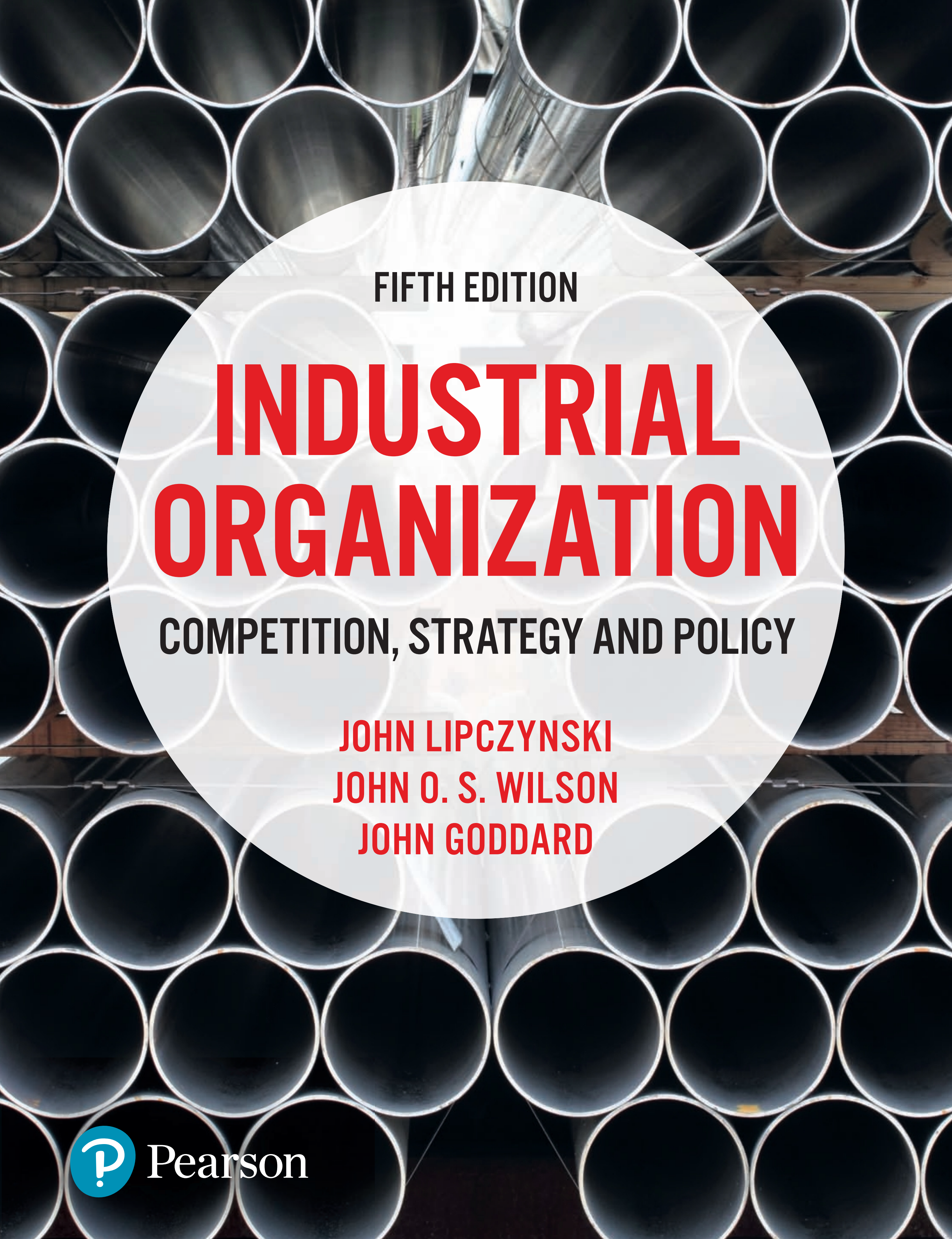

FIFTH EDITION

INDUSTRIAL ORGANIZATION

COMPETITION, STRATEGY AND POLICY

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Industrial Organization

		Firm B's budget		
		Low	*Medium*	*High*
Firm A's budget	**Low**	**40** *40*	**35** *45*	**10** *25*
	Medium	**35** *35*	**45** *30*	**15** *20*
	High	**30** *25*	**25** *15*	**20** *30*

Figure 9.3 Payoff matrix for the advertising budgets of firms A and B

of expenditure: low, medium or high. Both firms' payoffs from the advertising campaign depend on their own expenditure and on the expenditure of the other firm.

As before, consider firm A's choices:

- If B chooses *Low*, A's best response is **Low**.
- If B chooses *Medium*, A's best response is **Medium**.
- If B chooses *High*, A's best response is **High**.

