However, an alternative derivation of (24.8) is perhaps more insightful if more involved. As we know from Chapter 9, any increase in s will shift firm a's best response curve out and slide it along the best response curve of firm b. Symmetry and equation (24.2) tell us that response curve has slope -0.5, i.e., a small increase in q_a will lead to a reduction of 0.5 units in q_b. Since the demand curve has slope -1, this implies a consequent price increase of 0.5. Thus, as a first approximation, a small unit increase in q_a will raise the price at which all existing q_a units sell by 0.5, so that the marginal revenue from that small increase is approximately $0.5q_a$. The marginal cost of subsidizing one more unit is of course just s. The optimal subsidy s^* balances the marginal revenue against the marginal cost. With $q_a = (A - c + 2s)/3$, the optimal subsidy must therefore satisfy:

$$s^* = 0.5q_a = \frac{(A - c + 2s)}{6} \tag{24.9}$$

From which it follows that $s^* = \dfrac{A - c}{4}$ just as in equation (24.8).

Two key results may now be derived. First, substitution of the optimal subsidy value s^* from equation (24.8) into the net benefit $NB(s)$ function of equation (24.7) quickly reveals that when done optimally, the net benefit is positive and equal to

$$NB(s^*) = \frac{(A - c)^2}{72} \tag{24.10}$$

Second, substitution of the optimal subsidy s^* into equation (24.3) shows that firm a's output $q_a(s^*)$ is:

$$q_a(s^*) = \frac{A - c}{2} \tag{24.11}$$

This last expression should look familiar to you. It is the output that would be chosen by a Stackelberg leader when both firms have identical unit costs. As we emphasized in Chapter 12 (recall Dixit's (1980) model of entry deterrence), however, achieving the Stackelberg leader first-mover advantage requires the ability to credibly commit to that higher output level. This is the insight of the strategic trade literature. Government intervention—here in the form of a subsidy—acts as such a commitment in a manner that Alexander Hamilton would have readily understood. As a result of that subsidy and the production commitment it enables firm a to make, the additional profit more than covers the subsidy cost and overall benefits are positive for Country A.

24.1 **Practice Problem**

Imagine an international market shared by two firms, each from a different country, A and B. Demand in the market is described by the equation $P = 1000 - Q$. Each firm has a constant marginal cost of $c = 400$.

a. What is the Nash equilibrium output and profit of each firm in the absence of any subsidy?
b. If Country A subsidizes its "national champion" optimally, what is i) firm A's profit? ii) the cost of the subsidy? and iii) the net gain from the subsidy?

24.1.2 Strategic Tariffs and Scale/Scope Economies

The foregoing analysis of a strategic subsidy captures much in the spirit of Alexander Hamilton's goal of assisting the domestic industry. However, because he was interested in raising tax revenue and paying off the debt, Hamilton focused more on protective tariffs to encourage the expansion of domestic manufacturing. As it turns out, the use of tariffs as the strategic weapon actually adds a further dimension to the analysis that is worth exploring.

We again assume a Cournot model with two firms, firm a and firm b, from Country A and Country B, respectively, and assume that each country functions as a separate market, perhaps because the goods produced for A and B are not identical. That is, the firms are competing for the Country A widget market in which demand is described by $Q = A - P$, and the Country B gadget market, in which demand is again described by $Q = A - P$. To simplify the impact of a tariff, we also assume that each firm has a unit cost of not c but $c - s$.

From our earlier work, it is straightforward to work out the equilibrium in each case. Within each country the firms a and b produce and earn profit as shown in Table 24.3 below.

Firm a sells $(A - c + s)/3$ in Country A and also sells $(A - c + s)/3$ in Country B. The same is true for firm b. Now suppose that Country A puts a tariff of s per unit on imports. Effectively, this translates into a cost increase of s for firm b on all units sold in Country A. In other words, firm b now has a cost of c per unit within Country A. From the previous section, we know that this results in a reduction in firm b's output and profit in Country A and a corresponding rise in these values for firm a. If this were the end of the story, the new output and profit configuration would be as described in Table 24.4 below.

Table 24.3 Production and profit in the two-country Cournot game

	Country A		*Country B*	
	Production	*Profit*	*Production*	*Profit*
firm a	$\frac{(A-c+s)}{3}$	$\frac{(A-c+s)^2}{9}$	$\frac{(A-c+s)}{3}$	$\frac{(A-c+s)^2}{9}$
firm b	$\frac{(A-c+s)}{3}$	$\frac{(A-c+s)^2}{9}$	$\frac{(A-c+s)}{3}$	$\frac{(A-c+s)^2}{9}$

Table 24.4 Production and profit in the two-country Cournot game with a tariff on firm b in country A

	Country A		*Country B*	
	Production	*Profit*	*Production*	*Profit*
firm a	$\frac{(A-c+2s)}{3}$	$\frac{(A-c+2s)^2}{9}$	$\frac{(A-c+s)}{3}$	$\frac{(A-c+s)^2}{9}$
firm b	$\frac{(A-c-s)}{3}$	$\frac{(A-c-s)^2}{9}$	$\frac{(A-c+s)}{3}$	$\frac{(A-c+s)^2}{9}$

The outcome described in the table above implies that the tariff does not have any impact on the rivalry between the two firms in Country B. In that country, the two firms produce and earn profit just as before. The tariff so far affects only the market outcomes in Country A.

As Krugman (1986) shows, however, the foregoing results change if there are scale or scope economies. The reduction in firm b's output in Country A is also a reduction in its total output globally. If there are scale or scope effects such that a firm's unit cost rises as its output across the two markets declines, the production decline for firm b will mean that its unit cost is no longer $c - s$ but something higher. Likewise, the expansion in firm a's output may allow it to achieve even lower costs.

To work out the complete equilibrium would require that we fully specify the nature of the scale or scope effects and determine the Cournot equilibrium as those effects grow or diminish. Instead we adopt a convenient short cut here and simply assume that scale effects are exhausted for firm a so that its unit cost remains $c - s$, but that as the result of its output reduction firm b does experience a cost rise to c per unit in both countries. The consequent output and profit levels are shown in Table 24.5 below.

A comparison of Tables 24.5 and 24.3 shows that firm a's total profit has increased by $6s(A - c) + 11s^2$, while total output in Country A has fallen by $2s/3$. Given that aggregate demand in Country A is $Q = A - P$, this means that $2s/3$ measures the rise in price in Country A. Hence, Country A suffers a consumer surplus loss of $2s^2/9$. However, firm a now earns $[2s(A - c) + 3s^2]/9$ more in profit in Country B than it did previously. This is more than enough to compensate for the domestic welfare loss. Moreover, there is the additional profit firm a now earns in its home country that previously went to firm b. The tariff does more than protect domestic production. It acts as a commitment that firm a will be advantaged in Country A and therefore larger globally than its rival firm b. It is therefore a commitment to insure that firm a will have a lower unit cost than firm b. This leads firm b to lose additional market share and profit to firm a in *both* countries A and B."

The commitment role of the tariff merits emphasis. As Hamilton implicitly understood, the tariff allows Country A to insure that firm a will operate on a relatively large scale in its home market. Because that market is an oligopoly, that commitment acts as a non-negotiable claim for a larger share of the domestic oligopoly profit. Credibility of the commitment is cemented by the fact that it also prevents firm b from enjoying scale economies. Hence firm a is also advantaged in Country B further offsetting the tariff cost.

Table 24.5 Production and profit in the two-country Cournot game with a tariff on firm b in country A and scale economies

	Country A		*Country B*	
	Production	*Profit*	*Production*	*Profit*
firm a	$\frac{(A-c+3s)}{3}$	$\frac{(A-c+3s)^2}{9}$	$\frac{(A-c+2s)}{3}$	$\frac{(A-c+2s)^2}{9}$
firm b	$\frac{(A-c-3s)}{3}$	$\frac{(A-c-3s)^2}{9}$	$\frac{(A-c-s)}{3}$	$\frac{(A-c-s)^2}{9}$

Practice Problem 24.2

Solve the foregoing tariff model with demand in each country given by: $Q = 100 - P$, and the constant marginal cost given by $c - s = \$12$. Assume that if country A imposes a tariff of \$2 per unit, the loss in production raises firm b's unit cost to \$14 everywhere. Determine the net change in consumer and producer surplus in Country A as a result of the tarrif.

24.1.3 Strategic R&D Subsidies

One problem with either the direct subsidy or the tariff policy just described is that each violates the international trade laws negotiated by the World Trade Organization (WTO) to promote free, unfettered trading arrangements. As a result, they are likely to lead to punishments and trade sanctions that will undermine their net benefits. We return to consider the WTO and trading policies later. At this point, we wish to explore an alternative and slightly less direct route to assist the domestic firm, namely, to subsidize its R&D.

There are many ways to subsidize R&D. Large grants to universities and hospitals, the provision of information to farmers about crop rotation and other techniques, and the award of production grants that permit firms to work their way down the learning curve may all be viewed as government support for the creation and dissemination of technical information. While each of these may be justified for other reasons, there can be little doubt that each may also provide advantages to domestic firms. American pharmaceutical and bioengineering firms likely benefitted from the research support provided to university medical schools and faculty. American farmers clearly benefitted from the Agriculture Department's Extension Service, and Boeing's strong position in the aircraft market may well reflect the head start it received from developing aircraft for the US military. The same assertions could be made regarding firms in most other countries as well. In general, R&D subsidization of some sort is common. Indeed, this is what makes R&D subsidization so difficult to monitor as an unfair method of trade competition. It is difficult to distinguish policies meant purely to give a domestic firm an advantage over foreign rivals from policies to promote economic growth.

