University of Alberta

Testing for Predation in Airline Markets

by

Ewa Tomaszewska ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of Doctor of Philosophy

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Abstract

Although it is well recognized in the theoretical literature that predation can be a rational business strategy, few empirical studies on predation have been published. This thesis makes a contribution towards filling this gap in the literature. It develops a methodology that can be used in testing for predation and it carries out the empirical tests using data from a market where predation might have taken place.

The particular markets of interest in this study are city-pair airline markets. The testable predictions of non-strategic and predatory behaviour are derived from a theoretical model of competition in airline markets. In this model, it is assumed that airline firms compete in seating capacity, departure times, and fares. The predictions of non-strategic and predatory behaviour are derived for each of these variables. An attempt is made to distinguish between various models of predation which may apply to airline markets: the deep pocket model of predation and the reputation model of predation.

The implications of non-strategic and predatory behaviour for the fare setting and capacity decisions are then tested empirically using the data from the Vancouver - Toronto route over the period 1988 - 1994. As there were allegations that Air Canada was practicing predation against Canadian Airlines in early 1992, Air Canada is designated as the predatory airline and Canadian Airlines is designated as the victim airline. The capacity equation and the price equation are specified in a version implied by the deep pocket model and in a version implied by the reputation model of predation. Both equations are also specified in a general form where the predation structure is not imposed but it is controlled for. The empirical results are consistent with Air Canada being engaged in predation against Canadian Airlines during the April 1990 - August 1992 period. The

seating capacity scheduled by Air Canada was significantly higher and its price was significantly lower during this period than during the rest of the sample period. There is little evidence supporting the reputation model of predation but the data supports the deep pocket model of predation in that Air Canada's capacity tended to be higher and its fares tended to be lower when the financial results of Canadian Airlines were getting poor. The magnitude of the coefficients on the predation related variables is not very large but they are statistically significant.

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Chapter 1

Introduction

It is well recognized in the literature that in a market where a small number of firms is present, possibilities for strategic behaviour may arise. One form of strategic behaviour that has received a fair amount of attention is predation. There have been many theoretical studies explaining the practice of predation and showing that it may be a rational strategy in various market situations, even if it is costly in the short-run. The models developed in this literature can be divided into three broad categories (see Ordover and Saloner, 1989): deep pocket models of predation, reputation models of predation, and signalling models of predation. In deep pocket models, a firm with larger financial resources can outlast an equally efficient competitor in a predatory war and thus may be able to drive its rivals out of the market. In reputation models, the prospective entrants are uncertain of the established firm's business objectives and its commitment to prey on a recent entrant. This uncertainty provides an incentive to the established firm to engage in predation in order to build a predatory reputation and discourage other entrants from entering the market. Finally, in the signalling models it is shown that when the potential victim firm has incomplete information about the market, the incumbent can engage in predation in order to signal to the victim firm that market conditions are unfavourable to it and that it is better-off exiting the market.

In contrast to the well developed theoretical literature, few formal empirical studies on predation have been published, and there have been no studies where one model of predation is tested against an alternative model. There have been a number of case studies involving a comprehensive discussion and interpretation of records and court evidence on historical cases of alleged predation (for example McGee, 1958; Elzinga, 1970; Koller, 1971). These studies have provided interesting information about business conduct but they have not presented formal tests of predatory behaviour. There have also been a number of papers suggesting various cost-based rules for predatory pricing (for example Areeda and Turner, 1975; Posner, 1976; Baumol, 1979; Joskow and Klevorick, 1979). These rules have been widely used by courts to adjudicate predatory pricing cases.[1] However, most of the evidence from these cases is not available to the general public, and it is not clear how these tests would work in a particular case.[2] In academic research, cost-based tests do not appear very useful as they require detailed data on costs and prices which are not likely to be available to scholars. Moreover, a cost-based test is not likely to work well if the firm is using non-price forms of predation rather than predatory pricing.

Some of the more rigorous empirical studies on predation include von Hohenbalken and West (1984) and Dodgson *et al.* (1993). Von Hohenbalken and West (1984) analysed market areas of stores owned by supermarket firms in a city, and obtained results supporting the hypothesis that the dominant supermarket chain had engaged in spatial predation by building stores close to the recent entrants' stores so as to reduce the rival

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[1] Alvin Klevorick reviewed a number of recent predatory pricing cases in the United States and found that courts rely mostly on cost-based tests and Joskow-Klevorick two-tier analysis. In contrast, the advances in the theoretical literature on predation seem to have had very small impact on court rulings (see Klevorick, 1993).

[2] It has been pointed out in the literature that there may be cases when a firm is practising predation and passes a cost-based test (see for example Scherer, 1976; Schmalensee, 1979).

stores' market areas below the break-even level. Dodgson *et al.* (1993) examined competition in the bus industry in a town and found that both the incumbent operator as well as a recent entrant could have earned positive profits in the Nash equilibrium. However, both the incumbent and the entrant expanded their services to such a level that neither of them could operate profitably.

In related studies, Burns (1986) and von Hohenbalken and West (1986) focused on the effects of alleged predation. Von Hohenbalken and West (1986) tested a hypothesis that a dominant supermarket firm had created a predatory reputation, i.e. a reputation of fighting entry by building new stores in the neighbourhood of a new entrant's store so as to reduce its market area below the break-even level. Burns (1986) estimated expenditure for rival firms purchased by American Tobacco Company between 1891 and 1906 and obtained results indicating that the alleged predation significantly lowered the acquisition costs.

Given the size of the theoretical literature, there is a need for more empirical studies on predation in order to obtain empirical verification of the theoretical statements and find out how predation can be detected. An example of a market that seems to be susceptible to predation and which may be a good candidate for an empirical study is an airline market. It is well known in the airline industry that the carrier with the most flights and seats gets more than the proportionate share of business passengers. This group of travellers is sensitive to high flight frequency and availability of seats at the last minute and thus likely to prefer a carrier that offers many flights and a high capacity.[3] Business

[3] See for example Tretheway and Oum (1992), in particular Chapter 3 and Chapter 5.

passengers contribute to airline revenues more than their proportional traffic share, and financial viability of an airline firm may be reduced if the proportion of business travellers in the total number of passengers is very small. Thus, an airline may have an incentive to increase capacity in order to attract passengers away from one or more competitors and inflict losses on its rivals.

In fact, there are reasons to believe that some type of aggressive behaviour takes place in real airline markets. For example, in the United States on some routes the daily flight frequencies offered by the major carrier have more than doubled compared to 1990.[4] In 1984 when People Express, a "no frills" airline, entered the Minneapolis-New York route , Northwest, the major full service carrier, met their prices and scheduled additional flights (see Kahn, 1991). In Canada, airline industry analysts estimated in 1992 that there was 25 to 30 percent too much capacity in the market for Air Canada and Canadian Airlines, the two major Canadian carriers, to operate profitably.[5] In August 1992 the federal Bureau of Competition Policy launched an investigation into allegations that Air Canada had engaged in predatory pricing, and later that year, in November 1992, Canadian Airlines filed a predatory pricing lawsuit against Air Canada.

Airline markets, and Canadian airline markets in particular, are thus worthwhile examining for evidence of predation. Publicly available information on departure times, fares, seating capacity, and some other variables, make it possible to carry out tests for

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[4] See "Shuttle Diplomacy, Airline Style," *The New York Times*, 25 October 1996, p. C1-C3.

[5] See "Airlines Warned: 'Get it together or face controls'," *Globe and Mail*, 26 November 1992, p. B1 and B6.

predatory behaviour.

This dissertation makes a contribution to the empirical literature on predation. It develops a methodology that can be used to test for predation, and it carries out the empirical tests using data from a market where predation might have taken place. The analysis concentrates on airline markets, but the methodology may also be applied to other settings where market participants locate more than one product in a geographic or product space.

The discussion in this thesis proceeds as follows.

Chapter 2 reviews the literature related to the issues that are dealt with in this thesis, including studies on predation, contestability of airline markets, and competition in multi-product oligopolistic markets. Studies on predation are of primary interest because of the topic of the thesis itself. Research on contestability of airline markets is also of interest in that conclusions arising from that research have broader implications, some of them being the feasibility of strategic behaviour, and thus predation, in airline markets. Finally, studies on competition in multi-product oligopolistic markets are of interest as airlines can be regarded as multi-product firms.

Chapter 3 sets up the theoretical framework to analyse competition in airline markets, and derives testable implications of non-strategic and predatory behaviour. In this analysis, a simplifying assumption is made that airline firms are concerned with profit maximization on each route and that there are no network effects between routes. This makes it possible to concentrate attention on a single city-pair market. It is assumed that airlines compete in departure times, total seating capacity, and price. Departure times and fares are modelled within a spatial context (a nested logit model), and seating capacity is modelled within a non-spatial context.

Testable implications of non-strategic and predatory behaviour are derived for each choice variable. For seating capacity and price, these implications are based on the best response function associated with each of these variables. Non-strategic and predatory departure time scheduling are determined using computer simulation techniques as the complexity of the problem makes it difficult to derive the relationships of interest analytically.

An attempt is also made to distinguish between different models of predation that may apply to an airline market, the deep pocket model and the reputation model. Identification of the relevant model of predation is important as different models of predation may have different testable implications. In particular, it is argued that if the deep pocket is the relevant model, poor financial results of the victim airline, as well as declining demand for air travel, may encourage the predatory airline to behave more aggressively in the following time periods. On the other hand, if the reputation model of predation is the relevant model, an aggressive reaction by the predatory airline may be triggered by the victim airline's attempts to expand its business.

Chapter 4 discusses briefly the structure of the Canadian airline industry and the sequence of events that led to the allegations of predatory behaviour on the part of Air Canada in 1992. Then the data used in the estimation of the model are described. The city-pair market to be examined is the Vancouver - Toronto route (in the direction from Vancouver to Toronto) over the years from 1988 to 1994.

Chapter 5 develops the empirical methodology to test for predation in an airline market. Tests of predatory behaviour are developed, and predictions from two alternative models of predation, the deep pocket and the reputation model of predation, are tested. The analysis in this chapter concentrates on the price and the seating capacity predictions of the two predation models.

The empirical results are consistent with the hypothesis that Air Canada engaged in predation against Canadian Airlines during the period April 1990 - August 1992. All other factors remaining the same, Air Canada's prices were lower and seating capacity was higher during that period than during the rest of the sample period. The results support the deep pocket model of predation but there is little evidence supporting the reputation model of predation.

Chapter 6 contains a summary and conclusions.

Finally, the Appendix presents the simulation results of the nested logit model of departure time scheduling used in Chapter 3 to determine non-strategic and predatory scheduling patterns.

Chapter 2

Review of the predation, contestability, and multi-product oligopoly literature

The purpose of this chapter is to provide background information for the empirical analysis of predation in airline markets. First, we need some background on the theory of predation and empirical work on predation. We want to determine which model of predation may apply to the airline industry, and we want to know what approach was taken in previous empirical research on predation. Second, we need background on issues specific to the airline industry and which may be relevant to the analysis of predation. One issue of potential relevance is the contestability of airline markets. In perfectly contestable markets, strategic behaviour, and thus predation, cannot be rational. Thus, the rejection of the contestability hypothesis implies that airline markets may produce evidence of strategic behaviour. Another issue of potential relevance arises from the fact that airlines operate on many routes and on each route they operate many flights. Each route can be interpreted as a different market, and each flight can be seen as a product differentiated by its location along a linear market.

The literature related to this thesis can thus be divided into three groups: the literature on predation, the literature on contestability of airline markets, and the literature on multi-product oligopoly. The three strands of literature are reviewed in sections 2.1, 2.2, and 2.3, respectively. Section 2.4 provides a brief summary.

2.1. Predation

By now, it is well established that predation may be a feasible and effective business strategy to drive a competitor out of business. The literature has offered a variety of models which explain the practice of predation and show that it may be rational in many market situations. Ordover and Saloner (1989) presented an extensive survey of this literature. They divided the theoretical models of predation into three broad groups: deep pocket models of predation, reputation models of predation, and signalling models of predation.

In a typical deep pocket model of predation, it is argued that in the fight to the finish, a firm with larger financial resources can outlast an equally efficient rival. The firm with a deep pocket can sustain losses longer and thus be able to drive its rivals out of the market.

In the reputation models, the prospective entrants into a market are uncertain of the established firm's business objectives and motivations. In particular, there is a doubt in their minds as to the commitment of the established firm to prey on a recent entrant. For example, the established firm may be simply irrational and prey on each firm that challenges its market, or it may be the case that the market in question is a part of a larger game that is not fully understood by outsiders, and it is optimal for the established firm to engage in predation. In this situation, the established firm, even if it is not irrational, may have an incentive to engage in predation in order to build a predatory reputation to discourage other entrants from entering the market.

In signalling models, the victim firm does not have full information about some market conditions (for example demand or costs), and it is uncertain whether it can operate profitably. In this situation, a potentially predatory firm has an incentive to start predation in order to convince the rival that market conditions are inherently unfavourable to it and that it will be better-off exiting the market.

The three types of predation models identified above model price, or the quantity of output, as the choice variable and the mechanism that a predator uses to impose losses on a rival. But there are also non-price instruments that a predator could use to impose losses on a rival and thus achieve the same results as predatory pricing. Some of the predatory pricing models could probably be modified so as to also explain non-price predation. However, there have been few studies modelling non-price forms of predation explicitly. Some of the instruments discussed in the literature include product innovation, product preannouncement, advertising, and product location (or spatial predation).

The three models of predatory pricing are reviewed in sections 2.1.1, 2.1.2, and 2.1.3, respectively. Section 2.1.4 reviews the literature on non-price predation, and section 2.1.5 reviews the empirical and experimental literature.

2.1.1. Deep pocket models of predation

The deep pocket scenario was first modelled by Telser (1966). Telser assumed that the potential predator has large financial resources while its rival has limited internal resources and limited ability to raise debt and equity to finance a predatory war. The predator knows these limits and knows that the rival will shut down quickly if the price falls below costs. In these circumstances, if the monopoly profits are large enough to compensate the predator for the reduction in profits during the predation period, predation is both feasible and rational.

A similar result was obtained by Benoit (1984) in a more formalized game-theoretic model. In this model, as in Telser's model, the incumbent has larger financial resources and can outlast an entrant in a predatory war. This means that after a finite number of fights without cooperation, the entrant would be forced out of the market. The industry horizon is, however, infinite. Benoit shows that if it is profitable for the incumbent to engage in successful predation for just one period, the only perfect equilibrium involves the entrant not entering and the existing firm threatening to fight. This result is proved by backward induction. If the rivalry has reached the stage when the entrant has exhausted its financial resources, say stage n, it is optimal for the incumbent to fight for one more period to drive the entrant out of the market and enjoy monopoly profits forever. But if the entrant knows at the beginning of period $n-1$ that it will be driven out of the market in period n, it is optimal for the entrant to exit the market at the beginning of period $n-1$ to save what is left of its resources. This argument continues backwards to the first period in the usual way.

The Telser and the Benoit models can be criticized on the grounds that predation would never actually occur in these models, except by mistake. In Telser's model, if the targeted firm knows that eventually it has to go bankrupt and exit the market, it should leave the market at the first hint of predation rather than waste its resources in a pointless game. In Benoit's model, the prospective entrant actually stays out of the market in perfect equilibrium.[6] But as Ordover and Saloner (1989) indicate, an important result of these models is that having a deep pocket may generate a credible threat of predation.

An important issue that had to be explained to make the deep pocket story more convincing was the financial vulnerability of the targeted firm and its inability to borrow. Later research in the theory of financing under asymmetric information has provided arguments supporting the notion of financial vulnerability of the firm which does not have sufficient internal resources. One of the first papers in this area is due to Gale and Hellwig (1985). They showed that when financial institutions cannot observe firms' profits perfectly and monitoring is costly, a firm with a low net asset value will be denied financing. This result arises because a firm with a low asset value faces a temptation to default on a loan payment. If a debtor firm defaults, the bank financing the project may audit the firm and confiscate the entire return. But when the audit cost is high, the bank may be unwilling to finance the project at an interest rate acceptable to the firm.

A firm's financial vulnerability is not necessarily reduced even if the firm can sign a long-term contract that also covers the post-predation period. This result was demonstrated in Bolton and Scharfstein (1990). They consider a two-period model where there are two firms; one firm has a deep pocket but the other firm has to raise funds in capital markets. It is assumed that it is not possible to write enforceable financial contracts. (One reason why this assumption is sensible is that profits may be observable

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[6] Predation occurs in Benoit's model only if the game is modified so that the incumbent is uncertain about the entrant's commitment to the industry. This variant of the game is modelled in a similar manner as the Kreps and Wilson (1982) model discussed in section 2.1.2.

but not verifiable in courts). As a result, the debt contract itself has to be designed in such a way as to induce the firm to report profits truthfully and repay the loan. The optimal contract design involves staged financing where funding in the second period is contingent on the first-period performance. In particular, the investor cuts off funding if the firm reports low profits in the first period. The possibility of terminating funding in the second period induces the firm to perform well in the first period and report profits truthfully. But at the same time, this characteristic of financial contracts provides an incentive to the rival that has sufficient internal resources to engage in predation. Predation increases the probability that the funded firm's performance is indeed poor and that its funding is terminated at the end of the first period.

While these results provide an important argument for the deep pocket story, another question that arises is why entrants cannot finance with equity. If an entrant had access to full equity financing, the incumbent's incentive for predation would disappear. This question was addressed by Poitevin (1989). He shows that financing with debt arises endogenously due to an informational asymmetry between an entrant and an incumbent in financial markets. The entrant is at a disadvantage compared to the incumbent because financial institutions may be uncertain of the entrant's quality and therefore not able to price its securities fairly. This implies that the entrant may be unable to raise equity necessary to finance entry. To secure financing, the entrant has to send a signal to financial markets about its quality. A low-cost entrant tries to differentiate itself from a high-cost entrant by financing the initial fixed production costs with debt, at least partially. This debt is sufficient to bankrupt a high-cost firm, and thus it may be interpreted as a signal that the entrant is a low-cost firm. The entrant's financial structure, however, provides an incentive to the established firm to engage in predation as predation decreases the entrant's cash flow and increases its probability of bankruptcy. Because the probability of bankruptcy is larger than zero, predation may induce some entrants to exit permanently or temporarily.

Although the deep pocket models of predation typically discuss a situation where the predator is a well established firm and the victim firm is a recent entrant, it seems that some of those models may also be relevant to markets where both the predator and the victim firm are well established firms. In particular, these models may be relevant to airline markets. It is possible that one airline has a deep pocket while its rival does not have much internal resources and has to obtain some funding from financial institutions. For example, it is possible that for some reasons an airline firm finds itself in a difficult financial situation and has to find an investor in order to stay in business. The argument that financial institutions cannot easily observe a firm's performance and all its operations seem to apply to any industry. Thus, the result that financial institutions may make funding contingent on the net asset value or some measure of performance, and that this may provide an incentive to a rival airline to engage in predation, carries over to airline markets, as well.

2.1.2. Reputation models of predation

The idea that predation may have reputational effects that spill over into the future or into other markets where the incumbent is an active competitor seems to have been around among economists for a long time. Informally, it was expressed for example by Yamey (1972, p. 131) and Scherer (1970, p. 275; 1980, pp. 337-338).

However, Selten's "chain store paradox" demonstrates that rational strategies in one market cannot be affected by behaviour in another market. Thus the threat, or reputation, of fighting entry is not credible. To show this, Selten considers a finite-horizon game where a monopoly is threatened by entry. There are N prospective entrants who may try to enter the incumbent's market one by one in the subsequent time periods. If an entrant enters, the incumbent can either fight or accommodate entry. The one-period payoffs are such that fighting generates lower payoffs than accommodating entry does. (This expresses the idea that predation is costly.) However, the monopoly payoff is larger than the accommodation payoff. For the entrant it is profitable to enter the market if the incumbent accommodates entry. But if the incumbent fights, the entrant is better-off if it stays out. Selten shows that in this game the only perfect equilibrium is that an entrant enters the market in each period and the incumbent accommodates entry. This result is proven by backward induction. In the last period the incumbent does not have an incentive to prey since predation involves a sacrifice of profits. Thus the incumbent accommodates entry. In the second-to-last period the incumbent knows that it will accommodate entry in the last period. But then, it will make no sense to fight entry in this period, either. This argument proceeds backwards to the first period.

A formalized model where reputation matters and where the incumbent may have an incentive to engage in predation in order to establish a predatory reputation was simultaneously developed by Kreps and Wilson (1982) and Milgrom and Roberts (1982). In both models it is shown that uncertainty as to the incumbent firm's behaviour can generate reputational effects and change Selten's predictions regarding the rationality of predation.

Kreps and Wilson (1982) consider a model similar to Selten's model. However, there is a small probability that the incumbent's one-period payoff is actually larger when it fights entry than if it accommodates entry. Such an incumbent is called "tough." If the incumbent's one-period payoff from accommodating entry is larger than the one-period payoff from preying, the incumbent is called "weak." There is a large number of entrants who one after another will attempt to enter the incumbent's market. The entrants do not know whether the incumbent is tough or weak; they know only the probability, p, that the incumbent is tough. This probability is revised based on what was observed in the past. If peaceful reaction was observed at an earlier stage of the game, an entrant will infer that $p=0$.

In this game it is quite obvious that a strong incumbent always fights entry. But Kreps and Wilson (1982) show that if the number of periods in the game is moderately large, a weak incumbent will also fight entry at an early stage of the game, even if p is quite small. The intuition behind this result is that by fighting, a weak incumbent acquires a reputation of a strong incumbent. The reputation of being strong forestalls entry in the future and preserves the monopoly profits. The entrants, however, realize that they may face a weak incumbent who mimics a strong one, and an entrant may decide to enter in the later stages of the game even if entry was fought in the past.

In Milgrom and Roberts (1982) there is an established firm operating in a number of markets which are threatened by entry. In a one-period game, the established firm prefers sharing a given market to preying upon the entrant. However, there is an element of doubt in the minds of the entrants about the established firm's options and motivations. In particular, the entrants believe that there is a small probability that past behaviour is repeated when similar circumstances arise. For example, the established firm may be a pacifist competitor who always shares a market, or it may be an aggressive competitor who always responds to entry with predation. At each stage of the game, each firm knows the history of the moves taken to that stage by it and by the other firms. An entrant uses this information to update its beliefs about the established firm. The objective of the established firm is to maximize the present value of its profits at each stage of the game.

Milgrom and Roberts show that in the circumstances described above, the established firm has an incentive to engage in predation in the early stages of the game. A failure to prey on an entrant reveals to all other entrants that the established firm is not committed to fighting entry, and entry will occur in all other markets. On the other hand, once the established firm has preyed, entrants regard predation as certain. The only entrants which will attempt entry after one predatory episode has been observed are those whose outside alternatives are so poor relative to the profits available by entry that they are willing to face certain predation. In this model, the established firm sees predation at an early stage as leading to a stream of monopoly profits interrupted only by occasional episodes of predation.

In practice, an incumbent may be threatened by entry in several markets simultaneously, not just one market at a time as assumed by Kreps and Wilson (1982) and Milgrom and Roberts (1982). Easley *et. al* (1985) modified the Kreps and Wilson model to this case. They also allow for the possibility that eventual entry in all markets is inevitable but that it may be profitable for the incumbent to slow down the rate of entry into its markets. The potential entrants do not know all the competitive aspects of the monopolist's markets. In particular, they are uncertain about the type of the monopolist they face and how the monopolist would react to their entry. The monopolist may be of an aggressive type (when single market Nash equilibrium generates losses for the entrants), or of a "beneficial" type (when the market is inherently competitive and there is room for another competitor). If an entrant experiences losses in one market, it will revise its expectations of the profitability of entry into another of the monopolist's markets. But if entry is profitable for the entrant, then the monopolist reveals itself as a "beneficial" type. Easley *et al.* show that the monopolist may have an incentive to engage in predation even if it can only slow down the rate of entry into other markets but be unable to prevent eventual entry.

The existing reputation models of predation consider a game of entry where an established firm tries to protect its markets, or at least slow down the rate of entry. These models may apply to airline markets in situation where an established airline firm faces a possibility of entry. It seems, however, that these models do not apply to situations where there is no threat of entry, and all competitors are well established firms, unless something has happened that makes the market participants believe that there has been a change in a rival's objectives and market behaviour. An example of such an event may be a change in management.

2.1.3. Signalling models of predation

In contrast to reputation models of predation where the incumbent is concerned with deterring entry, in signalling models, the motive of the incumbent is to induce exit of a firm that is already in the market. The difference between the signalling models and the deep pocket models lies in the driving force behind the predatory actions. In deep pocket models it is the financial vulnerability of the potential victim firm. In signalling models the driving force arises from the fact that the potential victim firms have incomplete information about the industry, for example about the demand level, or costs. The victim firms know only the range of values of the variable in question; for example they know only the probability that demand is high. Because the potential victim firms do not have complete information, they are uncertain whether they can operate profitably, and they have to make inferences in this regard based on what they observe in the market. In this situation, a predator may have an incentive to confuse, or mislead, the victim firm as to its future profitability.

Several models which express this basic idea have been developed. Typically, these models consider a market which will be open for two periods. The incumbent engages in predation in the first period in order to induce the rival firm to exit at the end of the first period. If predation is successful, the incumbent enjoys a monopoly in the second period. If predation is unsuccessful, both firms compete as duopolists in the second period.

For example, in Roberts (1986) the target firm is uncertain about the level of demand which may be high or low. The incumbent knows, however, the level of demand. If demand is high, the continued operation under Cournot competition would be profitable for the entrant. But when demand is low, the entrant would prefer leaving the market. Initially, both firms compete in quantities. Then each observes the price but not the other's quantity choice. (Knowing the price and the quantities, the victim firm could infer the level of demand.) In these circumstances, the incumbent firm has an incentive to expand output in the first period in order to depress the price and mislead the entrant that demand is low when in fact demand is high. On the other hand, when demand is low, both the incumbent and the entrant are better-off if the latter exits. But to signal the information of low demand credibly, the incumbent firm will have to depress the price so far that were the level of demand actually high it would not be worthwhile to generate this price to induce exit. As a result, the possibility of inducing exit leads to prices being lower than those that would prevail in the absence of this possibility.

In Fudenberg and Tirole (1986a) the entrant is uncertain about its fixed costs, which may be high or low. The only piece of information that may help the entrant to infer the level of these costs is total profit. Both firms compete in prices in the first period. (The entrant cannot observe the incumbent's price but the incumbent may or may not observe the entrant's price.) The incumbent has an incentive to engage in predatory pricing. A low price may depress the entrant's profits and mislead the entrant that its costs are high and induce it to exit the market at the end of the first period.

The early literature on predation suggested that the motive of predation may be to lower acquisition costs of a rival firm rather than to induce it to exit the market. A formal model based on this argument has been developed by Saloner (1987). In this model, the potential victim firm, say firm 2, is uncertain about the costs of its rival, firm 1. The firms play the following three-stage game. In the first stage both firms compete as Cournot duopolists. In the second stage, firm 1 makes a merger offer to firm 2. This offer can be either accepted or rejected. In the third stage, if the offer is accepted, the merged firms enjoy the monopoly profits. If the offer is rejected, the firms engage once more in Cournot competition with one-sided incomplete information. In this situation, the incumbent has an incentive to engage in predation in the first stage (by expanding output) to convince the uninformed firm that it is a low cost firm, whether its costs are actually low or not. This first-stage predatory strategy results from the fact that the expected third-stage profits of the uninformed firm are decreasing in the probability, P, that the incumbent is a low cost firm. This is so because the low-cost firm's best response function lies further to the right as compared to the high-cost firm's best response function, and the low-cost firm's equilibrium output is higher than the high-cost firm's output. For firm 2, the third stage profits are the next best alternative to the merger with firm 1. If firm 2 expects that its output, and thus profits, will be low in the third stage, it will be more willing to accept a merger offer from firm 1. Thus, the higher P is, the better the takeover terms (the acquisition price) for firm 1 are as firm 2 will be more willing to accept a low (i.e. relatively unfavourable) offer.

