A STRATEGIC CAPACITY PLANNING TOOL
FOR A FIRM IN THE NEWSPRINT INDUSTRY

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ABSTRACT

A strategic planning tool has been developed to help a firm in the North American newsprint industry decide whether to expand its capacity. This tool can also be used as an industry model, to forecast capacity decisions under various conditions. Key features of the model are the explicit consideration of the interdependence between firms and the recognition of the lumpiness of capacity expansion. Individual firms and groups of firms are modelled. All firms are assumed to determine their best capacity option taking into consideration the capacity decisions of other firms. The model uses an open loop Nash equilibrium concept to solve the capacity expansion problem. Firms also simultaneously determine their profit-maximizing production in each year, given their capacities. Demand functions for each year are specified, and demand scenarios may be subject to uncertainty.

The model was applied to the newsprint industry for the 1979 to 1983 time period. The top five firms in the industry were modelled as individual firms. The next eight firms were modelled as two groups of four identical firms. The behaviour of the fringe (i.e., the remaining 20% of total industry capacity) was forecast exogenously. Historical firm and industry capacities, production levels and prices were compared to model simulations under three different assumptions for firm objectives: profit maximization, market share maximization subject to a profitability constraint, and maximization of expected utility assuming exponential utility functions for all firms (with different assumptions about attitudes of firms towards risk). The constrained market share maximization hypothesis best explained observed behaviour. Multiple equilibria were often computed and methods for addressing this problem were discussed.

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CHAPTER I

INTRODUCTION

1.1 Objectives

The problem of when and how much to expand capacity is a key problem for firms in the newsprint industry in North America. Because of economies of scale, large increments in capacity are generally added. Long lead times and the high costs of exit or retrenchment mean that capacity expansion decisions are risky. In the past, many firms have added capacity at the same time, leading to overcapacity and low profitability in the industry.

A planning tool has been developed to help a firm decide whether to expand its newsprint capacity. This tool can also be used as an industry model, to forecast capacity decisions under various conditions, since all North America newsprint firms are included in the model. A key feature of the model is the explicit consideration of the effects of a firm's decision on the decisions of other firms. This is crucial because of the oligopolistic nature of the newsprint industry in North America; the relatively few number of competitors means that the decisions of firms are interdependent.

1.2 Organization

Chapter II presents an overview of the North American newsprint industry, in terms of its market structure and behaviour. Chapter III summarizes the literature relevant to the modelling of the capacity planning problem. Chapter IV contains a detailed description of the newsprint capacity planning model. Chapter V describes the application of the model to the newsprint industry for the 1979 to 1983 time period. The development of the database is outlined as well as the calibration of the model to historical data. The results of a sensitivity analysis are reported for the production and pricing portion of the model. Chapter VI then describes the validation and results of the model. Results are compared with historical data, and sensitivity analysis carried out. The analysis is extended to include uncertainty in future demand, focussing on the effects of risk/return tradeoffs on model outcomes. Some examples of the use of the model as a tool of strategic analysis are then illustrated. Chapter VII concludes with an overall evaluation of the model and its application to the newsprint industry, and a discussion of future work.

CHAPTER II

THE NEWSPRINT INDUSTRY

2.1 Introduction

In order to develop a decision-making model to help a firm with its capacity expansion choice, a clear understanding of the industry structure, behaviour and environment is needed. This permits us to structure the model to focus on key variables and behaviours, and to make useful simplifications. Economic theory provides a framework for analysis of competitive behaviour, since the structure of the market and the nature of its dynamics affect the type and range of competitive behaviours. The industrial organization (IO) field of economics provides the industry analyst with theories for firm behaviour in oligopolistic markets. The theory of IO seeks to predict market performance from firm conduct, where firm conduct is causally related to market structure and basic conditions of supply and demand. The degree of concentration of buyers and sellers, barriers to entry, cost structures, etc., that describe the structure of the market, lead to the pricing behaviour, investment strategies, product choice strategies, etc., of firms. IO tends to ignore all but basic size differences between firms; factor endowments and competences that lead to strategy and performance differences between firms are not considered, since the focus is on overall market performance from society's point of view (Porter 1981, Rumelt 1984).

On the other hand, strategic management planning is the development of strategies to achieve a firm's objectives. The differences between firms are highlighted and exploited to achieve a firm's objectives. The focus is on the individual firm and how that firm can improve its competitive position. The model developed here focusses on these firm differences, but its development is also dependent upon the structural organization of the industry.

One characteristic that is important in the analysis of competitive behaviours is the degree to which coordination between firms is possible. The type and effectiveness of coordination between firms in an oligopoly depend on several key factors: (1) the number and relative size of competitors, (2) the number and relative size of customers (countervailing power), (3) the homogeneity of the industry in terms of both product (including quality) and costs of production, (4) the structure of costs (e.g., the ratio of fixed to variable costs in the short run), (5) the barriers to entry and exit, (6) the information structure, and (7) the characteristics of the external environment (e.g., the stability and rate of growth of demand). Other characteristics that are important in competitive analysis are the possibilities for learning about the behaviour of rivals, and the history of the market.

This chapter provides an introduction to the structure of the newsprint industry and the behaviour of firms in light of these important factors. This will have important implications in the development of the model and its structure.

2.2 Industry structure

2.2.1 General structure

The newsprint industry is very important to the economy of Canada. Newsprint is a major export, comprising almost 40% by value of pulp and paper exports and 5% by value of all exports. Canada produces 32% of the world's newsprint and accounts for over 60% of the world's exports in newsprint by volume. Over 70% of Canada's production is shipped to the U.S. market. The U.S produces about 18% of the world's production, but exports little, and is the world's leading consumer of newsprint, using an estimated 40% of world supply. Thus the North American industry is relatively self-contained, with only 10 to 15% of total shipments exported outside of North America, and with total imports of between zero and four percent of demand. Thus it is reasonable to consider a model of North American demand and supply, with imports and exports forecast exogenously.

In 1979 there were 30 firms in the North American newsprint industry, 15 of them based in Canada, with a total of 64 mills. Table 2.1 shows the capacity distribution of firms in 1979. Seventy percent of capacity was in Canada, although only about 45% of North American capacity was controlled by Canadian-based companies; all but 3% of the remaining was controlled by U.S. firms. The number of firms and mills has remained relatively constant since the early 1960's. In 1979, the largest four firms had about 42% of capacity and the top ten about 70%. The top four (top ten) concentration ratio has not varied much over time, from 41% (69%) in 1950, 39% (70%) in 1960, 36% (70%) in 1970, 42% (70%) in 1980, 36% (66%) in 1989.

Industry concentration results from a number of factors such as economies of scale (EOS) and other barriers to entry. The large capital requirement needed in order to capture EOS in production discourages new entrants to the newsprint industry. The minimum efficient scale (MES) of a newsprint machine has increased over time from 150,000 tonnes per year in the 1960's to about 220,000 tonnes per year in 1989. (Older machines range in size from 15,000 tonnes per year.) The MES for a mill is also high (350,000 to 400,000 tonnes per year) (Woodbridge, Reed 1988). This has not increased significantly over time, thus the number of MES machines required per mill has declined from between three to five, to two.[1]

There are other barriers to entry besides EOS. All producers are vertically integrated into pulp production, the major resource input, which increases the capital cost requirement. Many are also integrated as far back as the basic timber resource, and access to timber resources is becoming an increasing barrier to new entrants. Suppliers' long term contracts with buyers make it more difficult to gain an entry into the market. Before a new mill is built, the output will usually be at

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[1] The actual number of machines at a mill runs from one up to about eight, depending on the individual machines' capacities and total mill capacity. With total North American production of about 15 million tonnes per year, this translates into about 75 MES machines, whereas there are about 350 machines in use in North America.

TABLE 2.1: Capacity and number of mills for North American newsprint firms, 1979.

	Capacity (1000 t)	Capacity Share (%)	No. of mills
Abitibi-Price	1,926	14.9	11
International Paper	1,281	9.9	5
Bowater Inc.	1,165	9.0	4
MacMillan Bloedel	1,107	8.6	3
Consolidated Bathurst	909	7.0	4
Kimberly Clark	683	5.3	2
Ontario Paper	635	4.9	2
St. Regis Paper	584	4.5	2
Boise Cascade	519	4.0	3
Kruger	409	3.2	2
Crown Zellerbach	393	3.0	3
Great Lakes Forest Products	372	2.9	1
Publishers Paper	350	2.7	2
SUBTOTAL	10,333	79.9	44
Reed Paper	313	2.4	1
Great Northern Nekoosa	295	2.3	1
Garden State	280	2.2	2
British Columbia Forest Products	255	2.0	1
Domtar	248	1.9	3
Donohue	227	1.8	1
FF Soucy	149	1.2	1
Maclaren	149	1.2	1
Southwest Forest Industries	144	1.1	1

TABLE 2.1– Continued

	Capacity (1000 t)	Capacity Share (%)	No. of mills
Nova Scotia Forest Industries	143	1.1	1
FSC	95	0.7	1
Ocean Falls	88	0.7	1
Weyhaueser	73	0.6	1
Southeast Paper	68	0.5	1
Inland Paper	27	0.2	1
Georgia Pacific	23	0.2	1
St. Raymond Paper	4	0.0	1
TOTAL	12,941	100.0	64

SOURCE: CPPA Annual Newsprint Supplement and ANPA Newsprint Statistics, various years.

least partially allocated on a contract basis to buyers. Production technology is sufficiently different from other industries to be a substantial barrier except to producers of other paper products. It is also much cheaper for an incumbent to add on a new machine at an existing mill than for a new firm (or an incumbent) to build a new mill (Pöyry and Rennel 1987).

Most new entrants over the years have either been firms already established in the forest industry or newspaper publishing firms. These two types of entrants have fewer barriers because of the positions of their industries.

