borrowers, because borrowers can repay their loans with dollars that are worth less. Other costs include high effective tax rates, distortions to relative prices, shoe-leather costs, and menu costs.

7. The government budget constraint says that the government has three basic ways to finance its spending: through taxes, borrowing, and printing money. When governments find it hard to reduce spending, raise taxes, or borrow, they will be forced to print money to satisfy the budget constraint. Hyperinflations are generally a reflection of such fiscal problems.

KEY CONCEPTS

central bank independence	hyperinflation	quantity equation
the classical dichotomy	inflation	the quantity theory of money
deflation	the inflation tax (or seignorage)	real interest rate
the Fisher equation	monetary base	reserves
the government budget constraint	the neutrality of money	the velocity of money
	nominal interest rate	

REVIEW QUESTIONS

1. What is inflation? Suppose an individual's retirement plan consists of putting \$100 into a safe. What effect does inflation have on this plan?
2. A concise summary of the quantity theory of money is that inflation occurs because of too much money chasing too few goods. Explain.
3. Explain how a rise in $\overline{M}_t$, $\overline{V}$, and $\overline{Y}_t$ affects the price level according to the quantity theory.
4. Why do economists think the classical dichotomy holds in the long run?
5. What is the difference between a real interest rate and a nominal interest rate? What is the intuition behind the Fisher equation?
6. What are the costs of inflation, and how can these costs be avoided?
7. What is the government budget constraint? How does it help us understand the causes of high inflation?
8. How can we understand the Great Inflation of the 1970s? Does the government budget constraint help?
9. Who pays the inflation tax?

EXERCISES

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1. **How much is that?** Using the data on the consumer price index reported in Table 8.1, calculate the value in 2012 of the following items (refer to the nearest year in the table to do each calculation):
   (a) The salary of a worker in 1900: \$1,000 per year.
   (b) Babe Ruth's salary in 1932: \$80,000.
   (c) A bottle of Coke or Pepsi in the late 1940s: one nickel.

(d) A quarter pounder from McDonald's in 1972: 55 cents.
(e) A movie ticket to see *Star Wars* in 1977: about \$2.25.
(f) A pack of M&M candies in 1991: 45 cents.

2. **Calculating inflation:** Compute inflation rates in the following cases.
   (a) Suppose the consumer price index in the future takes the following values: $P_{2015} = 110$, $P_{2016} = 113$, $P_{2017} = 118$, $P_{2018} = 120$, $P_{2019} = 125$. Viewing these price levels as prevailing at the *end* of each year, calculate the inflation rate for the years 2016, 2017, 2018, and 2019.
   (b) Consider the data on the CPI from Table 8.1. Compute the average annual rate of inflation that prevailed between 1980 and 2012. (*Hint*: This calculation is similar to the computation of an average annual growth rate, say for real GDP.)
   (c) Referring to the same CPI data in part (b), compute the average annual inflation rate between 1970 and 1980. What was the rate between 1900 and 2012?

3. **The quantity theory of money:** What is the key endogenous variable in the quantity theory? Explain the effect on this key variable of the following changes:
   (a) The money supply is doubled.
   (b) The velocity of money increases by 10%.
   (c) Real GDP rises by 2%.
   (d) The money supply increases by 3% while real GDP rises by 3% at the same time.

4. **Inflation and the quantity theory:** Suppose velocity is constant, the growth rate of real GDP is 3% per year, and the growth rate of money is 5% per year. Calculate the long-run rate of inflation according to the quantity theory in each of the following cases:
   (a) What is the rate of inflation in this baseline case?
   (b) Suppose the growth rate of money rises to 10% per year.
   (c) Suppose the growth rate of money rises to 100% per year.
   (d) Back to the baseline case, suppose real GDP growth rises to 5% per year.
   (e) What if real GDP growth falls to 2% per year?
   (f) Return to the baseline case and suppose the velocity of money rises at 1% per year. What happens to inflation in this case? Why might velocity change in this fashion?

5. **Price stability:** Suppose you are the head of the central bank and your mandate is to maintain the price level at a constant value. Explain what you would do to the money supply in response to each of the following events:
   (a) Real GDP increases by 4% during a boom.
   (b) Real GDP declines by 1% during a recession.
   (c) Real GDP is growing at 3% per year.
   (d) The velocity of money increases by 2%.
   (e) The velocity of money declines by 1%.

6. **Interest rates:** The Fisher equation relates real (R) and nominal (i) interest rates to the rate of inflation (π). Given two of these values below, calculate the third.

(a) $R = 1\%$, $\pi = 3\%$. What is i?
(b) $\pi = 5\%$, $i = 10\%$. What is R?
(c) $R = 2\%$, $i = 6\%$. What is π?
(d) $R = 1\%$, $\pi = 12\%$. What is i?
(e) $\pi = 6\%$, $i = 2\%$. What is R?
(f) $R = 1\%$, $i = 10\%$. What is π?

7. **Real and nominal interest rates:** Suppose the real return on investing in a machine is 5% and the inflation rate is 4%.
   (a) According to the Fisher equation, what should the nominal interest rate be?
   (b) Suppose bank A charges a nominal interest rate on loans equal to 8%. What happens?
   (c) Suppose bank B advertises its nominal rate on savings accounts as 12%. What happens?

8. **Earning the nominal return:** Suppose the inflation rate is 5%. Suppose the marginal product of capital in a firm is 8% but that in the course of production, 6% of capital is worn out by depreciation. What is the nominal return associated with an investment in capital, and why? What is the Fisher equation in this example?

9. **Can interest rates be negative?** Consider the following two questions.
   (a) Can the real interest rate be negative? In what circumstances?
   (b) Can the nominal interest rate be negative? Discuss.