As we can see in the models discussed above, typical signalling models of predation have a few characteristics in common. First, the incumbent firm is better informed about some payoff-relevant variables, such as costs or demand, than the entrant is. Second, the incumbent, is assumed to be the "natural" predator who undertakes some actions to convey, or signal, some information to a rival that this rival lacks.[7]

It is not clear how the signalling models can be applied to airline markets, in

[7] There have been some related papers where information as well as firms' actions are symmetric, for example Riordan (1985) and Fudenberg and Tirole (1986b). These papers, however, do not address the issue of predation explicitly.

particular to situations where there are two well established airlines. First, it seems that airlines have a good idea about the demand; some important variables necessary to infer the level of demand, such as rivals' prices and capacities, are observable. The prices of major inputs, the aircraft fuel and aircraft equipment, are known to all airlines. It is thus not clear what the predatory airline may want to signal. Second, the signalling models typically refer to situations where the targeted firm does not have full information about the market (because it is new to the market and thus inexperienced) while the incumbent has most of the necessary information. Thus, if in the market to be examined the competing airlines are all well established firms, it is not clear what event can give one firm an informational advantage over the rivals and make it a predator.

2.1.4. Non-price forms of predation

The previous three sections discussed predatory pricing models. There may also be other instruments, besides price, which a predator can use to inflict losses on a rival and thus achieve the same results as predatory pricing. However, non-price forms of predation have attracted relatively little attention. Some of the predatory pricing models could probably be modified to model non-price forms of predation. But there are few rigorous studies where non-price predation is addressed explicitly. Some forms of non-price predation are briefly discussed below.

Ordover and Willig (1981) suggest that one of the instruments of non-price predation may be product innovation. If consumers value a new product more than the old product, a predator may introduce a new product, price it at a little bit less than consumers' valuation, and serve the entire demand. The victim firm who produces only the old product (which is identical to the incumbent's old product) makes no sales and may be forced to exit the market.

It has also been argued that even a product pre-announcement may eliminate competition (Farrell and Saloner, 1986). This may happen in industries where there are some demand-side economies of scale so that consumers may become locked-in to a technology that achieves a sufficiently large base of users. In such industries it may be difficult to adopt a new technology. Early adopters of this technology would bear large incompatibility costs, and they may not be willing to do this. The new technology has a greater chance to succeed, however, if the firm announces in advance the introduction of this technology. This may discourage the existing customers from switching to another supplier and to encourage those intending to buy soon to wait until the new technology becomes available.

Another instrument that a predator could use to harm a rival is advertising. An advertising campaign may be designed in such a way as to reduce the apparent novelty of an entrant's product, confuse consumers, and reduce their ability to differentiate the incumbent's product from the entrant's product. This idea is formally modelled in Masson (1986). Masson considers a market where firms locate their products along a linear market where location is interpreted as product characteristics. Consumers do not know the true characteristics of a product, and they must infer them from consumption experience and advertisements heard. In this context advertising provides consumers with information, but it can also provide misinformation. An incumbent may have an incentive to start "noisy" advertising against a recent rival. This causes the location of the critical consumer, the consumer indifferent between the incumbent's product and the entrant's product, to shift towards the incumbent, thereby reducing the entrant's customer base.

In a spatial market, where competition is localized, an entrant's customer base could also be reduced if the incumbent engages in spatial predation by physically relocating its product closer to the entrant's product (Campbell, 1987). Such relocation makes the incumbent's product more attractive to some of those consumers who previously were buying the entrant's product. These consumers switch to the incumbent's product, and as a result, the entrant's customer base, or market area, shrinks.

It seems that non-price predation can also be practised in airline markets. For example, departure time scheduling seems to be very important in consumers' decisions which flight they should take. An airline could thus engage in spatial predation by scheduling its flights so as to reduce the attractiveness of the rival flights.[8] Another potentially powerful instrument of predation may be frequent flier programs. The airline with the more attractive frequent flier program may be able to attract more passengers and make them reluctant to switch to the competitor.

2.1.5. Empirical and experimental evidence

Empirical studies on predation are very rare compared to the large theoretical literature. There have been a number of case study analyses based on court evidence (McGee, 1958; Koller, 1971; Elzinga, 1970) but this research is descriptive in nature and it does not

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[8] Some caution is, however, required in this regard. For example, it seems at first that scheduling a flight to depart at exactly the same time as a rival flight is predatory in nature. But, as will be explained in section 2.3, rival firms may locate their products at exactly the same point in the market even under non-strategic competition.

involve formal tests of predatory behaviour. Some of the studies that do carry out formal tests for predation include von Hohenbalken and West (1984), Burns (1986), and Dodgson (1993).

Von Hohenbalken and West (1984) analysed market areas of supermarket stores owned by Canada Safeway in Edmonton, Alberta. They point out that the predator operating in the supermarket industry would be expected to locate its new stores in the neighbourhood of the victim stores. This strategy is designed to reduce the market area of the victim stores, possibly below the break-even level, and eventually drive them out of business. The authors obtained results supporting the hypothesis that the dominant supermarket chain had engaged in this type of spatial predation against the smaller competitors. As a result, the average market area of the victim stores was smaller than the average market area of the predator's stores for each year in the sample period. At the same time, the average market area of non-targeted stores was larger than that of the victim stores, even for the subset of the non-targeted stores who had a predator's store in their neighbourhood.[9]

Burns (1986) estimated expenditure for rival firms purchased by the old American Tobacco Company between 1891 and 1906. He employed a firm's valuation model in which the total value of a firm depends on a number of factors such as expected real earnings and their standard deviation, cost of capital, expected return on new investment, and the correlation coefficient between the firm's returns and the market portfolio. In this

[9] Additional tests for spatial predation were carried out in West and von Hohenbalken (1984) and tests for predatory reputation appear in Von Hohenbalken and West (1986).

framework, predation could lower acquisition costs by reducing different components of the victim firm's value. In fact, Burns found that the episodes of alleged predation significantly lowered the acquisition costs. The targeted firms were acquired at a price below their true market value as predation lowered their expected earnings and expected growth. The discount due to predatory pricing was as large as 56 percent in some segments of the market. There was also a reputation effect of American Tobacco's actions that induced other (non-targeted) firms to sell at a discount, presumably to avoid the costly warfare. The average discount from reputation effects was estimated to be equal to 25 percent. These results are interpreted as providing evidence of the predatory nature of the price cutting policy practised by American Tobacco Company because the intent of this policy was to drive the competitors out of business.

Dodgson *et al.* (1993) examined competition in the bus industry in Inverness, Scotland, where there were two bus operators: Highland Scottish Omnibuses (HSO), an established firm, and Inverness Traction (IT), a recent entrant. In this study, Dodgson *et al.* used a modified definition of predation suggested by Phlips (see for example Phlips (1996), Section 3). According to this definition, a firm's behaviour is predatory in nature if it turns a profitable entry opportunity into an unprofitable one.

Based on the existing data on demand and costs, Dodgson *et al.* estimated the Nash equilibrium level of bus services and profits for HSO and IT and found that both firms could have earned positive profits. But both competitors were suffering large losses. IT was taken over twice by another bus operator, and HSO eventually went bankrupt and exited the market. The losses could have been avoided if both firms had decreased their level of services. In this particular situation it was the entrant rather than the incumbent who could be accused of predation against the rival, at least at the beginning. IT entered with a level of output so high that HSO was left with no possibility of a profitable response in the short run. On the other hand, IT could have avoided the losses by entering at a lower scale.

An attempt to test for predation has also been made by Kahai *et al.* (1995) who addressed the concerns and allegations that the relaxed regulation of AT&T resulted in predation on the part of this company. They estimated the number of long-distance carriers in a state as a function of various factors and found that in states which had removed the rate-of-return regulation on AT&T pricing the number of long-distance carriers was not significantly different compared to the states that retained controls over AT&T. This result is interpreted as inconsistent with the predation hypothesis as no exit of competitors has taken place. Consequently, the authors recommend rejection of the allegations of predatory behaviour on the part of AT&T.[10]

Predation has also been the subject of experimental studies. In these studies, experimenters design a game of market competition (which is subject to some rules and structural market conditions) to see whether predation arises in a laboratory environment.

The first of such studies reported in the literature is due to Isaac and Smith (1985). In their game there are two firms in the market: one large incumbent firm, and a small prospective entrant. The larger firm has a cost advantage over the small firm and it also

[10] However, the authors admit that this test has some limitations. For example, it cannot be used in a case in which predation is alleged to be occurring, but has not yet had its intended effect of driving a competitor out of business.

has larger endowments. The latter factor corresponds to the idea of having a deep pocket. In addition, in some sessions of the game sunk entry costs were introduced in order to discourage re-entry by entrants driven out of business in the earlier periods of the game. These structural market conditions were supposed to give the larger firm an incentive to engage in predation. However, in none of the plays of the game did predation emerge, and none of the players left the market. Only when the large firm was instructed by the experimenters to price repeatedly at predatory levels, did the small firm leave the market.

Isaac and Smith (1985) interpret their results as being consistent with the hypothesis that predation is a rare phenomenon. However, these results were obtained within an environment of symmetric information (firms had complete information about the competitor's costs, and they did not know the demand they were facing) and where the reputation of a player did not matter. Moreover, the authors do not make any comments on the experience, or experience formation, of the subjects. Yet it seems quite intuitive that the reputation and the level of experience may affect the results in this type of game. As shown in a later study by Jung *et al.* (1994), these are indeed important qualifications. In Jung *et al.*'s 1994 experiment, incomplete information, reputational effects of the incumbent firm's actions, as well as the experience of the subjects with the game being played, did give rise to predation.

The game designed by Jung *et al.*(1994) closely resembles the Kreps and Wilson (1982) model with a monopolist trying to maintain its monopoly position. When faced with entry, a strong monopolist has higher payoffs from fighting entry than from accommodating entry, and a weak monopolist prefers accommodating entry to fighting.

However, both types are better off if entry does not occur at all. The prospective entrant can either enter the market or stay out. The entrant is better-off entering if the monopolist is weak, but it is better-off staying out if the monopolist is strong. The entrants know only the probability that the monopolist is strong but the monopolist knows its own type.

Under this experimental design, predation occurred in 100 percent of the games played by experienced players, and entry rates were near zero in the early stages of the game. A game in which all incumbent firms were weak was also considered. In this case, predation occurred in 85 percent of the games, and entry rates in the early stages were as low as 30 percent.

There is also a fair amount of descriptive evidence about possible predatory practices in the airline industry. Levine (1987), Kahn (1991), and Hanlon (1994) described some of these practices and documented a few cases of apparent predation. For example, when People Express, a "no-frills" airline entered the Minneapolis - New York route, Northwest, a major full service carrier , met their prices and scheduled additional flights (see Kahn, 1991). The unrestricted economy fare offered by Northwest fell from $263 to $95. To remain competitive, People Express reduced its price to $75 which was also met by Northwest. After People Express exited the market, Northwest increased their fares back to the original pre-entry level. In Great Britain on the Edinburgh - Manchester route, Longair operated for years four daily flights while British Airways had only one flight. This route was profitable to Longair until British Airways decided to match Longair's frequency (see Hanlon, 1994). Longair started losing money on this route and complained to the regulatory agency (Civil Aviation Authority) arguing that at eight daily flights on this route the frequency was quite excessive in relation to demand. To preserve competition on this route, the Civil Aviation Authority restricted the frequency of British Airways flights to just two a day.

Airline markets seem to be particularly susceptible to predation. For example the widespread practices of price discrimination and "yield management" allow the airlines to respond to a competitive threat in such a way as to neutralize the rival's offer at a relatively low cost to itself. The strategy may involve, for example offering low priced seats on off-peak flights with low load factors while withdrawing them from peak times or when competitive threats disappear (see Levine, 1987). The effectiveness of a low pricing policy may be increased by the use of frequent flier programs which give passengers an incentive to concentrate their purchases with one airline. Airlines can thus calibrate the rewards in their frequent flier programs and increase them temporarily on routes where there is increased competition.

However, despite its susceptibility to predation, and episodes of apparent predation, airline markets have not been, to our knowledge, a subject of formal studies of this type of strategic behaviour.

2.2. Contestability of airline markets

A perfectly contestable market is defined as a market where entry is absolutely free and exit is absolutely costless.[11] Such a market is subject to potential entry by firms that have

[11] See Baumol (1982), page 3.

no disadvantage relative to incumbents, and that asses the profitability of entry on the basis of the incumbents pre-entry prices.[12] The crucial feature of a contestable market is its vulnerability to hit-and-run entry. Any profit opportunity, even very temporary, may attract new entrants as they can enter the market before prices change, and leave the market should competition become hostile. As a result, a contestable market never offers more than a normal rate of profit, and prices are equal to marginal cost (unless the industry in question is a natural monopoly in which case price equals average costs.)[13]

The implications of the theory of contestable markets are very strong. In particular, predation cannot be used as an instrument to drive a rival out of business because as soon as the predator starts enjoying monopoly profits, there will be hit-and-run entries into the industry on the part of potential entrants who are just waiting for emerging profitable opportunities.

When the theory of contestable markets was developed, airline markets were cited as an example of contestable markets. The strongest argument in favour of the contestability hypothesis in airline markets was a high degree of aircraft mobility. Planes can be easily moved from one route to another, rented out, or sold. The high fixed costs of airport

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[12] See Baumol *et. al* (1986), page 342.

[13] It has been recognized in the literature that an equilibrium in a contestable market may not exist. This happens when, for example, the industry average cost curve is U-shaped and the market demand curve intersects the average cost curve slightly to the right of the minimum point. Even if price equals average cost and industry profits equal zero, there are profitable entry opportunities. Entrants can enter at a scale of output at which the average cost curve reaches the minimum, charge a lower price than the established firm and earn a positive profit. Some remedies for this existence problem have been suggested such as an assumption that the average cost curve has a fairly large flat bottom. (This assumption is also consistent with the empirical evidence.) For details see Baumol *et al.* (1982).

facilities are born not by the airlines themselves but by the local municipalities who lease the gate space to airlines. These facts were interpreted as implying low entry and exit barriers and making strategic behaviour irrational (see Bailey and Panzar, 1981).

Contrary to these theoretical expectations, the contestability hypothesis has been rejected in many empirical studies.

As will be shown below, a number of studies examine the determinants of air fares. In these studies, average fares, or some form of a price index such as the average revenue, are regressed on variables describing the cost of servicing a passenger, market structure, and dummy variables controlling for market or airport-specific effects. The estimating equation typically includes variables such as market concentration, distance, number of passengers carried, load factor, dummy variables for slot-constrained airports, etc. If airline markets are in fact contestable, air fares should not depend on variables describing market structure. However, many studies found that this is not the case. For example, Bailey *et al.* (1985) found that in the second quarter of 1981 the average fares in markets served by four equal sized airlines were 11 percent lower than in a similar market served by a monopolist. In markets where newly certificated carriers were present, average fares were 20 percent lower than in similar markets where there were no new entrants. Similar estimates were obtained by Graham *et al.* (1983) and Call and Keeler (1985). In another study, Hurdle *et al.* (1989) found that in 1985 average revenue per passenger mile tended to be higher in highly concentrated markets than in markets where concentration was low. On the other hand, in markets where a potential entrant was present, average revenue tended to be lower. At the sample means, a reduction in the average number of incumbents from three to two firms would increase average revenue by 4 to 12 percent, and in the absence of likely potential entrants, the merger of the only two incumbents would increase average revenue by 12 to 30 percent.

However, high market concentration does not necessarily benefit small carriers. For example, Borenstein (1989) included in a typical pricing equation measures of market concentration (route Herfindahl index and average Herfindahl indices for passenger originations at the two end-points of the observed route) as well as measures of market share of the observed airline on the route in question (route share and weighted average share of daily passenger originations at the two end-point airports). The estimation results indicate that fares tend to increase with market share.[14] In contrast, the effects of market concentration are indeterminate. The intuition behind the latter result is that high market concentration (when there are a few large firms) facilitates tacit or explicit collusion which tends to increase prices. But when in the observed market there are many small firms and just one large competitor, i.e. when market concentration is low, the dominant firm may have a competitive advantage (for example through various marketing devices) and be able to charge higher prices than the small firms. The average fare in these markets may be relatively low. In another study, Abramowitz and Brown (1993) also found that average fares increase with route share and airline size. But the effect of market concentration (measured by the Herfindahl index) depends on the assumed minimum traffic share that a

[14] However, in another study Oum *et al.* (1993) came to the conclusion that fares decrease with market share.

carrier must have in order to be included in the estimation.[15] Route share, in turn, increases with scheduled capacity and dominance at the end-point airports measured by the gates or enplanement share.

As indicated earlier, some studies suggest that potential competition has at least a moderating effect on fares (for example Hurdle *et al.*, 1989). Other studies suggest that welfare is higher in markets where at least one potential competitor is present (Morrison and Winston, 1986, 1987). Morrison and Winston interpret this effect as consistent with "imperfect contestability" in the sense that the mere presence of potential competition improves the market performance. But Petaraf (1995) challenges the view that airline markets may be at least imperfectly contestable. Her study of monopoly airline markets revealed that it was the aggressive price cutting reputation of potential entrants rather than just the mere presence of potential competitors that was limiting price-cost margins realized by the airline monopolist.

The rejection of the contestability hypothesis suggests that airline markets are not inherently competitive and that it may be profitable for the established airline firms to engage in some form of strategic behaviour, possibly predation, to protect their dominant position or to drive a competitor out of business in order to achieve a monopoly.

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[15] In the base case the authors used a 10 percent share screen (i.e. a rule that a carrier must have at least 10 percent share of the total traffic in order to be included in the estimation) and report a negative coefficient on the Herfindahl index. In a footnote, they mentioned that the price equation was re-estimated with a 5 percent share screen and with a 2 percent share screen. With the 5 percent share screen the effect of the Herfindahl index was statistically insignificant, and with the 2 percent share screen it was positive.

2.3. Multi-product oligopoly

Most literature on oligopolistic competition assumes that firms produce a single product. Even in most product differentiation or spatial location models each firm offers just one product or locates just one outlet at a single point in geographic or product space. This simplifying assumption is at odds with real market observations that firms typically produce more than just one product or have more than just one outlet.[16]

The question then arises whether the number of products and their characteristics can be used strategically. This possibility arises, for example, in Eaton and Lipsey's (1979) model. They showed that a foresighted monopolist would introduce another product in a growing market before the demand is sufficiently large to support it. This strategy has an entry deterring effect on prospective rivals and allows the established firm to maintain a monopoly.

One of the first studies to address the question of product selection in an oligopolistic market directly is Brander and Eaton (1984). They examine a market where there are two firms and four products. The product pairs (1, 2) and (3,4) are close substitutes, whereas the other pairs are more distant substitutes as defined by price cross-elasticities. The firms compete in quantities as well as in product lines. The equilibrium market structure depends on the magnitude of demand and the type of the game being

[16] One reason for this simplification is, perhaps, analytical complexity of oligopoly models with multi-product firms. Typically, there is no closed form solution, except for very simple cases, and there is no guarantee that an equilibrium exists. Some empirical studies deal with this problem by choosing a proxy. For example, Dodgson *et al.* (1993) in their study of predatory behaviour in the bus industry chose total bus-miles as a proxy for frequencies and departure times. Higher bus-miles imply higher frequencies and lower average distance in minutes between an operator's buses.

played. In the Nash equilibrium (i.e. when product lines are selected simultaneously) both segmentation (i.e. the situation where firm 1 produces pair (1, 2) and firm 2 produces pair (3, 4)) and interlacing (i.e. the situation where firm 1 and firm 2 produce product pairs which are more distant substitutes) can be an equilibrium. However, under a segmented market structure all firms earn larger profits. Thus, if the game being played is a sequential product selection, or the Stackelberg game, rather than the simultaneous product selection, segmentation will be the equilibrium market structure.

The intuition that firms would always prefer a multi-product or multi-establishment structure to a single product and single outlet structure (when fixed costs are zero) is at odds, however, with some theoretical findings. For example, Martinez-Giralt and Neven (1988) analyse the problem of product choice in a spatial market. In their model, there are two firms and each firm can open two outlets in a circular market. The firms position their outlets in the first stage of the game and compete in prices in the second stage. Consumers are uniformly distributed over the circle and buy one unit of the product from the seller that offers the lowest delivered price. Surprisingly, in the Nash equilibrium, each firm locates its two outlets at the same point and symmetrically opposite end to the rival's outlets. The result that firms locate their two outlets at exactly the same point is equivalent to the firms' choice to open just one outlet. The intuition behind this result is that opening another store increases a firm's market share, but at the same time it increases price competition with the rival stores, and with quadratic transportation costs the negative effect of price competition outweighs the positive effect of a larger market share. This result still holds in a linear market. But Bensaid and dePalma (1994) have shown in a similar circular model that when there are three firms in the market allowed to open two outlets each, a variety of equilibria exist where each firm has two stores at distinct locations. Equilibria with two firms opening two stores at distinct locations result also when consumer demand is price-elastic (Anderson, 1985). In this case firms have an incentive to open another outlet to serve a part of the market that would have been unserved in the absence of a second store.

As suggested earlier, there are some indications that product selection could be used strategically. For example, in Bensaid and dePalma (1994) two firms operating in a market threatened by new entry may open two outlets each at two distinct locations in order to deter entry, even though they open just one outlet each in the pure Nash equilibrium. It also seems that firms could relocate their stores or products closer to rival stores or products in order to reduce their market share, intensify price competition, and impose losses on them. In fact, Anderson (1985) indicates that a situation when rival firms open their outlets at exactly the same location cannot be an equilibrium because a simple relocation of one firm will necessarily increase profits. The analysis of Brander and Eaton (1984) suggests that a large firm that can play as Stackelberg leader could engage in strategic behaviour and produce more distant substitutes rather than closer substitutes so that the resulting market structure is interlaced. In this way this firm could reduce a rival's profits relative to the amount that could be realized under a segmented market structure.

However, it should be noted that clustering of rival firms may also arise under non-strategic competition. For example, Thill (1992) considers a model where firms locate their stores in a two-dimensional space. The problem that the firms face may be interpreted as the choice of the geographic location and the quality value to offer to consumers. Consumers are uniformly distributed over the geographic and preferences space. When they buy from a store whose location and quality value does not match their personal tastes and location, they suffer a disutility. It is assumed that a consumer buys a product only if this disutility is not larger than a certain threshold value. The demand each store faces is probabilistic with the choice probability by consumers depending on the disutility from the store in question relative to the disutility from all other stores. Equilibria were simulated numerically. For small disutility thresholds, the equilibria are strongly dispersed, but when this threshold is larger, rival firms tend to form pairs with a rival outlet.[17] The intuition behind this result is that a low willingness to shop at less desirable locations results in market segmentation as stores are able to establish a local monopoly. When the willingness to shop at less ideal shops increases, all stores have an incentive to move from peripheral locations toward the centre. This is so because, with probabilistic demand, the increase in demand from consumers located at the opposite end of the market is larger than the loss in demand from consumers located close to the old position of the store.

Clustering of rival firms' outlets may arise in equilibrium also if consumers incur a fixed cost of using a supplier (Klemperer, 1992). This is so because if firms offer identical products, consumers find it not worthwhile to buy from more than one firm. As a result, price competition between firms is reduced and price can be larger than marginal costs. Klemperer shows that in the clustered market structure price may be even larger than in

[17] The author reports that for some disutility thresholds no equilibrium was found.

the dispersed, or interlaced, market structure.

Rival firms may also form a cluster if there are economies of agglomeration, or if consumers engage in comparison and multi-purpose shopping. Rival firms may locate in clusters, such as a shopping centre, to facilitate multi-purpose and comparison shopping. A large shopping centre attracts a large number of customers, and this positive market area effect may outweigh the negative effect of intensified competition within the centre (see for example Stahl, 1982). However, it seems that comparison shopping and multipurpose shopping do not explain consumer behaviour in airline markets. Moreover, in this literature it is typically assumed that one firm has just one outlet (or has one product), and it is not clear how the conclusions arising from these models apply to a multi-product setting. Because of these reasons, this literature is omitted in this review.

Summing up, there are some indications in the theoretical literature that product location can be used strategically. Some caution is required, however, as the mere observation that two rival firms have located their products at exactly the same point in the geographic or product space does not necessarily imply that one firm is preying on the other. Detailed non-strategic and predatory location patterns have yet to be established.

2.4. Summary

There is a widespread agreement among economists that predation may be a rational business strategy in many market situations. This result as well as the fact that the contestability hypothesis, even in its weaker form of "imperfect" contestability, has been rejected in many studies indicates that predation in airline markets may be both feasible and rational.

The most appropriate theoretical models of predation to use in the empirical analysis are the reputation model of predation and the deep pocket model of predation. The signalling model of predation seems to be a less likely alternative explaining the behaviour of airline firms.

An airline firm can engage in price predation, but it seems that non-price forms of predation, such as departure time scheduling, are also possible in this industry.

The literature has offered little general predictions regarding product location and competition in multi-product industries. Thus, the theoretical foundations of competition in airline markets have yet to be developed. A theoretical model of competition in airline markets is developed in the next chapter, Chapter 3. This model forms the basis for the empirical analysis which will be carried out in Chapter 5.

Chapter 3

A theoretical model of competition in airline markets

In order to derive testable predictions of predatory behaviour, it is necessary to develop a model of competition in an airline market that would shed light on the nature of non-strategic competition in these markets. Knowing the predictions of non-strategic behaviour, it will be possible to discuss how predation is likely to change these predictions. This chapter sets up the theoretical framework to analyse competition in airline markets and derives testable implications of non-strategic and predatory behaviour.

The discussion in this chapter is organized as follows. Section 3.1 specifies the assumptions and explains the modelling approach. The basic assumption is that airlines are concerned with maximizing their profits. As will be explained in this section, profit maximization in the airline industry can be modelled as a multi-stage process. Here, it is assumed that it is a three-stage process. Each stage is then discussed in sections 3.2, 3.3, and 3.4. Section 3.5 contains a brief summary.

3.1. The assumptions and the modelling approach

Let us assume that there are two airline firms, Airline 1 and Airline 2, competing in a city pair market. We also assume that airlines are concerned with maximizing their profits in each city-pair market, and consider competition in one of such markets.[18] The airlines

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[18] Consequently, the network effects of competition in the airline industry are ignored.

compete in the following variables describing their flight schedule: total seating capacity, departure times, and ticket prices.[19] Profit maximization in this industry is a multi-stage process. In the first stage the total seating capacity is chosen. In the second stage, airlines choose departure times of their flights. In the last stage, airlines determine fares.[20, 21] Seating capacity can be interpreted as the output of airline firms and, thus, as a standard variable affecting the magnitude of profits. Departure times enter the profit maximization problem because they determine the spatial structure of the market, spacing of flights and neighbour relations, which may affect the demand facing each airline. Finally, The level fares affects the number of seats the airline will sell.

This approach to the problem of competition in the airline industry combines both spatial and non-spatial dimensions of profit maximization. The spatial dimension relates to the scheduling of flights around the 24 hour clock, as well as to the fares charged on each flight. The non-spatial dimension relates to the choice of capacity. Departure times and fares will be modelled in a spatial context, and the capacity decision problem will be modelled in a non-spatial context.

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[19] Another important variable that airlines choose is flight frequency. Including this variable as a choice variable, however, makes the problem more complex. First, there is a trade-off between attracting high-yield traffic through high flight frequency and high cost associated with this strategy. Second, the assumption that airlines choose both the capacity and the number of flights also implies that they have full flexibility as to the size of the planes they use, and this does not seem to be realistic in the short-run. In this thesis flight frequency is exogenous. Higher flight frequency will manifest itself through a higher seating capacity and/or through more departure time slots .

[20] Arrival times may also be important but typically they are a consequence of departure times.

[21] This structure of the model reflects the idea that the flexibility that airlines have in each of the variables is not the same. For instance, prices can be updated very quickly through the computer reservation systems, but it may be more difficult to adjust seating capacity quickly.

Strategic behaviour may occur in all stages of profit maximization, or only in one or two of them, as in each stage there is the potential to inflict losses on the rival. Consequently, testable predictions regarding strategic and non-strategic behaviour are derived for each choice variable.

Because the model is a sequential game, it can be solved using backward induction. The spatial variables, fares and departure times, have to be calculated first, and the spatial context of the model is discussed first. Because of the complexity of the problem, a computer simulation program is used to determine non-strategic and predatory scheduling patterns. Predictions regarding non-strategic and predatory fares are based on the last stage best-response function, which is derived from the profit function. Next, the non-spatial context of the model is discussed. Similarly as in the case of fares, predictions regarding the non-strategic level and the predatory level of seating capacity are based on the first stage best-response function.

