■ Answers to Textbook Problems

Review Questions

1. A production function shows how much output can be produced with a given amount of capital and labor. The production function can shift due to supply shocks, which affect overall productivity. Examples include changes in energy supplies, technological breakthroughs, and management practices. Besides knowing the production function, you must also know the quantities of capital and labor the economy has.

2. The upward slope of the production function means that any additional inputs of capital or labor produce more output. The fact that the slope declines as we move from left to right illustrates the idea of diminishing marginal productivity. For a fixed amount of capital, additional workers each add less additional output as the number of workers increases. For a fixed number of workers, additional capital adds less additional output as the amount of capital increases.

3. The marginal product of capital (*MPK*) is the output produced per unit of additional capital. The *MPK* can be shown graphically using the production function. For a fixed level of labor, plot the output provided by different levels of capital; this is the production function. The *MPK* is just the slope of the production function.

4. The marginal revenue product of labor represents the benefit to a firm of hiring an additional worker, while the nominal wage is the cost. Comparing the benefit to the cost, the firm will hire additional workers as long as the marginal revenue product of labor exceeds the nominal wage, since doing so increases profits. Profits will be at their highest when the marginal revenue product of labor just equals the nominal wage.

   The same condition can be expressed in real terms by dividing through by the price of the good. The marginal revenue product of labor equals the marginal product of labor times the price of the good. The nominal wage equals the real wage times the price of the good. Dividing each of these through by the price of the good means that an equivalent profit-maximizing condition is the marginal product of labor equals the real wage.

5. The *MPN* curve shows the marginal product of labor at each level of employment. It is related to the production function because the marginal product of labor is equal to the slope of the production function (where output is plotted against employment). The *MPN* curve is related to labor demand, because firms hire workers up to the point at which the real wage equals the marginal product of labor. So the labor demand curve is identical to the *MPN* curve, except that the vertical axis is the real wage instead of the marginal product of labor.

6. A temporary increase in the real wage increases the amount of labor supplied because the substitution effect is larger than the income effect. The substitution effect arises because a higher real wage raises the benefit of additional work for a worker. The income effect is small because the increase in the real wage is temporary, so it doesn’t change the worker’s income very much, thus the worker won’t reduce time spent working very much.

   A permanent increase in the real wage, however, has a much larger income effect, since a worker’s lifetime income is changed significantly. The income effect may be so large that it exceeds the substitution effect, causing the worker to reduce time spent working.

7. The aggregate labor supply curve relates labor supply and the real wage. The principal factors shifting the aggregate labor supply curve are wealth, the expected future real wage, the country’s working-age population, or changes in the social or legal environment that lead to changes in labor force

participation. Increases in wealth or the expected future real wage shift the aggregate labor supply curve to the left. Increases in the working-age population or in labor-force participation shift the aggregate labor supply curve to the right.

8. Full-employment output is the level of output that firms supply when wages and prices in the economy have fully adjusted; in the classical model of the labor market, this occurs when the labor market is in equilibrium. When labor supply increases, full-employment output increases, as there is now more labor available to produce output. When a beneficial supply shock occurs, then the same quantities of labor and capital produce more output, so full-employment output rises. Furthermore, a beneficial supply shock increases the demand for labor at each real wage and leads to an increase in the equilibrium level of employment, which also increases output.

9. The classical model of the labor market assumes that any worker who wants to work at the equilibrium real wage can find a job, so it is not very useful for studying unemployment.

10. The labor force consists of all employed and unemployed workers. The unemployment rate is the fraction of the labor force that is unemployed. The participation rate is the fraction of the adult population that is in the labor force. The employment ratio is the fraction of the adult population that is employed.

