Name ____________________

Midterm Exam

Intertemporal Choice

Fall, 2023

You are expected to answer all parts of all questions. If you cannot solve part of a question, *do not give up*. The exam is written so that you should be able to answer later parts even if you are stumped by earlier parts.

Write all answers on the exam itself; if you run out of room, use the back of the previous page.

Part I: Short Questions

1. Consider a `TractableBufferStock` model, except that consumers now discount the future for two reasons: They have the usual time discount factor $\beta < 1$, but they also face some probability of dying D between periods (and we will call the probability of not dying $\not{\mathsf{D}} = 1 - \mathsf{D}$). (Utility when dead is zero, so expected utility from a future period is the probability of being alive times the discounted utility obtained conditional on being alive.)

   a) Write the employed consumer's optimization problem in the form of a Bellman equation, including the Dynamic Budget Constraint.

   b) Explain why a 'growth impatience condition' will be required to guarantee that the consumer has a target value for $\check{m}^e$. *After* you explain it in words, produce the formula for the growth impatience condition. (You will not get full credit just for reproducing the formula without an explanation).

The foregoing model captures the behavior of a single individual person. We now want to consider an economy populated by many such consumers. In order to get there, we make two assumptions:

- When a consumer gets hit by the 'unemployment' (or retirement) shock, that consumer leaves the economy and moves somewhere else (probably some place cheaper, as retiring British people move to Spain). The consequence of this assumption is that the wealth remaining in this economy will be the wealth of employed consumers only
- A consumer who dies is replaced by a new 'heir' who is born in the same period and receives the dying consumer's wealth as a bequest. The heir's wage rate will be the same as the parent's wage rate would have been if the parent had not died. Note, however, that the dying person does not care about the utility of the heir; the only reason the bequest occurs is that the dying person's date of death was uncertain until it happened

c) Explain why, even if this economy were originally composed of consumers with different levels of wealth, it would tend toward a steady state in which each 'dynasty' is identical, and describe what the growth rate of aggregate income, wealth, and consumption will be in steady-state in this economy. Discuss how these steady-states can be reconciled with the Euler equation for individual consumption growth.

d) Suppose that the probability of death suddenly falls because a new vaccine is invented. Using diagrams like those presented in the tractable buffer stock handout, show and explain the effects on consumption growth, market resources, and income growth in this economy.

2. **Secular Stagnation.** In 2013, Larry Summers delivered a widely discussed lecture at which he warned that the U.S. and European economies may face a risk that the next decade will be a period of "secular stagnation" like the one that has gripped Japan over the past 25 years. He proposed that a substantial increase in government spending could be an effective way to respond to this risk.

   a) If the extra spending advocated by Summers were directly in the form of transfers to households with a high marginal propensity to consume, can the argument described above be completely understood as an assertion that the U.S. is now in a state of "dynamic inefficiency?" (Hint: Mention Ricardian Equivalence in your answer).

   b) In fact, Summers did not advocate that the extra spending should all be directed to households who would spend it. He has advocated substantial increases in government investment in infrastructure, education, and other "investment" goods. Explain under what conditions this advice is what would be called for in a dynamically inefficient economy. Explain why this would or would not be an appropriate response.

c) Elsewhere, DeLong and Summers (2012) have argued that when the economy is operating far below full employment, an increase in "aggregate demand" may be able to call forth a substantial increase in aggregate supply. This is essentially a Keynesian story. If DeLong and Summers (2012) are right, how would that relate to your answer to question (b) about dynamic inefficiency?

Part II: Medium Questions

1. **Habit Formation, Sticky Expectations, and Measurement Error.**

Although the baseline `RandomWalk` model of consumption implies that consumption growth is unforecastable, the models in the handouts `Habits` and `StickyExpectations` are both consistent with serial correlation in 'true' consumption growth that takes forms like:

$$\Delta C_{t+1} \quad = \quad \alpha_0 + \alpha_1 \Delta C_t + \epsilon_{t+1} \tag{1}$$

a) Explain what the coefficient α_1 is interpreted as measuring in each of the two theories, and give some intuition for why the coefficient in this regression can be interpreted as measuring that object.