There are also barriers to exit, mainly the nontransferability of technology and machines to other products, although some other paper grades can be produced with the same technology. By changing the furnish mix (i.e., percentage of mechanical pulp, chemical pulp and fillers), one can upgrade to various groundwood papers with little change in machine requirements. This is a strategy that producers have followed with their older newsprint machines, rather than retire them completely. The specialty nature of these papers means that smaller and slower machines can be profitable, since smaller production runs are common. Groundwood papers also generally command a higher price than newsprint. It is also possible to convert newsprint mills to other papers, such as kraft or linerboard (although these require kraft pulp). The basic input to newsprint is mechanical pulp, for which there is little market (i.e., most users of mechanical pulp produce their own). This irreversibility of investment increases the risk for a firm.

While there has been some movement of firms in and out of the industry, basically the participants have remained much the same over time. Since 1960, the top five firms have remained the same: International Paper, Abitibi (later Abitibi-Price), Bowater, Consolidated Bathurst and MacMillan Bloedel. (In 1983, International Paper sold its CIP mills, the bulk of its newsprint division, to Canadian Pacific). This high degree of stability means that participants have the opportunity to observe and get to know each other quite well in terms of behaviours, reactions, goals, etc.

Firms have a great deal of information about each other as a result of trade associations (e.g., the Canadian Pulp and Paper Association, the American Paper Institute), as well as numerous trade journals, industry directories and newsletters. These trade associations collect, summarize and circulate data from member companies.[2] There is publicly available information on machine sizes and capacities by mill. The similarities in technology between producers and availability of regional input price differentials mean that firms can estimate their rivals' costs fairly accurately.

Thus barriers to entry and exit have led to a loose oligopolistic structure, with several large firms and a number of smaller firms with significant shares. The industry is not highly concentrated, so that coordination between firms is not easy, however the fact that firms tend to stay in the industry for a long time means that learning can occur.

2.2.2 Cost structure

There is not a uniform cost structure in the industry. Older machines have lower capacities, and require more labour per unit of output than new machines. There are also regional differences in input costs, as well as transportation costs to market. Canadian firms tend to be much older than U.S. firms, and have older machines (many date from the 1920's and 1930's and most are two to three decades old). Despite rebuilds and speed-ups, these machines have lower productivity and thus higher costs than machines in U.S. mills. Some U.S. mills also have an advantage in terms of fibre costs and transportation distances.

Because of the high capital intensity of the industry, firms have high fixed costs relative to their variable costs, and this can cause pricing discipline problems when demand is poor.

The U.S. exchange rate has an important influence on the competitiveness and profitability of Canadian firms. Prices are quoted in U.S. dollars, but their costs are incurred in Canadian dollars. This factor is not controllable by firms, and thus introduces uncertainty into their planning horizons.

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[2] See Kirby (1988) for an interesting article on trade associations in oligopolies as information exchange mechanisms.

2.2.3 Firm differences

As noted earlier, firms differ in the amount of capacity they own and in the age and production costs of that capacity. However, there are other important differences between firms. In 1979, most firms competing in the newsprint industry were predominantly forest products companies, although several (e.g., Publishers Paper, Ontario Paper, Garden State) were owned by newspaper firms. Firms differed substantially in terms of size, with sales of the top 13 firms ranging from 340 thousand dollars (Great Lakes Forest Products[3]) to 4,500 million dollars (International Paper). The importance of newsprint in the companies product mix also varied dramatically, from a low of about 5% (Crown Zellerbach) to a high of about 72% (Bowater). These differences indicate possible differences in firm behaviour, risk-taking attitudes and objectives (see Table 2.2).

2.2.4 Demand

The newsprint industry is generally considered to be mature, with demand growth averaging about 2% per year. A demand growth of 2% per year translates into about 250 to 300 thousand tonnes of newsprint per year, or one to two MES machines. Demand is dependent upon economic growth and is thus cyclical. The cyclical nature of the economy and thus demand means that machines are not added one per year, but are added in lumps over time. The major uses of newsprint are daily and weekly newspapers and commercial printing end uses such as preprinted newsprint inserts. Daily newspapers comprise close to 75% of total U.S. consumption. Demand is quite inelastic: a large decrease in price will only result in a small increase in demand.

Demand is uncertain as a result of a number of factors, the main one being the uncertainty associated with the prediction of economic growth. However, other factors that affect

[3] Great Lakes Forest Products was actually 65% owned by Canadian Pacific.

TABLE 2.2: Total sales and percentage of newsprint in total sales (1979).

Firm	Total Sales (Millions $US)	Percentage of Sales Attributable to Newsprint
Abitibi-Price	1,723	46
International Paper	4,533	12[a]
Bowater	625	72
MacMillan Bloedel	1,882	16
Consolidated Bathurst	1,062	30
Kimberly Clark	2,218	12[a]
Tribune (Ontario Paper)	1,105	22
St. Regis	2,498	8
Boise Cascade	3019	7[a]
Kruger	n.a.	57[a,b]
Crown Zellerbach	2,804	6[a]
Great Lakes Forest Products	289	44[a]
Times Mirror (Publishers)	n.a.	8[b]

SOURCE: Annual reports.

NOTE: n.a. = not available

[a] Estimated using production or capacity data and average newsprint price.
[b] Figure is for 1983.

demand are also uncertain, such as the price of substitute products, exchange rates (that affect export and import quantities), and strikes in the producer and consumer sectors. The long term relationship between quantity demanded and price is also uncertain, since this relationship may change over time. The uncertainty increases as the planning horizon increases. The evaluation of capacity investments requires at least 15 years of demand function projections, since the investment will be in operation for at least that long, and will take a number of years before it has a net positive return.

2.3 Key strategic decision variables

Capacity is a key strategic decision variable in the newsprint industry. Because of their high costs, long lead times and irreversibility, capacity decisions have a major impact on the profitability of the firm.

There are other decisions that are important to the success of a firm in the newsprint industry. These are the operating decision variables of operating rate (or production level) and price.[4] These are intimately related to the capacity decision, since they are key determinants of the profitability of the decision. Newsprint is a commodity product, with little quality differentiation between producers, thus firms do not compete in quality. Similarly, strategic variables such as customer relations, and size of distribution networks, while important to some firms because of their special positions as niche players, are not key variables in the decisions of most firms.

2.3.1 Pricing

In an oligopoly, there are few enough competitors so that firms recognize their interdependence. This makes a firm's determination of "optimal" prices and output quantities difficult, because each firm's decision is dependent upon its rivals' decisions. Firms must therefore rely on communication and coordinating mechanisms that reduce the risk of price wars,

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[4] Inventory levels may also be important, since a firm may choose, for example, to accumulate inventory rather than reduce production.

yet that do not break antitrust laws. Industries such as the newsprint industry, with inelastic demand and high fixed costs in production, are particularly vulnerable to price competition. In addition, when buyers are few and large (such as in newsprint where large newspaper publishers have purchasing power), pressure can be exerted on producers to decrease price. Producers under these conditions may use a number of mechanisms to adjust to changes in cost and demand conditions.

One mechanism that the newsprint industry appears to use is barometric price leadership. Under a barometric price leadership system, the leader's price is followed only because, and to the extent that, its price reflects market conditions. The price leader has no power to coerce the rest of the industry into accepting its price, and occasional lags or outright rejections of the price leader's movements occur. In the newsprint industry, the price leaders are usually the largest firms, with no one particular firm being the dominant leader. This is illustrated in Table 2.3 which shows the price leaders for changes in list price since 1970.[5] The leader's price tends to formally validate price reductions already initiated by others through off-list concessions. List price cuts can restore industry discipline by providing a rallying point at which prices can be held, and by raising the implicit threat of further list price reductions in response to off-list shading. Between 1953 and 1989, list prices have only been cut once (in 1982, initiated by Kimberly Clark). Discounts from list however, have been as high as 20%. See Table 2.4 for a comparison of transaction and list prices.

List price increases tend to follow increases in input costs (e.g., Abitibi-Price and MacMillan Bloedel in 1987 cited increases in labour costs). These cost increases are easily seen by others in the industry, and the motives for a price increase are clear. This reduces uncertainty about the rationale for price changes. A tight supply situation will also cause price increases, partly

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[5] The price leader was determined as the firm that first announced a price change that prevailed. This may not be the first announcement of a price change, if a different price ends up prevailing.

TABLE 2.3: Newsprint list prices, East and West.

	EAST			WEST		
	List Price (US$/ton, 32 lb.)	Price Leader	Effective date (m/d)	List Price (US$/ton, 32 lb.)	Price Leader	Effective date (m/d)
1970	152		1/1	147		1/1
1971	160		4/1	155		1/1
1972	165	Southland	2/1	163	Crown Z	1/1
1973	170	GNN	2/1	168	n.a.	3/1
1973	175	Bowater	6/1	178	MB	10/1
1973	200	CIP	11/1	200	n.a.	12/1
	(US$/ tonne 30 lb.)			(US$/tonne 30 lb.)		
1974	259	GNN	7/1	235	MB	3/1
1974				270	MB	8/1
1975	287	Price	1/1	309	Southwest	1/1
1976	314	IP	3/1	331	MB	7/1
1976	336	CB	11–12/1			
1977	336	–		331	–	
1978	353	Bowater	2–4/1	353	MB	4/1
1979	380	GLF	2/1	380		
1980	413	CB		413		
1980	440	CB	5/1	440		
1980	470	IP	11/1	470		
1981	500	CB	7/1	500		
1982	(540)[a]	CB	3/1			

TABLE 2.3 – Continued

	EAST			WEST		
	List Price (US$/tonne, 30 lb.)	Price Leader	Effective date (m/d)	List Price (US$/tonne, 30 lb.)	Price Leader	Effective date (m/d)
1982	(525)[a]	Abitibi	4,6,10/1			
1982	468	KC	11/1	468	MB	11/1
1983	500	CB	7–9/1	445	MB	7/1
1984	535	GLF/Reed	7/1	500	MB	3/1
1984	535			535	MB	10/1
1985	(570)[a]	Abitibi	1,4,7,9/1			
1986	570	CB	10/1	570	MB	10/1
1987	610	Abitibi	7/1	600	MB	7/1
1988	650	Bowater/CIP	1/1	630	MB	1/1

SOURCES: Pricebook II (1986), New York Times Index, newspaper reports, Canadian Paper Analyst (1987).

