Solow model continued

1. For each of the economic changes listed in (a) and (b), assess the likely impact on the growth rate and the level of output over the next five years and over the next five decades.
    a. A permanent reduction in public deficits.
    b. A increase in technological progress.

2. Suppose that only two goods are produced in an economy: haircuts and banking services. Prices, quantities and the number of workers occupied in the production of each good for year one and for year two are given in the following table:

	Year 1			Year 2		
	P1	Q1	W1	P2	Q2	W2
Haircuts	10	100	50	12	100	50
Banking	10	200	50	12	230	60

    a. What is nominal GDP each year?
    b. Using year one prices, what is real GDP in year 2? What is the growth rate of real GDP?
    c. What is the rate of inflation using the GDP deflator?
    d. Using year one prices, what is real GDP per worker in year one and year 2? What is labour productivity growth between year one and year 2 for the whole economy?

    Now suppose that banking services in year 2 are not the same as banking services in year 1. Year 2 banking services include telebanking, which year one banking services did not include. The technology for telebanking was available in year 1, but the price of banking services with telebanking in year 1 was $13, and no one chose to purchase this package. However, in year 2, the price of banking services with telebanking was $12, and everyone decided to have this package (i.e. in year two, no one chose to have the year one banking services package without telebanking). (Hint: Assume that there are now two types of banking services: those with telebanking and those without. Rewrite the preceding table but now with three goods: haircuts and the two types of banking services.).

    e. Using year one prices, what is real GDP for year 2? What is the growth rate of real GDP?
    f. What is the rate of inflation using the GDP deflator?
    g. What is labour productivity growth between year one and year 2 for the whole economy?
    h. Consider this statement: 'If banking services are mismeasured, for example, by not taking into account the introduction of telebanking – we will overestimate inflation and underestimate productivity growth.' Discuss this statement in light of your answers to parts (a) to (g).

3. Suppose that the economy's production function is:

$$the\ the\ Y = \sqrt{K}\sqrt{AN}$$

that the saving rate, s, is equal to 20%, and that the rate of depreciation, δ is equal to 10%. Suppose further that the number of workers grows at 1% per year and that the rate of technological progress is 6% per year.

   a. Find the steady-state values of the variables listed in (i) to (v):
      i. The capital stock per effective worker
      ii. Output per effective worker
      iii. The growth rate of output per effective worker
      iv. The growth rate of output per worker
      v. The growth rate of output

   b. Suppose that the rate of technological progress rises to 10% per year. Recompute the answers to part (a). Explain.
   c. Now suppose that the rate of technological progress is equal to3% per year, but the number of workers now grows at 4% per year. Recompute the answers to (a). Are people better off in (a) or in (c)? Explain.

4. The data on output, capital and labour can be used to construct estimates of the rate of growth of technological progress. We modify that approach in this problem to examine capital growth per worker. The function:

$$Y = K^{1/3}(AN)^{2/3}$$

gives a good description of production in rich countries. Following the same steps as in the appendix, you can show that:

$$(2/3)g_A = g_Y - (2/3)g_N - (1/3)g_K = (g_Y - g_N) - (1/3)(g_K - g_N),$$

where g_Y denotes the growth rate of Y.

   a. What does the quantity g_Y - g_N represent? What does the quantity g_K - g_N represent?
   b. Rearrange the preceding equation to solve for the growth rate of capital per worker
   c. Look at below and using your answer to part (b), substitute in the average annual growth rate of output per worker and the average annual rate of technological progress for the United States for the period 1985 to 2013 to obtain a crude measure of the average annual growth of capital per worker. (Strictly speaking, we should construct these measures individually for every year, but we limit ourselves to readily available data in this problem.) Do the same for the other countries listed in table below(where data goes to 2014). How does the average growth of capital per worker compare across the countries? Do the results make sense to you? Explain.

Average annual rates of growth of output per worker and technological progress in selected rich countries since 1985

	Rate of growth of output per worker (%) 1985–2014	Rate of technological progress (%) 1985–2014
Denmark	1.3	0.6
France	1.3	1.4
Germany	1.0	1.1
Italy	0.7	0.3
Netherlands	0.9	0.5
Spain	1.0	0.3
Sweden	1.8	0.8
United Kingdom	1.9	1.4
United States	1.7	1.4
Japan	1.6	1.7

Source: Calculations from OECD Productivity Statistics.