In practice, a difficulty of estimating either of these models is that actual reported consumption data from government statistical agencies contains measurement error. Suppose that we have data on measures of the true beliefs, collected at date t, about consumption growth from these sources:

- $\mathbb{B}_t^{\text{hhs}}[\Delta C_t]$: Answers from a survey of households who are asked directly about what they believe their consumption growth was
- $\mathbb{B}_t^{\text{fed}}[\Delta C_t]$: Estimates of produced by the Federal Reserve based on aggregate statistics like surveys of retailers

Consider performing regressions of the form

$$\Delta C_{t+1} \quad = \quad \alpha_0 + \alpha_1^{\bullet} \mathbb{B}_t^{\bullet}[\Delta C_t] + \zeta_{t+1} \tag{2}$$

where the $\bullet$ is a stand-in for the different methods of measuring beliefs. This generates a potentially different estimate of α_1 for each of the different measures of consumption beliefs.

a) Suppose first that the estimates of α_1 are similar for all measures of consumption growth beliefs, say $\{\alpha_1^{\text{hhs}}, \alpha_1^{\text{fed}}\} = 0.75$.

i. Under these conditions and using only these data, the two theories are obviously basically indistinguishable. Can you think of any other kinds of data which might be more useful in distinguishing these theories from each other? How would you go about using those data to distinguish the theories?

Suppose now that if we somehow had access to data on 'true' consumption data, we would be able to show that households have perfect contemporaneous knowledge of their own consumption, $\mathbb{B}_t^{\text{hhs}}[\Delta C_t] = \Delta C_t$, while the Fed's contemporaneous beliefs are equal to the truth plus some mean-zero measurement error, $\mathbb{B}_t^{\text{fed}}[\Delta C_t] = \Delta C_t + \xi_t$ with some variance $\sigma_\xi^2 > 0$

b) Now suppose the estimates using these beliefs produce different results. In particular, suppose the coefficient estimates fit the pattern $\{\alpha_1^{\text{hhs}} > \alpha_1^{\text{fed}}\}$. Can you reach any new conclusions about the validity of the two theories?

Suppose that, although Fed's direct measure of consumption expenditures is imperfect, its supervision of the banking sector allows it to measure past income Y_{t-n}, bank balances B_{t-n}, and saving S_{t-n} perfectly (where saving is income minus consumption: $S_{t-n} = \mathsf{r}B_{t-n} + Y_{t-n} - C_{t-n}$ for $n \geq 0$.

c) How can the Fed use these data to improve its $\mathbb{B}_t^{\text{fed}}[\Delta C_t]$?

Now suppose the Fed, again through its banking regulatory powers, has microeconomic data about individual households indexed by i on the same variables that are measured in the aggregate data, for example $c_{t,i}$ etc.

d) Can the Fed use these data to distinguish the two theories? How?

2. **Consumption Dynamics in a Deaton (1992)-Friedman (1957) Model With Transitory and Permanent Shocks.**

   Consider a consumer solving the maximization problem

$$\max_{\{\mathrm{C}\}_t^\infty} \quad \mathbb{E}_t \left[\sum_{s=0}^{\infty} \beta^s \mathrm{u}(C_{t+s}) \right]$$

   subject to the transition equations

$$\begin{aligned} B_{t+1} &= (M_t - C_t)\mathsf{R} \\ P_{t+1} &= P_t + \Psi_{t+1} \\ Y_{t+1} &= P_{t+1} + \Xi_{t+1} \\ M_{t+1} &= B_{t+1} + Y_{t+1} \end{aligned}$$

   where Ξ and Ψ are respectively the unpredictable transitory and permanent shocks to the level of income, satisfying $\mathbb{E}_t[\Psi_{t+n}] = \mathbb{E}_t[\Xi_{t+n}] = 0 \ \forall \ n > 0$.

   a) Rewrite the problem in Bellman equation form, and derive the Euler equation for consumption.

