition of monetary shocks which is endogenous. They should not look at strange events but rather the intents of the FED.
  - Friedman and Schwarz do not formally ”test” any statistical hypotheses. R&R do.
  - R&R extend Friedman and Schwarz into the post-war era. They also say this is a better era during which to look at the impact of monetary policy because the role of the FED was already established and the ideology of the FED remained constant over time.

# Identification: Romer and Romer III

- R&R claim that Friedman and Schwartz, defining monetary shocks as unusual actions as opposed to by intentions, introduced endogeneity bias. They would have the same critique of VARs which by definition look at actions. They claim that the best way to look at the causal impact of monetary policy is to figure out central bank intentions… so they suggest a ”narrative” approach

- First, they use their definition of a shock (intention of the FED to reduce inflation) and compare with Friedman and Schwartz. They claim Friedman and Schwartz have an imprecise definition… what is ’unusual’? R&R find some events which Friedman and Schwartz do not define as a shock as well as some events which Friedman and Schwartz define as an event but R&R do not.

# Identification: Romer and Romer IV

- R&R find 6 post-war episodes of monetary shocks from looking at FED FOMC meeting notes.

- They then run the following regression:

$$y_t = \alpha + \sum_{i=1}^{11} \beta_i M_{it} + \sum_{j=1}^{24} \gamma_j y_{t-j} + \sum_{k=0}^{36} \gamma_k D_{t-k} + \varepsilon_t$$

- They use monthly data where is y is industrial production, M are month dummies (why are there only 11?), and D are the dummies for the shocks in addition to 36 lags. Note that D takes on the value of 1 in 6 consecutive months defined to be an episode. There are 6 total episodes.

# Identification: Romer and Romer V

- The use monthly data from 1948 through 1987.
- For unemployment, they use

$$y_t = \alpha + \sum_{i=1}^{11} \beta_i M_{it} + \sum_{j=1}^{24} \gamma_j y_{t-j} + \sum_{k=0}^{36} \gamma_k D_{t-k} + \delta t + \varepsilon_t$$

- What do you think of the inclusion of the time trend?
- They then get estimates for the dummy variables on monetary shocks and lagged monetary shocks. Most are negative and significant
- They then run impulse responses and find that the effects of shocks peak around 1 as well as 2 years after the shock. They find very strong, negative effects. However, they find much weaker results for the prewar period. What does this suggest?

# Identification: Romer and Romer Questions I

- Why did R&R only look at attempts of the FED to reduce inflation (i.e. monetary contractions)? What are the benefits as well as problems with contractionary focus?

- Why do R&R argue that monetary disturbance events should be classified based upon the intentions not the actions of the FED? Do you agree? Why or why not?

- Why do R&R define the policy decision period to be a 6 month window? Do you think this is a good strategy?

- Do R&R estimate a VAR? How do you calculate an impulse response in the R&R framework? Are there feedback effects? How do you interpret an impulse response to output in R&R's framework?

# Identification: Romer and Romer Questions II

- R&R use dummy variables to classify monetary events. What could other classification strategies have been? What is the implicit comparison R&R make when they use dummy variables for moentary events? Is this approach essentially the same as a difference in differences estimator?

- What do you think about the criticism of R&R that they only look at monetary shocks in very special periods when the impact of monetary policy was particularly strong?

- What do you think are the main weaknesses and strengths of the paper?

- On net, did you like the paper? Do you believe the conclusions? Why or why not?