While solving the model using the backward induction procedure suggests that the last stage of profit maximization should be examined first, the discussion starts with the intermediate stage. Then, it returns to the last stage, and proceeds to the first stage. This sequence results from the complexity of the spatial specification of the model. Once the spatial context has been specified and the solution methodology explained, it is easier to discuss departure times scheduling at once rather than delay it until a later section.

The three stages of profit maximization, the choice of departure times, the choice of fares, and the choice of seating capacity, are discussed in sections 3.2, 3.3, and 3.4, respectively.

3.2. The intermediate stage: the choice of departure times

In the intermediate stage of profit maximization seating capacity is fixed, and the airlines choose departure times for their flights. Departure times can be regarded as an instrument of horizontal differentiation, and can be modelled as distributed around a 24 hour clock. To uncover the theoretical predictions regarding the pattern of non-strategic scheduling, a nested logit model is used.[22, 23]

There are two airlines, Airline 1 and Airline 2, which schedule n_1 and n_2 flights, respectively. The number of flights for the given total capacity is given exogenously. Each consumer can buy at most one ticket per period of time. Consumers are discretely[24] distributed over space at locations d_k, k=1, 2,...z. The number of consumers at location k is N_k. The distribution of passengers is bi-modal with one peak from 7:30 a.m. to 11:00 a.m. and another peak, higher but narrower, from 5:00 p.m. to 7:00 p.m. This distribution

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[22] This section is a part of research on location in multi-product oligopoly, a joint project with Robin Lindsey.

[23] A logit specification is frequently used to model situations where consumer behaviour is affected by non-systematic factors such as tastes. For example, in airline markets a consumer may choose a flight operated by Airline 1 even if Airline 2 offers another flight that matches more closely his or her departure time preferences. This decision may be due to, for example, a positive experience with Airline 1. In this setting, consumers have a stochastic utility function, rather, than a deterministic one. The total demand facing a firm, say firm i, is determined, beside the magnitude of demand (or the number of consumers in the market), by the probability that an individual chooses one of the alternatives offered by firm i. The nested logit model is an extension of multinomial logit, and it is used to model situations where consumer behaviour can be interpreted as a multistage process. For example, consumers' choice of a differentiated product, such as different flights, can be decomposed into the choice of the firm to patronize (the first stage), and the choice of the product (the second stage). This framework seems to fit the airline markets fairly well. For a review of the logit model and its applications see Anderson *et al.* (1992).

[24] The assumption that the distribution of consumers is discrete is made for computational reasons. In general, the distribution can be assumed to be continuous.

is taken from Miller (1972, Figure 2). Consumers' location in the space is interpreted as the most preferred departure time, MPD. The schedule delay time, the time in minutes from MPD to the nearest scheduled flight, is interpreted as the transportation cost that consumers have to bear in addition to the fare.

Each consumer's choice can be described by a two-stage process. In the first stage the consumer decides whether to fly and if so which airline to patronize. If the consumer decides to fly, then in the second stage she picks a flight from the chosen airline. This two-stage process can be solved via backward induction by considering the second stage first.

Consumer k located at d_k, or having MPD= d_k, receives an indirect utility from buying a ticket for flight j operated by airline i:

$$V_{ji}^{k} = a_{ji} + y^{k} - p_{ji} - T(d_k - d_{ji})^2 + \mu_2 \cdot \epsilon_{ji}^{k} + \eta_i^{k} \ , \qquad \textbf{(1a)}$$

where y^k is consumer k's income, p_{ji} is the ticket price for flight j operated by airline i, d_{ji} is the location (departure time) of that flight, a_{ji} is its quality, and T is a factor of proportionality. The ϵ_{kj}'s are identically and independently double exponentially distributed random variables with a scale parameter μ_2 . The random variable $\eta_i{}^k$ is distributed so that $max_{\,j=1 \dots ni} V_{ji}^{k}$ is double exponentially distributed with scale parameter μ_1. It may be shown that the probability of purchasing a ticket for flight j conditional on patronizing airline i is (see Anderson *et al.* (1992), in particular Chapter 2 and Chapter 7):

$$P_{j|i}^{k} = \frac{\exp[(a_{ji} - p_{ji} - T(d_k - d_{ji})^2)/\mu_2]}{\sum_{j=1}^{n_i} \exp[(a_{ji} - p_{ji} - T(d_k - d_{ji})^2)/\mu_2]} \ . \tag{2}$$

In the first stage, the consumer chooses between flying with one of the airlines or not flying at all. The expected benefit for consumer k from patronizing airline i, A_i^k, is (see Anderson *et al.* (1992)):

$$A_i^k = E(\max_{j=1,\dots n_i} V_{ji}^k) = \mu_2 \ln \sum_{j=1}^{n_i} \exp[(a_{ji} + y^k - p_{ji} - T(d_k - d_{ji})^2)/\mu_2] \ . \tag{3}$$

A consumer can also decide not to fly at all. In this case, she receives an indirect utility:

$$V_0^k = y^k + v_0 + \mu_1 \cdot \epsilon_0^k , \tag{1b}$$

where v_0 is the satisfaction associated with non-purchase, ϵ_0^k is double exponentially distributed with scale parameter 1. ϵ_0^k is also distributed independently of ϵ_{ji}^k and η_i^k. The probability that consumer k patronizes airline i is then:

$$P_i^k = \frac{\exp(A_i^k/\mu_1)}{\sum_{j=1}^{2} \exp(A_j^k/\mu_1) + \exp(v_0/\mu_1)} \ . \tag{4}$$

Parameters μ_1 and μ_2 characterize the heterogeneity of consumer tastes. μ_2 measures the degree of heterogeneity of flights on the schedule, and μ_1 measures the degree of heterogeneity of airlines. Because choice at the first stage is influenced by idiosyncratic tastes for both airlines and flights, whereas choice at the second step is influenced only by tastes for flights, $\mu_1 \geq \mu_2$.

The probability that consumer *k* buys a ticket for flight *j* operated by airline *i* is the product of the probabilities expressed in equations (2) and (4):

$$P_{ji}^{k} = P_{i}^{k} \cdot P_{j|i}^{k} \quad . \tag{5}$$

This probability allows us to derive demand facing airline *i* and its profit function. The expected demand for flight *j* is:

$$D_{ji} = \sum_{k=1}^{z} N_k \cdot P_{ji}^{k} , \tag{6}$$

and the total profit of airline *i* is:

$$\pi_i = \sum_{j=1}^{n_i} (p_{ji} - c_{ji}) D_{ji} - F(n_i) \tag{7}$$

where $F(n_i)$ is the fixed cost of scheduling n_i flights and c_{ji} is the marginal cost of service.

It is assumed that the objective of airline firms is to maximize profits. As explained earlier, profit maximization is a multi-stage process; the choice of fares follows the choice of departure times. A non-cooperative equilibrium $(p_i^*, d_i^*, p_{-i}^*, d_{-i}^*)$ is defined by the condition

$$\pi_i(p_i^*, d_i^*, p_{-i}^*, d_{-i}^*) \geq \pi_i(p_i, d_i, p_{-i}^*, d_{-i}^*)$$
$$\text{for any feasible } p_i,\ d_i,\ i=1,2\ , \tag{8}$$

where p's are the vectors of prices and d's are the vectors of locations (departure times).

Equilibria were computed using a computer simulation program. The computation procedure involves a series of iterations. Starting from an initial configuration at iteration 1, Airline 1 searches for better departure times for its flights taking the locations of Airline 2's flights as given.[25] Then, Airline 2 searches for better departure times for its flights taking locations of Airline 1's flights as given. Iteration 2 proceeds as iteration 1 with the semi-revised schedules obtained at iteration 1 as the initial configuration. Iterations continue until there is no revision of any flight of either airline. In an attempt to reduce the computation time, the initial configuration was sometimes chosen as a "guess" of the equilibrium configuration. Also to reduce the computation time, the grid search was sometimes not extended to the early hours of the morning (before 4:00 a.m.) or to the late hours of the evening (after 8:00 p.m.). In no instance was a case of multiple equilibria encountered. Simulations were performed for several values of n_1, n_2, μ_1, μ_2, T, and ν_0. The detailed results are presented in the Appendix. A summary of the non-strategic and strategic scheduling patterns follows.

3.2.1. Non-strategic scheduling pattern

The results obtained in numerical simulations were as follows:

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[25] However, prices are adjusted each time when any of the airlines changes the location of its flights.

1. When both airlines operate the same number of flights, or when one airline operates one flight more than the other airline, the equilibrium market structure is interlaced, i.e. there are no instances where two neighbouring flights are operated by the same airline. An interlaced market structure was obtained even if the number of flights for each airline was increased to six,[26] and even when the starting configuration for the algorithm was segmented, i.e. if there were some nearest flights operated by the same airline. It has not been determined yet under what conditions, if any, a segmented market structure can arise in equilibrium.[27] It may be the case that a segmented market structure can generate higher profits than an interlaced market structure,[28] and firms may use this information when choosing locations.
2. The distribution of flights across the flight schedule is non-uniform. The peak flights tend to form pairs consisting of one flight operated by each airline. The time distance between nearest flights depends on whether the flights in question are peak or off-peak flights, the idiosyncratic utility, and the utility associated with non-purchase. The distance between two peak flights is, as expected, smaller than the distance between two off-peak flights. When one of the airlines, Airline 1, operates four flights and Airline 2 operates only three flights, Airline 1 schedules two flights during the evening

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[26] These results are not reported in the Appendix but are available from the author.

[27] As indicated in chapter 2, interlaced equilibria were obtained by Bensaid and dePalma (1994) for three firms and two products in a model with deterministic inelastic demand.

[28] In the segmented equilibrium for three firms and two products in Bensaid and dePalma (1994), profits for each firm were more than three times higher than in the interlaced equilibrium for the same number of firms and products.

peak while Airline 2 has only one flight during that time period. The time distance between flights also decreases when the idiosyncratic utility is high, or when the utility associated with non-purchase increases.

3. When the idiosyncratic utility is high, a perfectly paired market structure may arise in equilibrium (see Simulations 1, 3 and 6), i.e. rival flights leave at the same time.[29]
4. The scheduling pattern appears to be insensitive to the perceived heterogeneity of flights, i.e. to parameter μ_2. A larger μ_2 had a very small effect on prices, demand, and profits (compare simulations 3 and 4). However, increasing μ_1, the perceived heterogeneity of airline firms, by 100 percent increased profits by approximately 70 percent. (Compare Simulations 1 and 3.)

3.2.2. Predatory scheduling pattern

The results obtained in the numerical simulations were as follows:

1. Rescheduling Airline 1's flight and locating it at the same time slot as one of its rival's flights can reduce the rival's profit. Deep price cutting for the rescheduled flights increases the magnitude of losses incurred by the victim airline. Still, the reduction in Airline 2's profits was quite small. However, the assumed fixed costs were set equal to zero, and total revenues rather than profits were measured. If fixed costs are sufficiently high, predation will result in negative profits for the victim airline.

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[29]This low differentiation is a direct result of consumers' buying behaviour. When μ_1 is large, non-systematic factors, such as tastes, become an increasingly important determinant of utility compared to flight characteristics. When flight j moves from the left to the right and closer to flight k, it gains additional customers located between j and k and those located to the right of k. It also loses some passengers located to the left of j but this loss is more than compensated by the gain just described. (For a detailed discussion of this effect and the resulting minimum product differentiation see dePalma *et al.*, 1985.)

2. The effectiveness of predation may be larger if the victim airline is "squeezed" in the sense that its total market area decreases. In Simulation 7, the squeezing strategy involved rescheduling the last flight on the schedule closer to the second-last flight on the schedule which was a rival flight.
3. Predation may also involve scheduling a new flight rather than rescheduling one of the established flights. When Airline 1 operated four flights and Airline 2 operated only three flights Airline 2's profits decreased 3.6 percent while Airline 1's profits increased by 19.2 percent compared to the case when each airline operated only three flights.
4. It has not been determined yet whether targeting peak flights is more successful than targeting off-peak flights. In Simulation 7, targeting the 18:00- flight was most effective in terms of depressing Airline 2's profits. However, taking Airline 2's locations obtained in Simulation 1 as given and considering the best locations for a fourth flight for Airline 1, it turns out that the profit maximizing location for this flight coincides with the off-peak flight operated by Airline 2; this location also yields a profit minimum for Airline 2.
5. Predation appears to be a costly strategy. Let $R \equiv |\Delta\pi_1|/|\Delta\pi_2|$ denote the loss in profit incurred by the predatory airline per unit of lost profits incurred by the victim airline. In all simulation considered R exceeded 2.

3.2.3. Testable predictions of non-strategic and predatory scheduling patterns

A given pattern of departure times scheduled by an airline, say Airline 1, is predatory in nature if it inflicts losses on a rival and is inconsistent with simple short-run profit maximization for Airline 1. Suppose, for example, that a change in Airline 1's departure times has inflicted some losses on Airline 2 and at the same time resulted in a decrease in profits for Airline 1. This change in Airline 1's departure times can be considered as predatory in nature as non-strategic behaviour does not involve changing the schedule in a fashion that depresses own profits.

As we are interested in the direction of changes rather than the magnitude of realized profits, the model specified in this section in conjunction with the assumed parameter values and the actual departure times could be used to calculate the changes in profits corresponding to each change in the flight schedule to determine whether changes in the actual departure times are consistent with non-strategic behaviour. A change in Airline 1's flight schedule at time t+1 will be considered as predatory in nature if for d_{1t} not equal to $d_{1,\,t+1}$ we have

$$\pi_{1t+1}(p_{1t+1},\ p_{2t+1},\ d_{1t+1},\ d_{2t}) < \pi_{1t}(p_{1t},\ p_{2t},\ d_{1t},\ d_{2t})$$

and

$$\pi_{2t+1}(p_{1t+1},\ p_{2t+1},\ d_{1t+1},\ d_{2t}) < \pi_{2t}(p_{1t},\ p_{2t},\ d_{1t},\ d_{2t}).$$

Unfortunately, the data that are necessary to implement the departure time scheduling model for a specific market, such as the Vancouver - Toronto route, were not available.[30] Therefore, tests for predatory behaviour will be based on predictions derived

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[30] To implement the simulation model, data on the distribution of demand across the times of day would be required. These data were not available. Other tests for predatory scheduling, based on examination of the changing pattern of neighbour relations between flights, were considered but

from the fare setting and capacity decisions stages of the airline competition model. These will be discussed next.

3.3. The last stage: the choice of fares

The algorithm used in Section 3.2 to solve the logit model allowed us to calculate numerically the optimal departure times and the corresponding fares for each flight. We are, however, interested in a general algebraic expression for prices that could be used as a basis for a price equation in the regression analysis. This expression for prices may be derived as below.

In the last stage of profit maximization the flight schedules are already determined. Optimal prices can be obtained by differentiating profit equation (7) with respect to p_1 and then solving the resulting expression for p_1. To simplify the analysis, let us make the following assumptions:[31] (1) each airline charges the same price for each of its flights; (2) the quality of a flight is the same for all flights and both airlines and equal to *a*; and (3) the marginal cost of service on flight *j* operated by airline *i*, c_{ji}, is the same for each flight and equals MC_i for *i*=1, 2. Differentiation of the profit equation (7) with respect to p_1, and solving it for p_1, gives an expression of the following form:

$$p_1 = p_1(p_2,\ d_1,\ d_2,\ MC_1,\ \mu_1/T,\ v_0,\ a). \tag{9}$$

ultimately rejected because of certain ambiguities in the predictions and measurement problems in the neighbour relation variables.

[31] A reason for making these assumptions is that the data would not allow us to incorporate the differences listed in (1) - (3).

(Note that the parameter μ_2 has been omitted in the price reaction function as the simulation results indicate that the idiosyncratic taste variation at the flight level is insignificant.)

The simulation results of Section 3.2.1 indicate that the equilibrium flight schedules are a function of the number of flights offered by each airline, and all other specified parameters. Let us assume that seating capacity is proportional to the number of flights. Thus, Airline 1's equilibrium flight schedule can be written as:

$$d_1 = d_1(K_1,\ K_2,\ MC_1,\ \mu_1/T,\ v_0,\ a) \tag{10}$$

where K_1 and K_2 are Airline 1's and Airline 2's capacity, respectively. Similarly, Airline 2's flight schedule can be expressed as:

$$d_2 = d_2(K_1,\ K_2,\ MC_2,\ \mu_1/T,\ v_0,\ a). \tag{11}$$

At the stage when prices are chosen, departure times are already fixed. We can thus substitute (10) and (11) into (9). This procedure gives Airline 1's last stage best response function expressed in terms of rival prices and seating capacity, Airline 2's prices and seating capacity, and all exogenous parameters.

Note that the choice probabilities in the logit model, P_i^k and $P_{j|i}^k$, in equations (4) and (2), respectively, are independent of consumer income, and the resulting price is also independent of consumer income. This is satisfactory for the purposes of a static analysis in which income is given. However, in a dynamic context, changes in income are likely to cause changes in demand and thus prices. Air travel demand is an increasing function of the number of consumers , and the number of consumers in the market is likely to be a function of the average consumer income (for example, when consumer income increases, more people enter the market and start making purchases). If marginal costs are constant and capacity constraints do not bind, fares still do not depend on the number of consumers. But in the more general case of a U-shaped short-run average cost curve, it becomes increasingly expensive to produce larger quantities and, thus, the price has to increase. Therefore, we include an additional explanatory variable into the price equation, average consumer income, y.

We also assume that marginal cost of service is a function of input prices which are the same for both airlines. Then, after suppressing parameters a, μ_1/T , and v_0, equation (9) can be written as:

$$p_1^* = h^*(\overset{+}{p_2}, \overset{-}{K_1}, \overset{-}{K_2}, \overset{+}{w}, \overset{+}{y}), \tag{12}$$

where the asterisks indicate that the specified function describes the optimal non-strategic fares. The sign above each variable denotes the expected sign of the partial derivative with respect to that variable. The expected effect of each variable is discussed below.[32]

- *Airline 2's price.* Prices of substitutable products produced by competing firms are typically thought of as strategic complements: when one firm lowers the price, it is optimal for the other firms to do the same.

[32] Because of the functional complexity of the logit model, it does not appear feasible to derive the derivatives analytically. Numerical solutions are possible, but these are parameter specific.

- *Airline 1's seating capacity.* Prices and output are jointly determined: a higher output depresses the price, and a lower price requires a higher output to satisfy demand. In the airline industry context, an increase in capacity will require a reduction in price in order to stimulate the demand, otherwise planes will fly empty.
- *Airline 2's seating capacity.* An increase in Airline 2's capacity decreases Airline 1's market share of scheduled capacity. This is likely to decrease demand facing Airline 1 as schedule delay times associated with Airline 2's flights may become lower. Moreover, an increase in capacity also increases the probability that a consumer obtains a ticket for her most preferred flight operated by Airline 2. The optimal fare for Airline 1 goes down.
- *Input prices.* An increase in input prices will result in higher fares. This is a standard result in oligopoly theory: an increase in production costs causes prices to go up.
- *Income.* An increase in income shifts the demand curve to the right, driving up price.

Specification (12) applies to the optimal non-strategic price. However, if Airline 1 behaves in a strategic fashion using fares as an instrument of predation, relations derived from simple short-run profit maximization may not hold in general. The rest of this section discusses how predation changes the testable predictions for fares charged by Airline 1. Our preliminary hypothesis is that the effects of the variables included in equation (12) and/or additional relevant variables, depend on the nature of the underlying behaviour, or which model of predation best explains Airline 1's actions.

3.3.1. Reputation model of predation

In the reputation model of predation, an established airline firm could engage in predation against a rival airline in order to establish a reputation for toughness. Reputation is built through aggressive responses to all, or almost all, of a rival's attempts to expand business (Kreps and Wilson, 1982; Milgrom and Roberts, 1982). If it is Airline 1 that engages in predation against Airline 2, then Airline 1 should cut prices in response to Airline 2 cutting prices or expanding capacity. Unfortunately, this type of behaviour may be difficult to distinguish from non-strategic behaviour as a decrease in price in response to a decrease in p_2 or an increase in K_2 are also consistent with non-strategic behaviour. Consequently, it is not clear whether these actions can credibly demonstrate to Airline 2 that Airline 1 has become a "tough" competitor.

Another instrument that could potentially be used by the predatory airline to demonstrate "toughness" is income. Suppose that consumer income increases. Under non-strategic competition we would expect an increase in price as higher income increases demand. But if Airline 1 wants to demonstrate "toughness" and its commitment to monopolizing the market, it may consider decreasing prices when income rises. By reacting in this way to increasing incomes, Airline 1 may gain a large market share and acquire an image of the most significant competitor in the market. When consumer income decreases, Airline 1 may want to increase prices to demonstrate its ability to stay in the market even when demand conditions are unfavourable. (The ability to stay in the market could be a result of factors such as consumer loyalty, perceived superiority of Airline 1 compared to Airline 2, or some other factors not fully understood by Airline 2.) Thus, the derivative of price with respect to income is expected to be negative.

3.3.2. Deep-pocket model of predation

According to the deep pocket argument in the theory of predation, the incumbent firm may engage in predation in order to decrease a rival's profitability or cash flow (Bolton and Scharfstein, 1990; Poitevin, 1989). Lower profits would increase the probability of defaulting on a loan payment. When this happens, financial institutions may cut off further funding, and the victim firm may be forced to declare bankruptcy. Low profitability may also make it difficult for the rival to obtain funding in the first place, or to obtain funding for new projects (Gale and Hellwig, 1985). If this is the case, then a rival firm's financial results may be relevant for the choice of capacity and predatory strategy. For example, declining profits experienced by the rival, or a declining price of its stock, or increasing debt, may induce the predatory airline to play more aggressively as aggressive behaviour increases the probability that the rival can be driven out of the market at a low cost to the predator.[33] Financial losses increase the probability that the rival defaults on a loan payment and that it is denied further financing. If the rival is looking for an investor, or is in the process of negotiating a financial agreement (but the agreement has not been signed yet), low profitability, low asset value, or a declining market share may discourage a prospective investor as investing in such a firm may be more risky.

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[33] It may also be the case that low profitability creates some uncertainty among passengers regarding the prospects of their frequent flier programs. If they perceive financial troubles experienced by Airline 2 as a higher risk of this airline going out of business and their frequent flier points being lost, they may switch their demand to Airline 1. This in turn increases the optimal capacity for Airline 1, and it may encourage Airline 1 to engage, or to intensify, predation to make sure that Airline 2's financial results are indeed poor.

Equation (12) could thus be expanded by additional variables describing Airline 2's financial situation. Some of the relevant variables include the lagged financial results (such as total profits, earnings per share, revenues), the lagged stock price, and a dummy variable equal to one when the observation refers to a time period when Airline 2 was negotiating a financial agreement and zero otherwise. The partial derivatives with respect to the financial variables are expected to be positive, and the derivative with respect to the financial agreement dummy variable is expected to be negative.

3.3.3. A more general specification

The analysis in Sections 3.3.1 and 3.3.2 suggest that equation (12) be replaced by a more general specification:

$$p_{1t} = h(p_{2t},\ K_{1t},\ K_{2t},\ w_t,\ y_t,\ EARNINGS_{2,t-1},\ STOCK_{2,t-1},\ AGRE_{2t}) \quad \textbf{(12')}$$

where: $EARNINGS_2$ = a measure of Airline 2's financial results,

$STOCK_2$ = Airline 2's stock prices,

$AGRE_2$ = a dummy variable, with $AGRE_2=1$ if the observation refers to a time period when Airline 2 was negotiating a financial agreement or collecting funds to satisfy the conditions of an agreement, and $AGRE_2=0$ otherwise.

A time subscript has been appended to each variable in order to indicate the presence of lagged explanatory variables. The predictions regarding the signs of the partial derivatives in (12') are summarized below.

- Non-strategic pricing behaviour implies:

$$\frac{\partial p_1}{\partial p_2}>0, \quad \frac{\partial p_1}{\partial K_1}<0, \quad \frac{\partial p_1}{\partial K_2}<0, \quad \frac{\partial p_1}{\partial w}>0, \quad \frac{\partial p_1}{\partial y}>0, \quad \frac{\partial p_1}{\partial EARNINGS_2}=0,$$
$$\frac{\partial p_1}{\partial STOCK_2}=0, \quad \frac{\partial p_1}{\partial AGRE_2}=0.$$

The first five derivatives summarize the discussion on non-strategic pricing. The last three results follow from the discussion of predatory pricing. Financial results achieved by Airline 2 do not enter Airline 1's profit maximization problem, and thus all three derivatives are equal to zero.

- Reputation model of predation implies:

$$\frac{\partial p_1}{\partial p_2}>0, \quad \frac{\partial p_1}{\partial K_1}<0, \quad \frac{\partial p_1}{\partial K_2}<0, \quad \frac{\partial p_1}{\partial w}>0, \quad \frac{\partial p_1}{\partial y}<0, \quad \frac{\partial p_1}{\partial EARNINGS_2}=0,$$
$$\frac{\partial p_1}{\partial STOCK_2}=0, \quad \frac{\partial p_1}{\partial AGRE_2}=0.$$

The first five derivatives follow from Section 3.3.1. The signs of the derivative of Airline 1's price with respect to Airline 2's price and capacity, and the derivative of Airline 1's price with respect to Airline 1's (i.e. own) capacity are the same as for the optimal non-strategic price. As argued in Section 3.3.1, the derivative with respect to income is expected to be negative. The derivatives with respect to variables describing Airline 2's financial situation are all equal to zero because the predatory airline that is striving to establish a reputation for toughness will engage in predation regardless of Airline 2's financial situation.

- Deep pocket model of predation implies:

$$\frac{\partial p_1}{\partial p_2}>0,\ \frac{\partial p_1}{\partial K_1}<0,\ \frac{\partial p_1}{\partial K_2}<0,\ \frac{\partial p_1}{\partial w}>0,\ \frac{\partial p_1}{\partial y}>0,\ \frac{\partial p_1}{\partial EARNINGS_2}>0,$$
$$\frac{\partial p_1}{\partial STOCK_2}>0, \frac{\partial p_1}{\partial AGRE_2}<0.$$

The signs of the first five derivatives are the same as for non-strategic pricing. If Airline 1's pricing is predatory in nature, we will observe that it cuts prices when Airline 2 is negotiating a financial agreement (captured by a negative derivative with respect to $AGRE_2$), or when Airline 2 is experiencing poor financial results and a declining stock price (captured by positive derivatives with respect to $EARNINGS_2$ and $STOCK_2$).

3.4. The first stage: the choice of seating capacity

Equation (6), the expected demand for flight j scheduled by airline i, derived in Section 3.2, implies that total demand facing Airline 1, D_1 , is a function of the number of flights scheduled by the two airlines, their prices, schedule delay times incurred by consumers, and the number of consumers. D_1 can be thus expressed as a function of the following form:

$$D_1 = D_1(n_1,\ n_2,\ p_1,\ p_2,\ l^1,\ l^2,\ N), \qquad \textbf{(13)}$$

where l^1 and l^2 are the schedule delay times associated with Airline 1's flights and Airline 2's flights, respectively, $N = (N_1 \ldots N_z)$ is the number of consumers at each location, and other variables are the same as in the previous sections. As the spatial aspect of competition (departure time scheduling) is not studied in this section, we make a simplifying assumption that all elements in I^1, I^2, and N have equal impact on total demand. Then, total demand may be expressed as a function of the average delay time and the total number of consumers. Given the distribution of consumers, the average delay time depends on the number of flights scheduled by each airline. Equation (13) may be then rewritten as:

$$D_1 = D_1(n_1,\ n_2,\ p_1,\ p_2,\ N^T), \tag{13'}$$

where N^T is the total number of consumers. Using the assumption made in section 3.3 that seating capacity is a function of the number of flights scheduled by each airline and that the number of consumers is a function of average consumer income, (13') can be rewritten as:

$$D_1 = D_1(K_1,\ K_2,\ p_1,\ p_2,\ y). \tag{13''}$$

Thus, Airline 1's profit function is:

$$\pi_1 = D_1(K_1,\ K_2,\ p_1,\ p_2,\ y)p_1 - C_1(D_1,\ K_1,\ w) - rK_1, \tag{14}$$

where C_1 is the short run cost for Airline 1, and r is the opportunity cost of capital.