For the remainder of the problem, assume that $\mathsf{R}\beta = 1$; the utility function is quadratic; and the consumer's level of resources is too small for consumption ever to reach the 'bliss point.'

b) Show that under these assumptions, $\mathbb{E}_t[C_{t+n}] = C_t \ \forall \ n > 0$.

c) Use the fact that the intertemporal budget constraint must hold in expectation to prove that optimal consumption in period t is given by

$$C_t = (\mathsf{r}/\mathsf{R})(B_t + H_t + \Xi_t) \tag{3}$$

where, designating the infinite horizon present discounted value by the operator $\mathbb{P}_t(\bullet)$,

$$\begin{aligned} H_t &= \mathbb{E}_t[\mathbb{P}_t(Y)] & (4) \\ &= (\mathsf{R}/\mathsf{r})P_t & (5) \end{aligned}$$

d) Show that

$$\mathbb{E}_t[\Delta Y_{t+1}] \quad = \quad -\Xi_t \tag{6}$$

and explain the intuition for this result.

e) The 'Haig-Simons' definition of saving is the change in resources from one period to the next. Consistent with this, define

$$S_t \quad = \quad B_{t+1}/\mathsf{R} - B_t$$

and show that

$$\begin{aligned} \mathbb{E}_t[\Delta Y_{t+1}] &= -S_t\mathsf{R} - \mathsf{r}B_t & (7) \\ &\approx -S_t\mathsf{R} & (8) \end{aligned}$$

if $\mathsf{r}B_t$ is small. Explain this result intuitively, and discuss its relationship to Friedman's PIH.

f) Suppose we now construct a forecast of income growth using (8) and perform a regression

$$\Delta C_{t+1} = \alpha_0 + \alpha_1 \, \mathbb{E}_t[\Delta Y_{t+1}]$$

What should our empirical estimate of α_1 be? How do you reconcile this with the fact that the level of consumption is positively related to the level of income?

g) Now suppose that consumption data are measured with iid (=white noise = unpredictable) error,

$$\tilde{C}_{t+1} = C_{t+1} + \chi_{t+1}$$

where $\mathbb{E}_t[\chi_{t+n}] = 0 \ \forall \ n > 0$ and the variance of χ is $\mathbb{E}_t[\chi_{t+1}^2] = \sigma_\chi^2$.

Suppose that we wish to use $\Delta\tilde{C}_t$ to forecast $\Delta\tilde{C}_{t+1}$ from an equation of the form

$$\mathbb{E}_t[\Delta\tilde{C}_{t+1}] = \gamma\Delta\tilde{C}_t.$$

Define the expected squared errors from the forecasting equation as

$$SSE = \mathbb{E}_t[(\Delta\tilde{C}_{t+1} - \mathbb{E}_t[\Delta\tilde{C}_{t+1}])^2]$$

Defining the variance of 'true' changes in consumption as $\mathbb{E}_t[(\Delta C_{t+1})^2] = \sigma_{\Delta C}^2$, show that the choice of γ which minimizes the sum of squared errors from such a forecast is

$$\gamma = -\left(\frac{\sigma_\chi^2}{\sigma_\chi^2 + \sigma_{\Delta C}^2}\right)$$

Explain why this makes sense intuitively and discuss how it relates to the previous result about forecasting income growth. Hint: Your problem is to find the value of γ which minimizes the expected sum of squared errors:

$$\min_\gamma SSE \tag{9}$$

and you can use the fact that 'true' consumption growth and measurement error are both iid: $\mathbb{E}_t[\Delta C_{t+1}\Delta C_t] = \mathbb{E}_t[\Delta C_{t+1}\chi_t] = \mathbb{E}_t[\Delta C_{t+1}\chi_{t-1}] = \mathbb{E}_t[\chi_{t+1}\Delta C_t] = \mathbb{E}_t[\chi_{t+1}\chi_{t-1}] = 0$.

References

DEATON, ANGUS S. (1992): *Understanding Consumption.* Oxford University Press, New York.

DELONG, J BRADFORD, AND LAWRENCE H SUMMERS (2012): "Fiscal Policy in a Depressed Economy [with Comments and Discussion]," *Brookings Papers on Economic Activity*, pp. 233–297.

FRIEDMAN, MILTON A. (1957): *A Theory of the Consumption Function.* Princeton University Press.