Modeling the impact of a strategic R&D subsidy requires modeling the impact of R&D on the firm's production technology as well as the cost of doing that R&D. This is complicated and we save the details for the Appendix. However, the intuition can be readily understood.

We will continue to assume a Cournot duopoly with quantity competition. When it comes to R&D, we will now make the further assumption that while R&D spending works to lower a firm's unit production cost c, this effect is subject to diminishing returns. As a result, the R&D cost of reducing c grows quickly as one tries to push it lower and lower with more and more R&D. In this plausible scenario, the R&D spending choices for the two firms are, like their output choices, strategic substitutes. As *firm a* increases its R&D spending x_a, firm b's best response is to curtail its own x_b.

The market outcome is now described by Figures 24.1 and 24.2. In the first of these, the best response function for each firm in terms of its R&D is shown by the heavy black curves. In the absence of any subsidies, the Nash equilibrium would be where these curves intersect at A. However, if Country A subsidizes firm a's R&D, its best response curve shifts out as shown by the dashed curve, and the new equilibrium now moves to B. Notice that in this equilibrium, firm b now does less R&D.

Because the subsidy changes the R&D level at both firm a and firm b, it also alters their unit costs and, hence, their equilibrium outputs. Figure 24.2 illustrates these effects.

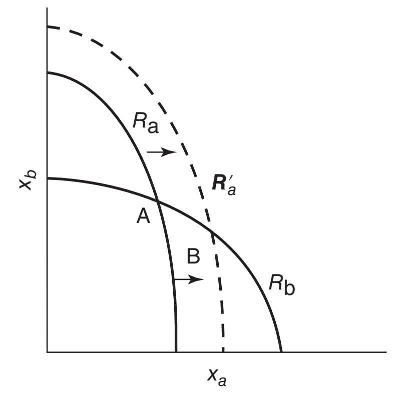

Figure 24.1
Competition in R&D spending levels

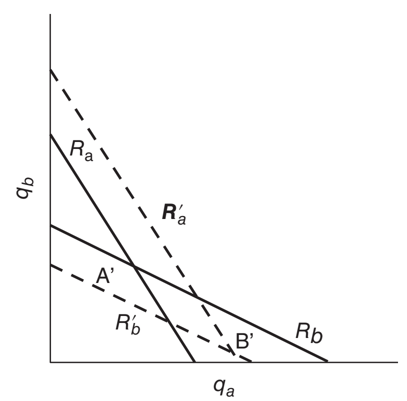

Figure 24.2
Competition in output levels

In the absence of any subsidy, the R&D equilibrium at A in Figure 24.1 would yield symmetric research efforts and therefore identical unit costs at the two firms. In Figure 24.2, the resultant Cournot equilibrium is where the two heavy black best response functions intersect at A'. The subsidy though has a double barrel effect of both lowering firm a's cost and, by way of less R&D, raising firm b's cost. This is shown in Figure 24.2 by the outward shift of firm a's best response function and the inward shift of firm b's best response function. The result is a two-fold assault on firm b's output, which now shrinks dramatically as the equilibrium in Figure 24.2 moves from A' to B'.

24.2 TRADE AGREEMENTS AS COMMITMENT DEVICES

We have now worked through three separate cases in which a country may enjoy net gains by intervening in international markets so as to advantage the domestic firm vis-à-vis foreign rivals. A natural question that arises in this context is why Country B should not react to Country A's intervention by doing the same thing. What happens if both impose tariffs or subsidize domestic firms?

Essentially, these questions point to a deeper level game than the ones we have so far considered. This is the game between the governments of each country in which the variable of strategic choice is either a tariff, or production cost subsidy, or R&D subsidy. In general, the Nash equilibrium of this game has a prisoners' dilemma in which both countries subsidize or impose tariffs to a greater extent than they would if they played cooperatively. Absent any formal agreement mechanism, however, cooperative play is not feasible.

This is where international trade agreements and organizations such as the WTO have become important. By joining such institutions, the member countries pledge themselves not to give in to the short-run temptation of intervening on behalf of domestic firms. Two features make this commitment more credible. First, such organizations act to police and to punish members who violate their free trade promises. In this view, organizations such as the WTO may be analyzed using the same logic that we used to discuss the ability of firms to cooperate in Chapter 14. The necessary elements are an ability to detect violations and then to punish them. In this respect, one feature that is helpful in the case of the WTO is that while violations are typically directed by one country at another, punishment is meted out by all members. Thus, if the United States imposes tariffs or intervenes to aid domestic producers of LCD screens against the Korean giant, Samsung, and if this action is deemed a violation of the WTO agreement, the penalty may include restrictions on US exports to all member nations and not just South Korea.

A second source of credibility is that to some extent, joining the international agreement insulates domestic politicians from political pressure. When pressured by domestic industry representatives for unfair assistance, the domestic authorities can respond by saying that while they would like to help, the rules of membership are clear and "their hands are tied." The strengths of such commitment devices should not be minimized. A central feature of the US Constitution was that it reserved jurisdiction over interstate commerce to the federal government. Prior to the Constitution's adoption, when the US government was organized under the Articles of Confederation, the states had considerable power to levy taxes and otherwise hinder the products of other states in an effort to protect their own. The result was a nightmare web of barriers to trade and inefficiencies as each state tried to protect its industry and raise revenue to pay its debts by taxing the products of out-of-state producers. In this light, the interstate commerce clause may be seen as a conscious effort to bind the states more fully to their commitment to trade freely with each other. Perhaps it is no wonder then that it was that student of commitment, Alexander Hamilton, who was one of the leading advocates for the Constitution's adoption.

24.3 EMPIRICAL APPLICATION: STRATEGIC SUBSIDIES AT THE CANADIAN WHEAT BOARD

We have seen that strategic intervention by a government can, in the case of imperfectly competitive international markets, serve as a commitment that enhances the competitive position of domestic firms. In turn, the additional profit that this allows the domestic firm(s) to earn can more than offset the cost of the intervention, e.g., more than offset the cost of a subsidy to production or research. A compelling example of such intervention may be the case of the Canadian Wheat Board (CWB), as work by Hamilton and Stiegert (2002) reveals.

Reality Checkpoint

Subsidizing the Dream

The international market for commercial jet aircraft is dominated by two firms, Boeing and Airbus (part of the European Aeronautic Defense and Space Company (EADS) N.V group). In addition to producing for the commercial aircraft market, however, both firms have extensive operations supplying equipment for military use, space exploration, and other government-funded activities. Indeed, EADS is partly owned by a consortium of European governments. Hence, it is not surprising that both firms have close governmental relations.

The perception of those ties has historically led each firm to claim that its rival has benefitted from unfair subsidies for research and development. These claims and counterclaims have been litigated at the World Trade Organization (WTO). In the most recent case, Airbus complained that Boeing received explicit subsidies from both the US Defense Department and the National Aeronautics and Space Administration to develop lightweight carbon composite materials that the manufacturer subsequently used in 50 percent of the main structure of its newest, most-fuel efficient jet, the Boeing 787, nicknamed the *Dreamliner*. Ultimately, the WTO agreed finding that the implicit subsidies Boeing received in government contracts since the late 1970s amounted to about $5 billion. This prompted one European official to refer to the 787 as "the Subsidy Liner."

Yet while the finding was a blow to Boeing, its advocates still claimed victory in that the amount of subsidy found by the WTO was much less than that originally alleged by Airbus. Perhaps more importantly, the $5 billion in subsidies the WTO found went to Boeing was much less than the $15 billion that the WTO had earlier found that Airbus had received in grants and below-market interest rate loans in its development of the A380 superjumbo jet. Therefore, both sides have claimed victory.

In both cases, WTO rules require that the firms document new procedures to end the subsidies. Otherwise, the rival's home country can impose tariffs and other trade measures as a punishment. Boeing claims to have done this. Airbus has yet to make a full response. Airbus may have less to worry about though than it seems. Since its commercial introduction, the Boeing 787 has been plagued with technical failures and the airline has currently grounded these aircrafts. Boeing's subsidies may have been funding a pretty scary dream.

Source: C. Drew and N. Clark, "In Appeal, W.T.O. Upholds a Decision against Boeing," *New York Times*, March 12, 2012, p.B7.

The CWB is an example of State Trading Enterprise (STE). STE's are either explicitly government agencies or quasi-public agencies closely associated with government policy designed to control either exports or imports or both of a particular set of commodities. In the case of the CWB, the central commodity is durum wheat for which the CWB has total monopoly power. In brief, the CWB buys wheat from Canadian producers at a specified price w and then acts as the sole exporter of wheat from Canada to the rest of the world. Canadian producers are expected to meet the production demands of the CWB at price w, knowing that the CWB will subsequently distribute the profits from its sales back to the producers based primarily on each producer's share of the production.