11. An *unemployment spell* is a period of time that a person is continuously unemployed. *Duration* is the length of time of an unemployment spell. Two seemingly contradictory facts are that most unemployment spells have a short duration and that most people who are unemployed at a particular time are experiencing spells with long durations. These can be reconciled by realizing that there may be a lot of people with short spells and a few people with long spells. On any given date, a survey finds a fairly long average duration for the unemployed, because of the people with long spells. For example, suppose that each week one person becomes unemployed for one week, so there are fifty-two such short unemployment spells during the year. And suppose that there are four people who are unemployed all year, so there are four long unemployment spells during the year. In any given week five people are unemployed: one unemployed person has a spell of one week, while four have spells of a year. So most spells have a short duration (fifty-two short spells compared to four long spells), but most people who are unemployed at a given time are experiencing spells with long duration (one short spell compared to four long spells).

12. Frictional unemployment arises as workers and firms search to find matches. A certain amount of frictional unemployment is necessary, because it is not always possible to find the right match right away. For example, an unemployed banker may not want to take a job flipping hamburgers if he or she cannot find another banking job right away, because the match would be very poor. By remaining unemployed and continuing to search for a more suitable job, the banker is likely to make a better match. That will be better both for the banker (since the salary is likely to be higher) and for society as a whole (since the better match means greater productivity in the economy).

13. Structural unemployment occurs when people suffer long spells of unemployment or are chronically unemployed (with many spells of unemployment). Structural unemployment arises when the number of potential workers with low skill levels exceeds the number of jobs requiring low skill levels, or when the economy undergoes structural change, when workers who lose their jobs in shrinking industries may have difficulty finding new jobs.

14. The natural rate of unemployment is the rate of unemployment that prevails when output and employment are at their full-employment levels. The natural rate of unemployment is equal to the amount of frictional unemployment plus structural unemployment. Cyclical unemployment is the

difference between the actual rate of unemployment and the natural rate of unemployment. When cyclical unemployment is negative, output and employment exceed their full-employment levels.

15. Okun's Law is a rule of thumb that tells how much output falls when the unemployment rate rises. It is written either in terms of the levels of output and unemployment, as in Eq. (3.5), $(\bar{Y} - Y)/\bar{Y} = 2(u - \bar{u})$, or in terms of changes in output and unemployment, as in Eq. (3.6), $\Delta Y/Y = 3 - 2\,\Delta u$. Since the Okun's law coefficient is 2, a 2 percentage point increase in the unemployment rate causes output to decline by 4%.

Numerical Problems

1. (a) To find the growth of total factor productivity, you must first calculate the value of A in the production function. This is given by $A = Y/(K^{.3}N^{.7})$. The growth rate of A can then be calculated as

$[(A_{\text{year 2}} - A_{\text{year 1}})/A_{\text{year 1}}] \times 100\%$. The result is:

	A	**% Increase in *A***
1960	13.392	—
1970	15.791	17.9%
1980	16.447	4.2%
1990	18.298	11.3%
2000	21.237	16.1%
2010	23.169	9.1%

(b) Calculate the marginal product of labor by seeing what happens to output when you add 1.0 to N; call this Y_2, and the original level of output Y_1. [A more precise method is to take the derivative of output with respect to N; $dY/dN = 0.7A(K/N)^{.3}$. The result is the same (rounded).]

	Y_1	Y_2	***MPN***
1960	2829	2859	30
1970	4266	4304	38
1980	5834	5875	41
1990	8027	8074	47
2000	11,216	11,273	57
2007	13,063	13,129	66

2. (a) The *MPK* is 0.2, because for each additional unit of capital, output increases by 0.2 units. The slope of the production function line is 0.2. There is no diminishing marginal productivity of capital in this case, because the *MPK* is the same regardless of the level of K. This can be seen in Figure 3.8 because the production function is a straight line.