Similarly, consider firm B's choices:

- If A chooses **Low**, B's best response is *Medium*.
- If A chooses **Medium**, B's best response is *Low*.
- If A chooses **High**, B's best response is *High*.

There are no strictly dominant strategies, and no weakly dominant strategies, for either firm A or firm B. By inspection, however, it can be confirmed that (**High**, *High*) is a Nash Equilibrium. If B chooses *High*, then **High** is also A's best response; and if A chooses **High**, then *High* is also B's best response. Unfortunately, in the absence of strictly dominant strategies, there is no simple decision-making procedure that will enable the two firms to reach the Nash Equilibrium easily. If this solution is achieved by some means, however, it is stable in the sense that there is no incentive for either firm to depart from it, given the zero conjectural variation assumption.

It is important to notice that firms A and B could both be better off by cooperating or agreeing to choose (**Low**, *Low*) in Figure 9.3, rather than remaining at the Nash Equilibrium of (**High**, *High*). In contrast to the Nash Equilibrium, however, this cooperative solution is unstable. If A chooses **Low**, B has an incentive to 'cheat' and choose *Medium* instead of *Low*. But if B chooses *Medium*, A would also prefer **Medium**; and then if A chooses **Medium**, B would prefer *Low;* and so on. The cooperative solution is vulnerable to defection by one or both of the firms, and is likely to break down.

9.3 The prisoner's dilemma game

Production game with prisoner's dilemma structure

Figure 9.4 presents another simultaneous game, with a structure similar to Figure 9.1, but a different set of payoffs. Applying the same reasoning as before, from A's perspective:

- If B selects *Low*, **Low** yields a payoff of **3** for A, while **High** yields a payoff of **4**. If B selects *Low*, A's best response is **High**.
- If B selects *High*, **Low** yields a payoff of **1** for A, while **High** yields a payoff of **2**. If B selects *High*, A's best response is **High**.

And from B's perspective:

- If A selects **Low**, *Low* yields a payoff of *3* for B, while *High* yields a payoff of *4*. If A selects **Low**, B's best response is *High*.
- If A selects **High**, *Low* yields a payoff of *1* for B, while *High* yields a payoff of *2*. If A selects **High**, B's best response is *High*.

High is a strictly dominant strategy for A and *High* is a strictly dominant strategy for B. Accordingly, it seems that A should select **High** and B should select *High*, in which case both firms earn a payoff of 2. As before, the Dominant Strategy Equilibrium (**High**, *High*) is also a Nash Equilibrium. Given that B selects *High*, if A switches from **High** to **Low**, A's payoff falls from **2** to **1;** and given that A selects **High**, if B switches from *High* to *Low*, B's payoff also falls from *2* to *1*. However, this time something appears to be wrong. If both firms had selected the *other* strategy (**Low**, *Low*), either by cooperating or perhaps by acting independently, both firms would have earned a superior payoff of 3 each, rather than their actual payoff of 2 each.

Figure 9.5 is an example of a special class of single period non-constant-sum game, known as the **prisoner's dilemma**. In a prisoner's dilemma game, there are strictly dominant strategies for both players that produce a combined payoff that is worse than the combined payoff the players could achieve if they cooperate, with each player agreeing to choose a strategy other than his strictly dominant

Firm A's strategies	Firm B's strategies: *Low*	*High*
Low	**3** *3*	**1** *4*
High	**4** *1*	**2** *2*

Figure 9.4 Payoff matrix for firms A and B: prisoner's dilemma example

		Brian's strategies	
		Not confess	*Confess*
Alan's strategies	**Not confess**	**−2** *−2*	**−10** *−1*
	Confess	**−1** *−10*	**−5** *−5*

Figure 9.5 Payoff matrix for Alan and Brian: original prisoner's dilemma

strategy. In other words, in a prisoner's dilemma, gains can be made by both players if they cooperate or collude.

The original prisoner's dilemma

To see why this type of game is called prisoner's dilemma, consider a situation where the police hold two prisoners, Alan and Brian, who are suspected of having committed a serious crime together. The police have insufficient evidence to secure a conviction unless one or both prisoners confesses. The prisoners are separated physically and there is no communication between them. Each is told the following:

- If you both confess to the serious crime, you both receive a reduced punishment of five years in prison.
- If neither of you confesses to the serious crime, you are both convicted of a minor crime and you both receive the full sentence for the minor crime of two years in prison.
- If you confess to the serious crime and your fellow prisoner does not confess, you receive a reduced sentence of one year in prison for the minor crime (and your punishment for the serious crime is cancelled).
- If you do not confess to the serious crime and your fellow prisoner confesses, you receive the full sentence for the serious crime of ten years in prison.