A moment's thought will reveal how the CWB payment system may be structured to achieve precisely the subsidy effect discussed earlier in this chapter. By setting w below marginal cost, the input price to the CWB is lowered. The agency's best response function shifts out accordingly with the result that Canadian wheat exports expand while those of other producers shrink. If the market behaves as in our earlier analysis and if w is chosen correctly, then the resultant increase in total profit is more than enough to compensate wheat producers for their initial selling at a price below marginal cost.

Hamilton and Stiegert (2002) collect data on wheat prices ($/ton) and quantities for the period 1972 through 1995, which they use to estimate a model of the world wheat market with more general demand and supply behavior and more than two firms. The underlying intuition of the model, though, is the same as outlined above. These data allow the authors to calculate estimates of both the actual implicit subsidy and the theoretically optimal subsidy in each of the twenty-four years. How well these two values match then provides a test of the extent to which the CWB structured its payments to Canadian wheat producers so as to maximize their net surplus.

We need to note first, however, that our derivation of the optimal implicit subsidy s was based on a standard assumption reflected in all Cournot best response functions of which equation (24.2) is a good example. The standard Cournot best response function for any firm is derived under the assumption that the output of the rivals is given, i.e., that the firm's action will not induce further responses. Another way to say this is that in the standard Cournot game, each firm believes that a change in its own output will map one-for-one into a change in total market output as no other firms will react. In turn, this means that the optimal subsidy we derived is predicated on the assumption that for any one firm $\Delta Q = \Delta q_i$. Of course, this may not be the case. In the wheat market, for example, the CWB may anticipate that its best response will induce further output changes from rivals. This means that any test of the CWB price-setting is really a test that of the assumption that $\Delta Q = \Delta q_C$ as well as a test of strategic subsidization given that assumption. For this reason, Hamilton and Stiegert (2002) structure their analysis so that it also yields an estimate of the parameter λ in the equation:

$$\Delta Q = \lambda \Delta q_c \tag{24.12}$$

Here, λ is the conjectural variations parameter described in Chapter 9. It measures how much the CWB conjectures the production of other exporters will respond to the CWB's choices.

The key results of the Hamilton and Stiegert (2002) analysis are shown in Table 24.6, below. We first show the estimated value of the conjectural variations parameter λ, along with its standard error. We then display the observed and estimated optimal value of the subsidy for each year in the data.

The first thing to notice is that Hamilton and Stiegert (2002) estimate of the conjectural variations parameter λ is very close to 1. In fact, the hypothesis that it is equal to 1 cannot be rejected by the data implying less than fully independent production choices. Thus, we can now turn to comparing the observed subsidy against the hypothetically optimal subsidy assuming that λ is in fact 1 just as the Cournot model predicts.

In this respect, note that while the observed unit subsidy s and the optimal unit subsidy s^* are notably different in a few specific years, they are generally close in most years and also close—judging by the mean and the median—over the entire twenty-four year sample period. Hamilton and Stiegert (2002) test this similarity further using nonparametric tests such as the Wilcoxen signed rank and Spearman coefficient of rank tests that do not assume

Table 24.6 Estimated conjectural variations parameter λ and actual and optimal implicit CWB price subsidies by year

λ (*Complete Sample*) = 1.058 (*Standard Error* < 0.52)

Year	*Observed Subsidy s*	*Optimal Subsidy s**
1972	42.08	14.18
1973	88.22	76.58
1974	74.55	63.82
1975	18.00	32.29
1976	30.22	19.02
1977	16.54	24.60
1978	17.07	12.19
1979	33.82	21.47
1980	0.49	32.43
1981	21.79	18.11
1982	8.74	22.74
1983	17.54	22.46
1984	17.13	15.54
1985	13.66	8.97
1986	13.18	8.36
1987	44.02	13.65
1988	10.11	10.99
1989	9.91	15.94
1990	0.00	13.48
1991	30.61	13.51
1992	28.80	8.88
1993	34.27	32.44
1994	36.04	38.74
1995	17.98	82.29
Mean	**26.03**	**25.95**
Median	**17.99**	**18.56**

the underlying distributions to be normal. Here, again, they cannot reject the null hypothesis that s and s^* are the same over the sample period.

In short, the evidence in Hamilton and Stiegert (2002) is broadly consistent with the view that during the years 1972 through 1995, the CWB structured its payments to Canadian wheat producers so as to subsidize exports implicitly and thereby to appropriate additional rent or surplus from the world wheat market. The observed annual subsidy implicit in the initial below-market price to wheat producers is close to the estimated optimal value each year. It therefore appears that the behavior of the CWB in these years is exactly what strategic trade theory predicts.[2] The implication, then, is that while Canadian consumers may have been hurt by higher prices, the gains to Canadian wheat farmers and to the CWB may have been enough to more than offset consumers' loss.

[2] It is important that the analysis ends in 1995 as that is about the time that the World Trade Organization emerged along with stricter rules on the behavior of State Trading Enterprises.

Summary

Threats or promises can only be effective if the threats are credible, i.e., part of a subgame perfect strategy. In many cases, this credibility can only be obtained by making some commitment that binds the player to carrying out that threat or promise in the event that a rival takes the action that the threat or promise was designed to prevent. Commitment is the key to credibility.

International trade is an area in which understanding the role of commitment can have dramatic implications for public policy. In particular, the economist's traditional admonition that tariffs and other trade interventions will be detrimental to domestic welfare may be overturned when one allows for imperfect competition and therefore a role for strategic commitment. Imperfect completion and economies of scale and scope offer a role for the strategic use of trade barriers and subsidies to domestic firms that enable them to claim more of the surplus from international commerce. Such tactics effectively commit the domestic firm to an aggressive strategy that often results in a gain similar to a first-mover advantage.

Unfortunately, other countries will likely pursue the same policies and the non-cooperative outcome of this game between nations will typically exhibit a prisoners' dilemma feature in which both countries are worse off than if neither had intervened. In this light, trade institutions like the WTO can be seen as a mechanism by which countries truly commit to their free trade promises. Yet this effort may ultimately trigger retaliation. The success achieved by the US adoption of the interstate commerce clause and by institutions such as the WTO suggests that a commitment to permit free competition may be the best policy both in theory and in practice.

Problems

1. Assume a two-country duopoly market where each country, A and B, is represented by a national champion—firm a for Country A and firm *b* for Country B. Inverse demand is given by: $P = 100 - Q$ and the marginal cost of each firm is $c_a = c_b = 400$.

   a. Determine the equilibrium profit for each firm if there is no subsidy.
   b. Determine the profit to each firm if Country A optimally subsidizes firm *a*.
   c. Determine the profit to each firm if both Country A and Country B offer their champion firms the optimal subsidy derived in 1c.
   d. In 1c above is the cost of the subsidy covered by the change in profit that results from the no-subsidy setting?

2. California Instruments manufactures musical equipment for the North American market. Its major rival is H. Hill Products located in Iowa. Demand facing the two firm is described by: $P = 100 - Q$, and each has a marginal cost of 20.

3. Consider the "Battle of the Sexes" technology game in which each of the two firms agree that compatibility is best but differ over which technology should be the standard as shown below. Firm 1 is from Country 1 and firm 2 is from Country 2. What sort of strategies might Country 1 choose in order to commit to its particular technology?

		Firm 2	
		Technology 1	Technology 2
Firm 1	Technology 1	8, 5	3, 3
	Technology 2	3, 3	4, 10

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Appendix

Formal Analysis of Research Subsidies & International Trade

Here, we present formally the strategic subsidy model originally due to Spencer and Brander (1983). We again assume a Cournot duopoly in which there is now just one international market with inverse demand $P = A - Q$. The output and profit of firm a and firm b initially are:

$$q_a = \frac{(A - 2c_a + c_b)}{3}; q_b = \frac{(A + c_a - 2c_b)}{3} \tag{24.A1}$$

$$\pi_a = \frac{(A - 2c_a + c_b)^2}{9}; \pi_b = \frac{(A + c_a - 2c_b)^2}{9} \tag{24.A2}$$

As in the Dasgupta and Stiglitz (1980) model (Chapter 20), each firm's unit cost c is a function of its R&D spending x, i.e., $c = c(x)$, with $c'(x_a) < 0$ and $c''(x_a) < 0$. We therefore rewrite equations (24.A1) and (24.A2) as follows:

$$q_a = \frac{[A - 2c(x_a) + c(x_b)]}{3}; q_b = \frac{[A + c(x_a) - 2c(x_b)]}{3} \tag{24.A3}$$

$$\pi_a = \frac{[A - 2c(x_a) + c(x_b)]^2}{9} - x_a; \pi_b = \frac{[A + c(x_a) - 2c(x_b)]^2}{9} - x_b \tag{24.A4}$$

Because each firm's unit cost, output, and profit depends on its R&D spending, that spending is the ultimate strategic variable. Differentiating equation (24.A4) with respect to x_a yields the following first-order condition, which implicitly defines a's best R&D response function:

$$[A - 2c(x_a) + c(x_b)]c'(x_a) = -\frac{9}{4} \tag{24.A5}$$

The slope of the implicit best response function dx_a/dx_b is:

$$\frac{dx_a}{dx_b} = \frac{-c'(x_a)c'(x_b)}{[A - 2c(x_a) + c(x_b)]c''(x_a) - 2[c'(x_a)]^2} \tag{24.A6}$$

The numerator of equation (24.A6) is definitely negative. The denominator will be positive so long as $c''(x_a)$ is relatively large, which we assume here. Hence, the best response function for firm a (and by symmetry firm b) slopes downward in a curve as shown in Figure 24.1. The positions of the output best response functions, shown in Figure 24.2 depend on the unit cost of each firm and therefore the R&D equilibrium. An R&D subsidy in Country A, shifts out firm a's best R&D response and commits the firm to a level of R&D that it could not credibly threaten on its own. Because R&D levels are strategic substitutes, firm b now does less R&D. The resultant increase in the equilibrium value of x_a lowers c_a. The decrease in x_b has the opposite effect for firm b. Output market equilibrium moves from A' to B'. Spencer and Brander (1983) show that the optimal R&D subsidy is always positive.