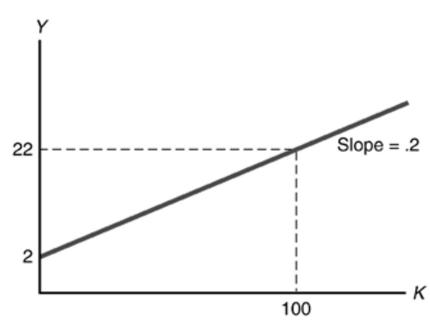

Figure 3.8

(b) When N is 100, output is $Y = 0.2(100 + 100^{.5}) = 22$. When N is 110, Y is 22.0976. So the *MPN* for raising N from 100 to 110 is $(22.0976 - 22)/10 = 0.00976$. When N is 120, Y is 22.1909. So the *MPN* for raising N from 110 to 120 is $(22.1909 - 22.0976)/10 = 0.00933$. This shows diminishing marginal productivity of labor because the *MPN* is falling as *N* increases. In Figure 3.9 this is shown as a decline in the slope of the production function as *N* increases.

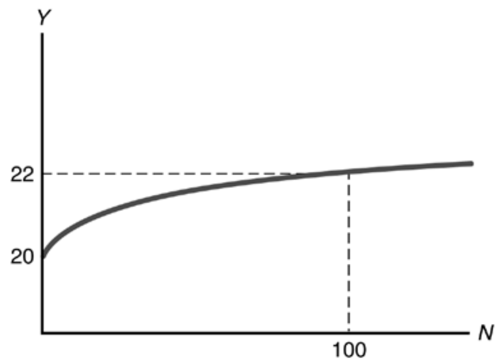

Figure 3.9

3. (a)

N	*Y*	*MPN*	*MRPN* (*P* = 5)	*MRPN* (*P* = 10)
1	8	8	40	80
2	15	7	35	70
3	21	6	30	60
4	26	5	25	50
5	30	4	20	40
6	33	3	15	30

(b) *P* = $5.

(1) *W* = $38. Hire one worker, since *MRPN* ($40) is greater than *W* ($38) at *N* = 1. Do not hire two workers, since *MRPN* ($35) is less than *W* ($38) at *N* = 2.

(2) *W* = $27. Hire three workers, since *MRPN* ($30) is greater than *W* ($27) at *N* = 3. Do not hire four workers, since *MRPN* ($25) is less than *W* ($27) at *N* = 4.

(3) *W* = $22. Hire four workers, since *MRPN* ($25) is greater than *W* ($22) at *N* = 4. Do not hire five workers, since *MRPN* ($20) is less than *W* ($22) at *N* = 5.

(c) Figure 3.10 plots the relationship between labor demand and the nominal wage. This graph is different from a labor demand curve because a labor demand curve shows the relationship between labor demand and the real wage. Figure 3.11 shows the labor demand curve.

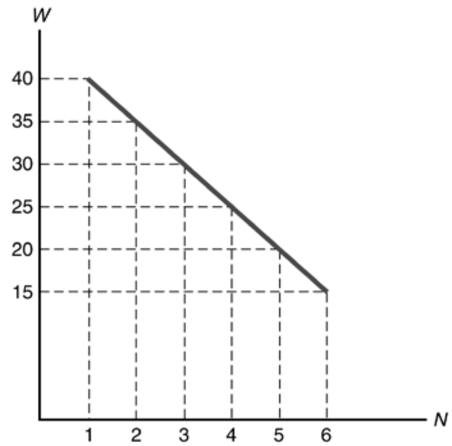

Figure 3.10

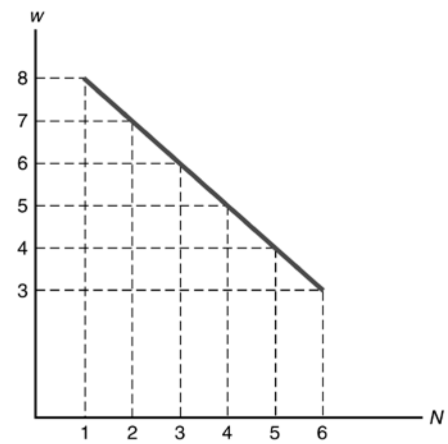

Figure 3.11

(d) P = \$10. The table in part a shows the *MRPN* for each N. At W = \$38, the firm should hire five workers. *MRPN* (\$40) is greater than W (\$38) at $N = 5$. The firm shouldn't hire six workers, since *MRPN* (\$30) is less than W (\$38) at $N = 6$. With five workers, output is 30 widgets, compared to 8 widgets in part a when the firm hired only one worker. So the increase in the price of the product increases the firm's labor demand and output.