NOTES:
CB=Consolidated Bathurst
GLF= Great Lakes Forest Products
GNN=Great Northern Nekoosa
IP=International Paper
KC=Kimberly Clark
MB=MacMillan Bloedel
n.a.=not available

[a] Indicates failed attempt to initiate price increase

TABLE 2.4: List and transaction prices (US$/tonne, 30 lb basis weight).

Year	List Price	Eastern Transaction Price	List Price	West Coast Transaction Price
1974	259	259	270	270
1975	287	284	309	309
1976	314/336	314	331	331
1977	336	336	331	331
1978	353	353	353	353
1979	380/413	380/314	380/413	380/413
1980	440	440/470	440	440
1981	470/500	490	470/500	470
1982	468.5	445/468.5	468.5	445
1983	500	475	468.5[a]	445
1984	535	510	500/535	508.25
1985	535	505/510	535[b]	508.25
1986	535/570	480/500/535/550	535/570	508.25/514.5
1987	570/610	530/550/553/570	570/600[c]	514.5/552.9

SOURCE: Miller Freeman (1988)

[a] West Coast producers announce 5% discount from list.
[b] A second 5% discount added by West Coast producers.
[c] One previously implemented 5% discount reduced to 3%.

due to the increased costs incurred as a result of producing at above capacity by bringing older machines into production, but also because of the increased bargaining power of suppliers over buyers.

The basic price for newsprint is the contract or list price, set by contracts between newsprint producers and buyers. Most sales of newsprint are made on a contract basis between the newsprint producers and newspaper publishers. A large portion of a mill's volume of newsprint is usually committed to specific buyers through long-term (i.e., one or two year) contracts. Prices are ordinarily quoted f.o.b.[6] mill, full or sometimes partial freight allowed (Guthrie 1972). List prices occasionally differ between producers, but not by much. Volume discounts for large orders are common. Although price is also set in these contracts, these prices are subject to change in response to changing market conditions. "Newsprint contracts essentially have no teeth" (Pricebook II 1986). Transaction prices differ from list prices in most cases (see Table 2.4). Information on discounts from list, while not publicly available, travels quickly among producers and buyers. Thus transaction prices tend to be more or less equal between producers, and it is reasonable to assume that "one price" prevails.[7]

In industries such as newsprint where fixed costs are high relative to total costs, there is a tendency for serious breakdowns in pricing coordination during recessions (Scherer 1980). In highly capital intensive industries, capacity utilization is an important determinant of unit cost because as capacity utilization goes down, per unit costs increase, as the fixed cost must be allocated over fewer units. When demand is slack, this puts pressure on producers to increase capacity utilization by increasing output and reducing price. This may lead to a breakdown in pricing coordination, driving prices closer to costs.

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[6] F.o.b. mill means free on board-mill. This means that the buyer pays for the cost of shipping the product from the mill to the final destination.

[7] Note that since the early 1960's there has often been up to a $20 difference between Eastern and Western list prices. Southern mills may also be a couple of dollars lower than the Eastern list.

There is, however, evidence that even in bad times, firms attempt to coordinate prices. Firms will take downtime (i.e., shut down a machine or a mill) for a few days or weeks in order to reduce inventories, and to reduce the quantity of newsprint on the market, when demand is slack. Large firms such as Abitibi-Price, MacMillan Bloedel, Consolidated Bathurst, etc., are usually the first to take downtime and tend to take a larger percentage of the downtime than smaller firms, i.e., they "hold the umbrella" for smaller firms. Firms announce downtime in news releases that are reported in newspapers and trade journals, so that other firms are well aware of their actions. Several empirical models of newsprint pricing have provided support for the hypothesis that firms use a markup over cost coordinating rule, where the markup is dependent on the operating rate of the industry (see, e.g., Booth et al. 1990).

The prices of uncoated groundwood and coated groundwood papers provide upper constraints on newsprint prices.[8] When price differentials narrow, newspaper publishers and commercial printers may upgrade paper quality for end uses such as newspaper inserts and Sunday magazines, without incurring much of a cost increase over newsprint.[9]

Technological innovation makes pricing coordination more difficult by increasing the diversity of cost structures in the industry. Differences in cost structures as a result of age differences in capital and regional competitive advantages, as well as exchange rate differences, means that the price preferred by firms may differ (Scherer 1980).

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[8] A significant factor in newsprint pricing is also the price of imports from Europe. Exchange rates can make the U.S. market very attractive for European producers. Although only about two to five percent of all newsprint is imported from overseas, the exchange rate can make the imports very competitive, and put a lid on North American prices as a result of the threat of further overseas entry into the market. The effect of imports on prices is not considered in the current version of the model.

[9] Some older, high cost Canadian newsprint machines have been converted to uncoated groundwood production. Uncoated groundwood paper are manufactured to have better printing characteristics and are priced above standard newsprint. There has been an increasing strategy of quality differentiation in the newsprint industry, exemplified not only by the recent conversions of machines to groundwood specialties, but also by the increasing number of grades of newsprint beyond the "standard" grade. This increasing quality differential makes pricing coordination more difficult, but also makes it less important, as products can be priced differently based on their quality. The current model considers only standard newsprint.

The large U.S. newspaper publishers are in a strategic position to exert pressure on producers to reduce prices, particularly in times of demand downturns. The big newspaper chains are sophisticated and astute observers of market conditions, and most are taper integrated (see Table 2.5), so they have a good grasp of costs as well as bargaining power through threats of increases in production. They gain price concessions through playing salesmen off against each other. Although most tonnage is sold under long-term contracts, the price is still negotiated based on market conditions. Concessions can be gained in soft markets; price hikes are common in tight markets. The effect of these large buyers may be to increase the competitiveness of the newsprint market (e.g., lower prices).[10]

The structure of the market indicates that the newsprint industry is an oligopoly. On the one hand, the large number of competitors, the lack of one significant market leader, the diversity of cost structures, the lack of differentiation, and the strength of buyers all increase the competition in the industry. On the other hand, there are some firms with a significant market share whose production decisions affect market prices. There is also great deal of information about participants available, and firms tend to compete in the industry for a long time, thereby allowing learning over time and the development of tacit coordination.

2.3.2 Capacity expansion

Capacity expansion in the newsprint industry tends to take place in lumps over time, in the sense that many firms add machines over a short time span, and then no firm adds capacity for a few years. "Many machines are built at the same time, causing overcapacity and low prices for several years. The low prices cause no new paper machines to be built, which eventually creates a tight market. The tight market leads to good prices and high prices, leading everyone to add new

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[10] The ownership of mills by newspaper publishers may affect a mill's production levels. If production is tied to buyers through vertical integration, then production levels will be less vulnerable to downturns in the economy.

TABLE 2.5: Presence of newspaper publishers (1986)

Newspaper Company	(Percent Ownership), Mill, Location, (Other Major Owner)
1.[a] Gannett	(44.6%) Donohue Charlevoix, Que. (Donohue 55.4%)
2. Knight Ridder	(33%) Southeast Paper, Dublin, GA
3. Newhouse Paper Group	(49%) Catawba Newsprint,Catawba,SC (Bowater 51%)
4. Tribune Co.	(100% subsidiary) Ontario Paper, Thorold, Ont., and Quebec Norshore, Baie Comeau, Que.
5. Dow Jones	(40%) FF Soucy, Riviere du Loup, Que.(50% Soucy)
	(30%) Bear Island Paper, Doswell, VA
8. New York Times	(49%) Gaspesia P&P, Chandler, Que. (Abitibi-Price 51%)
	(49.5%) Spruce Falls Power and Paper, Kapuskasing, Ont. (Kimberly Clark 50.5%)
	(35%) Donohue Malbaie, Que. (Donohue 65%)
10. Thompson Newspapers	(50%) Augusta Newsprint, Augusta, GA (Abitibi-Price 50%)
11. Cox Enterprises	(33%) Southeast Paper, Dublin, GA
16. Washington Post	(49%) Bowater Mersey, Liverpool, NS, (51% Bowater)
	(30%) Bear Island, Doswell, VA
Media General	(20%) FSC Paper Corp, Alsip, Ill.
	(33%) Southeast Paper, Dublin, GA
	(100%) Garden State, Pomona, CA and Garfield, NJ

[a] Rank of newspaper company in U.S., based on 1982 daily circulation (Rennel 1984).

paper machines. Many machines are built..." (PPI 1987). Figure 2.1 shows the capacity development over time, and the corresponding operating rates and industry prices.