Answers to Practice Problems

Chapter 1

No Practice Problems in this chapter.

Chapter 2

2.1 a. Profit Maximization implies MC $= 2q + 10 = P$. Hence, $q = (P - 10)/2$.
   b. With 50 firms, horizontal summation of the individual marginal cost curves yields: $Q^S = 50(P - 10)/2 = 25P - 250$.
   c. Equilibrium: $P = \$30$ and $Q = 500$.
   d. $q = (P - 10)/2 = 10$. Revenue $= Pq = \$300$. Total cost $= 100 + q^2 + 10q = \$300$. Profit $= 0$.

2.2 a. Inverse demand curve is: $P = (6{,}000 - 9Q)/50$. Hence, MR $= 120 - (18Q/50) = 120 - (9Q/25)$.
   b. MC $= 10 + Q/25$. Equate with MR to obtain: $Q = 275$. At this output, $P = \$70.50$.
   c. Total revenue = \$19,387.50. Each plant produces 5.5 units and incurs a total cost of \$185.25. Each plant earns a revenue of \$387.75. Profit at each plant is \$202.50.

2.3 a. Consumer surplus is the area of the triangle above the equilibrium price but below the demand curve $= (1/2)(\$120 - \$30)500 = \$22{,}500$. Producer surplus is the area of the triangle below the equilibrium price but above the supply curve $= (1/2)(\$30 - \$10)500 = \$5{,}000$. Total Surplus $= \$22{,}500 + \$5{,}000 = \$27{,}500$. Note: Surplus is a marginal concept. Producer fixed cost is not considered.
   b. Total surplus falls by area of deadweight triangle. Height of triangle is given by reduction in output which is $500 - 275 = 225$. Marginal cost at $Q = 275$ is \$21. Base of triangle is given by price less marginal $= \$70.50 - \$21 = \$59.50$. So deadweight triangle has area equal to: $= (1/2)(\$49.50)225$ or \$5,568.75. The new total surplus is the competitive surplus less the deadweight loss $= \$27{,}500 - \$5568.75 = \$21{,}931.25$.

2.4 a. Efficiency requires $P = MC$. Marginal cost is \$10. So, $P = \$10$ ($Q = 30$) is efficient outcome.
   b. Profit maximization requires setting the monopoly price. Because inverse demand is $P = 25 - Q/2$, MR $= 25 - Q$. Equating MC and MR then yields $10 = 25 - Q$ or $Q = 15$ and $P = \$17.5$ is profit maximizing output and price.
   c. Welfare loss is WL $= 0.5(\$17.5 - \$10)(30 - 15) = \$56.25$.

2.5 a. Present value of incremental cash flows from driving out Loew $= -\$100{,}000 + \dfrac{R}{1-R}$ $\$10{,}000 = -\$16{,}629$. Driving out Loew is not a good investment.

b. Present value of incremental cash flows from buying Loew $= -\$80{,}000 + \dfrac{R}{1-R}$ $\$10{,}000 = \$3{,}330$. This is a good investment.

Chapter 3

3.1 a. $CR4^A = 70\%$; $CR4^B = 76\%$. $HI^A = 2698$; $HI^B = 1660$. Industry A has one firm that dominates the industry. Industry B has five firms that control 90 percent of the production. But these five firms may compete fiercely. The Herfindahl-Hirschman index seems to better capture the greater potential for monopoly power in Industry A.

b. With the merger of the three, second largest firms in Industry A, the new values are: $CR4^A = 80\%$; $HI = 2992$. Both measures rise.

Chapter 4

4.1 In this case, we have discrete and not continuous changes in output. Hence we have to use the average value of marginal cost at output 11. This is calculated as the average of the marginal cost of increasing output from 10 to 11 units ($137) and the marginal cost of increasing output from 11 to 12 units ($165), which is just $151. Average or unit cost at 11 units is equal to $\$1407/11 = \$127.91$. Hence, $S = AC/MC = \$127.91/151 = 0.847 \approx 0.85$.

4.2 a. $AC = TC/q = 50/q + 2 + 0.5q$. $AC(q = 4) = 16.5$; $AC(q = 8) = 12.25$; $AC(q = 10) = 12$; $AC(q = 12) = 12.167$; $AC(q = 15) = 12.833$.

b. $MC = \Delta TC$ per unit change. For decreases: $\Delta TC = 50 + 2q + 0.5q^2 - [50 + 2(q - 1) + 0.5(q - 1)^2] = 2 + q - 0.5$. For increases: $\Delta TC = 50 + 2(q + 1) + 0.5(q + 1)^2 - [50 + 2q + 0.5q^2] = 2 + q + 0.5$. The average of these two value is $2 + q$.

c. $S > 1$ for $q < 10$; $S = 1$ for $q = 10$; $S < 1$ for $q > 10$.

Chapter 5

5.1 a. Total moviegoers is the sum of daytime and evening moviegoers. Note that we assume the price is the same in the daytime and in the evening. This allows us to derive an overall demand function for daytime and evening, which is $Q_{\text{Total}} = 100 - 10P_D + 140 - 10P_E = 240 - 20P$. The monopolist maximizes the profit function $\Pi = Q(P - c) = (240 - 20P)(P - 3)$, where $d\Pi/dP = 300 - 40P = 0$. Solving leads to $P = 7.5$, $Q_D = 25$, $Q_E = 65$, and $\Pi = 405$.

b. With third-degree price discrimination the monopolist treats daytime and evening as two separate markets, so P_D and P_E can vary. Profit for the daytime is $\Pi_D = Q_D(P_D - c)$ and profit for the evening is $\Pi_E = Q_E(P_E - c)$. Plugging in the demand equations, we get $\Pi_D = (100 - 10P_D)(P_D - 3)$ and $\Pi_E = (140 - 10P_E)(P_E - 3)$. Setting $d\Pi_D/dP_D = 0$ and $d\Pi_E/dP_E = 0$, we find $P_D = 6.5$, $P_E = 8.5$, $Q_D = 35$, $Q_E = 55$, $\Pi_D = 122.5$, $\Pi_E = 302.5$. Total attendance is 90 as in part (a), but aggregate profit is now 425.

5.2 a. The chowder is being sold in three distinct markets. To solve, we can find separate equilibria for each market. First define the profit function for each market, which is just $\Pi_i = Q_i(P_i - c_i)$. Substitute in the demand equation and the marginal cost for each market. For Boston this is $\Pi_B = (10{,}000 - 1{,}000P_B)(P_B - 1)$, for New York it is $\Pi_{NY} = (20{,}000 - 2{,}000P_{NY})(P_{NY} - 2)$, and for Washington it is $\Pi_W = (15{,}000 - 1{,}500P_W)(P_W - 3)$. Take the first derivative $d\Pi_i/dP_i$ and set it equal to 0 to find the profit maximizing prices. For Boston this is \$5.50, for New York it is \$6, and for Washington it is \$6.50. Plugging price back into the demand equation gives the equilibrium daily quantity. These are $Q_B = 4500$, $Q_{NY} = 8000$, $Q_W = 5250$. Quantities are given in units per day.

b. Plug price and quantity back into the profit equations to find the daily profit in each market. $\Pi_B = \$20{,}250$, $\Pi_{NY} = \$32{,}000$, $\Pi_W = \$18{,}375$.

5.3 Total welfare is the sum of consumer surplus and producer surplus (profit). Consumer surplus is the total amount "saved" by all consumers who paid less than they were willing to pay for the movie. Geometrically, on a graph of price and quantity in the movie market, consumer surplus is the triangle bounded on the left by the y-axis (the line $Q = 0$), on top by the demand curve, and on the bottom by the price curve ($P = P$).

In the non-discriminatory market, the theater's profit $\Pi = 405$. Inverse demand curves are $P_D = 10 - Q_D/10$ and $P_E = 14 - Q_E/10$. From these curves it is clear that the reservation price of the consumers with greatest willingness to pay in the daytime and evening markets are 10 and 14, respectively. The consumer surplus is sum of the areas of the triangles with heights $(10 - 7.5)$ and $(14 - 7.5)$ and bases 25 and 65. Total consumer surplus is $\frac{1}{2}(10 - 7.5)(25) + \frac{1}{2}(14 - 7.5)(65) = 242.5$. Total surplus is $405 + 242.5 = \$647.5$.

In the discriminatory market, consumer surplus is once again the sum of the consumer surpluses in the daytime and evening markets. Total consumer surplus is $\frac{1}{2}(10 - 6.5)(35) + \frac{1}{2}(14 - 8.5)(55) = 212.5$. Total surplus is $425 + 212.5 = 637.5$, which is \$10 less than the non-discriminatory total surplus.