(e) If output doubles, *MPN* doubles, so *MRPN* doubles. The *MRPN* is the same as it was in part d when the price doubled. So labor demand is the same as it was in part d. But the output produced by five workers now doubles to 60 widgets.

(f) Since $MRPN = P \times MPN$, then a doubling of either P or *MPN* leads to a doubling of *MRPN*. Since labor demand is chosen by setting *MRPN* equal to W, the choice is the same, whether P doubles or *MPN* doubles.

4. $MPN = A(100 - N)$

(a) $A = 1$. $MPN = 100 - N$.

(1) W = \$10. $w = W/P$ = \$10/\$2 = 5. Setting $w = MPN$, $5 = 100 - N$, so $N = 95$.

(2) W = \$20. $w = W/P$ = \$20/\$2 = 10. Setting $w = MPN$, $10 = 100 - N$, so $N = 90$.

These two points are plotted as line ND^a in Figure 3.12. If labor supply = 95, then the equilibrium real wage is 5.

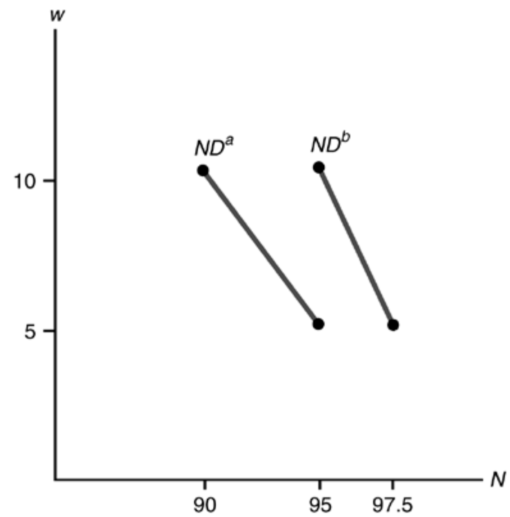

Figure 3.12

(b) $A = 2$. $MPN = 2(100 - N)$.

(1) $W = \$10$. $w = W/P = \$10/\$2 = 5$. Setting $w = MPN$, $5 = 2(100 - N)$, so $2N = 195$, so $N = 97.5$.

(2) $W = \$20$. $w = W/P = \$20/\$2 = 10$. Setting $w = MPN$, $10 = 2(100 - N)$, so $2N = 190$, so $N = 95$.

These two points are plotted as line ND^b in Figure 3.12. If labor supply = 95, then the equilibrium real wage is 10.

5. (a) If the lump-sum tax is increased, there's an income effect on labor supply, not a substitution effect (since the real wage isn't changed). An increase in the lump-sum tax reduces a worker's wealth, so labor supply increases.

(b) If $T = 35$, then $NS = 22 + 12w + (2 \times 35) = 92 + 12\,w$. Labor demand is given by $w = MPN = 309 - 2N$, or $2N = 309 - w$, so $N = 154.5 - w/2$. Setting labor supply equal to labor demand gives $154.5 - w/2 = 92 + 12w$, so $62.5 = 12.5w$, thus $w = 62.5/12.5 = 5$. With $w = 5$, $N = 92 + (12 \times 5) = 152$.

(c) Since the equilibrium real wage is below the minimum wage, the minimum wage is binding. With $w = 7$, $N = 154.5 - 7/2 = 151.0$. Note that $NS = 92 + (12 \times 7) = 176$, so $NS > N$ and there is unemployment.