The optimal level of fares for Airline 1 was derived as equation (12) in Section 3. A similar equation can be derived for Airline 2. Both expressions could then be used to solve for the optimal values of p_1 and p_2 expressed as functions of both airlines' seating capacities and other exogenous variables. The results could then be substituted back into profit equation (14). Calculating the first order condition with respect to K_1 and solving it for K_1 would give an expression for the optimal non-strategic level of Airline 1's seating capacity, or the first stage best-response function:

$$K_1^* = f^*(\overset{-}{K_2}, \overset{-}{w}, \overset{-}{r}, \overset{+}{y}). \tag{15}$$

The asterisks indicate that the specified function describes the optimal non-strategic level of seating capacity. The sign above each variable indicates the expected sign of the partial derivative with respect to this variable.[34] The expected effect of each variable is discussed below.

- *Airline 2's seating capacity.* Outputs of competing firms are typically thought of as strategic substitutes: when one firm increases its output, it is optimal for the other firms to decrease their outputs. This implies that for strategic substitutes reaction functions slope downwards. Therefore, an increase in Airline 2's capacity lowers Airline 1's optimal non-strategic capacity.
- *Input prices.* An increase in costs will result in lower optimal capacity. This is a standard result in oligopoly theory: an increase in production costs causes the reaction function to shift to the left, and the quantity sold falls.
- *Opportunity costs of capital.* Opportunity cost can be interpreted as the price of using an asset. Thus, if r increases, the optimal seating capacity decreases.

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[34] It seems to be not possible to derive these results algebraically without imposing some assumptions about the functional forms of the demand for air travel, and costs. Additional assumptions are required to determine the signs of the second partial cross derivatives of Airline 1's capacity; the theory does not provide any guidance as to what the signs of these derivatives should be.

- *Income*. An increase in y increases the demand for air travel. As a result, the optimal capacity to serve the market increases, too.

Specification (15) applies to the optimal non-strategic level of capacity for Airline 1. However, if Airline 1 behaves in a strategic fashion, relations derived from simple profit maximization may not hold in general. There may also be other variables, not included in equation (15), that explain the choice of capacity, and variables included in equation (15) may affect capacity in a direction opposite to that indicated.

The rest of this section discusses how predation changes the predictions for capacity scheduled by Airline 1. As in Section 3.3, our preliminary hypothesis is that the effects of the variables included in equation (15) and/or additional relevant variables, depend on the nature of the underlying behaviour, or which model of predation best explains Airline 1's actions.

3.4.1. Reputation model of predation

As discussed earlier, the reputation model of predation implies that the predatory airline should be aggressive against the rival airline's attempts to expand its business. If it is Airline 1 that engages in predation against Airline 2, then Airline 1 should expand its capacity as Airline 2 increases its seating capacity. Thus, the sign of the partial derivatives with respect to Airline 2's capacity is expected to be positive.

3.4.2. Deep pocket model of predation

All arguments developed in Section 3 on pricing policy seem to be relevant for the choice of capacity, too. Poor financial results of Airline 2, as captured by the last quarterly earnings or stock prices, may encourage Airline 1 to play more aggressively, i.e. to engage in predation in the next period. The partial derivatives with respect to EARNINGS and STOCK are expected to be negative, and the derivative with respect to AGRE is expected to be positive as Airline 1 will expand capacity when Airline 2 is in financial difficulties.

If Airline 1 is engaging in predation against Airline 2, then the effect of consumers' income is expected to be opposite to that indicated in equation (17). During periods of low demand airline firms' profits are lower, and it may be easy to depress these profits further. Financial troubles are more likely to occur in bad times than in good times, and as argued earlier, financial troubles experienced by one airline may trigger predation on the part of the other airline.

3.4.3. A more general specification

Equation (15) can be replaced by a more general specification:

$$K_{1t}=f(K_{2t},\ w_t,\ r_t,\ y_t,\ EARNINGS_{2,t-1},\ STOCK_{2,t-1},\ AGRE_{2t}). \qquad \textbf{(15')}$$

A time subscript has been appended to each variable in order to indicate the presence of lagged explanatory variables. Predictions regarding the signs of the partial derivatives of Airline 1's capacity in (15') under different hypotheses are summarized below.

- Non-strategic capacity choice behaviour:

$$\frac{\partial K_1}{\partial K_2}<0,\quad \frac{\partial K_1}{\partial w}<0,\quad \frac{\partial K_1}{\partial r}<0,\quad \frac{\partial K_1}{\partial y_t}>0,\quad \frac{\partial K_1}{\partial EARNINGS_2}=0,$$
$$\frac{\partial K_1}{\partial STOCK_2}=0,\quad \frac{\partial K_1}{\partial AGRE_2}=0.$$

The first four expressions summarize the discussion on non-strategic capacity at the beginning of this section. The last three expressions follow from Section 3.4.2; variables describing Airline 2's financial situation are irrelevant for Airline 1's profit maximization and the non-strategic level of capacity.

- Reputation model of predation:

$$\frac{\partial K_1}{\partial K_2}>0,\quad \frac{\partial K_1}{\partial w}<0,\quad \frac{\partial K_1}{\partial r}<0,\quad \frac{\partial K_1}{\partial y_t}>0,\quad \frac{\partial K_1}{\partial EARNINGS_2}=0,$$
$$\frac{\partial K_1}{\partial STOCK_2}=0,\quad \frac{\partial K_1}{\partial AGRE_2}=0.$$

The first four expressions repeat the results discussed at the beginning of this section and Section 3.4.1. The predatory airline challenges Airline 2's attempts to increase capacity. Thus, the derivative with respect to K_2 is positive. The last three results follow from Sections 3.4.1 and 3.4.2. The predatory airline that strives to establish a reputation for "toughness", engages in predation regardless of Airline 2's financial situation.

- Deep-pocket model of predation:

$$\frac{\partial K_1}{\partial K_2}<0,\quad \frac{\partial K_1}{\partial w}<0,\quad \frac{\partial K_1}{\partial r}<0,\quad \frac{\partial K_1}{\partial y_t}<0,\quad \frac{\partial K_1}{\partial EARNINGS_2}<0,$$
$$\frac{\partial K_1}{\partial STOCK_2}<0,\quad \frac{\partial K_1}{\partial AGRE_2}>0.$$

The first four derivatives are the same as for the non-strategic choice of capacity. The derivative with respect to y is expected to be negative because financial difficulties are more likely to occur in bad times than in good times, and it may be easier to drive a firm out of the market in bad times than in good times. The derivatives with respect to financial results, EARNINGS, and the stock price, STOCK, are negative, and the derivative with respect to variable AGRE is positive because Airline 1 is more likely to engage in predation when Airline 2 is experiencing financial problems than when Airline 2 is in a good financial situation.

3.5. Summary of the theoretical modelling

This chapter discusses the theoretical modelling of competition in a duopolistic airline market. It is assumed that both airlines are concerned with profit maximization on each route and that there are no network effects between routes. This assumption allows us to simplify the analysis and examine one airline market at a time.

The airlines compete in total seating capacity, departure times, and fares. These variables are chosen sequentially. In the first stage, total capacity is chosen; in the second stage the airlines choose departure times; and in the third stage the airlines determine fares. The departure times and fares are modelled within a spatial context using a nested logit model, and the seating capacity is modelled within a non-spatial context.

Non-strategic and predatory departure time scheduling are determined using computer simulation techniques as the complexity of the logit model makes it difficult to derive the relationships of interest analytically. The results indicate that when both airlines operate the same number of flights, or when one airline operates just one flight more than its rival, the non-strategic market structure is interlaced. The distribution of flights across the flight schedule is non-uniform. Flights tend to be concentrated around the peaks in demand. In particular, when the idiosyncratic utility is sufficiently high, rival flights may form pairs of flights departing at exactly the same time. Rescheduling a flight closer to a rival flight does inflict losses on the rival airline. This strategy appears, however, to be costly in that the loss suffered by the victim airline is smaller than the sacrifice in profits made by the predatory airline.

The testable implications of non-strategic and predatory seating capacity and prices are based on the best response functions for each of these choice variables. Optimal non-strategic capacity is a function of a rival's capacity, input prices, opportunity cost, and exogenous factors affecting the demand for air travel, such as consumer income. An increase in a rival's capacity, or input prices, or opportunity cost may be expected to lower the optimal capacity. An increase in consumer income may be expected to increase the optimal capacity.

The optimal non-strategic price is a function of the rival's price, own and rival's seating capacity (capacities are already fixed when prices are chosen), input prices, and consumer income. An increase in capacity (own capacity or rival's capacity) may be expected to lower the optimal price. An increase in the rival's price, or input prices, or consumers' income may be expected to increase the optimal price.

If the airline examined behaves in a predatory fashion, relations derived from simple profit maximization may not hold in general. There may also be other factors determining the optimal choice of capacity or fares, and the impact of some of the factors mentioned above may be opposite to those predicted by non-strategic behaviour.

The testable implications of predatory prices and capacity depend on which model of predation explains best the behaviour of the airline examined. Two models of predation are considered to be relevant to the airline industry: the deep pocket model and the reputation model of predation.

If the deep pocket model of predation is the relevant model, declining profits experienced by the rival, or a declining stock price, or increasing debt, may induce the predatory airline to schedule more capacity and/ or to decrease the price as the rival may be driven out of business at a relatively low cost to the predator. In addition, a difficult economic situation may also induce the predatory airline to schedule more capacity as it may be easier to inflict losses during a period of low demand.

If the reputation model of predation is the relevant model, the predatory airline may be expected to react aggressively to the rival's attempts to expand business. The predatory airline will schedule more capacity in response to an increase in its rival's capacity. Regarding pricing policy, the predatory airline may be expected to cut prices when there is an increase in consumers' income to demonstrate that it can serve large demand at a low price.

Chapter 4

The market setting and the data

The empirical analysis of this thesis is based on the scheduling behaviour on the part of Air Canada, one of the dominant Canadian airlines, on the Vancouver - Toronto route. This chapter describes the market under consideration and the data used in the estimation of the empirical model. Section 4.1 discusses briefly the structure of the Canadian airline industry and the sequence of events that led to the allegations of predatory behaviour on the part of Air Canada in 1992. Section 4.2 follows with the description of the data.

4.1. The market setting

Trans-Canada Airlines, renamed Air Canada in 1964, was created by an act of Parliament in 1937. The business goals of the airline included the establishment of transcontinental air service and balanced provision of services to large and small communities. To achieve these goals, the airline practised cross-subsidization between routes and regions to insure a uniform distance related fare structure across Canada. Regulation of entry and pricing prevented privately owned airlines from entering into Air Canada's markets and undermining its profits. In fact, until 1959 Air Canada had a monopoly on every domestic route it flew. Starting from 1959 CP Air, a privately owned airline, was allowed to compete with Air Canada on some routes. But the development of this airline was restricted by capacity limits which were not lifted until 1979.[35] With the passage of the *Air Canada Act* in 1977, however, Air Canada was placed on the same regulatory footing as its competitors and was encouraged to regard profit as an important business objective.

Beginning in 1979, under the competitive influence of airline deregulation in the United States, a series of regulatory changes relaxed pricing, quality of service, and entry restrictions on the Canadian carriers. As already mentioned, in 1979 the government removed all capacity restrictions on CP Air, and the airline was allowed to compete head-to-head with Air Canada. By 1981, competition between Air Canada and CP Air on the Montreal/ Toronto - Vancouver routes was price-regulated but otherwise unrestricted.[36] Beginning in 1978 Canadian airlines also started to offer discounted fares for a controlled fraction of the total seating capacity, and in 1979 CP Air began its "SkyBus" with no-advance-booking and "no-frills" service at half the regular economy fare. The proportion of passengers flying on discounted fares was still quite small compared to the US (approximately 8 to 9 percent in Canada as compared to two thirds in the US).[37] But in summer 1982 the discounted fares accounted for a relatively large fraction of Air Canada's market and the magnitude of discounts was as large as 50 percent off the regular economy fare.[38] Full-scale deregulation of the Canadian airline industry began in January 1988 with

[35] See Reschenthaler and Stanbury (1983).

[36] See *Reforming Regulation*, Economic Council of Canada, 1981, p. 27.

[37] See Reschenthaler and Stanbury (1983), footnote 13, and *Reforming Regulation*, Economic Council of Canada, 1981, p. 29.

[38] In the Summer of 1982 almost half of Air Canada's domestic capacity was being flown on some form of discount basis as compared to approximately 10 percent in April of that year (see Reschenthaler and Stanbury, 1983).

the implementation of the *National Transportation Act* of 1987.

The changes in the regulatory environment were accompanied by a series of acquisitions and mergers. Both Air Canada and CP Air took over or acquired substantial control over a number of regional carriers that had emerged in the 1960's and 1970's.[39] In particular, in 1987 CP Air merged with PWA, a regional carrier operating in Western Canada, and formed Canadian Airlines International, a subsidiary of PWA Corp.

As a result of these changes, the Canadian airline industry became a near duopoly. For example, in 1989 Air Canada and Canadian Airlines offered 26.2 billion and 19.3 billion passenger-kilometres, respectively. The two airlines combined accounted for 85 percent of passenger-kilometres offered by level I carriers and 66 percent of passenger-kilometres offered by level I to IV carriers.[40], [41] These proportions became even larger after 1989 when Canadian Airlines took over Wardair, originally a charter carrier that had tried to compete in scheduled air service.

Until 1994, the last year of the sample used in the empirical analysis, the largest city-pairs were served almost exclusively by Air Canada and Canadian Airlines. For example, on the Toronto - Montreal route, which was the largest airline market in Canada in terms

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[39] For a review of these changes see Gillen *et al.* (1988).

[40] These figures are calculated from *Air Carriers Operations in Canada*, Statistics Canada, Cat. # 51-002, quarterly issues covering year 1988, Table 2.1 and Table 2.3.

[41] Classification of air carriers into groups, level I, level II, level III, etc., is based on the scale of operations of the given carrier. For example, level I carriers include those carriers which transported at least 1000000 revenue passengers, or at least 200000 tonnes of revenue goods in each of the two years preceding the report year. Level IV carriers include those carriers which reported gross revenue of at least $250000 and are not classified as level I, II, or III carriers. For details see *Air Carriers Operations in Canada*, Statistics Canada, Cat. # 51-002, the explanatory pages.

of the number of passengers flown, the two airlines combined operated 35 to 47 flights a day during the years from 1988 to 1994, while Wardair (before it merged with Canadian Airlines) operated only 3 flights. In 1990 Nordair started to serve the Toronto - Montreal route and in May 1990 it scheduled as many as 11 daily flights. But in early 1991 Nordair exited the market. The collected data indicate that there were also some foreign carriers serving this market, Air France and Air Portugal. However, foreign carriers were not allowed to pick up passengers at one Canadian airport and drop them off at another. For this reason, these carriers are irrelevant in the context of this study.

The competitive situation on the Toronto - Ottawa route, the second largest airline market in Canada, was similar. On the Vancouver - Toronto route, the third largest market, the share of Wardair was larger. But after the merger between Wardair and Canadian Airlines, the Vancouver - Toronto route remained a doupoly to the end of the sample period. More details regarding the structure of this market will be provided in the next section.

Another important change in the industry was the privatization of Air Canada in 1988 and 1989. The privatization shifted the prime business goals of Air Canada from public interest to efficiency and profitability and put this airline on a more equal footing in competition with Canadian Airlines.

Initially in the period following the merger between Canadian Airlines and PWA, both Air Canada and Canadian Airlines seemed to be doing well. Table 4-1 presents annual net income earned by both airlines over the period 1987 - 1994. As can be seen in this table, in 1988 Canadian Airlines reported a net income of over 30 million dollars, an increase of 5.5 percent compared to the year before. But in 1989 Canadian Airlines' financial situation deteriorated and the airline posted a loss of 56 million dollars. At the same time, Air Canada earned over 150 million dollars. But later Air Canada started to lose money, too. In 1990 the airline reported a loss of 74 million dollars and in 1991 a loss of 218 million dollars.

Table 4-1 Air Canada's and Canadian Airlines' annual net corporate income, millions of dollars.

Year	Air Canada	Canadian Airlines
1987	n/a	28.44
1988	91.5	30.3
1989	150.5	-56.0
1990	-74.0	-14.5
1991	-218.0	-161.7
1992	-454.0	-543.3
1993	-326.0	-291.8
1994	129.0	-37.8

Source: *Globe and Mail Report on Business* data base.

Until mid-1991, there were very few reports in the press discussing the developments in the Canadian airline industry, and there is not much publicly available information that could shed light on what was going on in the industry. But in early 1991 the amount of information reported by the press started to grow rapidly. In particular, the weak performance of the two airlines gave rise to speculation about a possible merger between the two airlines and discussions of whether the Canadian market is large enough to support two large carriers.[42]

Despite the poor performance and signs of an economic recession (i.e. a declining GDP), at least one of the two airlines tried to adopt a "strategy of growth." For example, in November 1991 Air Canada added new jets to its fleet even though load factors were falling,[43] and in February 1992 the new president and CEO of Air Canada, Hollis Harris, announced plans to increase capacity by another 10 percent.[44] These decisions seem to be at odds with the situation in the market place. Demand for air travel is known to be pro-cyclical and, thus, typically negatively affected by an economic recession (see for example Tretheway and Oum (1992), in particular Chapter 3, Section B). In fact, industry analysts estimated that in early 1992 there was 25 to 30 percent too much capacity in the market for Air Canada and Canadian Airlines to operate profitably.[45]

The data collected for this project indicate that in April 1992 Canadian Airlines almost went out of business. On April 5, 1992 the airline reduced its operations to just two flights on three out of four routes for which the data have been obtained. The affected routes included Toronto - Montreal, Toronto - Ottawa, and Vancouver - Toronto. But on May 1, 1992 the services were restored to a level typical for that time of year. It is difficult

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[42] See "Airlines' weak performance fuel speculation," *Globe and Mail*, March 1, 1991, p. B3.

[43] See "Air Canada adding capacity with 3 jumbos out of storage. Growth strategy called 'suicide' with so many empty seats," *Globe and Mail*, November 14, 1991, p. B1.

[44] See "PWA loses $161 million; chairman slams Air Canada: pursuing fare war is 'economic insanity' Eyton charges," *Globe and Mail*, February 28, 1992, p. B1, B4.

[45] See "Airlines warned: 'Get it together or face controls'," *Globe and Mail*, November 26, 1992, p. B3.

to interpret this awkward observation. Canadian Airlines officials and employees were complaining that Air Canada was flooding the market with excess capacity and driving down fares and load factors. It might have been the case that Canadian wanted to demonstrate that it was on the verge of shutting down and that complaints regarding anti-competitive behaviour on the part of Air Canada should be taken seriously.[46]

In fact, in August 1992 the federal Bureau of Competition Policy launched an investigation into the allegations that Air Canada had engaged in predatory practices in early 1992, and in November 1992 Canadian Airlines filed a predatory pricing lawsuit against Air Canada. There was no further information in the press regarding the results of the investigation or the lawsuit. For its part, Air Canada responded to the allegations by stating that it "[...] added capacity when and where it could do so at little additional cost,"[47] and that both airlines were "[...] nearly levelled regarding the capacity gains since the first quarter of 1989."[48] However, Air Canada also acknowledged on one occasion that there was too much capacity in the Canadian market.[49]

These events coincided with the search for an investor undertaken by Canadian Airlines. The airline was looking for an investor that could help it restore its competitive

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[46] Unfortunately, we do not really know what was going on at Canadian Airlines in April 1992 and what the true reasons for decreasing the capacity during that month were. The press did not make any comments on these facts.

[47] See "Canadian hits Air Canada with 1$ billion lawsuit," *Globe and Mail*, November 18, p. B1 and B6.

[48] See "Airlines at odds over statistics on capacity," *Globe and Mail*, December 8, 1992, p. B8.

[49] See "Air Canada's new offer gives PWA wider berth in merger," *Globe and Mail*, September 3, 1992, p. B1.

position and Air Canada was among those interested.[50] Despite its huge losses, Canadian Airlines was an attractive airline to invest in. It operated a number of routes to East Asia and the Pacific Rim region which, at that time, were some of the fastest growing markets for air travel.

In April 1992 Canadian Airlines signed an investment agreement with AMR Corp., the parent company of American Airlines. Under the proposal, AMR Corp. would obtain a 25 percent voting stake in PWA in exchange for a 250 million dollar equity injection. This agreement required that Canadian Airlines strengthen its balance sheet. Canadian Airlines was not able to satisfy this condition and in July 1992 the talks between PWA and AMR collapsed.

In August 1992 Air Canada made a merger offer to Canadian Airlines. However, to Canadian this merger offer looked more like a takeover and the offer was rejected. In September 1992 Air Canada made another merger offer to Canadian Airlines and this time the offer was accepted. In October 1992 the boards of directors of the two airlines signed an agreement setting the terms and conditions of the proposed merger. But in November 1992 Air Canada withdrew from the pre-merger agreement with PWA. According to Air Canada the terms of merger were not achievable, and its board had doubts about whether

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[50] For example, in late February 1992 both Air Canada and Canadian Airlines confirmed that they had held merger talks in the past but none were going on in early 1992 (see "Room for just one airline. Air Canada says 'Merger with Canadian has to be a possibility'," *Globe and Mail*, February 22, 1992, p. B1). But in March 1992 PWA Corp., the parent company of Canadian Airlines, announced that it had broken off talks with Air Canada and that it would try to conclude a deal with an American investor (see "PWA ends talks with Air Canada," *Globe and Mail*, March 20, 1992). For its part, Air Canada responded that it would try to block such a deal. This suggests that Air Canada was not indifferent to who would become Canadian Airlines' partner (see "Air Canada to try to stop rival's deal," *Globe and Mail*, March 31, 1992, p. A1).

the merged company would be viable.[51]

The sequence of events described above suggests that some form of strategic behaviour may have been practised by Air Canada during the period 1990 - 1992. Predation is one possible hypothesis, even if it failed to drive Canadian Airlines out of business. Because of its past as a Crown-owned corporation, Air Canada was perceived as having substantial financial resources, or a "deep pocket." A merger or a takeover of the rival would give Air Canada a virtual monopoly in the domestic airline markets and access to the lucrative Asian markets. Moreover, in February 1992 Air Canada named a new president and CEO, Hollis Harris, former CEO and president of Delta Airlines and Continental Airlines. Hollis Harris had a reputation of "getting things done" and thus a change in Air Canada's objectives and behaviour could be credible to a rival airline.

Canadian Airlines has survived as an independent major airline. In December 1992 PWA signed a second preliminary investment agreement with AMR Corp., and obtained loan guarantees for 120 million dollars from the federal government and the governments of Alberta and British Columbia. Canadian Airlines still had to overcome a few obstacles such as a reduction of its debt, release from its contractual commitments to the Gemini computer reservation system,[52] and approval of the agreement by the relevant federal authorities. In April 1994 the agreement between PWA and AMR Corp. was finalized.

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[51] See "Air Canada scuttles pre-merger agreement," *Globe and Mail*, November 4, 1992.

[52] Air Canada and Canadian Airlines operated jointly a computer reservation system called Gemini. One of the conditions imposed by AMR Corp. on the investment agreement with PWA was that Canadian Airlines would transfer to the American Airlines' computer reservation system called Sabre.

Financial difficulties did not end for Canadian Airlines, though. In 1995 Canadian posted a loss of 195 million dollars and in 1996 the airline lost another 187 million dollars. In November 1996 the airline found itself again on the verge of bankruptcy and had to negotiate a pay reduction with its employees, concessions from its creditors, and financial help from the federal and the provincial governments. At the same time, Air Canada seemed to be recovering from the 1991 - 1992 recession. The airline reported a net income of 52 million dollars for 1995 and 149 million dollars for 1996.

It is beyond the scope of this study to analyse the reasons for Canadian Airlines' continued financial difficulties. A high debt load and bad route network might have been factors, but the alleged predatory behaviour by Air Canada might have been an important factor as well.

4.2. The data

To test the hypothesis of strategic behaviour in airline markets, we require detailed time series data on flight schedules in markets where strategic behaviour on the part of market participants might have taken place, as well as data on air fares, airline firms' costs, and data on the demand for air travel. The time series should start before and end after the period of alleged predation so that any change in behaviour can be reflected in the data.

The theoretical literature on predation does not provide much insight as to the question which product, or products, in a multi-product industry is likely to be the target of predatory behaviour. If the reputation model of predation is the relevant model, it seems that predation should take place on all routes which generate monopoly profits (otherwise the commitment to prey would not be credible). But as indicated in Chapter 3, predation is costly, and the predator may want to choose those routes where the desired results can be achieved at a relatively low cost. From an empirical point of view, the route chosen for investigation should have sufficiently high variability so that a change in behaviour can be more easily detected. The city-pair to be examined in this study is the Vancouver - Toronto route (in the direction from Vancouver to Toronto), the third largest domestic airline market in Canada in 1991 and 1992.[53],[54] The Vancouver - Toronto city pair may be a good candidate for an empirical research also because connection traffic on this route is likely to be smaller than on the Toronto - Ottawa or Toronto - Montreal routes and because there are no good substitutes for an air trip from Vancouver to Toronto. (As the distance between Vancouver and Toronto is very large, competition from cars, buses, or trains, is likely to be very small.) The period examined is February 1988 - December 1994.

The data set on flight schedules contains the following information: departure time, arrival time, flight number and airline, number of stops, type of equipment, days of

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[53] See *Air Passengers Origin and Destination*, 1992, Statistics Canada, Cat. # 51-204, Table 3. The scale of city-pair markets in this table is measured in terms of passengers flown.

[54] The data described in this section were also collected for three other city-pairs: Toronto - Montreal, Toronto - Ottawa, and Vancouver - Calgary. The Toronto - Montreal route was briefly examined to determine whether the pattern of changes in flight schedules and prices were similar to changes in the Vancouver -Toronto market. The data suggest that there were some similarities in the patterns of changes on both routes. For the moths of July of each year in the sample, the trend in the number of flights offered by Canadian Airlines and Air Canada on both routes was similar: the capacity of Canadian Airlines decreased substantially (from 26 in 1988 to 14 in 1992) while Air Canada kept its level of service at a relatively stable level. However, similarities in the pattern of changes in the price on the two routes were less obvious. Further details concerning the other routes are not discussed here as these data were not used in the estimation of the empirical model.

operation, effective date, discontinue date, and capacity. The data come from the *Official Airline Guide, Desktop Guide, North American Edition* (OAG), and have been obtained from BACK Information Services, Toronto. The format of these data makes it possible to generate observations of any frequency, as the effective and discontinue dates allow us to reconstruct the flight schedule that was in effect on any day during the sample period. An example is given in Table 4-2. The arrival times have been omitted in Table 4-2. For all flights the flight times were almost identical (4 hours to 4 hours 20 minutes flight time plus 3 hours due to the time zone change), except for flights with one stop for which the flight time was longer.

As can be seen in Table 4-2, flight schedules tended to be in general interlaced. This characteristic of the market is consistent with the simulation model developed in Chapter 3. (This market structure also allows for some segmentation when one airline adds a new flight, or when one airline operates more flights than the rival.)

From the daily flight schedules a number of variables can be calculated, such as the number of flights or the seating capacity scheduled by each airline on a given day. The effective date and the discontinue date allow us to find the dates of changes in the flight schedule and determine the pattern of changes in the number of flights, the departure times, or the equipment and capacity during the whole sample period.

As this study concentrates on interactions between Air Canada and Canadian Airlines, other carriers serving the Vancouver - Toronto route were deleted from the sample. These carriers are considered to be competitive fringe firms, which are neither the likely targets of strategic behaviour, nor the aggressors. The carriers deleted from the

Table 4-2. Flight schedule on the Vancouver - Toronto route effective May 2, 1991.