10. **The costs of inflation:** Consider two possible inflation scenarios. In one, the inflation rate is 100% per year, but it has been at this level for three decades and the central bank says it will keep it there forever. In the other, the inflation rate was 3% for two decades but just this past year rose to 10%. Over the next 5 years, which economy do you think suffers a higher cost of inflation, and why?

11. **Hyperinflations:** Explain some of the costs of hyperinflations. If they are so costly to an economy, why do they occur?

12. **Inflation as fiscal phenomenon:** The complete version of the Thomas Sargent quote that began this chapter is "Persistent high inflation is always and everywhere a fiscal phenomenon." Why did Sargent include the modifiers "persistent high"?

13. **Revenue from the inflation tax:** The amount of money the government raises from the inflation tax is ΔM. Consult the statistical tables at the back of the *Economic Report of the President* (available online) to answer the following questions:
   (a) How much currency was in circulation in 1981? What was the size of the monetary base in 1981?
   (b) If the monetary base is the measure of M, how much revenue was raised from the inflation tax between 1980 and 1981, in dollars? What fraction was this of 1981 GDP?
   (c) Why does this exercise ask you to do these calculations for the year 1981 instead of some other year?

14. **A formula for the inflation tax (hard):** As in exercise 13, the amount of money the government raises from the inflation tax is ΔM.

(a) Write this amount as a ratio to nominal GDP. Multiply and divide by M to get an expression for the ratio of revenue from the inflation tax to GDP. Your answer should take the form of the product of a growth rate and a different ratio. Interpret this equation.

(b) Use the quantity theory to replace the growth rate of money in this product with a term that involves the inflation rate.

(c) How much revenue, as a share of GDP, would the inflation tax raise in the following episodes? Assume the growth rate of real GDP is 2% in these calculations:

i. The United States in 1981. (Use the tables from the *Economic Report of the President* to compute the answer. How does this compare with your answer to exercise 13?)

ii. The United States in 2005.

(d) Suppose there is a hyperinflation where the inflation rate rises to 2,000%. For a given value of M/Y, the formula you derived in (b) suggests that the inflation tax could raise more than 100% of GDP in revenue. Clearly this could not actually happen. Why not? (*Hint*: Think about what happened in the German hyperinflation example that began this chapter.)

15. **Reflections on a classic:** *A Monetary History of the United States, 1867 to 1960*, by Milton Friedman and Anna Schwartz, is a classic study of monetary policy and was published in 1963. Read the interview with Anna Schwartz available at www.minneapolisfed.org/pubs/region/93-09/int939.cfm, and explain what you think was the main contribution of this book. (Other interesting interviews with famous macroeconomists are gathered at http://minneapolisfed.org/pubs/region.)

WORKED EXERCISES

2. **Calculating inflation:**

(a) The inflation rate is the percentage change in the price level. By convention, we calculate this percentage change relative to the price that prevails in the initial period. Think of the prices reported in the exercise as being "end of year" prices. The inflation rate in the year 2016 is then $(113-110)/110 = 0.027$, or 2.7%. In the year 2017, it's $(118-113)/113 = 0.044$, or 4.4%.

Inflation in the other years can be calculated in the same way.

(b) To calculate the average annual rate of inflation between 1980 and 2012, think of the inflation rate as the average annual growth rate of the price level. That is, we are asked to undertake a growth rate calculation.

From our growth rate rules back in Chapter 3, recall that the average annual growth rate between two periods satisfies

$$p_T = p_0(1 + \pi)^T,$$

where π is the growth rate, p_T is the price level in the final period at date T, and p_0 is the price level in the initial period, date 0. The inflation rate is the growth rate of the price level.

We can solve this equation for the inflation rate to find that

$$\pi = \left(\frac{P_T}{P_0}\right)^{1/T} - 1.$$

Notice the similarity between this equation and the rule for calculating growth rates; for example, look back at equation (3.9) on page 52. Applying this equation to calculate the inflation rate between 1980 and 2012, we find

$$\pi = \left(\frac{100}{36.00}\right)^{1/32} - 1 = 0.032.$$

So the inflation rate averaged 3.2% during this period.

(c) You should now be able to compute these inflation rates using the formulas from part (b).

5. **Price stability:** Consider the quantity theory of money in its growth rate form, shown in equation (8.3):

$$\bar{g}_M + \bar{g}_V = g_P + \bar{g}_Y.$$

Rearranging to solve for the percentage change in the price level, we have

$$g_P = \bar{g}_M + \bar{g}_V - \bar{g}_Y.$$

Our goal is to keep the price level constant, so we want to maintain $g_P = 0$.

(a) If real GDP increases by 4% and the central bank does nothing, then the equation we have just derived says that inflation will be −4%. To restore inflation back to zero, the central bank must increase the money supply by 4% to keep the price level constant. Recall the summary of the quantity theory of inflation as "too much money chasing too few goods." In this case, the number of goods is going up, so we have to raise the amount of money in the economy to keep the price level constant.

(b) The same reasoning applies here. If real GDP falls by 1%, the central bank needs to reduce the money supply by 1% to keep the price level constant.

(c) If real GDP is growing at a constant rate of 3% per year, then the central bank needs to keep the money supply growing at 3% per year to maintain a constant price level (assuming velocity is constant).

(d) The quantity theory in its standard form, $MV = PY$, is especially helpful in seeing what needs to be done when the velocity of money changes. The quantity theory says that nominal GDP equals the "effective" quantity of money, MV. So if velocity changes and we want to keep the price level unchanged, we must move the money supply in the *opposite* direction to keep MV constant. In this problem, velocity increases by 2%, so we need to reduce the money supply by 2% to offset this change.

(e) Finally, if the velocity of money falls by 1%, we need to increase the supply of money by 1% to keep the price level constant.