6. Since $w = 4.5\,K^{0.5}\,N^{-0.5}$, $N^{-0.5} = 4.5\,K^{0.5}/w$, so $N = 20.25\,K/w^2$. When $K = 25$, $N = 506.25/w^2$.

(a) If $t = 0.0$, then $NS = 100w^2$. Setting labor demand equal to labor supply gives $506.25/w^2 = 100w^2$, so $w^4 = 5.0625$, or $w = 1.5$. Then $NS = 100\,(1.5)^2 = 225$. [Check: $N = 506.25/1.5^2 = 225$.] $Y = 45N^{0.5} = 45(225)^{0.5} = 675$. The total after-tax wage income of workers is $(1 - t)\,w\,NS = 1.5 \times 225 = 337.5$.

(b) If $t = 0.6$, then $NS = 100\,[(1 - 0.6)\,w]^2 = 16w^2$. The marginal product of labor is $MPN = 22.5/N^{0.5}$, so $N = 100\,[(1 - 0.6) \times 22.5/N^{0.5}]^2$, so $N^2 = 8100$, so $N = 90$. Then $Y = 45N^{0.5} = 45(90)^{0.5} = 426.91$. Then $w = 22.5/90^{0.5} = 2.37$. The total after-tax wage income of workers is $(1 - t)\,w\,NS = 0.4 \times 2.37 \times 90 = 85.38$. Note that there's a big decline in output and income, although the wage is higher.

(c) A minimum wage of 2 is binding if the tax rate is zero. Then $N = 506.25/2^2 = 126.6$, $NS = 100 \times 2^2 = 400$. Unemployment is 273.4. Income of workers is $wN = 2 \times 126.6 = 253.2$, which is lower than without a minimum wage, because employment has declined so much.

7. (a) At any date, 25 people are unemployed: 5 who have lost their jobs at the start of the month and 20 who have lost their jobs either on January 1 or July 1. The unemployment rate is 25/500 = 5%.
   (b) Each month, 5 people have one-month spells. Every six months, 20 people have six-month spells. The total number of spells during the year is $(5 \times 12) + (20 \times 2) = 100$. Sixty of the spells (60% of all spells) last one month, while 40 of the spells (40% of all spells) last six months.
   (c) The average duration of a spell is $(0.60 \times 1$ month$) + (0.40 \times 6$ months$) = 3$ months.
   (d) On any given date, there are 25 people unemployed. Twenty of them (80%) have long spells of unemployment, while 5 of them (20%) have short spells.

8. Number who become unemployed:

   From not in the labor force: 3% of 88.3 million = 2.649 million

   From employed: 2% of 142.2 million = 2.844 million

   Total = 5.493 million

   Number who become employed:

   From unemployed: 18% of 12.8 million = 2.304 million

   From not in the labor force: 4% of 88.3 million = 3.532 million

   Total = 5.836 million

   Number who become not in the labor force:

   From employed: 3% of 142.2 million = 4.266 million

   From unemployed: 21% of 12.8 million = 2.688 million

   Total = 6.954 million

9. Since $(\bar{Y} - Y)/\bar{Y} = 2(u - \bar{u})$, this can be rewritten as $\bar{Y} - Y = 2(u - \bar{u})\bar{Y}$ or $Y = [1 - 2(u - \bar{u})]\bar{Y}$, or $\bar{Y} = Y/[1 - 2(u - \bar{u})]$.
   (a) Using the formula above, this table shows the value of $\bar{Y}$, given values for u and Y.

Year	$\boldsymbol{u}$	$\boldsymbol{Y}$	$\boldsymbol{\bar{Y}}$
1	0.08	950	989.6
2	0.06	1030	1030.0
3	0.07	1033.5	1054.6
4	0.05	1127.5	1105.4

   b. The first calculation of $\Delta\bar{Y}/\bar{Y}$ comes from calculating the percent change in $\bar{Y}$ from part *a*. The second calculation of $\Delta\bar{Y}/\bar{Y}$ comes from using Eq. (3.6): $\Delta Y/Y = \Delta\bar{Y}/\bar{Y} - 2\,\Delta u$, so $\Delta\bar{Y}/\bar{Y} = \Delta Y/Y + 2\,\Delta u$.