Carrier	Equip-ment	Seating capacity	Departure time	Flight number	Stops	Days of operation	Discontinue date	Effective date
AC	320	156	08:00	164	1	12345 7	10/13/91	04/07/91
AC	767	179	08:00	136	0	6	05/17/91	05/01/91
AC	L15	214	08:00	136	0	12345 7	06/20/91	05/01/91
CP	767	222	08:00	982	0	123456	10/26/91	04/07/91
AC	767	179	09:00	142	0	1234567	10/26/91	04/15/91
CP	767	222	09:00	984	0	1234567	09/13/91	04/07/91
CP	D10	266	11:00	34	0	7	05/31/91	04/14/91
CA	74M	269	11:30	991	0	7	10/26/91	04/07/91
CA	74L	269	11:30	991	0	4	10/26/91	04/07/91
AC	767	179	12:00	148	0	1234567	10/26/91	04/07/91
CP	767	222	12:15	988	0	1234567	10/26/91	04/07/91
CP	767	222	13:15	990	0	1234567	09/13/91	05/02/91
AC	72S	136	14:15	100	0	7	05/19/91	04/07/91
AC	767	179	14:15	100	0	123456	05/17/91	04/22/91
CP	767	222	14:15	992	0	1234567	10/26/91	04/07/91
CP	310	180	16:15	994	0	12345 7	10/26/91	04/07/91
AC	320	156	16:30	152	0	6	08/31/91	04/07/91
CP	310	180	22:00	976	1	12345	10/26/91	05/01/91
CP	767	222	22:45	998	0	12345 7	10/26/91	04/07/91
AC	767	179	22:50	156	0	1234567	09/30/91	04/07/91

Legend:
- Carrier: AC = Air Canada, CP = Canadian Airlines International, CA = Air China;
- Equipment: 320 = Airbus A320, 767 = Boeing 767, L15 = Lockheed L1011-500, D10 = McDonnel Douglas DC10, 74M = Boeing 747 (mixed passenger/ freight), 74L = Boeing 747 SP, 72S = Boeing 727-200, 310 = Airbus A310;
- Days of operation: 1 = Monday, 2 = Tuesday, 3 = Wednesday, 4 = Thursday, 5 = Friday, 6 = Saturday, 7 = Sunday.

sample include Wardair (for the period February 1988 - January 1990), Cathay Pacific (for the period July 1990 - January 1991), and Air China. Wardair operated up to three daily flights (and one night flight), Cathay Pacific operated one daily flight, and Air China offered one daily flight once or twice a week. Air Canada and Canadian Airlines combined operated 11 to 18 flights, except for the month of April 1992 when, as mentioned in Section 4.1, Canadian Airlines' capacity fell to just 2 flights, and the two airlines combined operated 8 flights.

Another issue to be considered is how the night flights should be treated. Typically, both Air Canada and Canadian Airlines operated one night flight each, except for the period mid 1990 to late 1991, May - October 1993, and May - August 1994 when Canadian Airlines operated two night flights[55] and Air Canada just one. But studies on demand for air trips indicate that consumers generally prefer to fly first thing in the morning or in the early evening (see for example Tretheway and Oum (1992), in particular Chapter 3 and Chapter 6). Thus, there are two big peaks in the distribution of demand across the times of day, the first between 8 a.m. and 9 a.m., and the second between 4:30 p.m. and 6:30 p.m. Some exceptions to this rule are eastbound flights departing from the west coast around midnight. Because of the time zone change, the departure and the arrival times separately may be acceptable to a traveller. For example, a flight departing from Vancouver at approximately 11 p.m. arrives in Toronto at 6 a.m. Night flights, however, deprive the passenger of her or his sleep at night and may be perceived as inferior compared to day flights. In fact, the price data indicate that airlines were typically offering special discounted fares for night flights which were the lowest available fares

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[55] When the additional night flight was added in 1990, one of the mid-day flight was cancelled.

from that airline. For these reasons, night flights should probably not be treated on the same basis as day flights. Consequently, all night flights were deleted from the sample.[56]

Data on prices and the number of tickets sold at each price and data on average revenues are confidential and were not available for this study. Thus, the listed fares, which are available to the general public, had to be used instead. One source of this type of data is the OAG, the version that comes out with a fare supplement. Another source of information on air fares is Airline Tariff Publishing Company (ATPCO). ATPCO is a business organization transmitting information on current fares charged by airlines to the computer reservation systems . The historical data on these fares can be obtained from the ATPCO Electronic Tariff Filing System, and data for the periods prior to 1993 can also be obtained from a bi-weekly publication *Airline Tariff Publishing Company Passenger Tariff Set*.

Both the OAG and the ATPCO data contain information on the price in Canadian dollars, by class of service, airline, and the fare code referring to the restrictions associated with the particular fare type. The OAG data are available on a twice-monthly basis, and the ATPCO data can be extracted from the data base on any required frequency basis (as fares in effect on a particular day).

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[56] The inclusion of the night flights in the capacity equation is not likely to change the results reported in Chapter 5. As indicated earlier, both Air Canada and Canadian Airlines operated just one night flight each for most of the sample period. The size of the equipment on which these flights were operated remained fairly stable over the entire sample period. Thus, the inclusion of the night flights in the data set would be almost equivalent to increasing the dependent and the explanatory variables by a constant. In a linear regression this will change only the intercept; the source of variation in Air Canada's capacity would still be the same: the daily flights, and the magnitude of the changes would still be the same. The results of the price equation could be different. However, the fare offered on night flights may not have been available on other flights, and thus the conclusions arising from this regression could be misleading.

The twice-monthly OAG price data and the twice-monthly ATPCO price data (with information on the effective and discontinue date) were collected during a visit to the National Transportation Agency in Ottawa. The ATPCO price data were collected only for the period 1990 - 1994 as data prior to 1990 were not available at the National Transportation Agency.

The ATPCO data set appears to be more complete than the OAG data set. For example, from approximately late 1990/ early 1991 the number of fare categories listed in the OAG was very small. The list of available fares included business, economy, and just one or two discounted fares. For late 1992 and early 1993 discounted fares were not reported at all. For the same periods, the ATPCO data set contained many entries on discounted fares. Because of these reasons, the ATPCO data set was chosen as the main source of price data. The OAG data supplement the ATPCO data for the missing years.

The price and flight schedule data were supplemented by monthly data on crude oil prices, consumer income, economic activity, consumer price index, and interest rates published by Statistics Canada and made available in electronic form in the CANSIM data base.

The financial data used to test the deep pocket model of predation, quarterly income and earnings per share reported by each airline in official financial statements, come from the *Globe and Mail Report on Business* data base and were obtained from the Data Library at the University of Alberta.

Chapter 5
The empirical model

The empirical model of competition in airline markets consists of two equations, a capacity equation and a price equation. The empirical capacity equation is based on the theoretical capacity equation:

$$K_{1t}=f(K_{2t},\ w_t,\ r_t,\ y_t,\ EARNINGS_{2,t-1},\ STOCK_{2,t-1},\ AGRE_{2t}),$$

and the empirical price equation is based on the theoretical price equation:

$$p_{1t}=h(p_{2t},\ K_{1t},\ K_{2t},\ w_t,\ y_t,\ EARNINGS_{2,t-1},\ STOCK_{2,t-1},\ AGRE_{2t}).$$

These equations appear in Chapter 3 as equations (15') and (12'), respectively. In order to carry out the empirical analysis, these equations must be given specific functional forms, and an estimation method has to be specified.

This chapter discusses the specification and estimation of the empirical model. Issues such as functional forms, diagnostic tests, endogeneity of right hand side variables are addressed, and tests of predatory behaviour implied by the theory are carried out. The analysis is organized as follows. Section 5.1 discusses the specification of the capacity equation, and Section 5.2 discusses the specification of the price equation. Section 5.3 discusses estimation issues and presents econometric results. Section 5.4 contains a brief summary.

5.1. The capacity equation

The deep pocket model of predation and the reputation model of predation imply different empirical specifications as different factors explain the behaviour of the predator in each case. Inclusion of all variables in one "nested" specification may produce inefficient estimates if one of the models is irrelevant, and statistical inferences would be invalid. As a result, the two models of predation have to be tested separately.

The empirical analysis starts, however, with a more general specification and a general test of predatory behaviour which does not depend on a specific model of predation. The purpose of this stage is to determine whether there is any evidence that sometime during the sample period the seating capacity scheduled by the potentially predatory airline was indeed higher than during the rest of the sample period. The relevant predation period determined in this stage will be used later in testing the deep pocket model and the reputation model.

This section is organized as follows. Section 5.1.1 discusses the general specification of the capacity equation and suggests a general test of predation. Section 5.1.2 discusses the empirical approach to testing the deep pocket model of predation, and Section 5.1.3 discusses testing the reputation model of predation.

5.1.1. The general specification of the capacity equation

We examine the following general dynamic form of the theoretical capacity equation:[57]

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[57] An alternative methodology to test for predation could probably involve estimating the conjectural variations. This approach has been used, for example, by Brander and Zhang (1990, 1993) to test the oligopoly models (Cournot, Bertrand, or cartel). With such an approach, there would be no need to specify the possible predation periods for the PRED-dummy variable. However, this approach requires detailed cost data which were not available for this study.

$$K_{1t} = \alpha_0 + \alpha_1 K_{1,t-1} + \alpha_2 K_{2t} + \alpha_3 r_t + \alpha_4 w_t + \alpha_5 ACTIV_t + \alpha_6 K_{2,t-1} + \alpha_7 r_{t-1} + \alpha_8 w_{t-1} + \alpha_9 ACTIV_{t-1} + \gamma_1 d_1 + \gamma_2 d_2 ... + \gamma_{11} d_{11} + \alpha_{10} PRED\tau, \quad \text{where } \tau = 1,2,3. \tag{16}$$

The construction of the variables is described below.

K_1 = seating capacity scheduled by Airline 1 (Air Canada), the potentially predatory airline. It is assumed that the relevant period of time for decisions regarding the flight schedule is one day, a week-day. Thus, the daily capacity, i.e. the sum of individual flights' capacities offered each day by Air Canada, is examined. If a flight was operated on planes of different sizes on different days of the week, the capacity of the flight in question was calculated as the weighted average. Flights with weekly frequency lower than four were deleted from the sample.[58]

As the model is intended to be estimated using monthly data, some form of an average, or a representative value of daily seating capacity for each month has to be constructed. If the daily capacity did not change during a month, this capacity is taken as the monthly observation on the daily capacity scheduled by an airline. However, sometimes the number of flights and the size of planes were changed within a month. It is not obvious how K_1 should be constructed in this case. One possibility is to take capacities that were in effect on a particular day of the month, for example the 15th day of each month. However, sometimes there were changes in the schedule one day,

[58] These flights accounted for a very small proportion of the sample. From 1988 to 1993 Canadian Airlines operated at most one such a flight (with frequency once a week) and Air Canada did not operate any. In 1994 each airline had up to two such flights, and their frequency was one to three times a week.

or a few days, after or before that day. Thus, the capacity constructed in this way may not be a good measure of the actual capacity. Another possibility is to take the weighted average of daily capacities during a month. But sometimes capacities were changed substantially (typically decreased) for a period of a few days, or a week, and then returned to the previous level. It is not obvious that these changes were caused by a change in demand for air travel on the route in question. They might have been caused for example by temporary technical problems somewhere in the system, or better opportunities temporarily available on other routes. Thus, a weighted average would not reflect the commitment to the particular airline market. The commitment to the market seems, however, to be important in a situation where strategic behaviour might take place. In view of these conceptual problems, the daily seating capacity most often offered each month (i.e. offered for the largest proportion of a month) is used in this study.

K_2 = seating capacity scheduled by Airline 2 (Canadian Airlines), the potential victim airline. This variable was constructed in exactly the same way as variable K_1.

r = opportunity cost of capacity. The true opportunity cost, or the interest rate used by airlines to calculate the cost of capital, was not available for this study. As a proxy for this variable, the 90 - day deposit interest rate, CANSIM series B113861 (the rate typical of those offered by major trust companies), was taken and deflated by the inflation rate calculated from the consumer price index. The series was constructed as an average monthly figure from weekly data reported by Statistics Canada.

w = input price. The major input in the airline industry is fuel. Aircraft fuel prices were not available for this study. As aircraft fuel is made from crude oil, prices of aircraft fuel and crude oil are likely to be highly correlated.[59], [60] Thus, in the estimation of this model crude oil prices were used (CANSIM series E13035 [61], West Texas Intermediate at Cushing). The series was deflated by the consumer price index.

ACTIV = a proxy for consumers' income. Studies on demand for air travel use income variables such as weighted average per-capita income in the two cities on the route examined (Gillen *et al.*, 1986), real average wage and consumers' assets (Alperovich, 1994), and GNP per capita (Gately, 1988). In the context of this analysis the best choice would probably be the weighted average income in Vancouver and Toronto or in the regions served by the two airports. However, these data were not available. Statistics Canada reports various provincial-level data on salaries and wages that are of potential use in demand analysis. But as demand for air travel consists of different segments, such as demand from business passengers and demand from leisure passengers, the income data must reflect this fact. One suitable choice is data on GDP, or the level of economic activity. In fact, demand for air travel is known to be strongly

[59] Statistics Canada reports quarterly data on cost and consumption of turbine fuel by each major airline (see *Air Carrier Operations*, Cat. # 51-002, Table 4.2). From these data the quarterly prices of turbine fuel paid by Air Canada were calculated and compared with average quarterly crude oil prices calculated from the CANSIM series E13035. The correlation coefficient between the two series was 0.75.

[60] Another important factor related to w are fuel taxes. However, the information published in *Provincial Tax Comparison* (Manitoba Department of Finance, issues dated January 1995, August 1992, June 1991, and October 1989) does not indicate that there were any significant changes in fuel taxation over the period 1989 - 1993.

[61] The CANSIM data base does not indicate whether the series was constructed as the average monthly price or the end-of-month price.

pro-cyclical (see Tretheway and Oum, 1992; in particular Chapter 3, Section B). In this study, an index of economic activity, CANSIM series D100031 (a composite index of 10 leading indicators) was used. This index refers to all of Canada as sub-provincial or provincial-level data were not available.[62]

$d_1, d_2, \ldots, d_{11}$ = monthly dummy variables. d_1 corresponds to January, d_2 corresponds to February, etc. The base month is December.

PRED1, PRED2, PRED3 = dummy variables corresponding to periods when predation might have taken place. During a period, or periods, of predatory behaviour simple relations derived from profit maximization may not hold, as there may be predation-related factors explaining the behaviour of the incumbent firm. The predation dummy variables used here are intended to control for these factors.

The periods when predation might have taken place were identified based on reports in the newspapers as well as on an examination of the data. The alleged predation most likely would have ended sometime in August 1992, the month when the Bureau of Competition Policy launched an investigation into allegations that Air Canada had engaged in predatory practices. The starting date of predation is more difficult to establish. The original complaint to the Competition Bureau filed by Canadian Airlines and accusing Air Canada of predatory practices suggested early 1992 as the predation period. However, there are some indications that predation might have started earlier than in 1992. For example, according to some financial

[62] These data were compared with the data on average weekly earnings in the province of Ontario and British Columbia combined. The coefficient of correlation between the two series was 0.89.

sources, Canadian Airlines might have been looking for an investor as early as June 1990 [63] and Air Canada might have been among the interested buyers earlier than in 1992.[64] Predation could have been used by Air Canada to convince Canadian Airlines to accept a merger offer in a fashion consistent with the "predation for merger" argument. In fact, as indicated in Chapter 4, already in early 1991 there were discussions about aggressive competition in the Canadian airline industry, and there was speculation about a possible merger between Air Canada and Canadian Airlines.[65] For the purpose of this study, the possible starting dates of predation were determined based on the following information.

(1) In April 1990 Air Canada added a new flight to its schedule and lowered the price.[66] April and May were typical periods of changes in the flight schedule, and Air Canada added a new flight also in April 1989. However, in 1989 this change was not accompanied by a decrease in price. It should also be noted that in early 1990 economic growth slowed down, and in late 1990 a recession began. These events suggest that predation might have started as early as April 1990, and the period April 1990 - August 1992 could be considered as a possible predation

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[63] See "Airlines' weak performances fuel speculation," *Globe and Mail*, March 1, 1991, p. B3.

[64] For example in February 1992 Canadian Airlines' president and chairman Rhys Eyton confirmed that his company and Air Canada had talks in the past (see "New Air Canada president welcomed with record loss," *Globe and Mail*, February 21, 1992, p. B1).

[65] See "Airlines' weak performances fuel speculation," *Globe and Mail*, March 1, 1991, p. B3.

[66] The price that is referred to is the price used in this study, the lowest discounted fare. The construction of the price variable is discussed in detail in Section 2.1. in this Chapter.

period.

(2) The recession of 1991 did not stop Air Canada from expanding capacity. A new flight was added in July 1991. Two more flights were added in May and July 1992. The expansion in capacity was accompanied by a downward trend in prices. In June 1991 prices expressed in constant dollars decreased (temporarily) by 23 percent reaching the minimum of the entire sample period. These developments suggest that an alternative date when predation may have started is June 1991. Consequently, the period June 1991 - August 1992 will be considered as an alternative predation period.

(3) In July and August 1991 prices were raised but in September 1991 they fell again and did not increase back to the previous level until June 1992. Therefore, September 1991 will be regarded as another possible starting date of predation, and September 1991 - August 1992 will be considered as another alternative predation period.

Thus the predation dummy variables are defined as follows:

PRED1 = 1 if the observation refers to September 1991 - August 1992 and 0 otherwise;

PRED2 = 1 if the observation refers to June 1991 - August 1992 and 0 otherwise;

PRED3 = 1 if the observation refers to April 1990 - August 1992 and 0 otherwise.

Equation (16) is intended to be estimated separately for each of the predation dummy variables specified above.[67]

The predictions regarding the signs of coefficients on the explanatory variables follow from Chapter 3. They are briefly summarized below.

- $K_{1,t-1}$. Adjustment of capacity is likely to be slow (as it takes time to sell tickets for a flight). The coefficient on the lagged dependent variable may be interpreted as a measure of the speed of adjustment of capacity to the desired level. If adjustment is instantaneous, past capacity will not explain current capacity, and this coefficient will be equal to zero. On the other hand, if adjustment is very slow, past capacity will explain current capacity to a large extent and the discussed coefficient will be close to one.
- K_{2t} , $K_{2,t-1}$. Outputs produced by rival firms are typically strategic substitutes. Thus, these coefficients are both expected to be negative.[68]
- w_t , w_{t-1} . An increase in input prices lowers optimal capacity.[69]

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[67] Note that the predation dummy variables defined in this way are continuous variables, i.e. it is assumed that predation first started and ended on the indicated dates. If the relevant model of predation is the reputation model, such a construction of the predation dummy variable is necessary for the credibility of the incumbent firm's actions (as shown by Kreps and Wilson (1982) and Milgrom and Roberts (1982), one event of peaceful reaction to an entry reveals that the incumbent is not really committed to predation and the incumbent loses its reputation). If the relevant model of predation is the deep pocket model, the predation dummy variable could be an on- and-off variable which is "turned on" during shorter periods of time when the probability of successful predation is large. This possibility is left as an avenue for future research. In this study we are mostly concerned with detecting a change in competitive behaviour which is consistent with the predation hypothesis.

[68] However, as argued by Bulow *et al.* (1985), one may also think of examples when outputs are strategic complements. This happens when the slope of the marginal revenue curve is larger than the slope of the demand curve.

[69] In the long run it may be possible that the relationship between fuel prices and scheduled capacity is positive. Rising fuel prices may induce airlines to use larger planes which typically have smaller per passenger operating costs than small planes.

- r_t , r_{t-1} . An increase in opportunity cost lowers optimal capacity.
- $ACTIV_t$, $ACTIV_{t-1}$. An increase in economic activity increases demand for air travel and therefore increases optimal capacity.
- PRED1, PRED2, PRED3. If the data are consistent with Air Canada being engaged in some form of predatory practices at some time during the period April 1990 - August 1992, at least one of the predation dummy variables should be positive and significant.

5.1.2. Testing the deep pocket model of predation

The test of significance of PREDτ indicates whether there is any evidence in the data consistent with some form of predation practised during the April 1990 - August 1992 period. In order to determine the form of the predation (deep pocket or predation for reputation), it is necessary to impose more structure on the estimating equation.

The deep pocket model of predation implies that poor financial results of Canadian Airlines may encourage Air Canada to schedule more capacity, and that predation is particularly likely to occur during periods of low demand. To test this hypothesis, the dummy variable PREDτ in equation (16) is replaced by a variable that measures the financial results of Canadian Airlines and a variable that measures the state of the economy. The equation to be estimated is:

$$K_{1t} = \alpha_0 + \alpha_1 K_{1,t-1} + \alpha_2 K_{2t} + \alpha_3 r_t + \alpha_4 w_t + \alpha_5 ACTIV_t + \alpha_6 K_{2,t-1} + \alpha_7 r_{t-1} + \alpha_8 w_{t-1} + \alpha_9 ACTIV_{t-1} + \gamma_1 d_1 + \gamma_2 d_2 + \ldots + \gamma_{11} d_{11} + \alpha_{10} FIN_{2t} + \alpha_{11} GROWTH_t . \quad (17)$$

The new variables that appear in equation (17), FIN_2 and GROWTH, are discussed below:

FIN_2 = a measure of the financial results of Canadian Airlines. Two measures were considered in the estimation of equation (17): earnings per share, and after-tax income reported quarterly by Canadian Airlines in official financial statements. To make these data compatible with monthly data, the quarterly figures are used as monthly figures for each month of the given quarter.[70]

It is not obvious how the earnings or the income variables should be constructed. Because demand in the airline industry is highly seasonal, corporate income and earnings per share may have a large variation over the period of one calendar year. In the first and the fourth quarters demand is typically slow, and low profits might then be reported. The predatory airline may not react to these seasonal changes in a rival's profits. It also seems that the reaction to poor financial results experienced by the rival will not be immediate, but that there will be a lag. Because of these problems, raw financial data may not be a good choice.

In this study, the sum of quarterly income/ earnings per share over the last four quarters, not including the current quarter is used. As financial results of Canadian Airlines matter only during predation, both versions of FIN_2 were used in interaction with the dummy variable $PRED\tau$ corresponding to the period of alleged predation determined from estimation of equation (16). Both income and earnings per share were deflated by the consumer price index. Income is measured in millions of dollars, and earnings per share are measured in dollars.

GROWTH = a variable measuring the state of the economy. Demand for air travel is known to be pro-cyclical (see for example Tretheway and Oum (1992), in particular

[70] Financial data are not available on a higher frequency than quarterly.

Chapter 3, Section B). Thus, the rate of economic growth may be a good indicator of whether demand was low or high. Because demand for air travel is highly seasonal, demand in the current month should be compared with demand the same month one year earlier. Consequently, the variable measuring the state of the economy was constructed as the annual growth rate of monthly ACTIV-indices, the ratio ($ACTIV_t$ - $ACTIV_{t-12}$)/$ACTIV_{t-12}$. The growth rate was used in interaction with the same dummy variable as FIN_2; the argument for using the rate of growth only during the period of alleged predation applies here as well.

If the deep pocket model of predation is consistent with Air Canada's behaviour, the coefficients on FIN_2 and GROWTH should be negative and significant. These variables should also be insignificant outside the predation period.

5.1.3. The reputation model of predation

The reputation model of predation implies that the effect of capacity scheduled by Canadian Airlines on capacity scheduled by Air Canada is positive as the predatory airline tries to "discipline" the rival attempting to expand its business. This hypothesis is tested using a method that is equivalent to testing the stability of the coefficient on K_2. The particular method employed in this exercise is the dummy variable method as outlined in Griffiths *et al.* (1993), Chapter 12. The K_1-equation is extended by another variable, K_2 interacted with a the dummy variable corresponding to the period when the impact of this variable might have been different (i.e. a dummy variable corresponding to the period of alleged predation). The equation to be estimated in this case is:

$$K_{1t} = \alpha_0 + \alpha_1 K_{1,t-1} + \alpha_2 K_{2t} + \theta_1 K_{2t}^P + \alpha_3 r_t + \alpha_4 w_t + \alpha_5 ACTIV_t + \alpha_6 K_{2,t-1} + \theta_2 K_{2,t-1}^P + \alpha_7 r_{t-1} + \alpha_8 w_{t-1} + \alpha_9 ACTIV_{t-1} + \gamma_1 d_1 + \gamma_2 d_2 + \ldots + \gamma_{11} d_{11}, \quad (18)$$

where $K_2{}^P = K_2$ interacted with the dummy variable corresponding to the period of alleged predation determined from the estimation of equation (16). In equation (18), the stability of both the coefficient on the current as well as the coefficient on the lagged value of K_2 are examined. As the adjustment of capacity is not immediate, the observed K_1 may be a reaction to K_{2t} as well as $K_{2,t-1}$.

The coefficient on K_{2t} corresponding to the period of alleged predation is $\alpha_2 + \theta_1$, and the coefficient on $K_{2,t-1}$ corresponding to the period of alleged predation is $\alpha_6 + \theta_2$. The coefficients corresponding to the rest of the sample period are α_2 and α_6, respectively. If there is no predation, α_2 and α_6 should be negative, and θ_1 and θ_2 should be statistically insignificant. But if there is predation, the effect of strategic substitution will be reduced, possibly to such an extent that K_1 and K_2 could be regarded as strategic complements. Therefore, if Air Canada's behaviour is consistent with the reputation model of predation, both θ_1 and θ_2 should be positive and statistically significant.

5.2. The price equation

For the same reasons as those discussed in the introduction to Section 5.1, the empirical analysis of the price equation starts in Section 5.2.1 with a general specification of the price equation and a general test of predatory pricing policy. This test is intended to determine the relevant predation period and provide possible statistical evidence that sometime during the sample period prices charged by Air Canada were indeed lower than during the rest of the sample period. Then the analysis goes on to the discussion of the deep pocket model and the reputation model of predation in Section 5.2.2 and Section 5.2.3, respectively.

5.2.1. General specification of the price equation

We specify the price equation in the following general dynamic form:

$$\begin{aligned} P_{1t} = {} & \beta_0 + \beta_1 P_{1,t-1} + \beta_2 P_{2t} + \beta_3 K_{1t} + \beta_4 (K_{1t})^2 + \beta_5 K_{2t} + \beta_6 w + \beta_7 ACTIV_t + \\ & \beta_8 P_{2,t-1} + \beta_9 K_{1,t-1} + \beta_{10} (K_{1,t-1})^2 + \beta_{11} K_{2,t-1} + \beta_{12} w_{t-1} + \beta_{13} ACTIV_{t-1} + \\ & g_1 d_1 + g_2 d_2 + \ldots + g_{11} d_{11} + \beta_{14} PRED\tau, \qquad where\ \tau = 1,2,3. \end{aligned} \tag{19}$$

The construction of the new variables is discussed below:

P_1 = price charged by Airline 1 (Air Canada). As price discrimination in the airline industry is a common practice, the ideal price variable in equation (19) would be the average price, or revenue per passenger. Data for this variable are, however, confidential and were not available for this study. As indicated in Chapter 4, the only price data available to the general public are fares published in the computer reservation systems. These data contain information on price in dollars and fare code denoting type of fare, applicable restrictions, routing, etc. Taking into account the available data sources, the best price variable for equation (19) would be one particular type of discounted fare. However, it was not possible to construct a series with the same fare code for the whole sample period. Because of these difficulties, the lowest fare available on the given route was taken, ignoring fares having words "NIGHT," or something similar in their codes.[71] The reason for choosing the lowest discounted fares is that they are most likely to indicate the extent of excess capacity and price predation. This is so because the marginal cost of serving an additional passenger who occupies a seat that would have remained empty in the absence of a seat sale is close to zero. Thus, if the load factor on a flight is low, the airline may have an incentive to sell unoccupied seats (or seats that can be expected to be unoccupied) at a deep discount. The price is expressed in Canadian dollars and was deflated by the consumer price index.

P_2 = price charged by Airline 2 (Canadian Airlines). P_2 was constructed in the same way as P_1 .

All other variables in equation (19) are the same as those in the capacity equation described in Section 5.1. The function of the predation dummy variables in equation (19) is the same as in the capacity equation, i.e. they control for all other factors that may have affected the pricing policy during a possible predation period. Equation (19) will be estimated separately for each of these predation dummy variables.

The expected impact of each explanatory variable on price follows from the discussion in Chapter 3 (except for the lagged dependent variable). This discussion is briefly summarized below.

- $P_{1,t-1}$. The coefficient on this variable may be interpreted, similarly as the coefficient on $K_{1,t-1}$ in the capacity equation, as the speed of adjustment to the desired price level. Slow adjustment of prices may be due perhaps to advertised seat sales. This

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[71] These fares typically apply to night flights, and night flights were excluded from the sample.

coefficient is expected to be positive and fall in the range between 0 and 1.