The payoff matrix is shown in Figure 9.5, with all payoffs shown as negative numbers, because in this case a large payoff (prison sentence) is bad, not good. Alan's reasoning might be as follows: if Brian confesses, I should confess because five years is better than ten years; and if Brian does not confess, I should confess because one year is better than two years. Therefore I will confess. Brian's reasoning is the same, because the payoffs are symmetric between the two prisoners. Therefore both confess, and both receive sentences of five years. But if they had been able to cooperate, they could have agreed not to confess and both would have received sentences of two years. Even acting independently, they might be able to reach the cooperative solution. Alan knows that if he does not confess, he receives a two-year sentence as long as Brian does the same. However, Alan is worried because he knows there is a big incentive for Brian to 'cheat' on Alan by confessing. By doing so, Brian can earn the one-year sentence and leave Alan with a ten-year sentence!

Brian is in a similar position: if he does not confess, he receives the two-year sentence as long as Alan also does not confess. However, Brian also knows there is a big incentive for Alan to cheat. The cooperative solution might be achievable, especially if Alan and Brian can trust one another not to cheat, but it is also unstable and liable to break down.

The prisoner's dilemma and the Cournot duopoly model

Section 7.3 analysed the choices of output levels by two duopolists. Comparing the Cournot–Nash and the Chamberlin solutions to the duopoly model shown in Figure 7.9, it is apparent that if the two firms operate independently according to the zero conjectural variation assumption, and each firm produces a relatively high output level of 1/3, the Cournot–Nash equilibrium is attained. In the terminology of the present section, this is a non-cooperative outcome. If, on the other hand, the two firms recognise their interdependence and aim for joint profit maximization, and each firm produces the lower output level of 1/4, the Chamberlin equilibrium is attained. In present terminology, this is the cooperative outcome.

Figures 9.6 and 9.7 show that if the two duopolists have to make their output decisions simultaneously, without knowing the other firm's decision, effectively

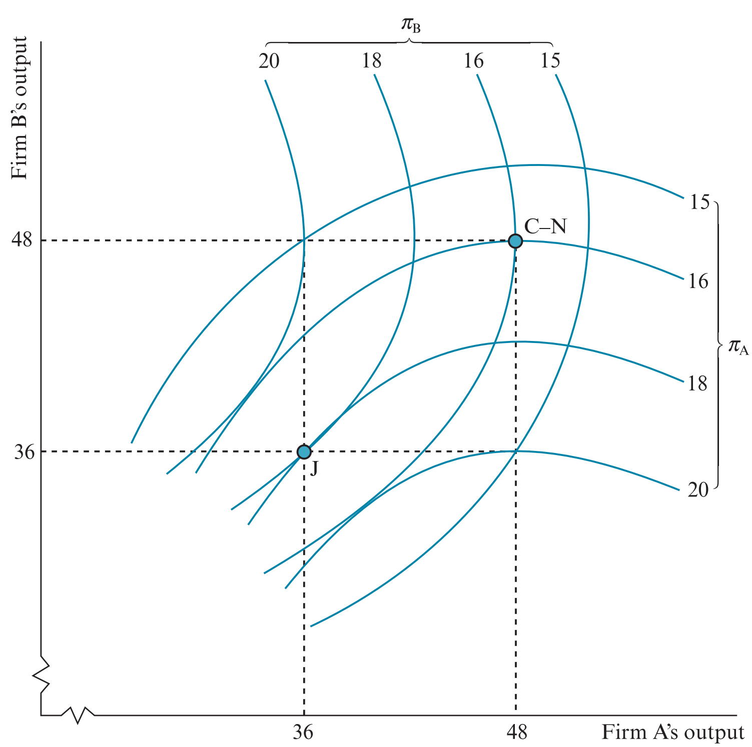

Figure 9.6 Isoprofit curves for firms A and B: Cournot–Nash versus Chamberlin's prisoner's dilemma

		Firm B's strategies	
		Low	*High*
Firm A's strategies	**Low**	**18** *18*	**15** *20*
	High	**20** *15*	**16** *16*

Figure 9.7 Payoff matrix for firms A and B: Cournot–Nash versus Chamberlin's prisoner's dilemma

they play a prisoner's dilemma game. The assumptions underlying Figures 9.6 and 9.7 are the same as in the original Cournot model developed in Section 7.3, with one exception. The two duopolists are assumed to produce an identical product and incur zero marginal costs. The one change involves a rescaling of the quantity axis for the market demand function, so that the maximum quantity that could be sold if the price falls to zero is 144 units (rather than one unit). As before, the price axis for market demand function is on a scale of $P = 0$ to $P = 1$, so when $P = 0$, $Q = 144$ and when $P = 1$, $Q = 0$. (Rescaling the quantity axis avoids the occurrence of fractional prices, quantities and profits.) You can verify that the prices, quantities and profits or payoffs shown in Figures 9.6 and 9.7 are equivalent to their counterparts in Figure 7.9 multiplied by a factor of 144.