Year	$\boldsymbol{\bar{Y}}$	$\boldsymbol{\Delta\bar{Y}/\bar{Y}}$	$\boldsymbol{\Delta Y/Y}$	$\boldsymbol{\Delta u}$	$\boldsymbol{\Delta\bar{Y}/\bar{Y}}$
1	989.6	—	—	—	—
2	1030.0	0.041	0.084	–0.02	0.044
3	1054.6	0.024	0.003	+0.01	0.023
4	1105.4	0.048	0.091	–0.02	0.051

   The two methods give fairly close answers.

10. (a) Total hours worked per week = 1900 workers × 40 hours per worker = 76,000 hours per week. Total output per week = 76,000 total hours per week × 10 units of output per hour = 760,000 units of output. The unemployment rate is 100 unemployed/2000 labor supply = 0.05, or 5%.

    (b) Employment falls 4% from 1900 to: (1 – 0.04) × 1900 = 1824. The labor force falls 0.2% from 2000 to: (1 – 0.002) × 2000 = 1996. With a labor force of 1996 and employment of 1824, unemployment is 1996 – 1824 = 172. The unemployment rate is 172/1996 = 0.086, or 8.6%. Hours worked per employed worker falls 2.5% from 40 to: (1 – 0.025) × 40 = 39. Total hours per week = 39 hours per worker × 1824 workers = 71,136. So total hours per week falls by (76,000 – 71,136)/76,000 = 0.064 = 6.4%. Total output per week falls 1.4% for every 1% drop in hours, so output falls by 6.4% × 1.4 = 8.96%. Since output was 760,000, it now falls to 760,000 × (1 – 0.0896) = 691,904. The Okun's Law coefficient is the percent change in output divided by the increase in the unemployment rate = 0.0896/(0.086 – 0.05) = 2.49.

Analytical Problems

1. (a) See Figures 3.13 and 3.14.