- K_{1t}, $K_{1,t-1}$. An increase in capacity will lead to a lower average load factor. In order to reverse the trend of the falling load factor, the airline will have to stimulate demand by decreasing its price. As demand for air travel is typically price-elastic (see for example Tretheway and Oum, 1992), the decrease in price may be smaller than proportionate to the increase in capacity. Higher capacity is thus likely to drive down fares but at a decreasing rate. As a result, the coefficient on K_1 is expected to be negative and the coefficient on $(K_1)^2$ is expected to be positive.
- K_{2t}, $K_{2,t-1}$. An increase in rival capacity lowers demand facing Air Canada. In a typical situation, this change may be expected to lower the optimal price for Air Canada.[72]
- w_t, w_{t-1}. An increase in input prices increases operating costs and therefore price.
- $ACTIV_t$, $ACTIV_{t-1}$. A higher level of economic activity leads to an increase in demand for air travel and an increase in prices.
- PRED1, PRED2, PRED3. If the data are consistent with Air Canada being engaged in predatory pricing practices during the period April 1990 - August 1992, at least one of the predation dummy variables should be negative and significant.

5.2.2. Testing the deep pocket model of predation

The deep pocket model of predation implies that poor financial results of Canadian Airlines may encourage Air Canada to lower prices. To test this hypothesis, the predation

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[72] However, should the demand curve shift back and rotate to become steeper, the result could be higher prices charged by Air Canada.

dummy variable PREDτ is replaced by the financial variables, income and earnings per share, which were discussed in Section 5.1.2. This yields the following estimating equation:

$$P_{1t} = \beta_0 + \beta_1 P_{1,t-1} + \beta_2 P_{2t} + \beta_3 K_{1t} + \beta_4 (K_{1t})^2 + \beta_5 K_{2t} + \beta_6 w_t + \beta_7 ACTIV_t + \beta_8 P_{2,t-1} + \beta_9 K_{1,t-1} + \beta_{10} (K_{1,t-1})^2 + \beta_{11} K_{2,t-1} + \beta_{12} w_{t-1} + \beta_{13} ACTIV_{t-1} + g_1 d_1 + g_2 d_2 + \ldots + g_{11} d_{11} + \beta_{14} FIN_{2t}, \tag{20}$$

where $FIN_{2t} = EARNINGS_{2t}$, or $INCOME_{2t}$.

If the deep pocket model of predation is consistent with Air Canada's pricing policy, the coefficients on the financial variables should be positive and significant. These coefficients should also be insignificant outside the predation period.

5.2.3. Reputation model of predation

The reputation model of predation implies that the effect of consumers' income on the price charged by the predatory airline is negative as this airline may want to demonstrate that it is "tough" and can serve large demand at a low price and can survive in a difficult economic situation. This hypothesis can be examined by testing the stability of the coefficient on ACTIV. The technique used in testing the reputation model in the capacity equation in section 5.1.3 can also be used in this exercise. The equation to be estimated is:

$$P_{1t} = \beta_0 + \beta_1 P_{1,t-1} + \beta_2 P_{2t} + \beta_3 K_{1t} + \beta_4 (K_{1t})^2 + \beta_5 K_{2t} + \beta_6 w_t + \beta_7 ACTIV_t + \kappa_1 ACTIV_t^P + \beta_8 P_{2,t-1} + \beta_9 K_{1,t-1} + \beta_{10} (K_{1,t-1})^2 + \beta_{11} K_{2,t-1} + \beta_{12} w_{t-1} + \beta_{13} ACTIV_{t-1} + \kappa_2 ACTIV_{t-1}^P + g_1 d_1 + g_2 d_2 + \ldots + g_{11} d_{11}. \tag{21}$$

where $ACTIV^P$ = variable ACTIV interacted with the dummy variable corresponding to the period of alleged predation determined from the estimation of equation (19). In equation (21), both the current and the lagged values of ACTIV were interacted with the predation dummy variable. The coefficient on $ACTIV_t$ corresponding to the predation period is $\beta_7 + \kappa_1$, and the coefficient on $ACTIV_{t-1}$ corresponding to the predation period is $\beta_{13} + \kappa_2$. The coefficients corresponding to the rest of the sample period are β_7 and β_{13}, respectively. If there is no predation, β_7 and β_{13} should be positive, and κ_1 and κ_2 should be statistically insignificant. But if there is predation, the tendency of increasing economic activity to drive up prices will be reduced, possibly to such an extent that the effect of higher ACTIV becomes negative. Thus, if the reputation model of predation is consistent with Air Canada's behaviour, both κ_1 and κ_2 should be negative and significant.

5.3. Estimation, results, and interpretation

Examining the capacity equation and the price equation, we can see that the dependent variable of the capacity equation is one of the explanatory variables in the price equation. At the last stage of profit maximization when the ticket prices are chosen, seating capacity is already fixed, and K_1 can be treated as a predetermined variable in the P_1 - equation. Thus, the empirical capacity equation and the price equation form a recursive system of equations which can be estimated independently.[73]

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[73] This system of equations may not be truly recursive, however, if the disturbances from the price equation and the capacity equation are correlated. This possibility was examined using capacity equation (16) and price equation (19). The functional forms chosen for these equations were those which passed the preliminary tests, the log-lin form for the price equation and the log-log and log-lin forms for the capacity equation. The system of equations was estimated for each predation dummy variable, PRED1, PRED2, and PRED3 (the same PRED-variable was used in each equation). The Breusch-Pagan LM test of a diagonal covariance matrix (a χ^2 - test with 1 D.F.) varied between

This section presents results obtained using single equation estimation techniques. Section 5.3.1 presents descriptive statistics. Section 5.3.2 reports the econometric results for the capacity equation. The results of the general specification are reported first, and the choice between the functional forms and the predation dummy variables is discussed. The following parts of this section report results for the deep pocket model and the reputation model of predation, and provide a numerical interpretation of the evidence of predatory behaviour. The discussion ends with a brief summary of the empirical results. Section 5.3.3 reports the econometric results for the price equation. The format of this section is similar to that of Section 5.3.2.

5.3.1. Descriptive statistics

The model is estimated using monthly observations over the period February 1988 to December 1994. The descriptive statistics of the data for the whole sample period and for one of the possible predation periods are presented in Table 5-1 and Table 5-2, respectively.

Air Canada and Canadian Airlines were charging the same price for most of the sample period. Thus, for the whole sample period the mean price charged by both airlines is almost identical, and the maximum price is exactly the same. During the possible predation period April 1990 - August 1992, the difference between prices charged by the two

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0.157 and 0.382. The LR test of a diagonal covariance matrix (a χ^2 - test with 1 D.F.) varied between 0.461 and 1.321. Thus, the null hypothesis of a diagonal covariance matrix could not be rejected at any conventional level of significance. Consequently, there is likely to be no gain in efficiency from joint estimation of the capacity equation and the price equation. In addition, the problems reported later in this section, autocorrelation and heteroscedasticity, make it difficult to obtain consistent and efficient estimates for a system of equations.

airlines was much larger. The minimum was lower for Canadian Airlines, but the mean and the maximum were lower for Air Canada.

Table 5-1 Descriptive statistics. Whole sample period: February 1988 - December 1994. 83 observations.

NAME	MEAN	ST. DEV	VARIANCE	MINIMUM	MAXIMUM
P_1	304.31	49.260	2426.6	217.84	474.19
P_2	308.94	51.845	2687.9	176.80	474.19
K_1	1087.3	182.15	33177.	844.00	1751.0
K_2	1228.5	228.56	52240.	354.00	1684.0
w	19.57	3.3149	10.988	12.715	34.373
r	8.59	2.9885	8.9313	3.8025	13.564
ACTIVITY	147.70	9.3357	87.156	136.60	171.40
$INCOME_2$	-119.99	159.31	25381.	-521.70	35.649
EARNINGS	-2.48	3.3785	11.414	-10.888	1.6535
GROWTH	3.38%	4.0%	0.16%	-5.91%	8.64%

Table 5-2 Descriptive statistics. The longest period of possible predation: April 1990 - August 1992. 29 observations.

NAME	MEAN	ST. DEV	VARIANCE	MINIMUM	MAXIMUM
P_1	263.46	23.386	546.91	217.84	295.40
P_2	277.28	47.648	2270.3	176.80	409.35
K_1	1079.3	122.54	15017.	895.00	1307.0
K_2	1214.6	261.35	68305.	354.00	1684.0
w	20.999	4.5635	20.826	16.586	34.373
r	9.0977	2.6239	6.8851	5.0200	13.564
ACTIVITY	141.61	2.8979	8.3977	136.60	146.10
$INCOME_2$	-75.237	47.141	2222.3	-136.68	-11.990
$EARNINGS_2$	-1.5814	1.2151	1.4765	-3.0804	0.47966
GROWTH	-0.27%	3.97%	0.15%	-5.91%	5.4%

Over the full sample period, the seating capacity scheduled by Air Canada was on average lower than the seating capacity scheduled by Canadian Airlines. The maximum capacity was larger for Air Canada, but this observation refers to late 1994, the last six months in the sample. It should also be noted that the minimum capacity for Canadian Airlines reported in Table 5-1 and Table 5-2, 354 seats, was not a typical observation. It refers to April 1992 when, as mentioned in Chapter 4, Canadian Airlines reduced its capacity to just two flights, approximately one third of the capacity that was in effect the same month one year earlier. In May 1992 the capacity was increased back to the level typical for that time of the year.

On average, Canadian Airlines was incurring losses during the period of alleged predation as well as during the whole sample period. The mean values of $INCOME_2$ and $EARNINGS_2$ are both negative. During the possible predation period, even the maximum value of $INCOME_2$ was negative and the maximum value of $EARNINGS_2$ was just 50 cents.

The variable GROWTH measuring the state of the economy was lower during the period of alleged predation than during the whole sample period (both the mean as well as the maximum were lower). For instance, during the period of alleged predation the mean value of GROWTH was -0.3 percent as opposed to 3.4 percent during the whole sample period.

5.3.2. The capacity equation

5.3.2.1. The general specification

Equation (16) was initially estimated in lin-lin, log-lin, log-log, and lin-log functional forms[74] using OLS. The equation was estimated separately for each predation dummy

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[74] To simplify the notation, the following terminology is used: lin-lin refers to the functional form where all variables are in linear (untransformed) form; log-lin refers to the functional form where the dependent variable is in logarithmic form and the explanatory variables are in linear form;

variable, PRED1, PRED2, and PRED3.

Preliminary tests revealed some form of heteroscedasticity in the data and serial correlation of up to 12th order. OLS estimation with a lagged dependent variable and correlated error terms may produce inconsistent and biased estimates as the lagged dependent variable is likely to be correlated with the error term. In general, other estimation methods are recommended in this case, for instance instrumental variables or maximum likelihood. The instrumental variables method gives consistent estimates regardless of the type of autocorrelation, but is generally inefficient. On the other hand, maximum likelihood estimation requires identification of the precise order of serial correlation and the estimation of the serial correlation coefficient(s) in the first step. In addition, the problem is complicated by the presence of heteroscedasticity.

To find out whether the estimation procedure can be simplified, Hausman-type tests of the correlation of the lagged dependent variable, $K_{1,t-1}$, with the error term were carried out, and the IV estimates were compared with the OLS estimates. As the instrument for $K_{1,t-1}$, the lagged value of the number of flights offered by Air Canada was used. For all functional forms and all predation dummy variables, the null hypothesis that $K_{1,t-1}$ is uncorrelated with the error term could not be rejected at any conventional level of significance.[75] Moreover, the instrumental variables method produced estimates very

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log-log refers to the functional form where all variables are in logarithmic form (except for dummy variables); and lin-log refers to the functional form where the dependent variable is in linear form and the explanatory variables are in logarithmic forms (again, except for dummy variables).

[75] These tests were carried out using standard errors obtained with the Newey-West heteroscedasticity and autocorrelation consistent covariance matrix of order 12.

similar to the OLS estimates. The difference between the two estimates was typically smaller than one third of the standard error.

As it is not obvious whether K_2, seating capacity scheduled by Canadian Airlines, should be treated as an endogenous or as an exogenous variable in the K_1-equation,[76] Hausman tests of the exogeneity of K_2 were carried out. As the instrument for this variable, the number of flights scheduled by Canadian Airlines was used. For all functional forms and all predation dummy variables examined, the null hypothesis of the exogeneity of K_2 could not be rejected at any conventional level of significance.

In view of these test results, the decision was made to proceed with the simpler OLS estimation while correcting the standard errors using the Newey-West heteroscedasticity and autocorrelation consistent covariance matrix of order 12. The diagnostic test results as well as the coefficients on PRED1, PRED2, and PRED3, the variables of primary interest, are reported in Tables 5-3, 5-4, and 5-5.

As can be seen in Tables 5-3, 5-4, and 5-5 the coefficient on PRED1 was statistically insignificant for all functional forms examined. However, the coefficient on PRED2 and PRED3 was positive and significant at the 10% level for all functional forms. The coefficient on PRED3 was also larger in magnitude and had a higher t-ratio. All functional forms of equation (16) performed quite well on specification tests. Log-log and log-lin specifications were chosen for further examination as both forms passed all RESET

[76] On the one hand, oligopoly theory says that in Nash equilibrium firms maximize their profits taking the choices of other market participants as given. On the other hand, one may argue that there will be a capacity equation similar to equation (18) for Airline 2, where K_1 will be a right hand side variable. A shock to K_2 will be transmitted to the K_1 - equation and then back to the K_2 - equation which implies that these two variables may be jointly determined.

specification tests, and the test of normality of residuals.

Table 5-3 Diagnostic test results of capacity equation (16) with the predation dummy variable PRED1.

	lin-lin	log-lin	log-log	lin-log
Coefficient on PRED1; 61 DF	6.1502 (0.2398)	0.33297E-02 (0.1465)	0.24029E-02 (0.1017)	4.7451 (0.1814)
R^2 adjusted	0.7125	0.7312	0.727	0.7084
Hausman test of correlation of $K_{1,t-1}$ and error; coefficient on $K_{1,t-1}$ hat; 60 DF	-0.76E-01 (-0.2417)	-0.346E-05 (-0.126E-01)	-0.177E-01 (-0.627E-01)	-97.272 (-0.3086)
Hausman specification test: Coefficient on K_{2t}hat; 60 DF	0.3955E-01 (0.19E-01)	-0.493E-06 (-0.379E-02)	0.3057E-01 (0.2099)	44.385 (0.1444)
Normality test; χ^2 with 2 DF	14.382	2.2745	3.0447	16.7183
Breusch-Pagan χ^2 test of heteroscedasticity ; 21 DF	42.755	45.59	44.885	41.726
Ramsey RESET tests RESET(2) F with 1 and 60 DF RESET(3) F with 2 and 59 DF RESET(4) F with 3 and 58 DF	 2.2886 1.1316 0.8767	 0.64915 0.31951 0.22169	 0.43612 0.21485 0.14477	 1.7744 0.87816 0.72128

NOTE: t-ratios in parentheses

Log-log and log-lin were tested against each other using the McKinnon non-nested test procedure (see McKinnon *et al.*, 1983). The results of this test are presented in Table 5-6. The log-lin specification could not be rejected against the log-log specification at any conventional level of significance. The log-log specification with the variable PRED3 could not be rejected against log-lin at the 5% level but it could be rejected at the 10% level. The log-log specification with PRED1 and PRED2 could be rejected against the log-lin specification almost at the 5% level. Therefore, the log-lin functional form was chosen as the preferred specification.

Table 5-4 Diagnostic test results of capacity equation (16) with the predation dummy variable PRED2.

	lin-lin	log-lin	log-log	lin-log
Coefficient on PRED2; 61 DF	40.711 (1.789)	0.33135E-01 (1.785)	0.325E-01 (1.742)	39.822 (1.779)
R^2 adjusted	0.7195	0.7378	0.7335	0.7151
Hausman test of correlation of $K_{1,t-1}$ and error; coefficient on $K_{1,t-1}$ hat; 60 DF	-0.919E-01 (-0.2649)	-0.193E-04 (-0.637E-01)	-0.355E-01 (-0.1159)	-117.58 (-0.3446)
Hausman specification test: Coefficient on K_{2t} hat; 60 DF	0.1496 (0.4974)	0.279E-04 (0.2046)	0.622E-01 (0.4006)	211.91 (0.6521)
Normality test; χ^2 with 2 DF	13.999	1.949	2.759	16.376
Breusch-Pagan χ^2 test of heteroscedasticity ; 21 DF	40.927	43.134	42.529	39.903
Ramsey RESET tests RESET(2) F with 1 and 60 DF RESET(3) F with 2 and 59 DF RESET(4) F with 3 and 58 DF	 2.9202 1.5058 1.0783	 0.9034 0.4799 0.3269	 0.7304 0.3795 0.2644	 2.4839 1.2842 0.9329

NOTE: t-ratios in parentheses

Table 5-5 Diagnostic test results of capacity equation (16) with the predation dummy variable PRED3.

	lin-lin	log-lin	log-log	lin-log
Coefficient on PRED3; 61 DF	46.801 (1.925)	0.4079E-01 (1.849)	0.4149E-01 (1.796)	49.581 (1.901)
R^2 adjusted	0.7213	0.7407	0.7369	0.7183
Hausman test of correlation of $K_{1,t-1}$ and error; coefficient on $K_{1,t-1}$ hat; 60 DF	-0.531E-01 (-0.1466)	0.2E-04 (0.634E-01)	-0.85E-03 (-0.27E-02)	-84.0 (-0.235)
Hausman specification test: Coefficient on K_{2t} hat; 60 DF	0.133 (0.4703)	0.496E-04 (0.3541)	0.938E-01 (0.5898)	197.06 (0.6497)
Normality test; χ^2 with 2 DF	14.428	1.677	2.112	15.677
Breusch-Pagan χ^2 test of heteroscedasticity ; 21 DF	40.896	42.952	42.33	39.783
Ramsey RESET tests RESET(2) F with 1 and 60 DF RESET(3) F with 2 and 59 DF RESET(4) F with 3 and 58 DF	 3.5433 1.8319 1.283	 1.2484 0.6789 0.4609	 0.8879 0.4775 0.333	 2.8293 1.4737 1.0613

NOTE: t-ratios in parentheses

Table 5-6 Results of the McKinnon t-test of the functional form. 60 DF.

Specification	PRED1	PRED2	PRED3
Log-lin against log-log	1.396 do not reject H0	1.437 do not reject H0	1.004 do not reject H0
Log-log against log-lin	1.941 reject H0 at less than 5%	1.958 reject H0 at less than 5%	1.788 reject H0 at 10%

The question that has to be addressed at this point is the choice of the relevant predation dummy variable, PRED1, PRED2, or PRED3. Higher coefficient estimates and higher t-ratios for PRED3 than for the other predation dummy variables could be interpreted as an indication that this variable represents the relevant predation period. However, to obtain further statistical evidence on which variable is relevant, all three models, i.e. the specifications with PRED1, PRED2, and PRED3, were tested against each other using the McKinnon non-nested test procedure. The results of this test are presented in Table 5-7.

Table 5-7 Results of the McKinnon t-test of the dummy variable specification in the capacity equation. 60 DF.

Specification	PRED1	PRED2	PRED3
Specification with PRED1 against		4.108 reject H0	2.354 reject H0
Specification with PRED2 against	-3.513 reject H0		1.28 do not reject H0
Specification with PRED3 against	-1.245 do not reject H0	0.165 do not reject H0	

As can be seen in this Table 5-7, the specification with PRED1 was rejected against both the specification with PRED2 and the specification with PRED3; the specification with PRED2 was rejected against PRED1, although it could not be rejected against PRED3; the specification with PRED3 could not be rejected by either PRED1 or PRED2 specifications.[77] In view of these results, it is assumed for further discussion that the

[77] This test was also carried out for the log-log functional form. The result were similar: PRED1 was rejected against PRED2 and PRED3, PRED2 was rejected against PRED1 and PRED3, and PRED3 could not be rejected against PRED1 or PRED2.

relevant predation period is April 1990 - August 1992.[78]

The coefficient estimates of the preferred specification are presented in Table 5-8. Monthly dummy variables are not reported; except for March, July and August they were all statistically insignificant.[79]

Table 5-8 OLS estimates of equation (16) with predation dummy variable PRED3.

	Dependent variable = ln K_1	
ln $K_{1,t-1}$	0.51415	(3.882)
K_{2t}	0.39332E-04	(1.483)
r_t	-0.15695E-01	(-1.203)
w_t	-0.2086E-02	(-0.6944)
$ACTIV_t$	-0.75712E-02	(-0.5058)
$K_{2,t-1}$	-0.33849E-04	(-1.049)
r_{t-1}	0.13329E-01	(1.013)
w_{t-1}	0.55581E-02	(1.754)
$ACTIV_{t-1}$	0.15266E-01	(1.002)
PRED3	0.40794E-01	(1.849)
CONSTANT	2.1752	(3.022)

NOTE: t-ratios in parentheses; 61 DF

[78] Note that the statistical insignificance of the coefficient on PRED1 does not necessarily imply that the predation period ended in September 1991. By definition, a dummy variable measures the difference between the expected capacity during the period designated as the predation period and during the rest of the sample period. If capacity was high during the predation period but it was also high sometime outside the predation period, the expected capacities referring to these two periods will not be much different. As a result, the coefficient on the predation dummy variable may turn out statistically insignificant.

[79] However, an F-test could not reject the null hypothesis that all monthly dummy variables were jointly insignificant (the results was F=7.931 with 11 and 61 DF).

As can be seen in this table, the coefficient on the lagged dependent variable is of the expected sign and magnitude (i.e. it is positive and smaller than 1). This implies that, as expected, the adjustment of capacity was quite slow. The lagged explanatory variables tend to be statistically insignificant. However, an F-test, F=2.895 with 4 and 61 DF, rejected the null hypothesis that these variables were jointly insignificant at the 5% level.

The result of primary interest is the coefficient on the relevant predation dummy variable. As can be seen in Table 5-8, the coefficient on PRED3 was positive and significant at the 10% level. This result is consistent with the preliminary null hypothesis that Air Canada was engaged in predatory practices sometime during the sample period. The seating capacity scheduled by this airline during the period April 1990 - August 1991 was significantly higher than during the rest of the sample period.

5.3.2.2. Deep pocket model of predation

Equation (17) was estimated using the same technique as previously, OLS with the Newey-West heteroscedasticity and autocorrelation consistent covariance matrix of order 12. The financial variables and GROWTH were interacted with PRED3. The coefficient estimates are presented in Table 5-9.[80]

As can be seen in Table 5-9, the coefficients on the financial variables have a negative

[80] Equation (17) was re-tested for autocorrelation and the correlation of the lagged dependent variable with the error term. In the equation with EARNINGS there was significant 5th and 12th order autocorrelation. However, all twelve coefficients of correlation of the error terms (i.e. 1st order autocorrelation , 2nd order autocorrelation, and so on) were jointly insignificant. In the equation with INCOME there was significant 5th, 7th, and 12th order autocorrelation. However, autocorrelation of up to 11th order was jointly insignificant. The Hausman test of the correlation between the lagged dependent variable and the error term could not reject the null hypothesis of no correlation at any conventional level of significance. In view of these results, the decision was made to use the OLS with the Newey-West heteroscedasticity and autocorrelation consistent covariance matrix.

sign and are significant at the 5% level. GROWTH is significant at the 10% level in the equation where INCOME is the variable examined, but it is insignificant in the equation with EARNINGS. These results provide evidence supporting the deep pocket model of predation.

Table 5-9 OLS estimates of the deep pocket model of predation for the capacity equation. Dependent variable = ln K_1

Explanatory variables	(1)		(2)	
ln $K_{1,t-1}$	0.5075	(3.991)	0.46266	(3.281)
K_{2t}	0.43267E-04	(1.616)	0.43889E-04	(1.639)
r_t	-0.18312E-01	(-1.299)	-0.16504	(-1.274)
w_t	-0.17123E-02	(-0.601)	-0.21699E-02	(-0.7661)
$ACTIV_t$	-0.39751E-02	(-0.181)	0.3108E-02	(0.1559)
$K_{2,t-1}$	-0.45216E-04	(-1.357)	-0.4432E-04	(-1.404)
r_{t-1}	0.1568	(1.03)	0.18694E-01	(1.351)
w_{t-1}	0.46112E-02	(1.556)	0.53349E-02	(1.83)
$ACTIV_{t-1}$	0.11722E-01	(0.5341)	0.56071E-02	(0.2889)
$GROWTH_t$	-0.998	(-1.331)	-1.2476	(-1.698)
$INCOME_{2t}$			-0.748E-03	(-2.326)
$EARNINGS_{2t}$	-0.23858E-01	(-2.069)		
CONSTANT	2.2337	(3.144)	2.3608	(3.103)
R^2 adj.	0.7371		0.7456	
Breusch-Pagan χ^2 test of heteroscedasticity ; 22 DF	44.488		44.062	
Ramsey RESET tests				
RESET(2) F with 1 and 59 DF	1.2509		1.4961	
RESET(3) F with 2 and 58 DF	0.65115		0.85914	
RESET(4) F with 3 and 57 DF	0.42756		0.58322	

NOTE: t-ratios in parentheses; 60 DF

If the deep pocket model of predation is correct, the financial variables and GROWTH should be insignificant outside the predation period. To find out whether this is in fact the case,the deep pocket model, equation (17), was re-estimated with FIN_2 and GROWTH variables included for the whole sample period. The results are reported in Table 5-10A. In Table 10-A, variables GROWTH, INCOME , and EARNINGS refer to the whole sample period (i.e. to the February 1988 - December 1994 period). Variables $GROWTH^P$, $INCOME^P$, and $EARNINGS^P$ refer to the period of alleged predation (i.e. to the April 1990 - August 1992 period), and are intended to measure the additional effect that these variables might have had during the period of alleged predation (the idea is the same as that outlined in Section 5.1.3 and 5.2.3 in the context of testing the reputation model of predation). As can be seen in Table 5-10A, the coefficient on GROWTH was insignificant outside the predation period. The coefficient on $GROWTH^P$ was also insignificant but opposite in sign, larger in magnitude, and it had a higher t-ratio. The coefficients on $EARNINGS^P$ and $INCOME^P$ were negative and statistically significant at the 5% level or better. This result indicates that the effect of INCOME and EARNINGS on K_1 during the predation period was significantly different than outside that period. The sum of the coefficients referring to the predation period and the rest of the sample period (not reported in Table 5-10A) was negative and significant almost at the 10% level. These results are consistent with the deep pocket scenario. But the effect of INCOME and EARNINGS outside the predation period was positive and statistically significant. This

Table 5-10A OLS estimates of the deep pocket model of predation with INCOME, EARNINGS, and GROWTH included for the whole sample period (i.e. February 1988 - December 1994). Dependent variable = ln K_1

Explanatory variables	(1)		(2)	
ln $K_{1,t-1}$	0.40676	(2.644)	0.3903	(2.556)
K_{2t}	0.5854	(1.716)	0.6386E-04	(1.839)
r_t	-0.36433E-01	(-2.449)	-0.3426E-01	(-2.241)
w_t	-0.1381E-02	(-0.4557)	-0.1642E-02	(-0.5369)
$ACTIV_t$	-0.1504E-01	(-0.7037)	-0.1698E-01	(-0.8163)
$K_{2,t-1}$	0.7666E-05	(0.2347)	0.1674E-04	(0.5045)
r_{t-1}	0.2197E-01	(1.717)	0.2459E-01	(2.015)
w_{t-1}	0.4592E-02	(1.532)	0.5271E-02	(1.709)
$ACTIV_{t-1}$	0.2463E-01	(1.134)	0.2608E-01	(-0.8536)
$GROWTH_t$	0.1517	(0.346)	0.7955	(1.198)
$GROWTH_t^{\ P}$	-0.9658	(-1.14)	-1.885	(-1.451)
$INCOME_{2t}$			0.1717E-03	(2.451)
$INCOME_{2t}^{\ P}$			-0.9941E-03	(-2.029)
$EARNINGS_{2t}$	0.87187E-02	(3.682)		
$EARNINGS_{2t}^{\ P}$	-0.2838E-01	(-2.187)		
CONSTANT	2.66	(3.146)	2.762	(3.296)
R^2 adj.	0.74466		0.7533	

NOTE: t-ratios in parentheses; 58 DF.

result was, however, generated by the last six observations in the sample. In late 1994, Air Canada started to use a new plane. This plane, Lockheed L1011, had a much larger capacity compared to other planes typically used on this route, either by Air Canada or Canadian Airlines; Lockheed L1011 has 361 seats, whereas Boeing 767 (the aircraft used most frequently by Air Canada and Canadian Airlines) has 179 - 222 seats. The deep pocket model was thus re-estimated with the financial variables and GROWTH included for the whole sample period except for the last six months. The results are reported in Table 5-10B.