Chapter 6

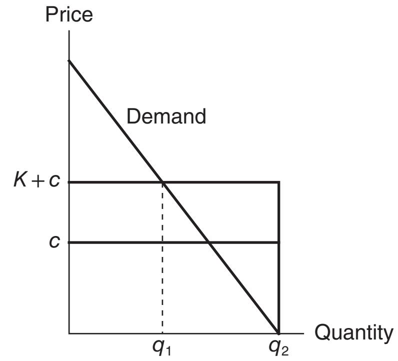
6.1 a. Because the demand curve is linear, it must be the line that passes through the two points, (5, \$40) and (10, \$25). The slope of this line is $(\$40 - \$25)/(5 - 10) = -3$, so $P = -3Q + b$. Plug in a point and solve for b to find the inverse demand equation, $P = 55 - 3Q$. The reservation price of the consumer with the greatest willingness to pay is \$55, the price when quantity is 0. At this point, the good is at its scarcest, so only the consumer with greatest willingness to pay will buy the good.

b. We can think of total demand as being the sum of demand for a first unit and demand for a second unit. Because every consumer is willing to pay \$8 less for the second unit, the demand curve for a second unit is just the demand for the first unit shifted down by \$8, or $P = 47 - 3Q_2$. Plugging in $P = 34$, we find 7 first units will be sold and 4.333 second units will be sold, for a total of 11.333 units sold.

6.2 a. The price per ride should be set at marginal costs, which is $k + c$ so $p = k + c$. The number of rides bought at this price is q_1. The admission fee T should be set to consumer surplus at this price p, which is the area under the demand curve and above $k + c$.

b. The price per ride $p = 0$ at which price the number of rides bought is q_2. The admission fee should be set to consumer surplus at this price, which is the total area under the demand curve.

c. In Policy A, the park's profit per customer is T. The price per ride just covers costs. In Policy B, the park's profit per customer is T′ minus the cost of q_2 rides. However, the cost of each ride is only c, because there is no need to issue tickets. Total profit will be the area under the demand curve minus a box of dimensions c by q_2. Which policy is better is uncertain without further information. Policy B gains profit whose area is the trapezoid bounded by c, $k + c$, and the demand function, but loses profit given by the triangle above the demand curve and below c.



6.3 a.

Low Demand Customers			*High Demand Customers*			
Number of Units in the Package	*Charge for the Package**	*Profit per Package*	*Consumer Surplus from Low-Demand Package*	*Maximum Willingness to Pay for 12 units*	*Charge for Package of 12 Units*	*Profit from Each Package of 12 Units*
0	0	0	0	$120.00	$120.00	$72.00
1	$11.50	$7.50	$4.00	$120.00	$116.00	$68.00
2	$22.00	$14.00	$8.00	$120.00	$112.00	$64.00
3	$31.50	$19.50	$12.00	$120.00	$108.00	$60.00
4	$40.00	$24.00	$16.00	$120.00	$104.00	$56.00
5	$47.50	$27.50	$20.00	$120.00	$100.00	$52.00
6	$54.00	$30.00	$24.00	$120.00	$96.00	$48.00
7	$59.50	$31.50	$28.00	$120.00	$92.00	$44.00
8	$64.00	$32.00	$32.00	$120.00	$88.00	$40.00
9	$67.50	$31.50	$36.00	$120.00	$84.00	$36.00
10	$70.00	$30.00	$40.00	$120.00	$80.00	$32.00
11	$71.50	$27.50	$44.00	$120.00	$76.00	$28.00
12	$72.00	$24.00	$48.00	$120.00	$72.00	$24.00

b. If the number of high- and low-demand customers is the same, then for each high-demand customer there is one low-demand customer. Thus, for each pair, the profit is profit from a low-demand package plus profit from a high-demand package. This sum is greatest when the low-demand package has 4 units and the high-demand package has 12 units, so that combined profit is $\$24 + \$56 = \$80$.

c. For each high-demand customer, there are now two low-demand customers. We want to pick the low-demand package to maximize 2^*profit low + profit high. This is maximized when the low-demand package has 6 units, so the profit from 2 low-demand customers and 1 high-demand customer is $108.

d. From the table, the profit maximizing prices would be $54 for the low-demand package, and $120 for the high-demand package. We want to know at what ratio the profit from only selling the high-demand package exceeds that of selling the high- and low-demand packages. This is equivalent to asking when $\$72^* N_{\text{High}} > \$44^* N_{\text{High}} + \$31.50 \times N_{\text{Low}}$. This equality reduces to $N_{\text{High}}/N_{\text{Low}} > 1.125$. Therefore, the monopolist should only offer the high-demand package when the ratio of high-demand to low-demand customers is greater than 1.125.

Chapter 7

7.1 He should locate in the middle, where he will have the greatest access to consumers. Consumers will buy from Henry as long as the price plus the travel cost is less than the reservation price, or $P + .5d < 10$, where d is the distance from Henry's in tenths of a mile. The marginal consumer will be located where $P + .5\underline{d} = 10$, or $\underline{d} = 20 - 2P$. The number of customers is just $2\underline{d}$, because people come to Henry's from both directions. However, $2\underline{d}$ cannot exceed 21, because that is the maximum number of people in the town. Henry's profit is $\Pi = 2\underline{d}\,(P - c) = 2(20 - 2P)(P - 2)$. To maximize profit, we set $d\Pi/dP = 0$ and solve for P, which in this case is $P = \$6$. At this price, $\underline{d}$ is 8 so the total number of customers supplied is 16, and $\Pi = \$64$.

With the mobile smithy, Henry can charge every customer their \$10 reservation price, but the travel cost of \$0.75 per tenth of a mile cuts into his profits. Henry will visit consumers as long as $.75^{*}d + 2 < 10$, so $\underline{d} = 10.67$. This would imply Henry would service 21.33 customers, but because there are only 21 customers, Henry just serves everyone in the town. He earns \$10 in revenue from the person at his position, \$9.25 from the two next nearest consumers, \$8.50 from the two second-nearest consumers … giving him revenue minus transport costs of $\$10.00 + 2(9.25 + 8.50 + 7.75 + \ldots + 2.50) = \$127.50$ and profit of $\$125.50 - \$42 = \$85.50$. The profit from traveling is clearly greater than the profit from staying in the same place, so Henry should travel.

7.2 a. The demand curve for a given quality is a line with slope $-1/z$, crossing the y-axis at $P = 4$. As z increases, the lines become shallower as the slope gets closer to 0, but always cross the y-axis at the same point.

b. For $z = 1$, $P = 4 - Q$ and $C = 1$. Profit $\Pi = Q(4 - Q) - 1$. The profit maximizing output is $Q = 2$. For $z = 2$, $P = 4 - Q/2$ and $C = 4$. Profit $\Pi = Q(4 - Q/2) - 4$. The profit maximizing output is $Q = 4$. For $z = 3$, $P = 4 - Q/3$ and $C = 9$. Profit $\Pi = Q(4 - Q/3) - 9$. The profit maximizing output is $Q = 6$.

c. For $z = 1$, $P = 2$ and $\Pi = 3$. For $z = 2$, $P = 2$ and $\Pi = 4$. For $z = 3$, $P = 2$ and $\Pi = 3$. The quality choice of $z = 2$ leads to the highest profits.

7.3 a. Both type A and type B customers are willing to pay more as quality z increases. The firm should set z as high as possible, so $z = 2$. The firm should then set price to extract all the indirect utility, so $P_A = 20(2 - \underline{z}_1)$ and $P_B = 20$.

b. The firm should offer two products only if $20N_a > 10(N_a + N_b)$, or $N_a > N_b$. We know $N_a = \eta N$ and $N_b = (1 - \eta)N$. Substituting in, we see that the firm should offer two products only if $\eta > 1/2$. If this is the case, the firm should offer a high-quality and a low-quality product. Quality for type A $z_a = 2$, and quality for type B $z_b = 20\, z_1/(20 - 10) = 2z_1$. $P_a = 20(2 - \underline{z}_1)$ and $P_b = 20^{*}10\underline{z}_1/(20 - 10) = 20\underline{z}_1$. For the $\eta < 1/2$ case, the firm produces only one good and $z_a = z_b = 2$. The firm will price to sell to both types of consumers.

c. If $\underline{z}_1 = 0$, then the only restriction on type A customers is that they will only buy a product whose quality is greater than 0. This restriction is implicit for type B customers as well. Profits are still increasing in z, though, so the firm should sell only one product at quality $z = 2$. At this quality, type A customers are willing to pay \$40 and type B customers are willing to pay \$20. The price should be $P = \$40$ if $40\eta N > 20(1 - \eta)N + 20N$, or $\eta > 2/3$. If $\eta < 2/3$, the price should be $P = \$20$.