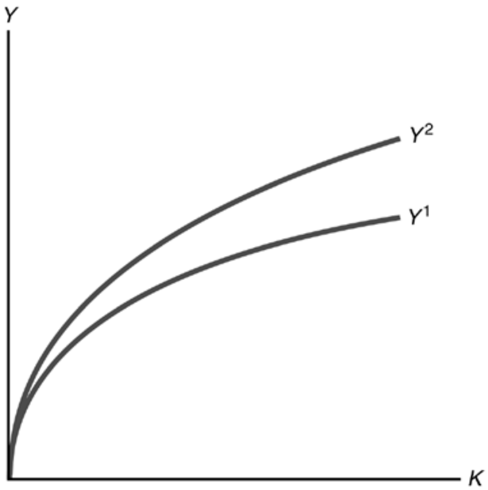

Figure 3.13

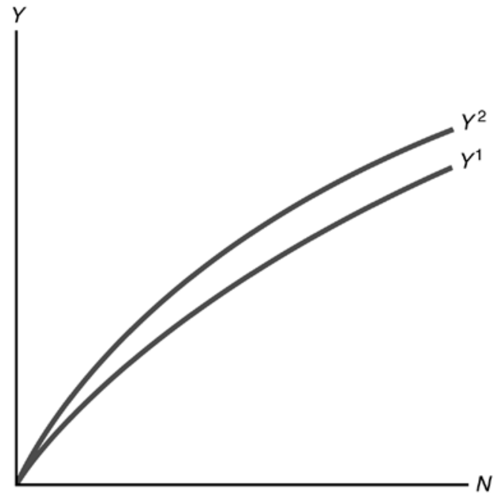

Figure 3.14

(b) In the initial situation, capital K_1 and labor N_1 produce output Y_1; when productivity rises they produce output 1.1 Y_1. Suppose that a small increase in capital to K_2 with labor left at N_1 produces output Y_2 in the initial situation. Then it produces 1.1 Y_2 when productivity rises by 10%. The marginal product of capital (*MPK*) in the initial situation is $(Y_2 - Y_1)/(K_2 - K_1)$; when productivity rises the new MPK is $(1.1\ Y_2 - 1.1\ Y_1)/(K_2 - K_1) = 1.1\ (Y_2 - Y_1)/(K_2 - K_1)$. So the new *MPK* is 10% higher than the old *MPK*.

This argument is completely symmetric, so it holds for *MPN* as well. If you substitute *N* for *K* everywhere and follow the same steps, you will show that the new *MPN* is 10% higher than the old *MPN*.

(c) Yes, it is possible for a beneficial productivity shock to leave the *MPK* and *MPN* unchanged. This could happen only if the shock was additive—that is, if it shifted the whole production function upward, but did not affect its slope at any point. In Figures 3.15 and 3.16 this is shown as a shift up in the production function, leaving the slope unchanged.

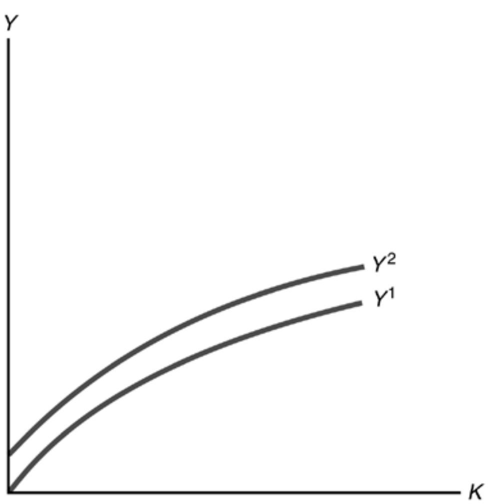

Figure 3.15

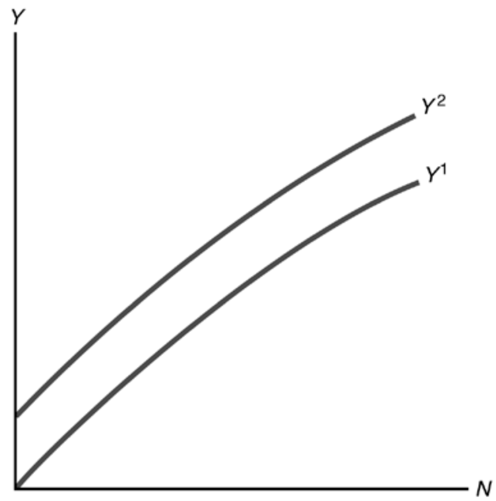

Figure 3.16

2. (a) An increase in the number of immigrants increases the labor force, increasing employment and increasing full-employment output.
   (b) If energy supplies become depleted, this is likely to reduce productivity, because energy is a factor of production. So the reduction in energy supplies reduces full-employment output.
   (c) Better education raises future productivity and output, but has no effect on current full-employment output.
   (d) This reduction in the capital stock reduces full-employment output (although it may very well increase welfare).

3. (a) As shown in Figure 3.17, when the real wage (*w*′) is above its market-clearing level, labor supply (*NS*′) exceeds labor demand (*ND*′). The difference is the amount of unemployment (*U*).