Table 5-10B OLS estimates of the deep pocket model of predation with INCOME, EARNINGS, and GROWTH included for the period February 1988 - June 1994; the capacity equation. Dependent variable = ln K_t

Explanatory variables	(1)		(2)	
ln $K_{1,t-1}$	0.4241	(2.61)	0.4179	(2.483)
K_{2t}	0.5481E-04	(1.102)	0.54923E-04	(1.105)
r_t	-0.27122E-01	(-2.256)	-0.2628E-1	(-2.037)
w_t	-0.3856E-02	(-2.513)	-0.3724E-02	(-2.375)
$ACTIV_t$	-0.4003E-01	(-1.912)	-0.4225E-01	(-1.921)
$K_{2,t-1}$	0.1237E-04	(0.418)	0.12447E-04	(0.418)
r_{t-1}	0.16854E-01	(1.666)	0.1518E-01	(1.642)
w_{t-1}	0.6037E-02	(2.683)	0.5901E-02	(2.558)
$ACTIV_{t-1}$	0.4544E-01	(2.124)	0.4779E-01	(2.122)
$GROWTH_t$	0.1313	(0.346)	0.1409	(0.3663)
$GROWTH_t^P$	-1.4603	(-1.35)	-1.0747	(-1.27)
$INCOME_{2t}$			0.2691E-04	(0.396)
$INCOME_{2t}^P$			-0.5363E-03	(-2.181)
$EARNINGS_{2t}$	0.1009E-02	(0.3946)		
$EARNINGS_{2t}^P$	-0.30762E-01	(-2.114)		
CONSTANT	3.1351	(3.641)	3.1622	(3.621)
R^2 adj.	0.6276		0.6278	

NOTE: t-ratios in parentheses; 52 DF.

As can be seen in Table 10-B, the financial variables are insignificant outside the predation period, while the coefficients on $INCOME^P$ and $EARNINGS^P$ are still negative and significant at the 5% level.

The results presented Table 5-10A and Table 5-10B provide thus some evidence that the deep pocket model is robust for most of the sample period. This provides further evidence supporting the deep pocket model.

5.3.2.3. Reputation model of predation

The fact that PRED3 was determined to be the relevant predation dummy variable provides preliminary evidence against the reputation model of predation. As argued in Chapter 2, the reputation model of predation in airline markets where there are two well established airlines, may be relevant if there has been an event in these market that makes the market participants believe that there has been a change in a rival's objectives and market behaviour. In the market examined, the only event that could be interpreted in this way was the nomination of Hollis Harris as the CEO and president of Air Canada in February 1992. (As explained in Chapter 2, Hollis Harris had a reputation of "getting things done"). But if that event had indeed marked the beginning of predation, PRED1 would be the relevant predation dummy variable.

Nevertheless, we proceeded with estimation of capacity equation (18) to determine whether there is any evidence supporting the reputation model during a longer period of time than that implied by PRED1. Capacity equation (18) was estimated using OLS with the Newey-West heteroscedasticity and autocorrelation consistent covariance matrix of order 12. Variable K_2 was interacted with PRED3. The results of this estimation are presented in Table 5-11.[81]

Table 5-11 OLS estimates of the reputation model of predation for the capacity equation.

	log-lin	
$\ln K_{1,t-1}$	0.49326	(3.676)
K_{2t}	-0.2596E-04	(-0.1969)
K_{2t}^{P}	0.84481E-04	(0.5957)
r_t	-0.18786E-01	(-1.597)
w_t	-0.24671E-02	(-0.7613)
$ACTIV_t$	-0.74049E-02	(-0.5132)
$K_{2,t-1}$	0.18139E-04	(0.1378)
$K_{2,t-1}^{P}$	-0.48945E-04	(-0.3429)
r_{t-1}	0.16568E-01	(1.311)
w_{t-1}	0.57701E-02	(1.747)
$ACTIV_{t-1}$	0.15403E-01	(1.039)
CONSTANT	2.2936	(3.099)
$\alpha_2 + \theta_1$	0.5852E-04	(1.9375)
$\alpha_6 + \theta_2$	-0.30805E-04	(-0.894555)
R^2 adj.	0.7734	
Breusch-Pagan χ^2 test of heteroscedasticity ; 22 DF	45.923	
Ramsey RESET tests RESET(2) F with 1 and 59 DF RESET(3) F with 2 and 58 DF RESET(4) F with 3 and 57 DF	 1.0545 0.54033 0.3689	

NOTE: t-ratios in parentheses; 60 DF.

[81] Equation (18) was re-tested for autocorrelation. Significant autocorrelation of up to 12th order was detected. However, the Hausman test of the correlation between the lagged dependent variable and the error term could not reject the null hypothesis of no correlation.

As can be seen in Table 5-11, the coefficients on K_{2t}^{P} and $K_{2,t-1}^{P}$ were insignificant, which implies that the reaction of K_1 (capacity scheduled by Air Canada) to K_2 (capacity scheduled by Canadian Airlines) was not much different during the period of alleged predation than outside that period. During the predation period, the coefficient on the current K_2 (i.e. $\alpha_2 + \theta_1$) was positive and statistically significant almost at the 5% level,[82] but the coefficient on the lagged value of K_2 (i.e. $\alpha_6 + \theta_2$) was statistically insignificant. There is thus little evidence supporting the reputation model of predation. This result, as well as the fact that PRED1 was ultimately rejected as the relevant predation variable imply that the reputation model of predation does not explain Air Canada's behaviour during the sample period.

5.3.2.4. Numerical interpretation

The numerical interpretation of the evidence of predatory behaviour on the part of Air Canada is difficult both because the dependent variable is in the logarithmic form and because there is a lagged dependent variable on the right hand side of the estimating equation. The logarithmic function is an increasing function of its argument but at a decreasing rate. Thus, an increase in the log of capacity implies an increase in capacity, but the magnitude of this increase depends on the initial capacity (i.e. the starting point). The lagged dependent variable on the right hand side of the estimating equation implies that initial predatory practices feed into the decision making process, and even months after

[82] This result is odd, as both α_2 and θ_1 are statistically insignificant, but possible if there is a negative covariation between the two variables. However, an F-test of the joint significance of α_2 and θ_1 could not reject the null hypothesis that both coefficients simultaneously equal zero (the test statistic was
$F = 1.908$ with 2 and 60 DF).

these practices have been discontinued, capacity might be much higher than what would have been the case in the absence of predation.

During the predation period, the log of capacity was higher as compared to the rest of the sample period by approximately 0.041 (see the coefficient on PRED3 in Table 5-8). At the level of 1087 seats, the mean capacity during the sample period, a change of this magnitude translates into 45 seats. This result is smaller than the size of a typical commercial plane.

The deep pocket model of predation gives larger estimates of predatory capacity if the maximum values of the predation related variables are used in the calculation. The coefficient on $INCOME_{2t}$ was -0.748E-03 (see Table 5-9). Given that Canadian Airlines's income decreased by 124 million dollars during the period of alleged predation, the log of capacity increased by 0.748E-03*124 = 0.0928. At the capacity level of 1087 seats this change implies approximately 106 more seats. The coefficient on GROWTH was -1.2476. Given that the growth rate decreased from approximately 0 percent at the beginning of the period of alleged predation to a minimum of almost -6 percent, the log of capacity increased by 0.06*1.2476 = 0.0749. This change implies 85 additional seats.

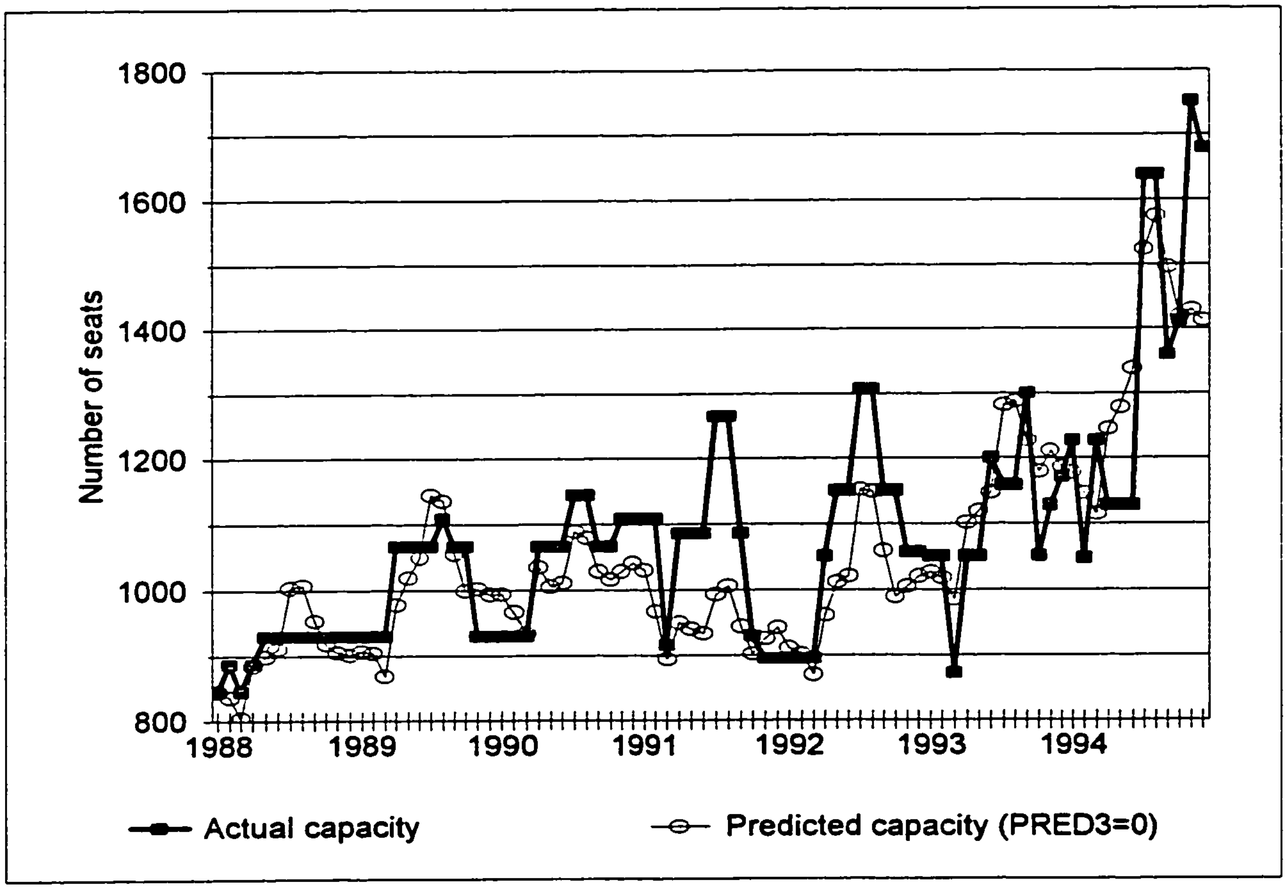
The magnitude of predatory capacity can also be inferred by comparing the actual capacity levels with the levels that could have been expected in the absence of predation. The expected non-predatory capacity can be calculated as the predicted value from one of the estimated capacity equations with the predation variables (i.e. PRED3, INCOME, EARNINGS, GROWTH, or K_2^P) set equal to zero. This exercise was carried out for equation (16) with the predation dummy variable PRED3 set equal to zero for the whole sample period. The results are presented in Figure 5-1.

In this figure, two series are plotted. One of them, labelled as "actual capacity," is the actual seating capacity scheduled by Air Canada over the period January 1988 to December 1994. The other series, labelled as "predicted capacity," is the predicted capacity that could be expected in the absence of predation.[83] As expected, there is a large discrepancy between the predicted capacity and the actual capacity during the period of alleged predation. The difference between the two series was not constant over the entire predation period, which indicates that the intensity of predation may vary over time depending on current conditions and factors unobservable to the researcher. The results are consistent with predation being most intensive in July and August 1991 when the difference between the actual and the predicted capacity levels amounted to 150 - 270 seats. There also was a second period when the discrepancy between the actual and the predicted capacity was high: in the spring and summer of 1992 the difference between the two series amounted to 130 - 150 seats.[84]

[83] The predicted capacity was also simulated with the estimates of the deep pocket model and the reputation model of predation. The estimates of the capacity expected in the absence of predation were very similar to those obtained using the general dummy variable model. Therefore, these models are not discussed here.

[84] Outside the predation period, the difference between the two series fluctuated between -80 and 80 seats, except for 1994 when the range of fluctuations was larger and amounted to -210 seats in June 1994 and 322 in November 1994.

Figure 5-1 Actual capacity and capacity predicted from the empirical model



5.3.2.5. Summary of the estimation results of the capacity equation

Capacity equation (16) was initially estimated in lin-lin, lin-log, log-log, and log-lin functional forms and for each of the specified predation dummy variables, PRED1, PRED2, and PRED3. The log-lin equation was the preferred functional form, and the PRED3 dummy variable was found to be the relevant specification of the predation period. The coefficient on PRED3 was positive and statistically significant at the 10 percent level. This result implies that the seating capacity scheduled by Air Canada during the period of alleged predation was significantly higher than during the rest of the sample period.

Estimation of the deep pocket model, capacity equation (17), produced results consistent with that model. During the predation period, Air Canada tended to schedule more capacity when financial results of Canadian Airline were poor and when the economic situation was difficult. Although the effect of the economic situation appears to be only marginally significant, the effect of the financial variables is significant at the 5 percent level. Moreover, as predicted by the theory, the financial variables and the variable measuring the state of economy are insignificant outside the predation period, except for the last six months.

The data are inconsistent with the reputation model of predation. First, the fact that the relevant predation dummy variable is PRED3, and not PRED1, is inconsistent with the sequence of events that could have initiated predation-for-reputation on the part of Air Canada. Second, the reputation model of predation is not supported by the empirical results of the capacity equation where PRED3 is used to model predation, either.

5.3.3. The price equation

5.3.3.1. The general specification

Equation (20) was initially estimated in lin-lin, log-lin, log-log, and lin-log forms using OLS. The equation was estimated for each predation dummy variable, PRED1, PRED2, and PRED3. Preliminary tests revealed some form of heteroscedasticity in the data. In addition, in the log-lin and log-log equations there was 8th order autocorrelation. As mentioned in Section 5.3.2.1, autocorrelation in the presence of a lagged dependent variable on the right hand side of the estimating equation renders the OLS estimates biased and inconsistent. However, in the case where the absolute value of the coefficient on the lagged dependent variable is expected to be in the (0, 1) range, and not too close to 1, the effect of higher order autocorrelation is very small. As an example consider a simple model:

$$Y_t = \theta Y_{t-1} + X_t \beta + u_t$$

where u_t is a random disturbance. Suppose that the form of autocorrelation is $u_t = \rho\, u_{t-8} + \epsilon_t$, i.e. only 8th order autocorrelation is present. Note that

$$Y_{t-1} = \theta Y_{t-2} + X_{t-1}\beta + u_{t-1}.$$

By backward substitution for Y_{t-2} in the above equation, Y_{t-1} may be expressed as a function of u_{t-8}:

$$Y_{t-1} = \theta^8 Y_{t-9} + \sum_{i=1}^{8} \theta^{i-1} X_{t-i}\beta + \theta^7 u_{t-8} + \sum_{i=1}^{7} \theta^{i-1} u_{t-i}.$$

The above equation shows that the impact of u_{t-8} on Y_{t-1} is very small, and thus the correlation between Y_{t-1} and u_t in the Y_t - equation is likely to be close to zero, as long as θ is not too close to 1 in absolute value.

In view of these results, the lin-log and log-log equations were re-estimated using OLS with the Newey-West heteroscedasticity and autocorrelation consistent covariance matrix of order 8, ignoring the possible correlation between the lagged dependent variable and the error term. The lin-lin and log-lin equations were re-estimated with the White heteroscedasticity consistent covariance matrix.

As it is not obvious whether P_2, the price charged by Canadian Airlines, should be treated as an endogenous or exogenous variable in the P_1 - equation,[85] Hausman type tests of the exogeneity of P_2 were carried out. As the instrument for P_2 , the interest rate r was used. [86] For all functional forms examined, the null hypothesis of the exogeneity of P_2 could not be rejected at any conventional level of significance.

The diagnostic test results of equation (19) and the estimates of the coefficient on the predation dummy variables, the estimates of primary interest, are presented in Tables 5-12, 5-13, and 5-14. As can be seen in these tables, in all functional forms PRED1 and PRED2 were statistically insignificant. PRED3 was significant at the 5% level or better in the lin-lin, log-lin, and log-log equations, and it was significant at the 10% level in the lig-log

[85] The argument of Section 5.1.1 regarding endogeneity or exogeneity of K_2 in the K_1 equation applies to the price equation as well.

[86] The interest rate affects the average operating costs and thus it may be correlated with the price used here. The correlation ratio between these two variables was 0.39 which was higher than the correlation with K_2 (which was 0.23) and w (which was 0.2).

Table 5-12 Diagnostic test results of price equation (19) with the predation dummy variable PRED1.

	lin-lin	log-lin	log-log	lin-log
Coefficient on PRED1; 57 DF	0.2997 (0.745E-01)	-0.1594E-01 (-1.048)	0.7688E-03 (0.59E-01)	4.776 (1.03)
R^2 adjusted	0.8876	0.8954	0.8852	0.8601
Hausman specification test: Coefficient on P_{2t}hat; 56 DF	-0.225 (-1.383)	-0.8E-03 (-1.689)	-0.837E-03 (-0.38)	-28.666 (-0.344)
Normality test; χ^2 with 2 DF	24.321	17.618	25.997	35.952
Breusch-Pagan χ^2 test of heteroscedasticity ; 25 DF	46.116	42.218	42.404	42.88
Ramsey RESET tests RESET(2) F with 1 and 56 DF RESET(3) F with 2 and 55 DF RESET(4) F with 3 and 54 DF	 14.491 7.17 6.093	 2.499 1.293 2.27	 8.473 4.656 -	 26.14 12.885 10.405

NOTE: t-ratios in parentheses

equation. The RESET specification tests reported in tables 5-12, 5-13, and 5-14 indicate that the specification of the price equation was less successful than the specification of the capacity equation. The log-lin regression passed at least one out of three RESET tests and had the lowest value of the χ^2 test statistic for the normality of residuals. This functional form was chosen for further examination.[87] The lagged explanatory variables were deleted from the version with PRED3 as they were individually and jointly insignificant.[88] The

[87] The log-lin specification was also tested for the exogeneity of K_1 and $(K_1)^2$ using the Hausman test . As an instrument for K_1 the number of flights scheduled by Air Canada was used, and as an instrument for $(K_1)^2$ the squared number of Air Canada's flights was used. The coefficients on K_1 hat and $(K_1)^2$ hat were individually and jointly insignificant. Thus, the null hypothesis of the exogeneity of K_1 in the P_1 - equation could not be rejected.

[88] The F-test of joint significance of the lagged explanatory variables was F=1.165 with 5 and 58 DF. Therefore, the null hypothesis could not be rejected at any conventional level of

specification test and the tests of autocorrelation do not indicate that deleting the lagged explanatory variables creates additional problems.[89]

Table 5-13 Diagnostic test results of price equation (19) with the predation dummy variable PRED2.

	lin-lin	log-lin	log-log	lin-log
Coefficient on PRED2; 57 DF	0.5616 (0.1064)	-0.2044E-01 (-1.173)	0.4796E-02 (0.313)	7.706 (1.201)
R^2 adjusted	0.8876	0.896	0.8853	0.8613
Hausman specification test: Coefficient on P_{2t}hat; 56 DF	-0.212 (-1.408)	-0.663E-03 (-1.302)	-0.108 (-0.455)	-32.558 (-0.448)
Normality test; χ^2 with 2 DF	24.513	16.215	26.756	36.837
Breusch-Pagan χ^2 test of heteroscedasticity ; 25 DF	47.237	43.047	43.901	43.51
Ramsey RESET tests				
RESET(2) F with 1 and 56 DF	17.375	4.097	9.991	28.427
RESET(3) F with 2 and 55 DF	9.221	2.019	5.063	14.051
RESET(4) F with 3 and 54 DF	7.72	3.2	-	11.49

NOTE: t-ratios in parentheses

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significance.

[89] Only 12th order autocorrelation was detected. However, as argued at the beginning of this sub-section, high-order autocorrelation is unlikely to create significant correlation between the lagged dependent variable and the error term if the absolute value of the coefficient on the lagged dependent variable is in the range (0, 1) and not too close to 1.

Table 5-14 Diagnostic test results of price equation (19) with the predation dummy variable PRED3.

	lin-lin	log-lin	log-log	lin-log
Coefficient on PRED3; 57 DF	-14.724 (-2.338)	-0.7066E-01 (-3.201)	-0.576E-01 (-2.83)	-12.445 (-1.771)
R^2 adjusted	0.8942	0.9076	0.8939	0.8634
Hausman specification test: Coefficient on P_{2t}hat; 56 DF	-0.171 (-1.051)	-0.156 (-0.302)	0.124 (0.483)	-77.629 (-0.915)
Normality test; χ^2 with 2 DF	13.168	8.254	11.721	24.345
Breusch-Pagan χ^2 test of heteroscedasticity ; 25 DF	45.292	40.639	41.186	42.861
Ramsey RESET tests RESET(2) F with 1 and 56 DF RESET(3) F with 2 and 55 DF RESET(4) F with 3 and 54 DF	 25.528 13.144 13.728	 5.205 2.579 5.617	 17.502 8.915 -	 47.464 23.313 22.609

NOTE: t-ratios in parentheses

As for the capacity equation, the question that has to be addressed at this point is the choice of the relevant predation dummy variable, PRED1, PRED2, or PRED3. To obtain statistical evidence on which specification is relevant, equation (19) with PRED1, PRED2 and PRED3 were tested against each other using the McKinnon test type procedure. The results of this test are reported in Table 5-15. As can be seen in this table, PRED1 could not be rejected against PRED2, but it was rejected against PRED3. PRED2 could not be rejected against PRED1 but it was rejected against PRED3. PRED3 could not be rejected against PRED1 or PRED2.[90]

[90] The test was also carried out for the case when the lagged explanatory variables were not deleted from the equation with PRED3. The test results were similar. PRED1 was rejected against PRED3 but it could not be rejected against PRED2. PRED2 was rejected against PRED3 but it could not be rejected against PRED1. PRED3 could not be rejected against PRED1. It could be rejected

Table 5-15 Results of the McKinnon t-test of the dummy variable specification in the price equation.

Specification	PRED1	PRED2	PRED3
Specification with PRED1 against; (56 DF)		0.785 do not reject H0	3.172 reject H0 at 5% level
Specification with PRED2 against; (56 DF)	-0.234 do not reject H0		3.345 reject H0 at 5% level
Specification with PRED3 against; (62 DF)	1.576 do not reject H0	1.424 do not reject H0	

In view of these results, it is assumed for further discussion that April 1990 - August 1992 is the relevant predation period, and that the dummy variable PRED3 is the relevant predation dummy variable.[91] The coefficient estimates of the preferred specification are reported in Table 5-16. (Monthly dummy variables are not reported.) As expected, the coefficient on the lagged dependent variable is positive and in the range between 0 and 1. The coefficient on P_2 is also positive and highly significant which indicates that prices charged by Air Canada and Canadian Airlines were indeed strategic complements. K_1 turned out to be statistically insignificant. ACTIV, w, and K_2 were significant at the 5% level but the signs of the coefficient estimates were opposite to those expected. The variable of primary interest, the dummy variable PRED3, was negative and significant at the 1% level. This result indicates that prices charged by Air Canada during the April 1990

against PRED2 at the 10% level of significance but not at the 5% level of significance.

[91] Note that the statistical insignificance of PRED1 and PRED2 does not necessarily imply that predation was limited to the April 1990 - June 1991 period. The argument outlined in footnote 78 applies here as well.

- August 1992 period were significantly lower than during the rest of the sample period.

Table 5-16 OLS estimates of price equation (19).

Dependent variable = $\ln P_{1t}$		
$\ln P_{1,t-1}$	0.15912	(2.472)
P_{2t}	0.2054E-02	(9.552)
K_{1t}	-0.35367E-03	(-1.265)
$(K_{1t})^2$	0.1502E-06	(1.395)
K_{2t}	0.90342E-04	(2.765)
w_t	-0.5557E-02	(-2.163)
$ACTIV_t$	-0.14226E-02	(-2.005)
PRED3	-0.75693E-01	(-3.784)
CONSTANT	4.5939	(11.61)
R^2 adj	0.9108	

NOTE: t-ratios in parentheses; 63 DF

5.3.3.2. Deep pocket model of predation

Equation (20) was estimated using OLS with the White heteroscedasticity consistent covariance matrix. The financial variables were interacted with PRED3. The results are presented in Table 5-16.[92] As can be seen in Table 5-17, the effect of $EARNINGS_2$ and $INCOME_2$ on P_1 is positive and statistically significant. The effect of INCOME is statistically significant at the 10% level, and that of EARNINGS is significant at the 2% level. These results support the deep pocket model of predation.

If the deep pocket model of predation is correct, the financial variables should be

[92] The deep pocket specification was re-tested for autocorrelation. Only 8th order autocorrelation was detected.

insignificant outside the predation period. To determine whether this is in fact the case, the price equation was estimated with the financial variables included for the whole sample period. The results are reported in Table 5-18.

Table 5-17 OLS estimates and diagnostic test results of the deep pocket model of predation for the price equation. Dependent variable ln P_{1t}

Explanatory variables	(1)		(2)	
ln $P_{1,t-1}$	0.20686	(3.186)	0.22408	(3.28)
P_{2t}	0.21582E-02	(9.283)	0.21464E-02	(8.969)
K_{1t}	-0.71764E-03	(-2.374)	-0.67826E-03	(-2.212)
$(K_{1t})^2$	0.26568E-06	(2.274)	0.25456E-03	(2.138)
K_{2t}	0.80983E-04	(2.428)	0.75114E-04	(2.303)
w_t	-0.69285E-02	(-2.652)	-0.74364E-02	(-2.789)
$ACTIV_t$	0.67343E-03	(1.236)	0.49099E-03	(0.8871)
$EARNINGS_{2t}$	0.155116E-01	(2.652)		
$INCOME_{2t}$			0.2571E-03	(1.709)
CONSTANT	4.2507	(10.62)	4.1689	(10.15)
R^2 adj.	0.8978		0.8927	
Breusch-Pagan χ^2 test of heteroscedasticity ; 19 DF	36.79		39.363	
Ramsey RESET tests:				
RESET(2) F with 1 and 62 DF	2.6062		2.5603	
RESET(3) F with 2 and 61 DF	1.2838		1.2597	
RESET(4) F with 3 and 60 DF	5.0694		6.3223	

NOTE: t-ratios in parentheses; 63 DF

In Table 5-18, variables INCOME and EARNINGS refer to the whole sample period. Variables $INCOME^P$, and $EARNINGS^P$ refer to the period of alleged predation. They are intended to measure the additional effect that these variables might have had during the period of alleged predation (the idea is the same as that outlined in Section 5.1.3 and 5.2.3 in the context of testing the reputation model of predation, and as in Section 5.3.2.2 where the robustness of the deep pocket model of predation for the capacity equation was tested). As suggested by the theory, the coefficients on the financial

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Table 5-18 OLS estimates of the deep pocket model of predation with the financial variables included for the whole sample period (i.e. February 1988-December 1994). Dependent variable = $\ln P_{1t}$

Explanatory variables	(1)		(2)	
$\ln P_{1,t-1}$	0.196	(3.187)	0.21427	(3.266)
P_{2t}	0.21355E-02	(9.09)	0.21252E-02	(8.732)
K_{1t}	-0.58659E-03	(-1.827)	-0.57689E-03	(-1.716)
$(K_{1t})^2$	0.20547	(1.622)	0.20868E-06	(1.563)
K_{2t}	0.87288E-04	(2.61)	0.77908E-04	(2.387)
w_t	-0.69753E-02	(-2.683)	-0.75284E-02	(-2.821)
$ACTIV_t$	0.1332E-02	(2.221)	0.972E-03	(1.656)
$EARNINGS_{2t}$	0.23931E-02	(1.498)		
$EARNINGS_{2t}^P$	0.15688E-01	(2.692)		
$INCOME_{2t}$			0.37521E-04	(1.042)
$INCOME_{2t}^P$			0.27483E-03	(1.794)
CONSTANT	4.1532	(10.1)	4.1094	(9.837)
R^2 adj.	0.898		0.8919	

NOTE: t-ratios in parentheses; 62 DF

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variables are insignificant outside the period of alleged predation. However, the coefficients on $INCOME^P$ and $EARNINGS^P$ are positive and significant at the 10% level or better. This result indicates that the effect of INCOME and EARNINGS on P_1 during the period of alleged predation was significantly different than outside that period. The sum of coefficients referring to the predation period and the rest of the sample period (not reported in Table 5-18) was also positive and significant at the 5% level for EARNINGS and at the 10% level for INCOME.