Chapter 8

8.1 a. The cable operator should set the price to maximize profits from each service. The profit maximizing prices are \$11 for the Basic Service and \$15 for the Disney Channel. If the price for the Basic Service is \$11, then families, hotels, and pensioners subscribe, and the cable operator makes profit $\Pi = 11^*3 - 3^*3 = 24$. If the price for the Disney Channel is \$15, then students, schools, and young adults subscribe, and profit is $\Pi = 15^*3 - 3^*3 = 36$.

b. The bundled service is the Basic Service and the Disney Channel together. Notice that the reservation prices for the bundled service for students, families, hotels, schools, young adults, and pensioners, are respectively \$20, \$20, \$20, \$20, \$17, and \$17. Thus, the price of the bundle should be \$20. The prices of individual items must be \$17, so that young adults and pensioners will still buy the individual services. The profit from mixed bundling is $\Pi = 20^*4 + 17^*2 - 8^*3 - 2^*3 = \$84$. Students, families, hotels, and schools buy the bundled service. Young adults only buy Disney, and pensioners only buy Basic. The cable company is clearly better off with the mixed bundling strategy.

c. The best that the cable operator can do with mixed bundling is price the bundle at \$20 and the individual services at \$17, as in part (b). This generates zero profit from sales of the bundle, because the marginal cost of the bundle is \$20 and \$7 each from sales of Disney to young adults and Basic Service to pensioners, giving a total profit from mixed bundling of \$14. The best that the cable operator can do is price the Basic Service at \$14, selling this to hotels and pensioners, and the Disney Channel at \$15, selling this to students, schools and young adults. Profit from this strategy is $\Pi = 14^*2 - 2^*10 + 15^*3 - 3^*10 = \$23$.

8.2 If film is sold separately from the camera, then the price charged to low- and high-demand customers must be the same. We can find the overall demand $Q_{\text{Total}} = Q_{\text{High}} + Q_{\text{Low}} = 28 - 2P$. Notice the profit is composed of two parts: Profit from the film and profit from leasing the camera. The profit from film is $\Pi_{\text{film}} = 1000^*(16 - P)(P - 2) + 1000^*(12 - P)(P - 2)$. The fee for leasing the camera is what would have been consumer surplus for the low-demand customers, but all 2,000 customers now have to pay it, so $\Pi_{\text{camera}} = 2000^*\,{}^1\!/\!_2(12 - P)^2$. Total profit is $\Pi = 1000(-P^2 + 8P + 88)$, so $d\Pi/dP = 1000(-2P + 8) = 0$, and $P = 4$.

With the 8- and 14-shot varieties, there is no charge for film and all profit comes from the lease. The 8-shot camera lease must be priced so as to leave no surplus for the low-demand customers but be less attractive to high-demand customers than the 14-shot variety. Likewise, the 14-shot variety must not generate surplus for the low-demand customers, and must be attractive to high-demand customers. When the low-demand customers take 8 shots, they are effectively paying a price of \$4 per shot, and are receiving \$32 in surplus. Thus the price of the 8 shot camera should be $\$32 + \$4^*8 = \$64$. At this price, all of the consumer surplus is extracted from the low-demand customers and turned into profit. However, high-demand customers can buy this package and get $\$8^*8 + \$32 - \$64 = \$32$ of surplus, because 8 shots are worth \$8 apiece to a high-demand customer. That means that the 14-shot camera must be priced to leave high-demand customers with at least \$32 of surplus if they are to choose it over the 8-shot. 14 shots are worth \$2 apiece to the high-demand customer, and after paying $\$2^*14$ they also get \$98 of consumer surplus. Therefore, the price for the 14-shot should be just less than $\$98 + \$2^*14 - \$32 = \$94$, so the 14-shot should be priced at \$93.99 to ensure the high-demand customers will buy. Notice that the high-demand customer still makes \$32.01 of consumer surplus from buying the 14-shot camera. Profit is $\Pi = 1000^*(\$64 - 8^*\$2) + 1000^*(\$93.99 - 14^*\$2) = \$113{,}990$.

a. If there are 1,000 low-demand customers and N_h high-demand customers, then from the text we know the profit from selling the 14-shot and 10-shot varieties is $\Pi = 1000^*(\$70 - 10^*\$2) + N_h{}^*(\$88 - 14^*\$2) = \$50{,}000 + N_h{}^*\$60$. If only the 14-shot is offered, then cameras are only sold to the high-demand customers, but the price does not have to be discounted to make sure there is at least \$32 of surplus, so profit is $\Pi = N_h{}^*(\$126 - 14^*\$2)$. Rowling will only sell the 14-shot variety if $98N_h > 50000 + 60N_h$, which is true when $N_h > \approx 1316$.

b. For the 14-shot and 8-shot varieties, profit from selling the 14-shot and 8-shot is $\Pi = 1000^*(\$64 - 8^*\$2) + N_h{}^*(\$93.99 - 14^*\$2) = \$48{,}000 + N_h{}^*\$65.99$. If only the 14-shot is offered, then once again the price does not have to be discounted to make sure there is at least \$32 of surplus, so profit is $\Pi = N_h{}^*(\$126 - 14^*\$2)$. Rowling will only sell the 14-shot variety of $98N_h > 48000 + 65.99N_h$, which is true when $N_h >\approx 1500$.

Chapter 9

9.1 The unique Nash equilibrium is: (Suspense, Suspense). In each of the other three possible outcomes (Romance, Romance), (Romance, Suspense), and (Suspense, Romance), at least one firm has an incentive to switch its strategy.

9.2 Best Response: $q_1 = 22.5 - q_2/2$, and vise-versa for q_2. Hence, $q_1 = q_2 = 15$. $Q = 30$; $P = \$40$; and $\pi_1 = \pi_2 = \$450$.

9.3 Best response function for Untel: $q_U = 2.5 - q_C/2$; best response for Cyrox: $q_C = 2 - q_U/2$. $q_C = 1$; $q_U = 2$; $Q = 3$; $P = \$60$; $\pi_C = \$20$ million; $\pi_U = \$80$ million. If $c_C = \$20$, then $q_1 = q_2 = 1.67$; $P = \$53.33$. Hence, $\Pi_U = \Pi_C = \$55.55$ million.

Chapter 10

10.1 a. Best response function for q_1 is: $q_1 = 45 - q_2/2$. By symmetry: $q_2 = 45 - q_1/2$. Hence, in equilibrium: $q_1 = q_2 = 30$. Therefore, market price is: $P = \$20 - \$Q/5 = \$8$. $\pi_1 = \pi_2 = \$180$.

b. $P_1 = P_2 = P = \$2$; and $\pi_1 = \pi_2 = 0$.

10.2 Market output $Q = q_S + q_R$. At price $P = \$110$, $Q = 2400$, which is the combined capacity of the two resorts. If Pepall Ridge sets a price $p_{SR} = \$110$, the residual demand curve for Snow Richards is $Q = 8000 - 60p_{SR}$, or $p_{SR} = 133.33 - Q/60$. The marginal revenue curve is $\text{MR} = 133.33 - Q/30$. On the interval $0 \le Q \le 1400$, marginal revenue is greater than marginal cost, so Snow Richards would increase production to its capacity of 1400. Conversely, if Snow Richards sets its price $p_{SR} = \$110$, the residual demand curve facing Pepall Ridge is $Q = 7600 - 60P$, or $P = 126.67 - Q/60$. The marginal revenue curve is $\text{MR} = 126.67 - Q/30$. Marginal revenue is greater than marginal cost on the interval $0 \le Q \le 1000$, so Pepall Ridge will increase production to its capacity of 1,000. Therefore, in the capacity constrained Nash equilibrium: $p_S = p_R = \$110$; $q_{PR} = 1000$; $q_{SR} = 1400$; and $\pi_{PR} = (\$110 - \$10) \times 1000 = \$100{,}000$; $\pi_{SR} = (\$110 - \$10) \times 1400 = \$140{,}000$.

10.3 a. Assume the entire market is served. Best response function for Cheap Cuts: $p_{CC} = \dfrac{p_R + c_{CC} + t}{2}$. Likewise, best response function for the Ritz is: $p_R = \dfrac{p_{CC} + c_R + t}{2}$. With $t = \$5$ and $c_{CC} = \$10$, Cheap-Cuts has a best-response function of $p_{cc} = 0.5p_R + \$7.50$. In contrast, The Ritz has a best-response function given by: $p_R = 0.5p_{CC} + \$12.50$. For every \$1 in one firm's unit cost the rival's optimal price rises by 50 cents.

b. Equilibrium prices: $p_{CC} = t + \frac{2}{3}c_{CC} + \frac{1}{3}c_R = \$18.33$; $p_r = t + \frac{1}{3}c_{CC} + \frac{2}{3}c_R = \$21.67$. When the two firms had the same unit cost $c = 10$, then $p_{CC} = p_R = \$15$. Prices rise now because c_R has risen and this induces a rise in p_R. In turn, because prices are strategic complements, the rise in p_R permits a similar rise in p_{CC}.

Chapter 11

11.1 a. $q_2 = 70 - q_1/2$.

b. $q_1 = 70$; $q_2 = 35$; $P = \$95$; profit to firm 1(leader) $= \$2{,}450$; profit to firm 2(follower) $= \$1{,}225$.

c. $q_1 = q_2 = 46.67$; $Q = 93.33$; $P = \$106.67$. Profit to firm1 = profit to firm2 = \$2,177.77. Firm 1 loses and firm 2 gains as game becomes Cournot rather than Stackelberg. Consumers enjoy more output and lower prices under Stackelberg.