5. Suppose an economy is characterised by the following equations:

$$\text{Price setting: } P = (1 + m)(W/A)$$
$$\text{Wage setting: } W = A^e P^e (1 - u)$$

   a. Solve for the unemployment rate if $P^e = P$ but A^e does not necessarily equal A. Explain the effects of (A^e/A) on the unemployment rate.
   b. Now suppose that expectations of both prices and productivity are accurate.
   c. Solve for the natural rate of unemployment if the mark-up (m) is equal to 5%.
   d. Does the natural rate of unemployment depend on productivity? Explain.

6. Discuss the following statement: 'Higher labour productivity allows firms to produce more goods with the same number of workers and thus to sell the goods at the same or even lower prices. That's why increases in labour productivity can permanently reduce the rate of unemployment without causing inflation.

7. Consider an economy in which production is given by:

$$Y = AN$$

   Assume that price setting and wage setting are described in the following equations:

   $$\text{Price setting: } P = (1 + m)(W/A)$$
   $$\text{Wage setting: } W = A^e P^e (1 - u)$$

   Recall that the relation between employment, N, the labour force, L, and the unemployment rate, u, is given by:

$$N = (1 - u)L$$

a. Derive the aggregate supply curve (i.e. the relation between the price level and the level of output, given the mark-up, the actual and expected levels of productivity, the labour force and the expected price level). Explain the role of each variable.

b. Show the effect of an equiproportional increase in A and Ae (so that A/A^e remains unchanged) on the position of the aggregate supply curve. Explain.
c. Suppose instead that actual productivity, A, increases, but expected productivity, A^e, does not change. Compare the results in this case with your conclusions in (b). Explain the difference.

8. We learned how the wage-setting and price-setting equations could be expressed in terms of labour demand and labour supply. In this problem, we extend the analysis to account for technological change. Consider the wage-setting equation:

$$W/P = F(u, z)$$

as the equation corresponding to labour supply. Recall that for a given labour force, L, the unemployment rate, u, can be written as:

$$u = 1 - N/L$$

where N is employment.

a) Substitute the expression for u into the wage-setting equation.
b) Using the relation you derived in (a), graph the labour supply curve in a diagram with u on the horizontal axis and W/P, the real wage, on the vertical axis. Now write the price-setting equation as:

$$P = (1 + m)MC$$

where MC is the marginal cost of production. To generalize somewhat our discussion in the text, we shall write:

$$MC = W/MPL$$

where W is the wage and MPL is the marginal product of labour.
c) Substitute the expression for MC into the price-setting equation and solve for the real wage, W/P. The result is the labour-demand relation, with W/P as a function of the MPL and the mark-up, m.

We assumed for simplicity that the MPL was constant for a given level of technology. Here, we assume that the MPL decreases with employment (again for a given level of technology), a more realistic assumption.
d) Assuming that the MPL decreases with employment, graph the labour-demand relation you derived in (c). Use the same diagram you drew for (b).
e) What happens to the labour-demand curve if the level of technology improves? (Hint: What happens to MPL when technology improves?) Explain. How is the real wage affected by an increase in the level of technology?

ADITIONAL QUESTIONS:
Label each of the following statements true, false or uncertain. Explain briefly.

1. The saving rate is always equal to the investment rate. Writing the production function in terms of capital and effective labour implies that as the level of technology increases by 10%, the number of workers required to achieve the same level of output decreases by 10%.
2. If the rate of technological progress increases, the investment rate (the ratio of investment to output) must increase to keep capital per effective worker constant.
3. In steady state, output per effective worker grows at the rate of population growth.

4. In steady state, output per worker grows at the rate of technological progress.
5. A higher saving rate implies a higher level of capital per effective worker in the steady state and thus a higher rate of growth of output per effective worker.
6. Even if the potential returns from research and development (R&D) spending are identical to the potential returns from investing in a new machine, R&D spending is much riskier for firms than investing in new machines.
7. The fact that one cannot patent a theorem implies that private firms will not engage in basic research.
8. Because eventually we will know everything, growth will have to come to an end.
9. Technology has not played an important part in Chinese economic growth.