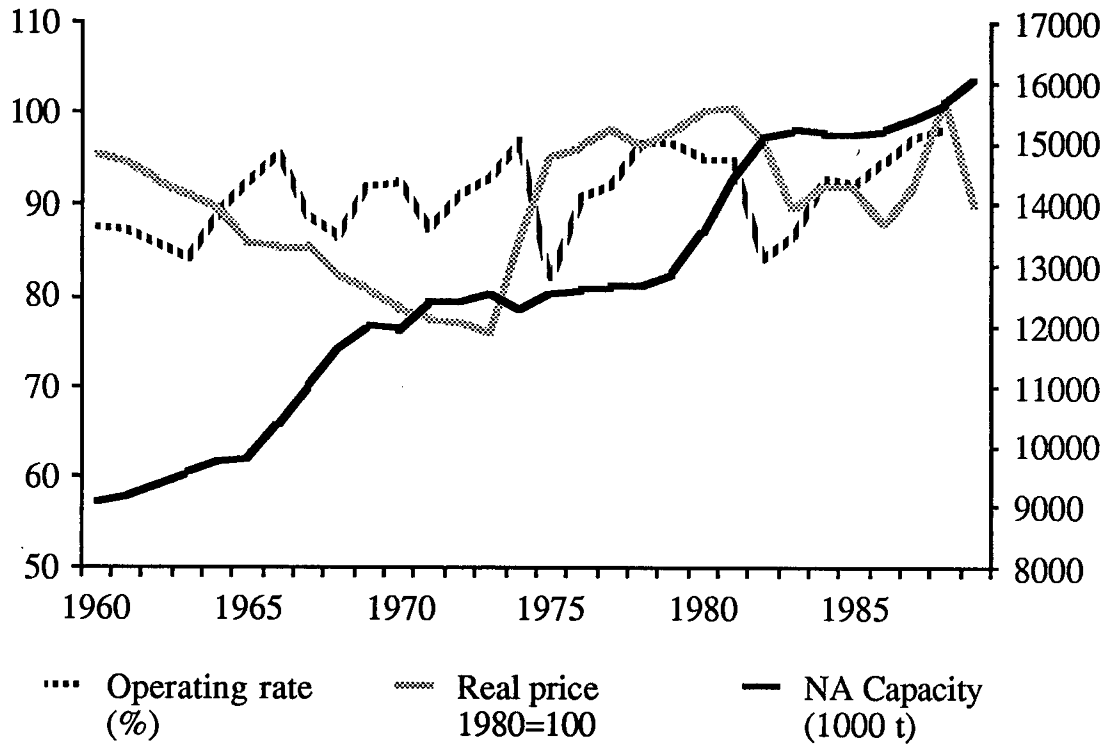
This bandwagon effect is caused by a number of factors. For example, there is a certain amount of pressure for firms to invest once others have announced plans for new capacity. This pressure may result from a desire to maintain market share. There is also a tendency for firms to follow the crowd because of risk averse managers. If a manager decides not to add capacity when every one else does, and then there is high demand and strong prices, his decision is hard to explain. However, if he does decide to add capacity, and demand proves to be low, then the blame for the poor outcome can be shared or attributed to industrywide factors out of his control (Porter and Spence 1982, Lieberman 1987). There is a similar tendency for managers to avoid adding capacity when others are not adding. The bandwagon effect can also be stimulated by the security analysts and stockholders, who may add pressure to managers to add capacity once others have announced.

This bandwagon effect is exacerbated by the tendency of firms to invest when their cashflows are high, i.e., when demand is strong and prices are high. Because of the lag time in actually bringing new capacity onstream, firms that decide on new capacity in good times tend to complete it after the peak in the cycle. All firms in the industry experience good times at the same time, therefore investments tend to be made at the same time.

This bandwagon effect is also exacerbated by the lumpiness of capacity additions. As noted above, the MES machine is about 180,000 to 220,000 tonnes. Thus when firms add capacity, they must add either nothing, or 220,000 tonnes. (Some capacity can also be added by increasing machine speeds, and updating equipment.)

A firm could try to preempt other firms by aggressively adding the quantity of capacity that would fill the expected demand growth, in order to deter competitors from expanding and to discourage new entry. This strategy is inherently risky, because substantial capacity must be

FIGURE 2.1: North American capacity, operating rates and real prices, 1960 to 1989



added before demand has materialized. If there is substantial uncertainty in the prediction of demand, then this strategy will not likely be attempted. Preemption is most likely to be successful under the following conditions (Porter 1980, Lieberman 1987): the size of the capacity expansion must be large relative to the size of the market growth expected by competitors; there must be economies of scale or a significant learning curve relative to total market demand; the preempting firm must be credible and able to signal its preemptive move before competitors act; competitors must be willing to back down. Firms may not back down if, for example, their goals include noneconomic criteria such as market share, they have a strong strategic commitment to the business, or they have better staying power and a willingness to trade short term profits for long term market position (Porter 1980). Preemption does not seem to be a likely strategy for firms in the newsprint industry, given these conditions.

Because most firms have been in the industry for a long time, their capacity is older and has a higher production cost than that of new capacity. Technological innovations in pulping (e.g., thermomechanical pulping) as well as machines (much higher capacities and machine speeds) mean that new capacity has a much lower production cost than existing capacity (although significantly higher capital costs). Advancements in technology have also led to improvements in sheet quality, providing another incentive for investment.

Extensive signalling through announcements of new expansions in trade journals and newspapers is used as a method of coordination, to try and deter competitors from expanding. Announcements are made as soon as projects are even considered, in order to discourage others. Often announced plans are deferred or never carried out, although it is rare for firms to announce these cancellation of plans.

Capacity can be added either through additions of machines (and usually pulping capacity) to existing mills, or by the building of new greenfield[11] mills. There has also been substantial

[11] A "greenfield" mill means that there is no existing infrastructure in terms of roads or buildings, etc.

amounts of capacity added in recent years through the modernizing and upgrading of older machines (e.g., through machine speedups).

It is significantly cheaper to add on new capacity to an existing mill than to build a greenfield mill, since of course one does not have to build the surrounding infrastructure. Thus firms will usually prefer to add on to existing plants, unless they are constrained, for example, by wood fibre shortages in a region, or by space considerations. Because of the high capital cost, long lead times, and resulting uncertainty, firms rarely add more than one machine or mill at a time (i.e., within a five year period). Any new entrants therefore usually enter as one machine "fringe firms".

2.4 Summary

The North American newsprint industry is relatively self-contained, with domestic demand being predominantly served by American and Canadian producers. It is moderately concentrated, with a ten firm concentration ratio of 70%.

Firms coordinate prices through barometric price leadership. Cost and size differences between firms mean that optimal prices vary by firm. Because of high fixed costs, pricing breakdowns may occur when demand is low, and some firms may overproduce to keep their operating rates high.

Economies of scale mean that MES newsprint machines are large and have a significant impact on the market. Capital costs for capacity are high, particularly for new mills, and because of the two to three year lag time between starting construction and starting production, there is considerable uncertainty about the economic consequences of a capacity decision. For these reasons, firms rarely add more than one machine over a five year time period. Historically, many firms have tended to add capacity at the same time, causing temporary overcapacity and reduced profits. This means that the immediate decision can be modelled as an "add"/"do not add" decision, where all firms are assumed to be making the capacity decision simultaneously, without knowledge of other firms' decisions.

CHAPTER III

CAPACITY EXPANSION AND STRATEGIC PLANNING MODELS

3.1 Introduction

Chapter II identified the structural characteristics of the newsprint industry and the decision variables that are important in the industry. Capacity, production and pricing decisions were identified as the key variables that determine the success of a firm in the industry. These, then, are the variables that must be included in a strategic planning model for a firm in the industry.

The objective is to develop a decision-making tool to help in a firm with its capacity expansion decisions. What are the characteristics of the model that is required to achieve this objective? In this chapter, the historical development of capacity planning and strategic planning models is discussed and important model features identified. This review of the literature, keeping in mind both the industry structure and the key decision variables already identified, provides a starting point for the development of the model. The history of industry models in the newsprint industries is also briefly reviewed.

3.2 Models of the newsprint industry

Various models have been developed of the North American newsprint industry. Econometric, linear programming, spatial equilibrium and simulation models have all been used to model the newsprint and pulp and paper sectors. Not all models considered capacity expansion, but those that did used a variety of different techniques to model capacity change.[1]

Dagenais (1976) and Buongiorno et al. (1983), for example, estimated econometric models of price formation in the newsprint industry. Muller (1978), Schaefer (1979) and Booth et al. (1990) estimated econometric models of the industry, including capacity expansion estimated as a function of variables such as price, cost of capital and lagged capacity. These researchers have all modelled the newsprint industry as an oligopoly. Spatial equilibrium market models have also been developed, e.g., Gilless and Buongiorno (1987), Guder and Buongiorno (1984), Ince et al. (1987). These use optimizing techniques such as linear programming to project regional prices, quantities and capacities, and assume that the industry is competitive (as opposed to oligopolistic).

Numerous other models of the forest sector and pulp and paper sector have been developed.[2] Several have used linear programming to determine optimal harvesting levels, production and capacity expansion on a regional basis by product (e.g., Bergendorff and Glenshaw 1980, Nilsson 1985). Nilsson (1985), for example, aggregated British Columbia pulp and paper mill capacities into 17 centres by product, and then determined the investment levels that maximized profits for the entire industry as a whole.

None of these models attempted to model the behaviour of the industry based on individual firms. These models were developed to improve the understanding of the industry, to provide forecasts and to evaluate alternative scenarios for policy analysis. They were not developed for strategic analysis and planning at the firm level.

This thesis develops a different kind of model, one that is useful as a planning tool for a firm to make its individual capacity decision. It can also be used to forecast industry behaviour, aggregating individual behaviours to determine industry outcomes.

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[1] Plantinga et al. (1989) report on approaches to modelling capacity change in the forest products industry. They discuss the various econometric and modelling approaches that have been used in recent years.

[2] See also Booth (1985) for a review of forest sector models and modelling techniques.

3.3 Capacity expansion models

Many models have been developed using the optimization techniques of operations research to help firms with their capacity expansion decision (see Manne 1967, Friedenfelds 1981, Luss 1982). The major concern addressed by these models has been the trade-off between economies of scale and the costs of installing capacity prematurely. The basic problem is one of determining the sizes of facilities to be added, the times when they should be added, and the locations (and/or capacity types). Given a pattern of demand over time, the objective is to minimize the net present value of costs of all expansions. The costs considered are typically costs for expansions, shortages, congestion, idle capacity, maintenance, and inventory. Constraints such as budgetary constraints, upper bounds on expansion sizes, excess capacity and capacity shortages may also be specified. Expansion size is usually assumed to be a continuous variable, and this assumption is inherent in many of the algorithms that have been developed (Luss 1982). A variety of optimization techniques have been employed, including linear programming, dynamic programming and stochastic processes. Models have been developed for communication networks and public services (e.g., electrical power, water resources, schools, roads).