In Figure 9.6, it is assumed that each firm has to choose between producing a high output of 48 units, or a low output of 36 units. If both firms select high, the Cournot–Nash equilibrium is attained, and both firms' profits are 16. If both firms select low, the Chamberlin joint profit-maximization equilibrium is attained, and both firms' profits are 18. If one firm selects low while the other selects high, the low-producing firm suffers and earns 15, while the high-producing firm prospers and earns 20. Figure 9.7 represents these outcomes in the form of a payoff matrix. Applying the same reasoning as before, from A's perspective:

- If B selects *Low*, **Low** yields a payoff of **18** for A, while **High** yields a payoff of **20**. If B selects *Low*, A's best response is **High**.
- If B selects *High*, **Low** yields a payoff of **15** for A, while **High** yields a payoff of **16**. If B selects *High*, A's best response is **High**.

Accordingly, it is best for A to select **High**, no matter what strategy B selects. The same is also true for B, because the two firms are identical. (**High**, *High*) is the Dominant Strategy Equilibrium, and is also a suboptimal non-cooperative Cournot–Nash outcome. As before, the cooperative or collusive outcome (**Low**, *Low*) might be achievable if the firms can trust each other to stick to the low output strategy and not defect and produce high output. This outcome is unstable, however, and is liable to break down. For the cooperative solution to hold in an oligopoly, any agreement between the firms might have to be accompanied by an enforceable contract (legal or otherwise).

Conflict *versus* cooperation

Not all prisoner's dilemma games generate suboptimal outcomes, especially when the assumptions are relaxed. First, the optimal (cooperative) outcome might be achieved if there is good communication between the players. If firms meet frequently, they can exchange information and monitor each other's actions. If the two prisoners, Alan and Brian, were not segregated, they could determine their best strategies by a continual examination of their options. The nuclear deterrence 'game' played by the United States and the Soviet Union in the 1960s and 1970s was likened to a prisoner's dilemma game. The choices were whether to attack the rival with a pre-emptive strike, or abide by the 'non-first use' agreement. Perhaps one reason why the optimal outcome (sticking to the agreement) was achieved was that the installation of a telephone hotline between Washington and Moscow permitted rapid communication and exchange of information at the highest levels of government. Alternatively, it might be possible to achieve a cooperative outcome if the players are able to recognise trustworthiness in other players through visual signals (Janssen, 2008).

Second, in practice an important characteristic of any game is the length of the reaction lag: the time it takes for a player who has been deceived to retaliate. The longer the reaction lags, the greater the temptation for either player to act as an aggressor. If Brian cheats on Alan, Alan may have to wait ten years to take revenge, unless he has friends outside the prison who are prepared to act more quickly. In cartels, the main deterrent to cheating is immediate discovery and punishment. In the nuclear deterrence game, short reaction lags were crucial to ensuring both sides kept to the agreement. Each side boasted that it could retaliate within minutes if attacked by the other, ensuring there was no first-mover advantage. This policy became known as mutually assured destruction (MAD).

Third, the dynamics of rivalry may also be relevant. Is the rivalry continuous, or 'one-off'? If rivalry is continuous in a repeated game, players learn over time that cooperation is preferable to aggression. Professional criminals have no problem with the prisoner's dilemma: experience has taught them that silence is the best option. In an oligopoly, firms change prices, alter product lines and determine advertising strategies, continuously. The firms may learn over time that aggressive behaviour leads to hostile (tit-for-tat) reactions from rivals, which tend to cancel out any short-term gains (see Case Study 9.1). Repeated or multiple-period games are examined in more detail below.

9.4 Mixed strategies

In some games, there is neither any Dominant Strategy Equilibrium nor any Pure Strategy Nash Equilibrium. In others there may be no Dominant Strategy Equilibrium, but more than one Pure Strategy Nash Equilibrium. In such cases, it may be beneficial for the firms (or other players) to adopt what are known as mixed strategies. A mixed strategy involves randomizing the choice between two or more options, with probabilities defined for each option.