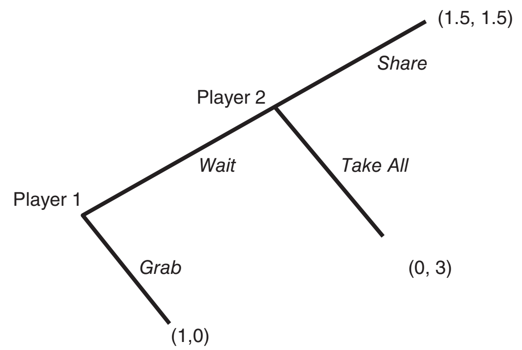
11.2 a. West End will be on its best response function: $p_{WE} = (p_{EE} + c + t)/2$. Demand for East End is: $p_{EE} = (p_{WE} - p_{EE} + t)N/2t$. Substitution and profit maximization then yields: $p_{EE} = c + 3t/2$ while $p_{WE} = c + 5t/4$, or: $p_{EE} = \$17.50$ and $p_{WE} = \$16.25$. Because of its higher price, East End will serve only $3/8$ of the 100 potential customers or 37.5. It earns a profit of $\$7.5 \times 37.5 = \$281.25$. West End serves 62.5 customers and earns a profit of $\$6.25 \times 62.5 = \$390.63$.

b. Prices in this sequential price game are higher than they are in the simultaneous game. Prices are strategic complements. With sequential price setting, the firms can exploit this complementarity and coordinate prices to some extent. Note, however, that going first is a disadvantage in this game. While both firms earn more profit than when play is simultaneous, the firm setting its price second earns the most.

11.3 a.

		Player 2	
		Take All	**Share**
Player 1	**Wait**	(0, 3)	(1.5, 1.5)
	Grab	(1, 0)	

b.



c. Take All is a dominant strategy for Player 2. The promise to play Share is not credible. Anticipating this, Player 1 will Grab the dollar.

Chapter 12

12.1 a. Entrant's residual demand described by: $q = (100 - Q_0) - P$ or, in inverse form: $P = (100 - Q_0) - q$.

b. $q = 30 - Q_0/2$.

c. Entrant profit $= (P - c)q - 100 = [100 - Q_0 - q - 40]q - 100$ Substituting in for q, entrant profit $= (30 - Q_0/2)^2 - 100 = 0$ if entry is to be deterred. $Q_0 = 40$, which implies that the price with optimal production by the entrant $[q = 30 - Q_0/2] = 10$, is $P = \$50$. The entrant will then earn only \$10 on each of its 10 units, leaving no profit after the \$100 sunk cost. So, the limit output is $Q = \overline{Q} = 40$ as this output removes any incentive to enter.

12.2 a. Because inverse demand is $P = 120 - (q_1 + q_2)$, the incumbent's marginal revenue is $MR_1 = 120 - q_2 - 2q_1$. the incumbent's marginal cost for output less than $\overline{k}_1$ is 30, hence, equating marginal revenue and marginal cost yields its best response function for this range of output of: $q_1 = 90/2 - q_2/2 = 45 - q_2/2$. For output greater than or equal to

$\overline{K}_1$, the incumbent's marginal cost is 60. Hence, equating marginal revenue and marginal cost for this range of output, yields a best response of: $q_1 = 30 - q_2/2$.

b. The entrant's marginal revenue is likewise: $MR_2 = 120 - q_1 - 2q_2$. However, the entrant's marginal cost is always 60. So, its best response function is always $q_2 = 30 - q_1/2$.

c. For monopoly, profit $= (P - c)q_1 - 30K_1 - \$200 = (120 - q_1 - 30)q_1 - 30K_1 - \$200 = (90 - q_1)q_1 - 30K_1 - \$200$. However, a monopoly firm will not keep capacity unused so long as MR > MC, so it will choose K such that $K_1 = q_1$. Hence, profit $= (90 - q_I)q_I - 30q_I - 200 = (60 - q_I)q_I - \$200$. Maximization then yields, $60 = 2q_1$ or $q_1 = 30$. Entrant's best response implies that if $q_1 = 30, q_2 = 15$. Total output = 45. Price = \$75. Incumbent profit = \$(75 − 30)30 − \$30 × 30 − \$200 = \$250. Entrant's profit = \$(75 − 60)15 − \$200 = \$25.

d. With $K_1 = 32 =$ committed value of q_1, then entrant's best response is $q_2 = 16$. Total output = 48 and price is \$72. Entrant's profit after entry cost is: (\$72 − \$60) × 16 = \$192. Fixed cost is \$200, so net profit is \$192 − \$200 < 0. Because the entrant cannot earn a positive profit, there will be no entry. The incumbent will produce at capacity because at q_1 and no rival, marginal revenue at $K_1 = 32 = q_1$, *is* \$56 > marginal cost = \$30. However, beyond that output of $q_1 = 32$, marginal cost rises to \$60, so the incumbent will produce no more than $q_1 = 32$. At this output level, P = \$88. Profit = (\$88 − \$60)32 − \$200 = \$696. Because this exceeds the Stackelberg profit, entry deterrence is worthwhile.

12.3 a. The incumbent will fight if 3 > 4 − C or if C > 1.

b. For C > 1, the initial expenditure of C implies the incumbent will always fight any entry, so entry does not occur. The incumbent therefore earns \$(8 − C) by expending C. If C is not spent, entry will occur and the incumbent earns \$4.50. Expenditure C is only worthwhile if \$(8 − C) > \$4.50. If C > 3.50, this condition is not satisfied.

Chapter 13

13.1 The bank would have to ask for at least \$137.5 million in a good year, and \$100 million in a bad year. It will then earn \$137.5 with probability 0.4 and \$100 million with probability 0.6 for an average of \$115 million. If it needs to earn an additional \$1.25 million to cover costs, then the bank can ask for \$140.625 in a good year so that its expected gross payment is: \$116.25 million. No, there is no change in the incentive for predation. The bank and Newvel can still expect to make a profit by entering in the second period.

13.2 a. $q_L = 45, q_f = 22.5, Q = 67.5, P = \$32.5; \pi_L = \$1{,}012.5; \pi_f = \$506.25$.

b. If the firms play the standard Stackelberg game in each period, then the leader earns \$1,012.5 each period or \$2,025 in total (we assume the discount factor is 1). If instead the leader predates, then in first period, $q_L = 90$ and $\pi_L = 0$. In second period, $q_L = 45$ and $\pi_L = \$2{,}025$. The leader does not gain from this strategy (and will actually lose if the discount factor $R > 1$ as all of the gains from this strategy come in the second period).

c. Offer entrant \$506.25 to stay out in 1st period. Earn \$2,025 − \$506.25 = \$1,518.75 in 1st period; \$2,025 in 2nd period.

13.3 The expected predation gain = the increased probability of Newvel failure times the value of Microhard's gain when this happens. Hence, the gain from predation is: (Δprob) × (\$325 − \$150) million. This must cover the cost of predation = \$30 million. Solving for Δprob yields the lowest increase Newvel's failure probability consistent with Microhard pursuing predatory practices is Δprob = 17.14 percent.

Chapter 14

14.1 (Confess, Confess) is the unique Nash Equilibrium.

14.2 The third period outcome must be the one-period Nash equilibrium with both producing 40 (thousand) and earning \$1.6 million each. Foreseeing the inevitability of this outcome will thwart any cooperation in period and 2. Hence, both will produce 40 (thousand) units in that period as well. In turn, foreseeing no cooperation in either period 2 or period 3, each firm will also produce 40 (thousand) units in period 1. The three-period game will simply be played as three one-period games.

14.3 a. If the firms collude they share the monopoly profit, so if the cartel is sustained we have $\pi^M = \dfrac{(A-c)^2}{8b}$. If the cartel fails, per-period profit is the Cournot-Nash profit $\pi^N = \dfrac{(A-c)^2}{9b}$. Now suppose that one firm sticks by the cartel agreement to produce $(A-c)/4b$ while the other cheats on the agreement. The cheating firm's best response is to produce $3(A-c)/8b$, with profit $\pi^D = \dfrac{9(A-c)^2}{64b}$. Substituting into equation (14.7) and simplifying gives the critical probability-adjusted discount factor $\rho_C^* = \dfrac{9/64 - 1/8}{9/64 - 1/9} = \dfrac{9}{17} = 0.529$.

b. If the firms collude they each earn π^M per-period as in part a. If the cartel fails we have $\pi^N = 0$. A firm that cheats on the cartel earns $\pi^D = \dfrac{(A-c)^2}{4b}$. Substituting into equation (14.7) and simplifying gives the critical probability-adjusted discount factor $\rho_B^* = \dfrac{1/4 - 1/8}{1/4 - 0} = \dfrac{1}{2} = 0.5$

Chapter 15

15.1 a. If demand is $P = A - BQ$ and there are N identical firms each with constant marginal cost of c, we know that the Cournot-Nash equilibrium profit is $\pi^C = \dfrac{(A-c)^2}{B(N+1)^2}$. Substituting $N = 20$, $A = 130$, $B = 1$ and $c = 30$ gives profit to each firm of \$22.67.

b. If six firms merge this reduces the number of firms in the industry to fifteen. Substituting $N = 15$ gives profit to each firm of \$39.06. So the merged firm earns profit post-merger of \$39.06 whereas as six independent firms they earn 6*\$22.67. This merger is not profitable.

c. From the text we know that the fraction of firms that have to merge for the merger to be profitable for the merged firms when there are N firms in the industry pre-merger is $a(N) = \dfrac{3 + 2N - \sqrt{5+4N}}{2N}$. Substituting $N = 20$ gives $a(20) = 0.8445$, so that at least 16.89 firms have to merge. That is, at least seventeen firms must merge. This can be double checked. If sixteen firms merge this leaves five firms in the industry, each with profit of \$277.78, whereas aggregate profit of these firms pre-merger is $16^*22.67 = \$362.81$. By contrast if seventeen firms merge this leaves four firms in the industry, each with profit of \$400 whereas aggregate profit of these firms pre-merger is $17^*22.67 = \$385.49$.