These types of models are appropriate for monopoly enterprises, and firms that compete in purely competitive markets. The demand curve faced by a firm in these markets is not dependent upon the decision it takes, nor on the reactions of other firms in the industry to its decisions. In an oligopoly, where there are few competitors, there is an interaction between the capacity expansion decisions made by a firm in one period and the demand function it may face in that and other periods.

These strategic impacts of capacity expansion decisions are key in oligopolistic markets such as the newsprint industry.

3.4 Strategic planning models

A strategy is the means or set of actions to be used to achieve a firm's objectives and goals (Ansoff 1965).[3] Strategic planning thus involves the development of strategies to achieve firm's objectives. Strategic planning is done at the corporate, business and functional levels. At the corporate level, strategic planning deals with the choice of business and products and their interrelationships. At the business level, strategic planning focusses on how to compete in a particular business. And at the functional level one tries to find the best use of the firm's resources. The planning levels are interlinked; each is constrained by the level above it.

A number of models have been developed over the last couple of decades to help firms formalize their strategic planning. A planning model can help a firm deal in a structured way with the uncertainties and complexities of its environment.

Different types of models have been developed to aid planning at the various levels. At the corporate level, portfolio planning models have been developed to help a firm decide which businesses it should be in, as well as the degree of investment in each business (e.g., Hamilton and Moses 1973, Boston Consulting Group 1972, Coate 1984). Business level models focus on the selection of marketing, production and/or organizational strategies to enable the firm to effectively compete in its market (e.g., Davis et al. 1973, Dutta and King 1980, Eppen et al. 1989). This study focusses on strategic planning and strategic planning models at the business level, since capacity planning is a key strategic decision made at this level. Only some of the models discussed below deal with the capacity expansion decision; some deal with other decisions at the business level, but their methodologies could also be applied to the capacity decision.

Business level strategic planning models have been developed with varying methods and amounts of detail and sophistication. Some of the methodologies that have been used are simulation, decision analysis, optimization, systems dynamics and game theory. Models also

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[3] A broader concept of strategy includes in the definition the setting of objectives in addition to the means to be used to achieve them (e.g., Chandler 1962).

TABLE 3.1: Development of strategic planning models

	UNCERTAINTY	
COMPETITORS	NO	YES
NO	Davis et al. 1973 Ogunsola 1975,1979 Hall 1976	Eppen et al. 1989
YES	Smallwood and Morris 1980	Braunstein 1983
GAME THEORY	Dutta and King 1980 Weigelt 1986 Weigelt and MacMillan 1988 Reynolds 1986	Porter and Spence 1982

differ in their treatment of uncertainty, types of objectives, and portrayal of competitors (see Table 3.1). Since many firms compete in an environment where the outcomes of strategic decisions are not independent of what their competitors do, explicit modelling of competitors is needed for realistic evaluation of decisions. The high degree of uncertainty in the economic environment of many firm means that models should explicitly incorporate this aspect of the environment. This permits the consideration of risk and return tradeoffs. Multiple or alternative objectives, in addition to those of expected profits and risk, may also be of importance for some firms. As planning models developed over time, these three aspects have been gradually incorporated in varying detail.

3.4.1 No uncertainty, no competitors.

One of the first comprehensive models developed for business level planning was Davis et al.'s (1973) model of the Bell System. This is a deterministic simulation model, developed to help determine the impacts of national economic and other environmental changes on various Bell system policies. The model is a series of equations, some of which were estimated econometrically from data while others represent actual relationships. There are three submodels. The Environment submodel provides a detailed description of the national economy and the regulatory environment. Macroeconomics models outside of the system are used to forecast the development of the U.S. economy. The corporate submodel describes the Bell System, including the demand it faces, a production module, pricing systems and a description of the financial workings of the firm. The third submodel, the management submodel, allows one to change corporate policy variables and provides (multiple) output indicators of corporate performance. Managers can test the impact of strategy variables such as debt/equity ratio, the input factor mix, wage levels and price levels. The model can be used to forecast quarterly for 8 quarters but for planning purposes can be run for 5 and 10 year periods. Because the firm operates in regulated industry, competitors were not considered in the model.

Ogunsola (1979) also used a simulation approach in the development of an integrated planning model for an oil company. Six modules–exploration, development, production, marketing, refining and finance–are linked to form the model. Demand for individual products was estimated econometrically, but the effects of other producers was not considered. Financial as well as quantity outputs are produced by the model.

Hall (1976) developed a Systems Dynamics simulation model of a magazine publishing company, the old Saturday Evening Post. The model was developed after the demise of the company, and so can not be described as a planning tool, however the methodology could be applied to other firms and industries in a planning context. A series of interlinked equations that represent the interrelationships of the firm with the environment are specified, including basic feedback mechanisms. The equations were estimated from historical data using regression analysis. The variables controllable by management (in this case magazine price, advertising prices and circulation promotion expense) can be manipulated to view their effects on the firm performance (in terms of three measures) in a series of experiments.

None of these models consider either uncertainty or the actions of other competitors. However, Davis et al.'s (1973) model illustrates the useful feature of incorporating external macroeconomic forecasts. Davis et al.'s and Ogunsola's breakdown of their models into explicit submodels is a good feature as well. Hall's model illustrates the use of feedback mechanisms as well as providing multiple performance measures.

3.4.2 Explicit modelling of uncertainty, no competitors.

Eppen et al. (1989) developed a stochastic mixed integer linear programming model with recourse for capacity planning in the General Motors Company. The decisions relate to the retooling and/or changing of capacity at a series of multiple product plants. They used a scenario approach to quantify the uncertainty about future demand and product prices. Competitors are considered only in that a certain percentage of demand is assumed to be lost to competitors if demand exceeds capacity (some percentage goes to other GM products). The objective function for the model is expected discounted cash flow, subject to a constraint on risk, as measured by the failure to meet a target profit (i.e., expected downside risk).

This model provides a good example of the use of scenarios to summarize possible uncertain futures. It also allows specific risk return tradeoffs.

3.4.3 Explicit modelling of competitors, no uncertainty.

Decision analysis has also been used as one method of evaluating and deciding upon capacity alternatives. Smallwood and Morris (1980) presented a decision analysis model that was used to help the Xerox company with a key business level strategic planning decision: whether and when to expand its capacity in a particular product area. They used a decision tree to structure the decision and generated the necessary members for the tree from a set of mathematical models. Thus for each possible decision of the firm, this set of detailed models describing the environment in terms of demand and competitors and the firm in terms of production levels and costs, were used to determine the financial consequences to the firm. Only one decision variable (when to expand) was considered, and one outcome variable (discounted cash flow), although the general framework would have permitted more. A single aggregate competitor was used to describe the behaviour of all competitors. In lieu of incorporating uncertainty, the authors carried out extensive sensitivity analysis, varying the over thirty state variables both singly and in combination. The disaster potential was examined by computing the probability of plant disaster that would have to arise for there to be a certain problem, thus avoiding having to ask managers for probability estimates that would be difficulty to determine.

While the consideration of other competitors is only crudely incorporated in this model, it does incorporate the use of scenarios analysis and extensive sensitivity analysis.

3.4.4. Explicit modelling of competitors and uncertainty.

Braunstein (1983) describes a decision analysis of a petrochemical expansion study, carries out in 1973 for Gulf Oil. This analysis was one of the first to explicitly model the actions of competitors. It also probabilistically modelled the interrelationship between the prices of petroleum products and petrochemicals. The decisions were whether to build a new olefins plant, how big it should be, and what feedstock to use. A detailed deterministic model of the industry was developed, that included a competitive model where the firm and its competitors considered the economics of alternative processes and the producer with the lowest profit criterion built the plant. In the probabilistic phase, probability distributions were estimated for those state variables found to be crucial in the sensitivity analysis. Thus a probability distribution of cashflows was calculated for each set of alternatives.

The inclusion of competitors is still crude in this model, but their explicit inclusion is important. Only one performance variable is considered, cashflow, but probability distributions of cashflows are calculated.

3.5 Game theory and strategic planning models

A number of recent papers in the economics literature use game theory to address the problems of capacity expansion, quantity competition and pricing in oligopolies (e.g., Kreps and Scheinkman 1983, Davidson and Deneckere 1986, Dixon 1985, Eaton and Grossman 1984, Brock and Scheinkman 1985). Oligopolistic behaviour can be modelled as a noncooperative game, in which each firm behaves in its own self-interest. The basic solution concept is an extension of the simple maximization process and is the Nash equilibrium. A solution is a Nash equilibrium if, given the actions of its competitors, a firm cannot improve its own profit by choosing a strategy other than the equilibrium strategy.

These game theoretic models provide a useful background for strategic planning models because of their explicit consideration of the interdependencies between firms. The economic models developed to address capacity expansion problems are used to develop an understanding of the structural development of an industry. These models were developed not as prescriptive planning tools for a firm, but as theoretical models of firm and industry behaviour, and thus are highly stylized. Simplifying assumptions are made in order to solve the models for closed form analytical solutions. However, these assumptions render the models too restrictive in their structural and behavioural assumptions for realistically modeling an industry. Less restrictive assumptions to accomodate the asymmetries and behaviours in an actual industry setting would make these models difficult to solve analytically. In addition, most do not incorporate uncertainty. Few have been empirically tested or applied.

In recent years, several researchers have begun to use some of the concepts of the theory of games in their strategic planning models . Thus in these models, not only the individual firm's but also some or all of its competitors' strategic choices are considered. This means that the actions of one firm affect the actions of other firms. The models are solved by finding equilibrium solutions, in the sense that all firms try and choose strategies that maximize their objectives, but taking into account what other firms are doing. The equilibrium results when all firms are using their best strategy given the strategies of all other firms and no firm would unilaterally like to change its strategy. Unlike the theoretical economic models mentioned above, these models are not solved for closed form analytical solutions, but are numerically solved, or simulations are run to test for possible equilibria.