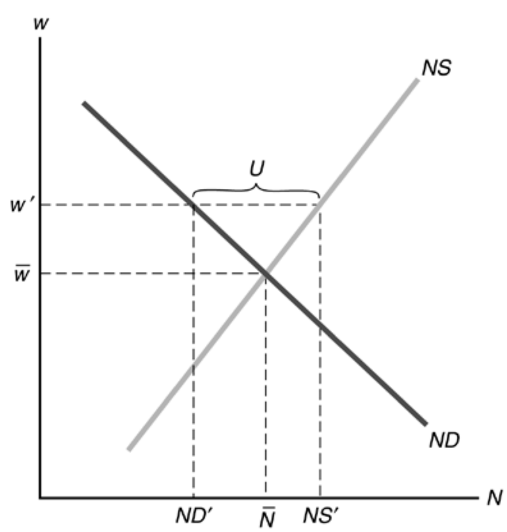

Figure 3.17

(b) Output is lower because of the real wage rigidity. With the real wage higher than the wage that clears the market at full employment, labor demand must be lower than it is at full employment, so employment and output are lower as well.

4. (a) The increased value of Helena's home increases her wealth. The rise in wealth leads to an income effect that leads Helena to reduce her labor supply.

(b) The permanent rise in Helena's real wage gives rise to offsetting income and substitution effects. The income effect of the higher wage reduces Helena's labor supply, but the substitution effect increases it. So the result is theoretically ambiguous.

Empirically, women tend to increase labor supply in response to a permanent increase in the real wage, and men tend to reduce labor supply in response to a permanent increase in the real wage.

(c) The temporary income tax surcharge is equivalent to a temporary reduction in the real wage, which reduces current labor supply, assuming that the income effect is smaller than the substitution effect.

5. The tax reduces the marginal product of labor by 6%, since that portion of output goes to the government rather than to the firm. Thus labor demand is reduced. With labor supply unchanged, the downward shift in labor demand reduces the real wage and employment, as shown in Figure 3.18.

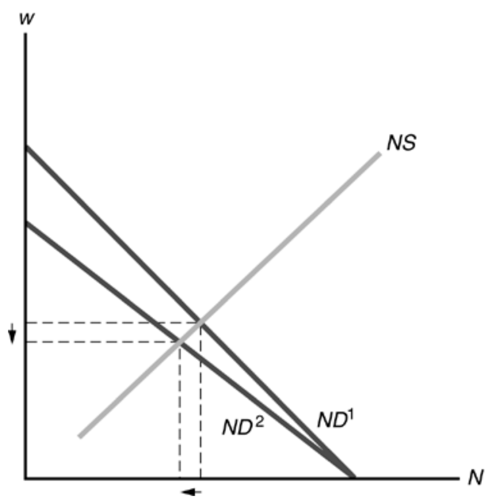

Figure 3.18

6. Yes, it is possible for the unemployment rate and the employment ratio to rise during the same month. For example, suppose the population falls, the labor force is constant, the number of unemployed rises, and the number of employed falls (but by less than the decline in population). Then the unemployment rate rises, since there are more unemployed but the same labor force, but the employment ratio rises, since population declines more than employment does.

Yes, it is possible for the participation rate to fall at the same time that the employment ratio is rising. For example, suppose that population is constant, the labor force declines, employment rises, and unemployment falls. The participation rate falls, since there are fewer people in the labor force from the same population. The employment ratio is rising, since employment rises while population is constant.

7. (a) Since Sally earns $150,000 per year, she is far above the cap, so the Social Security tax doesn't affect her after-tax wage (so there's no substitution effect)—the higher tax only affects her income—and thus has only an income effect. Since both proposals reduce Sally's income by the same amount, she'll increase her labor supply by the same amount under both proposals.

   (b) Under proposal A, Fred's labor supply doesn't change because his tax rate stays the same and he remains below the cap. So there's neither an income effect nor a substitution effect. Under proposal B, the Social Security tax rate Fred faces would rise to 13% from 10.4%, so Fred's after-tax wage rate declines and there's both an income effect and a substitution effect. The income effect leads Fred to work more, since the higher tax leads to a reduction in Fred's income. The substitution effect leads Fred to reduce his supply of labor, since the after-tax wage is lower, so there's less reward to working. Whether Fred will supply more labor or less labor under proposal B thus depends on whether the substitution effect is stronger or weaker than the income effect.