15.2 a. The general equation for output of a Cournot firm when there are N firms in the industry, when the marginal cost of firm i is c_i $(i = 1, .., 20)$ and when market demand is $P = A - B.Q$ is $q_i^C = \dfrac{A - (N+1) \times c_i + \sum_{j=1}^{N} c_j}{B(N+1)}$, the equilibrium price is $P = \dfrac{A + \sum_{i=1}^{N} c_i}{N+1}$, and profit to firm i is $\pi_i^C = \dfrac{\left(A - (N+1) \times c_i + \sum_{j=1}^{N} c_j\right)^2}{B(N+1)^2}$. In our example $A = 180, B = 1, N = 3, c_1 = c_2 = 30, c_3 = 30b$. This gives $q_1^C = \dfrac{180 - 4.30 + (30 + 30 + 30b)}{4} = \dfrac{120 + 30b}{4}$; $q_2^C = \dfrac{120 + 30b}{4}$; $q_3^C = \dfrac{180 - 120b + (30 + 30 + 30b)}{4} = \dfrac{240 - 90b}{16}$. Profit of the three firms, ignoring overhead costs, is $\pi_1^C = \dfrac{(120 + 30b)^2}{16}$; $\pi_2^C = \dfrac{(120 + 30b)^2}{16}$; $\pi_3^C = \dfrac{(240 + 90b)^2}{16}$. The equilibrium price is $P = \dfrac{180 + 30 + 30 + 30b}{4} = \dfrac{240 + 30b}{4}$. For firm 3 to be able to survive it is necessary that $240 - 90b > 0$ or $b < 2.67$.

b. The merger leads to the closure of firm 3, resulting in a duopoly with each duopolist having constant marginal cost of \$30. Output of each firm is $q_1^C = q_2^C = \dfrac{180 - 30}{3} = 50$. The equilibrium price is $P = \dfrac{180 + 30 + 30}{3} = \$80$. Profit of the merged firm is $\$2500 - 900a$ and of the nonmerged firm is $\$2500 - 900 = \$1400$.

c. The merger is profitable if $2500 - 900a > \dfrac{(120 + 30b)^2}{16} + \dfrac{(240 - 90b)^2}{16} - 1800$. This requires that $a < \dfrac{1}{72}(-16 + 180b - 45b^2)$.

15.3 a. This is just an application of the standard Cournot equation $q_i^C = \dfrac{A - c}{B(N+1)} = \dfrac{130 - 30}{21} = \dfrac{100}{21}$. So, total output $Q = 20 \times (100/21) = 95.24$. The equilibrium price is \$34.76.

b. Apply the equations from the text. Output of a leader firm is $q_l^* = \dfrac{A - c}{B(L+1)} = \dfrac{130 - 30}{6} = 16.67$. Output of a follower firm is $q_f^* = \dfrac{A - c}{B(L+1)(N-L+1)} = \dfrac{100}{6 \times 11} = 1.51$. Total output is $5 \times 16.67 + 10 \times 1.51 = 98.45$. The equilibrium price is \$31.55, lower than the price pre-merger.

c. This is just an application of the standard Cournot equation. With fifteen firms, total output is $(15/16)$ of the competitive output, or $(15/16) \times 100 = 93.75$.

Chapter 16

16.1 The retailer's marginal revenue curve is $MR = 3{,}000 - Q$ and the retailer maximizes profit by equating MR and MC, giving $r = 3{,}000 - Q$, which is also the manufacturer's demand curve. If the retailer has additional marginal costs of c^D then profit maximization gives $3{,}000 - Q = r + c^D$, which gives $r = (3{,}000 - c^D) - Q$ as the manufacturer's demand curve.

16.2 a. Profit maximization by WR implies $100 - 2Q = 5 + W_W \Rightarrow W_W = 95 - 2Q =$ WW'*s* demand curve. Profit maximization by WW implies: $95 - 4Q = 5 + W_M \Rightarrow W_M = 90 - 4Q =$ WM's demand curve. Profit maximization by WM implies: $90 - 8Q = 10 \Rightarrow Q = 10$; $W_M = \$50$; $W_W = \$75$; $P = \$90$. $\pi_{WM} = \$400$; $\pi_{WW} = \$200$; $\pi_{WR} = \$100$; total profit $= \$700$.

b. If WM and WW merge, then their cost of combined operation is \$15. Demand curve facing merged firm is $W_W = 95 - 2Q$. Profit maximization implies: $95 - 4Q = 15 \Rightarrow Q = 20$. Wholesale price to retailer falls to \$55. Price charged to consumers falls to \$80. Profit of the merged firm is $(55 - 15) \times 20 = \$800$. Profit of the retailer is $(80 - 60) \times 20 = \$400$. Total profit has increased, the merged firm has greater profits and the retailer has greater profits. Consumers are offered lower prices.

If WW and WR merge, WW will supply WR at marginal cost, which is $5 + w_m$. WR then equates MR with MC giving $100 - 2Q = 10 + w_m$ giving the demand function for WM of $w_m = 90 - 2Q$. Equating MR with MC gives $90 - 4Q = 10$ or $Q = 20$. This gives $w_m = \$50$. Profit to WM is \$800. The final product (retail) price is \$80. Profit to the merged firm is $\$(80 - 10 - 50) \times 20 = \$400$.

c. If all three firms merge, total cost of bringing good to market is \$20. Merged firm faces retail demand of $P = 100 - Q$, hence, $MR = 100 - 2Q = 20$ implies $Q = 40$ and $P = 60$. Merged firm profit is: $\$1600 > \$1200$ above.

16.3 a. Suppose that WI sets a wholesale price of w. GI maximizes profit by setting $\text{MC} = 0.1 + w = \text{MR} = 1 - 2Q_{gb}$ so $Q_{gb} = 0.45 - w/2$. TI maximizes profit by setting $0.1 + w = 0.75 - 0.4Q_{gn}$, so that $Q_{gn} = 1.625 - 2.5w$. This gives aggregate demand for WI of $Q = 2.075 - 3w$ or $w = 2.075/3 - Q/3$. Marginal revenue for WI is then $\text{MR} = 2.075/3 - 2Q/3$ and $\text{MC} = 0.1$. This gives profit maximizing total output $Q = 0.8875$. The wholesale price is $w = \$0.396$. Sales in Boston are 0.252 and in New York are 0.635. The price of gizmos in Boston is \$0.748 and in New York is \$0.623. Profits are: WI = \$0.263; GI = \$0.063; TI = \$0.081.

b. Suppose that WI sets a price w_b for widgets in Boston and w_n for widgets in New York. GI sets $\text{MR} = 1 - 2Q_{gb} = \text{MC} = 0.1 + w_b$, giving derived demand to WI of $w_b = 0.9 - 2Q_{gb}$. Marginal revenue is $MR = 0.9 - 4Q_{gb}$. Equating with MC of 0.1 gives $Q_{gb} = 0.2$. The wholesale price is $w_b = \$0.5$. The Boston gizmo price is \$0.8. Profit of GI is \$0.04. Profit of WI in Boston is \$0.08. Similarly, derived demand for WI in New York is $w_n = 0.75 - 0.4Q_{gn}$. Equating $\text{MR} = 0.75 - 0.8Q_n$ with $\text{MC} = 0.1$ gives $Q_n = 0.8125$. Wholesale price is \$0.425. The New York gizmo price is \$0.5875. Profit of TI is \$0.051 and of WI from sales in New York is \$0.264. Profit for WI increased and for TI and GI decreased.

c. Suppose that WI merges with GI in Boston. Widgets are supplied to GI at marginal cost. GI equates $\text{MR} = 1 - 2Q_{gb} = \text{MC} = 0.2$, giving $Q_{gb} = 0.4$. Price of gizmos in Boston = \$0.6, profit of the merged firm from Boston is \$0.16, aggregate profit is \$0.349. Now suppose that WI merges with TI in New York. Widgets supplied to New York at marginal cost. GI sets $\text{MR} = 0.75 - 0.4Q_{gn} = \text{MC} = 0.2$, giving $Q_{gn} = 1.375$. Price of Gizmos in New York \$0.475. Profit of the merged firm is \$0.458. So merger with TI is preferred.

d. i. Price in Boston rises and in New York falls. There is the opposite effect on consumer surplus.

ii. Price and consumer surplus in Boston are unaffected. Price in New York falls and consumer surplus increases.

16.4 a. Competitive price is equal to marginal cost equals r. Demand facing *WI* is $r = 100 - Q$, so $MR = 100 - 2Q = 10$ for profit maximization, or: $Q = 45$ and $r = P = \$55$. *WI* profit is \$2,025. Competitive retailers earn zero profit.