3.5.1 Game theory – no uncertainty

Dutta and King (1980) developed a competitive scenario decision support system that uses expert judgments and a "mutual anticipation" process to examine the stability of the market under alternative choices for each firm. The analysis starts with a hypothesized set of specific strategy choices (in terms of product price and quality) by players (firms) in a competitive setting, and examines the stability of the situation from the point of view of each firm. The system focusses on relationships of price and quality to market shares and profits, where the relationships are derived from judgments of panels of experts. It is based on the use of metagames–games derived from the original game where a firm is assumed to correctly predict other firms' decisions.

Weigelt (1986) and Weigelt and Macmillan (1988) present an interactive strategic analysis framework for evaluating alternatives based on Harsanyi's game of incomplete information. They applied it to a problem in the intravenous solution industry (a tight three firm oligopoly) and used it to model the bidding (i.e., pricing) process. A firm estimates subjective probability distributions of its beliefs about other players in order to evaluate its decisions. Firm utility functions include both market share and profit.

Reynolds (1986) used a dynamic game model of output and capital investment choice to model the American aluminum industry from 1950 to 1970. This was developed as an industry model, not a strategic planning model, however, it is presented here because of the relevance of its method. The three leading firms in the industry were modelled, plus an aggregate competitive fringe. He tested the effect on the industry of the entry of a fourth major producer after World War II.

These three models are similar in that they explicitly incorporate the game theoretic notions of equilibrium.[4] They model at most three firms (or players). Only the Reynolds model is dynamic (and it is not really a strategic planning model, but a model built to explain historic industry development). The Weigelt model incorporates uncertainty about the beliefs firms have about other firms; none of the models incorporate uncertainty in the environment. The Weigelt and Dutta and King models illustrate the use of multiple objectives.

3.5.2 Game theory – with uncertainty

Porter and Spence (1982) developed a strategic planning model to address the problem of capacity expansion in the corn-wet milling industry in the U.S. They assumed that each firm in the industry was trying to achieve its goals, subject to its resource constraints, taking into consideration the decisions of its competitors. They used decision scenarios to reduce the number of alternatives to consider, and aggregated the decisions of all firms when considering the decisions of one particular firm.

Porter and Spence's model still represents the state of the art in strategic planning models. They used their knowledge of the specifics of the industry under consideration to reduce the number of possible firm capacity expansion options, and to develop realistic decision scenarios. Their model explicitly recognized uncertainty in the external environment of the firm, and used environmental scenarios with joint probabilities to capture the interdependence of two uncertain state variables. The inclusion of different risk tolerances between firms, albeit on an ad hoc basis, introduced a further sophistication into the model.

[4] In a slightly different approach, Ghemawat (1984) presents a two-firm game theoretic model of capacity expansion, and then compares the comparative static theoretical results with anecdotal empirical evidence of capacity expansion behaviour in the U.S. titanium industry.

3.6 Building a strategic planning model for the newsprint industry

The concentrated nature of the newsprint industry means that a model should capture the interdependence between firms. Thus the model should be strategic, in the sense of the theory of games, where games of strategy are those in which the best course of action for each player depends on what the other players do (Schelling 1960). The capacity decision variable needs to be integer, reflecting the indivisibility of large-scale capacity additions. The lag time between firm decisions and actual additions to capacities needs to be incorporated. Key differences between firms, such as cost structures, objectives, initial capacities, discount rates and production behaviour, need to be captured for the major players in the market. Any constraints on behaviour should also be explicitly captured. Uncertainty in the economic environment, and its impact on the demand for newsprint, should explicitly be incorporated, so that risk/return tradeoffs can be considered. The model should, of course, also provide a realistic portrayal of firm and industry behaviour. Lastly, the model should be as simple as possible, in order to facilitate its understanding and use and reduce computational costs, yet there must be sufficient detail to capture the key complexities of the decision and the environment.

Given these criteria, Porter and Spence's (1982) model provides a good starting framework for further development. Their work was a major step forward in the development of useful strategic planning models, but it can be further extended to handle some of the problems and complexities not originally addressed. In particular, Porter and Spence did not explicitly address the questions of pricing and production, which are closely tied to the capacity expansion problem. They assumed that all firms produced at the same operating level (i.e., percentage of capacity utilized), and that the profit margin per unit of output was tied to this capacity utilization level. In commodity industries such as newsprint, capacity utilization can be a key strategic decision variable. The assumption that all firms share demand equally implies a strong constraint on firm behaviour. The different sizes and characteristics of a firm in an industry will affect how it behaves in terms of operating rates and will thus be a determinant of industry price.

Secondly, Porter and Spence incorporated objectives that included risk attitudes in a subjective and informal manner. Explicit incorporation of this capability into the solution system of the model is desired, as well as the possibility of objective functions incorporating factors besides risk and returns, for example market share.

The next chapter discusses the framework of the model that was developed, based on the industry structure presented in Chapter II and drawing upon notions from the strategic planning models presented in this chapter.

CHAPTER IV

DESCRIPTION OF MODEL

4.1 Introduction

The purpose of this chapter is to describe the structure of the model developed as a decision-making tool for a firm in the newsprint industry to help in its capacity expansion decision.

The industry is an oligopoly, thus a firm's decision will depend also on the decisions made by other firms. A reasonable assumption for a firm to make is that its competitors are rational and have a similar decision logic to that of the firm. This does not necessarily mean that competitors have the same objectives, but that they have symmetry in capabilities of reasoning and imagination with regard to options. Thus the firm considers that if it can imagine and respond to a possible move of a rival, that rival may anticipate that response and identify a counter response. This symmetry of reasoning implies that all key firms in the industry must be modelled and the interdependence of their decisions captured.

4.2 Mathematical structure of the model

4.2.1 Outline of the model

We will assume for the moment that firms are strictly profit maximizers. (Other possible firm objectives will be considered later). A firm wants to determine the amount of new capacity to add in each year t=1,...,R that will maximize the net present value of its total profits.

$$\text{i.e., Maximize}_{z_{it},\, t=1,R}\ \pi_i = \sum_{t=1}^{R} (\text{Revenues} - \text{Costs})/(1+r)^t$$

$$= \sum_{t=1}^{R} (\text{Price x Quantity} - \text{Variable Costs} - \text{Fixed Costs} - \text{Investment Costs})/(1+r)^t$$

where z_{it}=amount of new capacity to add in each year t and r is the discount rate for the firm.

In order to determine the most profitable capacity choice, a firm therefore needs to estimate the relevant revenues and costs for each possible capacity decision. Estimation of investment costs and fixed costs are relatively straightforward: they depend only on the total capacity of the firm and the amount of new capacity added. Variable costs are a function of the quantity produced and the amount of new capacity added, since new capacity may result in a shift of the cost function.

Quantity produced and the price received for that quantity are less straightforward, since firms compete with other firms, and the quantity they produce depends in part on the amount produced by others, which in turn depends upon the capacity choices of others. Thus a firm must know the capacity decisions of other firms in order to determine the profitability of a particular capacity decision. Other firms, however, are going through a similar decision process of determining the most profitable capacity decision. Each firm's decision depends upon what decisions other firms make about capacity. A solution to this interdependence problem lies in the equilibrium concept. That is, a firm determines its preferred capacity option, given the preferred options chosen by other firms, such that no firm has an incentive to unilaterally change its choice. Each firm's choice is optimal (i.e., profit-maximizing) given the choices of other firms.

Each firm i, i=1 to n, solves the following problem:

$$(4.1)\quad \text{Maximize}_{\{z_{i1}, z_{i2}, \ldots z_{iT}\}}\quad \pi_i = \sum_{t=1}^{T} \{\tilde{q}_{it} \cdot P_t\,(\sum_{j=1}^{n} \tilde{q}_{jt}) - C_{it}(\tilde{q}_{it}, k_{it}) - F_{it}(k_{it}) - I_{it}(z_{it})\}/(1+r)^{t-1}$$

$$+ V_i[(P_t,\ t=T+1,\ldots,R),\ k_{iT},\ K(\sum_{j=1}^{n} k_{jT})]$$

where $k_{it} = k_{it-1} + z_{it}$ $i=1,\ldots,n$

k_{i0} given, $i=1,\ldots,n$

z_{jt}, $j\neq i$, $t=1,\ldots,T$ given

z_{it}=new capacity added by firm i in year t

k_{i0}=initial capacity of firm i

k_{it}= capacity of firm i in year t

q_{it}= quantity produced by firm i in year t

$C_{it}(q_i,k_{it})$=firm i's variable cost of producing q_i in year t

$F_{it}(k_{it})$=fixed cost for firm i in year t

$I_{it}(z_{it})$ = investment cost for firm i in year t

$P_t(Q_t)$ is the inverse demand function in year t, i.e., P_t is price, Q_t is quantity demanded. $P_t(Q_t)$ is assumed to be linear.

$K(\sum_{j=1}^{n} k_{jT})$=total industry capacity in years T+1 to R as a function of the total industry capacity in year T, i.e., $K_{T+1},\ldots,K_R$, where $K_{T+1}=\sum_{j=1}^{n} k_{jT}$

CU= the average capacity utilization of the industry in years T+1 to R (a constant)

$V_i[(P_t,\ t=T+1,\ldots,R),\ k_{iT},\ K]$ = the net present value of future profits from years T+1 to R

r=the discount rate of the firm[1]

n= number of firms in the industry

and $\tilde{q}_{it}$ is the equilibrium quantity (defined below).

We solve for an equilibrium solution matrix

(4.2) $Z^*=(z_{it}^*, i=1,\ldots,n,\ t=1,\ldots,T)$ such that $\pi_i(z_i^*,z_{-i}^*,P,K)\geq\pi_i(z_i\ ,z_{-i}^*,P,K)$ for all i, where $z_{-i}=(z_1,z_2,\ldots,z_{i-1},z_{i+1},\ldots,z_n)$.