5.3.3.3. Reputation model of predation

As it was the case in Section 5.3.2.3 where the reputation model of predation for the capacity equation was tested, the fact that PRED3 was determined to be the relevant predation dummy variable provides preliminary evidence against this model. If the reputation model of predation is the relevant model to describe Air Canada's behaviour, PRED1 should be the relevant variable. Nevertheless, we proceeded with the estimation of the reputation model specified in price equation (21) to determine whether there is any evidence supporting the reputation model during a longer period of time than that implied by the dummy PRED1.

Equation (21) was estimated using the White heteroscedasticity consistent covariance matrix. As all lagged explanatory variables were deleted, only the current value of ACTIV was interacted with PRED3. The results are presented in Table 5-19.[93]
As can be seen in Table 5-19, the coefficient on $ACTIV^{P}$ was negative and highly significant. This result implies that Air Canada's behaviour was significantly different during the predation period than outside that period. The sign of this coefficient is consistent with the reputation model of predation. However, the coefficient on ACTIV

[93] The reputation model specification was re-tested for autocorrelation. Only 8th order autocorrelation was detected.

was also negative and statistically significant almost at the 5 percent level. Thus, what we detect is intensification of the typical practice.[94]

Table 5-19 OLS estimates and diagnostic tests results of reputation model of predation for the price equation.

Dependent variable = ln P_1		
ln $P_{1,t-1}$	0.15863	(2.458)
P_{2t}	0.20555E-02	(9.546)
K_{1t}	-0.36791E-03	(-1.319)
$(K_{1t})^2$	0.15464E-06	(1.438)
K_{2t}	0.90979E-04	(2.759)
w_t	-0.55673E-02	(-2.169)
$ACTIV_t$	-0.13546E-02	(-1.956)
$ACTIV_t^P$	-0.53018E-03	(-3.792)
CONSTANT	4.5953	(11.59)
R^2 adj.	0.9108	
$\beta_7 + \kappa_1$	-0.18847E-02	(-2.574)
Breusch-Pagan χ^2 test of heteroscedasticity ; 19 DF	39.311	
Ramsey RESET tests: RESET(2) F with 1 and 62 DF	5.1512	
RESET(3) F with 2 and 61 DF	2.538	
RESET(4) F with 3 and 60 DF	7.1098	

NOTE: t-ratios in parentheses; 63 DF

There is thus not much evidence on the empirical validity of the reputation model of predation.

[94] The negative coefficient on ACTIV, the variable referring to the period outside the predation period, may be due, perhaps, to using deeply discounted fares as an instrument attracting passengers. Airlines often advertise seat sales but information on the number of tickets sold at each price is confidential; it may be the case that the relationship between the average price and the state of the economy (as captured by ACTIV) is positive as suggested by the microeconomic theory.

5.3.3.4. Numerical interpretation

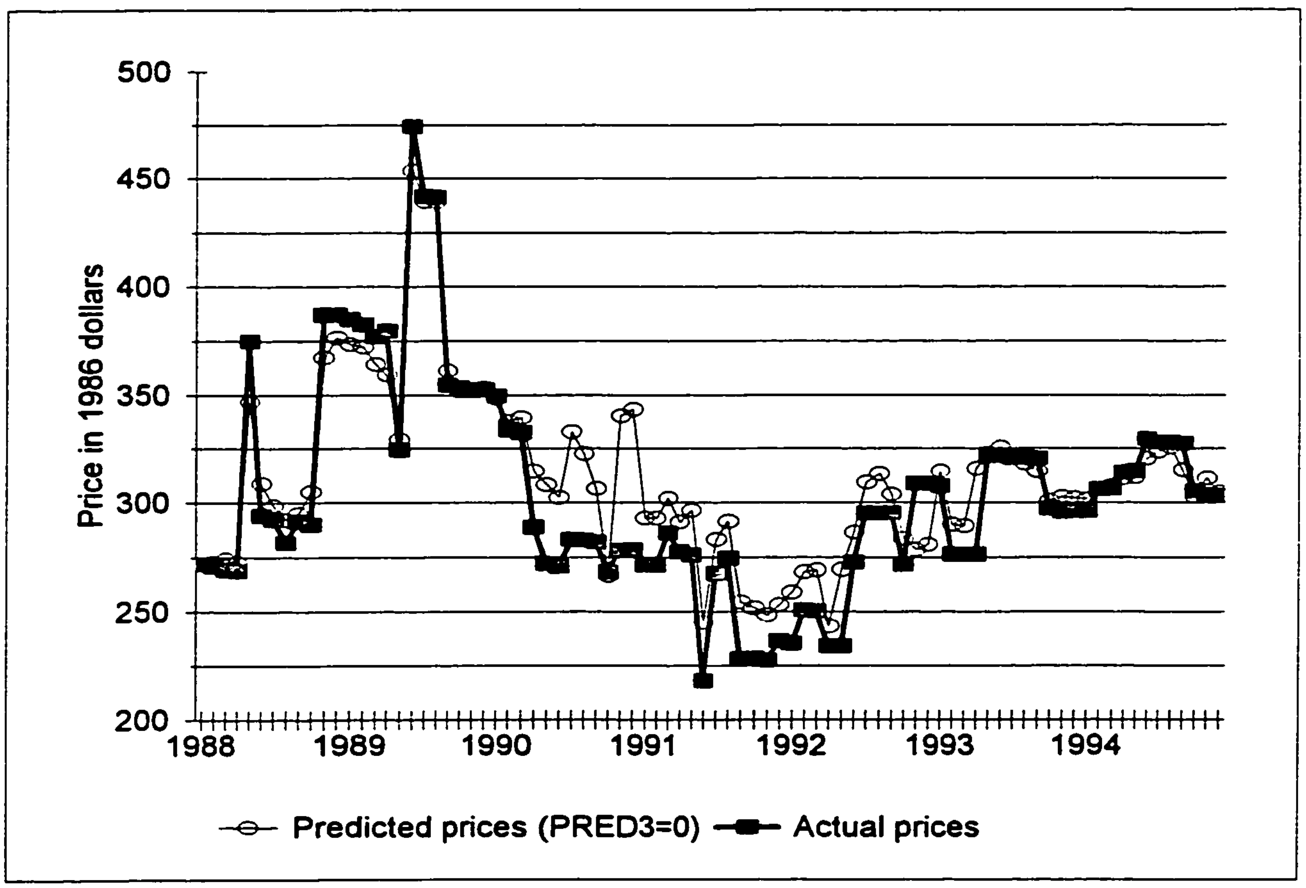
The numerical interpretation of the evidence of predatory pricing on the part of Air Canada is difficult for the same reasons as those discussed in the section on capacity: the dependent variable is in logarithmic form and there is a lagged dependent variable on the right hand side of the estimating equation.

During the predation period, the log of price was lower than during the rest of the sample period by 0.0757 (see the coefficient on PRED3 in Table 5-16). At the mean price of 304 dollars, a change of this magnitude implies a decrease in price by 22 dollars.

The deep pocket model of predation gives much smaller estimates of the magnitude of the price predation. The coefficient on income was 0.000257 and the coefficient on earnings was 0.0155 (see Table 5-17). Given that the profits of Canadian Airlines decreased by 124 million dollars during the period of alleged predation and that earnings per share decreased by approximately 2.5 dollars, the log of prices decreased during that period by 0.00025*124=0.032 or 0.0155*2.5=0.039. These changes imply a decrease in prices by 10 to 12 dollars.

The magnitude of the decrease in price can also be inferred from the difference between the actual prices and prices that could have been expected in the absence of predation. This exercise was carried out using the same methodology as that outlined in Subsection 3.2.4. Figure 5-2 presents the results. In this figure, one of the plotted series, labelled “actual prices,” is the actual price charged by Air Canada. The other series, labelled “predicted prices,” is the predicted price calculated using the estimates of equation (19) with the predation dummy variable PRED3 set equal to zero for the whole

Figure 5-2 Actual prices and prices predicted from the empirical model



sample period.[95]

As expected, there was a large discrepancy between the two series during the period of alleged predation. This discrepancy was not constant over the entire predation period. The difference between the two series was largest in 1990; in July and August it amounted to 50 and 40 dollars and in November and December to 62 and 65 dollars. During the rest of the period of alleged predation, the difference between the two series fluctuated between 14 and 37 dollars (except for October 1990 and April 1992 when it amounted to -2 and 9 dollars, respectively).[96]

5.3.3.5. Summary of the estimation results of the price equation

Price equation (19) was initially estimated in lin-lin, lin-log, log-log, and log-lin functional forms and for each of the specified predation dummy variable PRED1, PRED2, and PRED3. Log-lin was the preferred functional form, and PRED3 was determined to be the relevant specification of the predation period. The coefficient on PRED3 was negative and statistically significant at the 1 percent level. This result implies that Air Canada's prices were significantly lower during the period of alleged predation than during the rest of the sample period.

Estimation of the deep pocket model, price equation (20), produced results

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[95] This exercise was also carried out using the estimates of the deep pocket and the reputation model of predation with variables referring to predatory behaviour set equal to zero for the whole sample period. The estimates of price that could be expected in the absence of predation were very similar to those obtained using estimates of equation (19) with PRED3=0 for the whole sample period. Thus, they are not discussed here.

[96] Outside the predation period the difference between the two series fluctuated between -20 and 18 dollars, except for November 1992 (when this difference amounted to -31 dollars), April 1993 (40 dollars), and May 1988 (28 dollars).

supporting the deep pocket model. During the period of alleged predation, Air Canada tended to charge lower prices when the earnings per share and income of Canadian Airlines were decreasing. The effect of INCOME is statistically significant at the 10 percent level and the effect of EARNINGS is statistically significant at the 5 percent level.

There is not much evidence supporting the reputation model. First, even though Air Canada's pricing policy during the period of alleged predation was consistent with the predictions of the reputation model, this policy was being practised during a much longer period than that implied by the dummy variable PRED3. Second, the relevant predation period for the reputation model appears to be PRED1. But this variable was rejected against PRED3, a dummy variable which is consistent with the deep pocket model.

5.4. Summary of the empirical analysis

This chapter discussed the empirical specification and estimation of the model of competition in airline markets. The model consists of two equations: a capacity equation and a price equation. As each model of predation has different implications for the empirical specification, each equation is specified in the version implied by the deep pocket model of predation and in the version implied by the reputation model of predation. Initially, however, both equations are also specified in a general form which allows for predatory behaviour, but does not impose a particular predatory structure. This stage of the empirical analysis is treated both as a preliminary test of predation and as a device to determine the relevant predation period.

The model was estimated using single equation techniques (i.e. OLS). To correct the standard errors of the simple OLS estimates, the capacity equation was estimated using OLS with the Newey-West heteroscedasticity and autocorrelation consistent covariance matrix with order 12, and the price equation was estimated using OLS with the White heteroscedasticity consistent covariance matrix.

The statistical tests are consistent with the hypothesis that the relevant predation period is April 1990 - August 1992, and the coefficient estimates are consistent with Air Canada being engaged in predatory practices during that period. *Ceteris paribus*, the price charged by Air Canada was significantly lower and its seating capacity was significantly higher during that period than during the rest of the sample period.

While the data are consistent with the deep pocket model of predation, there is little evidence supporting the reputation model of predation. During the period of alleged predation, the price charged by Air Canada tended to be lower when the financial results of Canadian Airlines were getting poor. The seating capacity scheduled by Air Canada tended to be higher when the financial results of Canadian Airlines and the state of economy were bad.

The results of the tests of predatory behaviour and the tests of the deep pocket model of predation are statistically significant, but the implied magnitudes of the price predation and the predatory capacity are on average small. During the predation period, the decrease in price was less than 10 percent of the mean price, and the increase in capacity was smaller than the size of a typical commercial plane. However, the decrease in price and the increase in capacity might have been larger during shorter periods of time within the April 1990 - August 1992 period.

Chapter 6

Conclusions

The purpose of this study has been to develop a methodology that can be used to test for predation. Few empirical studies presenting formal tests of predation have been published, and in this regard this thesis contributes towards filling the gap in the literature. The particular market examined is an airline duopoly. But the methodology developed here is broader in scope and it could also be applied to other market settings, or be extended to more than two firms.

The tests of predatory behaviour used in this thesis have been derived from a theoretical model of competition in airline markets which is presented in Chapter 3. In this model, it is assumed that airlines maximize profits while competing in seating capacity, departure times of their flights, and fares. These variables are chosen sequentially; seating capacity is chosen first, then departure times are selected, and finally fares for each flight are determined. At each stage of profit maximization there is the potential to inflict losses on a rival, and testable implications of non-strategic and predatory behaviour are derived for each variable. For the choice of seating capacity and price, these predictions are based on the best response functions. For the choice of departure times, non-strategic and predatory scheduling patterns were determined using computer simulation techniques.

Regarding the departure times scheduling, the simulation results confirmed the intuition that the predatory airline could lower a rival's profit by rescheduling one of its own flights closer to a rival flight, or by adding a new flight and scheduling it to depart at the same time as one of the rival's flights. Thus, if an airline reschedules its flights in such a way that its own profits and its rival's profits are reduced, this change in the flight schedule can be considered as predatory in nature. Unfortunately, this test could not be implemented empirically because the necessary demand data, such as the distribution of consumers across times of day, were not available. Therefore, tests of predatory behaviour are based on predictions regarding the choice of capacity and fares.

The form of a test of predatory behaviour depends on what type of predation model (i.e. deep pocket model of predation, reputation model, or signalling model) is considered as relevant in the case examined. As discussed in Chapter 2, it seems that there are two models of predation which may apply to airline markets where there are two well established airline firms: the deep pocket model of predation, and the reputation model of predation. An attempt has been made to distinguish between these two alternatives, and then test them empirically. If the deep pocket model of predation is the relevant model, the predatory airline will lower its price and/ or schedule more seating capacity when the corporate profits of the rival airline fall. The predatory airline will also schedule more capacity when the state of the economy is bad. If the reputation model of predation is the relevant model, the predatory airline will schedule more capacity when the rival increases its capacity, and/ or lower its price when consumer income increases. However, if the airline examined behaves non-strategically, the effect of these predation-related variables on the choice of capacity and price will be quite different. Financial results of a rival airline will be irrelevant for the choice of capacity or price, difficult economic situation will not provide incentives to schedule more capacity, higher consumer income will tend to bid up prices, and capacities scheduled by the rival airlines will likely be strategic substitutes.

These implications of the choice of capacity and prices were tested empirically in Chapter 5 using data from a market where predation might have taken place. The particular market examined was the Vancouver - Toronto route over the years 1988 - 1994. As explained in Chapter 4, there were allegations that Air Canada was practising some form of predation against Canadian Airlines at some time during that period, so this market might produce evidence of predatory behaviour.

The price equation and the capacity equation were estimated using single equation techniques (i.e. using OLS). The regression results are consistent with Air Canada being engaged in predation during the April 1990 - August 1992 period. During that period, Air Canada's fares were significantly lower and its seating capacity was significantly higher than during the rest of the sample period.

Specific models of predation were then tested over the April 1990 - August 1992 period. The econometric results provide evidence supporting the deep pocket model of predation, while there is not much evidence supporting the reputation model of predation. During the period of alleged predation Air Canada's prices tended to be lower and capacity tended to be higher when Canadian Airlines' income and earnings per share were falling. There is also some evidence indicating that Air Canada's capacity tended to be higher when the state of economy was bad.

In this study, Air Canada was designated as the predatory airline because of the allegations that this airline was practising predation against Canadian Airlines. The possibility that Canadian Airlines was the predatory airline was also briefly examined. The preliminary results indicate that the results are not symmetric, and the data are not likely to be consistent with Canadian Airlines being engaged in predation against Air Canada.[97]

The empirical model developed in this thesis was estimated using data from only one market, the Vancouver - Toronto route. As explained in Chapter 4, this market was chosen because of its large size and because the connecting traffic on this route is likely to be relatively small. But the question arises as to whether the results would have been similar if other city-pair markets were used. As mentioned in Chapter 4 (footnote 54), another market, the Toronto - Montreal route, was briefly examined to determine whether there were any similarities in the pattern of changes in prices and capacities between this route and the Vancouver - Toronto route. There were some similarities between the two routes. But it is also possible that strategic behaviour takes place only on a subset of routes. Predation on a smaller scale (i.e. only on a subset of routes) involves a smaller commitment and smaller costs but may be just sufficient to produce the desired results (such as decreasing the cash flow of the targeted airline below the level required by an investor). Thus, re-estimation of the model using data from other airline markets in Canada is one possible extension of this study. These results could reveal whether there were any differences between markets and regions, such as Eastern Canada and Western Canada.

Another possible extension involves simulation of changes in profits of the two airlines resulting from changes in the departure times. As mentioned in Chapter 3, this

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[97] In the capacity equation, all PRED-variables were insignificant. In the price equation, PRED2 was negative and statistically significant in the log-log specification, and PRED3 was positive and statistically significant in the lin-log equation.

simulation requires more detailed data on demand, in particular data on the distribution of consumers across times of day. This exercise could provide evidence on spatial predation.

The model of competition in airline markets developed in this thesis has been designed in such a way that it can be estimated using publicly available data. The model does have some limitations. For example, the lack of data on load factors makes it impossible to estimate the demand, or to obtain a more precise estimate of excess capacity. Lack of data on the number of tickets sold at each price also prevents calculation of average revenue, average discounted fare, or the percentage of tickets sold at a deep discount. These data would give a better idea about the pricing policy practised by both airlines during the period of alleged predation, and could provide more precise evidence on predation.

Nevertheless, the fact that a change in Air Canada's behaviour has been detected and that this change is consistent with predatory behaviour, gives reasonable confidence about the empirical validity of the conclusions arising from this study.

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Appendix

This Appendix presents the simulation results of the nested logit model of airline scheduling described in Section 3.2. Simulations were carried out for a few values of n_1, n_2, μ_1, μ_2, T, and ν_0. In all simulations we made the following assumptions: $c_{ji} = 0$, $a_{ji} = 0$, $F(n_j) = 0$ for all j and i.

Simulation 1

The parameters were set at the following level: $n_1 = n_2 = 3$, $\mu_1 = 25$, $\mu_2 = 0$, $T = 10$, $\nu_0 = -25$. The departure times, fares, demand, and profits are presented in Figure A-1 and Table A-1.

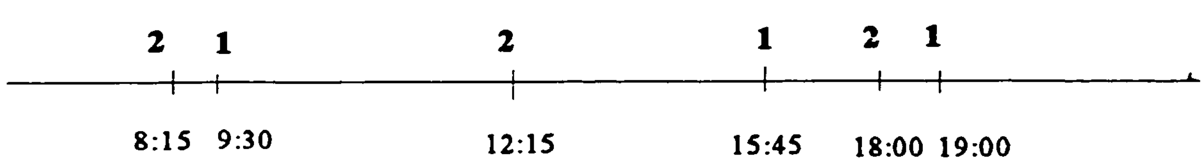

Figure A-1. Departure times obtained in Simulation 1

Airline	Fares (Demand)			Total demand	Total profits
	Flight 1	Flight 2	Flight 3		
Airline 1	33.7 (70.1)	35.0 (55.2)	34.0 (73.2)	198.5	6781.9
Airline 2	34.2 (63.5)	35.5 (53.7)	33.6 (85.7)	202.9	6962.3

Table A-1. Fares, demand, and profits in Simulation 1

Simulation 2

In this simulation, all parameter values were the same as in Simulation 1 except for the utility associated with non-purchase, v_0, which was set at $v_0 = 50$. The departure times, fares, demand and profits are depicted in Figure A-2 and Table A-2 below.

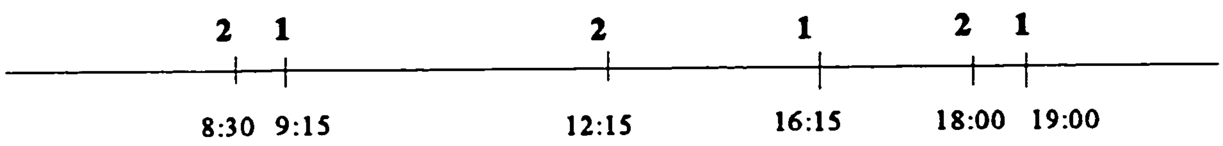

Figure A-2. Departure times obtained in Simulation 2

Airline	Fares (Demand)			Total demand	Total profits
	Flight 1	Flight 2	Flight 3		
Airline 1	25.8 (8.6)	25.9 (7.0)	25.9 (8.8)	24.4	631.7
Airline 2	25.9 (8.0)	25.9 (6.1)	25.9 (10.9)	24.9	646.0

Table A-2. Fares, demand, and profits in Simulation 2

Simulation 3

In this simulation, the value of μ_1 was increased to $\mu_1 = 50$. All other parameters were the same as in Simulation 1. The departure times, fares, demand and profits are depicted in Figure A-3 and Table A-3.

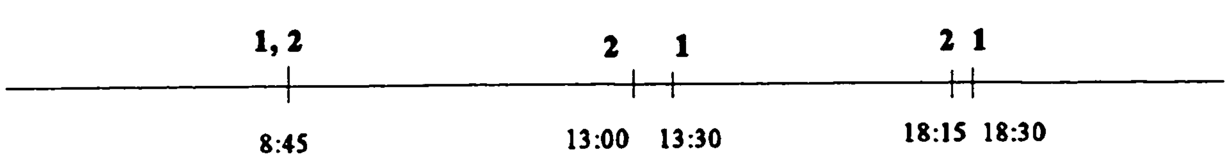

Figure A-3. Departure times obtained in Simulation 3

Airline	Fares (Demand)			Total demand	Total profits
	Flight 1	Flight 2	Flight 3		
Airline 1	63.0 (62.7)	62.7 (44.3)	63.0 (79.4)	186.4	11727.3
Airline 2	63.2 (63.2)	63.0 (63.0)	63.0 (63.0)	186.2	11738.0

Table A-3. Fares, demand, and profits in Simulation 3

Simulation 4

In this simulation, the value of μ_2 was increased to $\mu_2 = 10$. All other parameters were the same as in Simulation 3. The equilibrium departure times were exactly the same as in Simulation 3. Fares were somewhat higher, but the difference was not higher than 0.14. The demand facing each airline was higher by approximately 0.3. As a result, total profits increased slightly, and amounted to 11750.7 for Airline 1 and to 11759.0 for Airline 2.

Simulation 5

In this simulation, the number of flights operated by each airline remains the same as in the previous simulation but the other parameters were changed as follows: $\mu_1 = 10$, $\mu_2 = 2$, $T = 1$, $V_0 = -10$. The equilibrium departure times, fares, demand, and profits are presented in Figure A-4 and Table A-4 below.

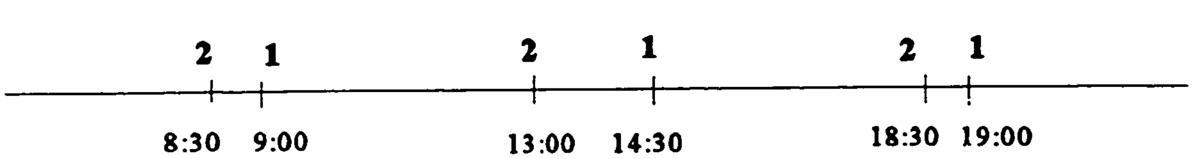

Figure A-4. Departure times obtained in Simulation 5

Airline	Fare (Demand)			Total demand	Total profits
	Flight 1	Flight 2	Flight 3		
Airline 1	13.6 (92.6)	13.7 (64.0)	13.6 (102.4)	259.0	3534.5
Airline 2	13.7 (81.2)	13.7 (63.2)	13.6 (114.5)	258.9	3538.0

Table A-4. Fares, demand, and profits in Simulation 5

Simulation 6

In this simulation, the number of flights operated by each airline was increased to four. All other parameter values were the same as in Simulation 5. The departure times, fares, demand, and profits obtained in this simulation are presented in Figure A5 and Table A5.

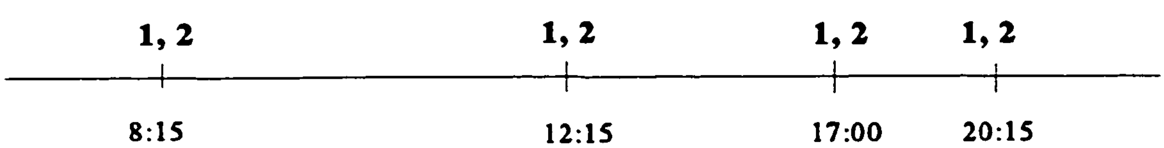

Figure A-5. Departure times obtained in Simulation 6

Airline	Fares (Demand)				Total demand	Total profits
	Flight 1	Flight 2	Flight 3	Flight 4		
Airline 1	13.7 (73.4)	13.8 (59.4)	13.8 (79.5)	13.8 (59.4)	271.1	3742.0
Airline 2	13.7 (73.4)	13.8 (59.4)	13.8 (79.5)	13.8 (59.4)	271.6	3741.8

Table A-5. Fares, demand, and profits in Simulation 6

Simulation 7

The purpose of this simulation was to determine the results of predatory actions undertaken by Airline 1 against Airline 2. The initial situation was the same as in

Simulation 1. Then, one of the flights operated by Airline 1 was rescheduled to a new location closer to Airline 2.

Airline 1's profit was decreasing in the distance from the optimal location. Airline 2's profit was decreasing, too, but the decrease was very small. For example, when the 19:00-flight was rescheduled to depart at the same time as one of Airline 2's flights, the 18:00-flight, Airline 2's profits decreased to approximately 6500. A similar decrease in profits was experienced by the victim airline when the morning peak flight was rescheduled to depart at the same time as Airline 2's morning flight. Rescheduling the off-peak late-afternoon flight resulted in a larger decrease, to approximately 6250.

When Airline 1 decreased the fare for the predatory flight, its profits decreased even more, and fell below 4500. The effect on Airline 2's profits was stronger but only in two cases did Airline 2's profits decrease to a level below 6000. One case involved rescheduling the off-peak flight from 15:00 to 17:45, and the other case involved rescheduling the peak evening flight from 19:00 to 18:00, i.e. at the same time as the rival flight.

In all these simulations the loss incurred by the victim airline, Airline 2, appear to be quite small. However, we have to remind the reader that the assumed fixed costs were equal to zero. Thus, we are in fact measuring total revenues rather than total profits. If fixed costs are sufficiently high, predation may result in negative profits for the victim airline.

On balance, predation appears to be a costly strategy. The cost of predation to the predatory airline, Airline 1, measured as the ratio $R = |\Delta\pi_1|/|\Delta\pi_2|$ expresses the loss in profit incurred by Airline 1 per unit of lost profits incurred by Airline 2. In none of the cases considered did R fall below 2.

Simulation 8

In this simulation, one of the airlines, Airline 1, operates four flights, while the other airline, Airline 2 operates only three flights. All other parameters were the same as in Simulation 1. The equilibrium departure times, fares, demand, and profits are presented in Figure A6 and Table A6 below.

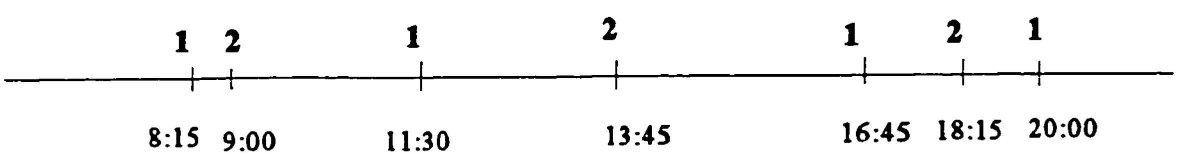

Figure A-6. Departure times obtained in Simulation 8

Airline	Fares (Demand)				Total demand	Total profits
	Flight 1	Flight 2	Flight 3	Flight 4		
Airline 1	33.9 (57.6)	35.1 (52.6)	34.5 (67.8)	34.7 (56.4)	234.4	8090.4
Airline 2	33.3 (67.1)	34.8 (46.1)	34.0 (84.4)	-	197.6	6708.2

Table A-6. Fares, demand, and profits in Simulation 8