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[1] The discount rate is the firm's cost of capital (see, e.g., Sugden and Williams 1978). It is assumed to be a constant, and does not change over time.

Capacity decisions. Firms in the newsprint industry either build a greenfield mill with one or two machines, or add pulping capacity and a newsprint machine to an existing mill. The MES (minimum efficient scale) machine has gradually increased over time, but at a particular point in time, all firms consider adding more or less the same size of machine. The choice is generally one of adding one machine or none, or building a new mill. It is significantly cheaper to add on to an existing plant; this will be dominant over a new mill decision unless the firm is constrained by, for example, wood fibre shortages in a region or space considerations. The decision is thus an integer problem in the sense that firms consider adding an integer number of machines (usually zero or one) in a year; they cannot add half a machine at half of the cost.

The above model of the capacity decision process uses the Nash equilibrium solution procedure. Firms are assumed to make decisions simultaneously, without knowledge of other firms' decisions. However, firms are also assumed to know each others' possible strategy choices, their objectives and costs. For a number of reasons discussed in Chapter II, many firms in the newsprint industry tend to consider adding capacity all at the same time. There is a high degree of knowledge of rivals in the industry, because of trade associations and the long history of the market. Signalling, in terms of announcements in trade journals and newspapers, can be considered as a way of indicating possible strategies to other firms. Since announced plans are often not carried out, at least not in the time frame initially announced, the announcements in many cases are not really indications of firms' final decisions. Firms also do not seem to consider past behaviour.

Capacity additions take two to three years to come onstream, after the decision has been made. Firms rarely add more than one machine at a time, or even within a five year period, because of the large capital expenditure involved, the large size of an MES machine, and the uncertainty inherent in the two year lag time. Thus it is reasonable to model the decision process as a one shot game; the decision is made now for capacity expansion over the immediate future, and then no more capacity is added for several years after that. The model is structured so that a firm considers only the short term, immediate capacity choice over the years 1 to T. In the longer run, from years T+1 to R, the industry is assumed to expand capacity in such a way that industry capacity and industry demand are balanced, according to some long run price growth projection.[2]

The model requires consistency between capacity choices in the first T years of the planning horizon and some aggregate industry projections of capacity made for the remaining R minus T years of the planning horizon. The simultaneous firm production problem is solved only for years 1 to T; after that we assume that firms all produce at the same operating rate, and that their capacity does not increase above k_{iT} (although total industry capacity, K, increases). Then, given the industry demand curve, the variable and fixed cost functions of the firm and the discount rate, the present value of profits in years T+1 to R, V_i, can be determined.

The function V_i is defined as follows:

$$(4.3) \quad V_i(P_t,k_{iT},K) = \sum_{t=T+1}^{R} \{P_t(CU \cdot K_t(\sum_{j=1}^{n} k_{jT})) \cdot CU \cdot k_{iT} - C_{it}(CU \cdot k_{iT}) - F_{it}(k_{iT})\}/(1+r)^{t-1}$$

Note that aggregate industry capacity K_t is assumed to increase, but the individual k_{it}'s do not; this means that $\sum_{j=1}^{n} q_{jt} \neq CU \cdot K_t$. We estimate $V_i(P_t,k_{iT},K)$ for the vector of $K=(K_{T+1},...K_R)$ such that $\sum_{j=1}^{n} k_{jT}=K_{T+1}$ and K grows at a rate such that demand and supply are balanced according to the assumed long run price increase.

The structure of the model limits the types of strategies that firms are assumed to consider. It does not permit preemption, but as discussed in Chapter II this is not a likely strategy for newsprint firms. All firms are assumed to make the capacity decision simultaneously, therefore firms are assumed not to respond or retaliate to other firms decisions. Firms' decisions are not history dependent, i.e., they do not consider previous strategies of rivals. Firms are assumed to make a decision for the immediate future, given what it thinks others will do, and then stick to this

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[2] We use T=5 and R=15 in the implementation of the model.

plan, despite what the others actually do. They are assumed to commit to the announced plan. This is reasonable for the near term, but obviously the further in the future one considers, the more likely it is that conditions will change, and therefore that the decision of the firm will change. This is why we only consider the immediate capacity decision for a firm (i.e., within the next five years) and an aggregate outlook is assumed for the long run industry development as a whole.[3]

Production and industry price. Newsprint is an undifferentiated product, so it is reasonable to assume that the firm's decision variable is quantity, as opposed to price. Firms must decide, based on their assessment of the market situation, how much newsprint to produce in a given period, taking into consideration the effect that they might have on industry price and thus their own profits. Because there is, in effect, only one price, the assumption that firms compete in terms of quantity is reasonable. Changes in price, in terms of discounts or list price changes, respond to the quantity decisions of firms. For example, to prevent pricing breakdown, producers will often take "downtime", i.e., they will close for several weeks in order to reduce total industry output. The largest producers (e.g., Abitibi-Price, MacMillan Bloedel) are usually the first to take down-time, and take the largest proportion of downtime.

For each possible firm capacity decision $z_i=(z_{i1},...,z_{iT})$, we must determine annual firm production and industry price. However, a firm's production decision is dependent on the production decisions of all other firms, and these decisions are themselves dependent upon the capacity decisions of these other firms. Therefore, the production decision of a firm must be evaluated given the capacities for all other firms. Given these firm capacities and a demand function in each year, we can determine each firm's optimal production level q_i in each year. The solution to this simultaneous problem is the Nash equilibrium, i.e., where each firm's production

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[3] The use of long run capacity projections and the assumptions on long run pricing are in lieu of a fully dynamic model, for example using a game theroetic variant of dynamic programming. A dynamic model was considered infeasible because of the integer nature of the decision variable, and the consequent "curse of dimensionality" problem. The number of state variables would be equal to the number of firms (i.e., the capacity of each firm), since this information would be needed to determine the production quantities. The number of states in each year t would be $(t+1)^7$ if firms had a choice of adding a machine or not in each year.

decision is optimal given the decisions of all other firms, and no firm would unilaterally wish to change its decision. Summing the firm production levels for that combination of firm capacities gives total industry production ($\sum q_i$), which, given the inverse demand curve, will determine the industry price in each year to be used to evaluate the capacity decision of each firm for that combination of capacities (this implies no changes in inventories).[4] For a given year, the industry demand function (where demand is a linear function of industry price) is assumed to be the same for all firms and to be known with certainty.[5]

We assume that once firms have chosen their capacity levels, firms seek to maximize one period profits. Therefore, to find the production level of each firm, we must solve the capacity-constrained profit maximization problem for all firms simultaneously in each year t=1,T. Without any constraints on capacity, this is just the simultaneous solution of the first order conditions for profit maximization (i.e., marginal revenue equals marginal cost) for each firm, where each firm's marginal revenue is a function of the decisions of the other firms. With capacity constraints, we find the Kuhn-Tucker conditions for optimization for each firm by introducing Lagrangean multipliers for each constraint and developing the Lagrangean function for each firm. We can then use these conditions to solve iteratively for the simultaneous solution (see Section 4.4.2).

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4 Strategic decisions about inventories may also be important. These are made simultaneously with decisions about production, since a firm may choose to accumulate inventory rather than cease production, or run off its inventory rather than increase production. By ignoring the strategic aspects of inventory management, we are assuming that a firm's inventory is roughly constant on average from year to year. The preferred method of dealing with this problem is to include inventory levels a third strategic decision variable. This may be done at a later stage in the development of the model.

5 The demand function faced by a firm, however, is a residual demand function, the value of which depends upon the firm's assumptions about its competitors. Under perfect competition, a firm faces a flat demand curve; it assumes it can produce as much as it wants at the industry price, without affecting the price, and does not consider its competitors. In an oligopoly, a firm is assumed to recognize that the small number of firms means that one firm's actions can indeed influence price. The demand curve faced by a firm is as follows:

$$q_i = D(P) - Q_{-i} = b_0 + b_1 \cdot P - Q_{-i}$$

where Q_{-i} is the quantity produced by the rest of the industry. If a firm anticipates that other firms will react to its quantity decision, then Q_{-i} may be a function of q_i.

The $\tilde{q}_{it}$ presented in problem 4.1 are thus defined as follows. In a particular year t=1 to T, each firm i is assumed to maximize one-period profits when determining its production level, given its capacity level k_{it}:

$$(4.4) \quad \max_{q_{it}} \pi_{it} = q_{it} \cdot P_t - C_{it}(q_{it}, k_{it})$$

$$\text{s.t. } 0 \leq q_{it} \leq k_{it}$$

$$q_{jt},\ j \neq i \text{ given}$$

$$q_{it} = D(P) - \sum_{j \neq i} q_{jt} = D(P) - Q_{-it}$$

We solve for an equilibrium vector $\tilde{q}$ such that

$$(4.5) \quad \pi_{it}(\tilde{q}_{it}, \tilde{q}_{-it}, P_t, k_{it}) \geq \pi_{it}(q_{it}, \tilde{q}_{-it}, P_t, k_{it}) \text{ for all i, i=1..n,}$$

$$\text{where } \tilde{q}_{-it} = (\tilde{q}_{1t}, \tilde{q}_{2t}, \ldots, \tilde{q}_{i-1t}, \tilde{q}_{i+1t}, \ldots, \tilde{q}_{nt}).$$

Under certain conditions (that are fulfilled in the empirical implementation of the model [e.g., C_{it} convex]), there will be a unique Nash equilibrium in $\tilde{q}$ (see proof in Appendix I).

The assumptions that firms make their decisions on annual production simultaneously and that the decision is a one shot game are strong ones. Clearly production is not a one shot decision, but a continuing decision over time. We chose not to model the production decision as a dynamic game (e.g., see Benoit and Krishna 1987, Brock and Scheinkman 1985, Shapiro 1989) for a number of reasons, the major ones being computational ease and simplicity. In addition, there are problems in choosing between multiple equilibria (and for our model we need to have only one equilibrium price per year and set of capacity choices), and the modelling is complex when demand and cost conditions change over time. Although we model the production decision as a one shot game, we can incorporate some "reactions" in the model by using the concept of conjectural variations.

This conjectural variation term, $\partial(Q_{-i})/\partial q_i$, is firm i's assumption about the change in the rest of the industry's quantity given a change in firm i's quantity. If firms are assumed to choose quantity levels, then a firm's reaction function is its profit-maximizing output as a function of its competitors' output decisions, i.e., $q_i = f(Q_{-i})$. The rate at which the firm's optimum quantity will change as a result of a change in its rivals' output is the slope of its reaction function. A firm makes conjectures about the slope of its competitors' reaction functions, and these are called conjectural variations (Kamien and Schwartz 1983). This is the firm's conjecture about how the rival's output will change with a change in the firm's output.

If firms take their rivals' outputs as given, i.e., they have zero conjectural variations, this is called the Cournot behavioural assumption. By assuming other values of conjectural variations, output quantities for firms may range from the competitive to the monopolistic solutions. For example, if each firm believes that any quantity increase will be matched by its competitor (conjectural variations equal to one), then the total industry quantity produced will be the same as that of a monopolist (see Kamien and Schwartz 1983).

There are conceptual difficulties in trying to capture the dynamics of the decision process within a static framework using conjectural variations.[6] However, the conjectural variation approach has the advantage of being simple to use and explain. In addition, a wide range of behavioural assumptions can easily be tested by simply changing the value of the conjectural variation term. Since industry structure and competitors remain fairly constant over time, firms get to know each other over time. If we assume that the firms are in a "steady state" type of situation, where they are not learning any new information about their competitors, then it is reasonable to model the quantity decision as if firms have constant conjectures about their rivals (although the value of these conjectures may differ between firms).

4.2.2 Incorporating uncertainty into the model through scenarios

Up to now, we have assumed that there is no uncertainty in the model. We can incorporate uncertainty through the use of probabilistic scenarios, that describe possible environments external to the model. A scenario presents a plausible future, a future state of the world (or of all factors of concern to the firms in the industry), and with it is associated a probability of occurrence. In the

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[6] See, for example, Dixit (1986), Boyer and Moreaux (1983), Makowski (1983), Kamien and Schwartz (1983) and Friedman (1983) for various arguements.

newsprint model, the main external influence that we consider is the industry demand function over time. In particular, for each demand scenario, the coefficient on price and the intercept in each year are specified for each year t=1..R (where the intercept is based on external forecasts of economic growth, price of substitutes, exports, imports and fringe firm growth). (See Chapter V).

The specification of the model is modified as follows to include uncertainty.

Each firm i, i=1,n solves the following problem:

$$(4.6)\quad \underset{\{z_{i1},z_{i2},\ldots z_{iT}\}}{\text{Maximize}}\ E(\pi_i)=\sum_{d=1}^{m}\{\sum_{t=1}^{T}[\tilde{q}_{idt}\cdot P_{dt}(\sum_{j=1}^{n}\tilde{q}_{jdt})-C_{it}(\tilde{q}_{idt},k_{it}) - F_{it}(k_{it})-I_{it}(z_{it})]/(1+r)^{t-1} + V_i[(P_{dt},\ t=T+1,\ldots,R),\ k_{iT},\ K_d(\sum_{j=1}^{n}k_{jT})]\}\cdot p_d$$

where $k_{it} = k_{it-1}+ z_{it}$ $i=1,\ldots,n$

k_{i0} given $i=1,\ldots,n$

z_{jt}, $j\neq i$, $t=1,\ldots,T$ given

z_{it}=new capacity added by firm i in year t

k_{i0}=initial capacity of firm i

k_{it}= newsprint capacity of firm i in year t

q_{idt}= quantity of newsprint produced by firm i in period t in demand scenario d

$C_{it}(q_i,k_{it})$=firm i's variable cost of producing q_i in year t

$F_{it}(k_{it})$=fixed cost for firm i in year t

$I_{it}(z_{it})$ = investment cost for firm i in year t

$P_{td}(Q_t)$ is the inverse demand function in year t for demand scenario d

$K_d(\sum_{j=1}^{n}k_{jT})$=total industry capacity in years T+1 to R as a function of the demand scenario d and total industry capacity in year T. $K_d(K_T)$ is a vector $(K_{T+1},\ldots,K_R)$ where $K_{T+1}=\sum_{j=1}^{n}k_{jT}$

CU_d= the average capacity utilization of the industry in years T+1 to R for demand scenario d (a constant)

$V_i[(P_{dt}, t=T+1,...,R), k_{iT}, K_d]$= the net present value of future profits from years T+1 to R

r=the discount rate of the firm

n= number of firms in the industry

m=number of demand scenarios

p_d=probability of demand scenario d

We solve for an equilibrium solution matrix

(4.7) $Z^*=(z_{it}^*, i=1,...,n,\ t=1,...,T)$ such that $\pi_i(z_i^*, z_{-i}^*, P, K) \geq \pi_i(z_i, z_{-i}^*, P, K)$ for all i, where $z_{-i}=(z_1, z_2,...,z_{i-1}, z_{i+1},...,z_n)$.

The $\tilde{q}_{idt}$ are as follows:

Each firm i solves the following in each year t, for a given demand scenario d.

(4.8) $$\max_{q_{idt}} \pi_{idt} = q_{idt} \cdot P_{dt} - C_{it}(q_{idt}, k_{it})$$

s.t. $0 \leq q_{idt} \leq k_{it}$

q_{jdt}, $j \neq i$ given

$$q_{idt}=D_d(P_{dt}) - \sum_{j \neq i} q_{jdt} = D_d(P_{dt}) - Q_{-idt}$$

We solve for an equilibrium vector $\tilde{q}_{dt}$ such that

(4.9) $$E[\pi_{idt}(\tilde{q}_{idt}, \tilde{q}_{-idt}, P_{dt}, k_{it})] \geq E[\pi_{it}(q_{idt}, \tilde{q}_{-idt}, P_{dt}, k_{it})] \text{ for all i, i=1..n}$$

The function V_i is defined as follows.

(4.10) $$V_i(P_{dt}, k_{iT}, K_d) = \sum_{t=T+1}^{R} \{ P_{dt}(CU_d \cdot K_{dt}(\sum_{j=1}^{n} k_{jT})) \cdot CU_d \cdot k_{iT} - C_{it}(CU_d \cdot k_{iT}) - F_{it}(k_{iT}) \} / (1+r)^{t-1}$$

FIGURE 4.1: Time line for the model

Node 1	2	3	4	5	...	Node T+3
Nature chooses probability distribution for demand function scenarios	Firms 1 to n choose capacity in years 1 to T	Demand function scenario revealed	Firms 1 to n choose production levels in year 1	Firms 1 to n choose production levels in year 2		Firms 1 to n choose production levels in year T

Thus the V_i are a function of the demand scenario, indicating the notion that industry capacity adjusts to demand in the long run.

Figure 4.1 shows the decision time line for the model. This illustrates the order of actions and events, not necessarily the passage of time.

4.3 Implementing the model

4.3.1 Firms in the model

The time period under study is 1979 to 1983, the most recent major capacity expansion period in North America. In 1979 there were 31 firms in the industry (see Table 2.1). The five largest firms, Abitibi Price, International Paper, Bowater, MacMillan Bloedel and Consolidated Bathurst, comprising 49% of capacity, were modelled individually. The next eight firms in terms of size were grouped into two consecutive groups of four, and modelled as "strategic groups" in the model. This resulted in seven "firms" in the model. This grouping of firms was necessary in order to reduce the size of the model to facilitate computations. The remaining 20% of capacity was assumed to be the fringe, and its behaviour forecast exogenously to the model.[7]

[7] The capacity and operating rate of the fringe firms are estimated, to give an estimate of production. This production quantity is then subtracted from the industry demand function.

There are two ways of modelling a group of firms in the model. First, one could assume that the firms collude, that joint decisions are made, and that the group acts as one large firm. This is not very realistic in the case of the newsprint industry. Thus firms that are grouped together are assumed to behave and make decisions in a similar manner to each other, but to act independently. The group is assumed to be a group of four identical firms that will make the same decisions under the same set of circumstances. It would have been preferable to group firms not only by size, but also by other strategic characteristics, such as objectives, reputation, costs, etc. However, this would have increased the number of firms and groups to an unmanageable size (in terms of computing time).

Firms or groups of firms can differ from each other in the model according to various dimensions. They may have different variable cost functions, sizes (capacity), discount rates, conjectures about rivals, and objective functions.

4.3.2 Planning horizon

The planning horizon for the model is flexible, but for the implementation for the newsprint industry the total planning horizon is 15 years (R=15). The "short-run" immediate capacity decision is how much capacity to add over the next five years (i.e., T=5).[8] With a two year lag time, a decision to add capacity now means that the capacity comes onstream in year three of the planning horizon. Years six to 15 are the "long-run". Over this time period, firms are assumed to add capacity in such a way that demand and supply are balanced according to some assumption about long run price growth; i.e., demand and supply may balance such that there is no real price growth, or one percent per year price growth, etc. A firm could implement the model on a "rolling plan" basis, where the model is rerun in each time period as information is revealed.[9]

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[8] The choice of five years and 15 years are consistent with observed industry practice (e.g, Sierila 1987).

[9] Easley and Spulber (1981) have shown that for a rolling horizon of sufficient length, implementing the stationary rolling plan in each period is approximately optimal in comparison with the stationary infinite horizon policy.

4.3.3 Capacity in the short and long run

In order to limit the size of the model, firms are assumed to consider only the choice of adding zero or one machine to an existing facility, which comes onstream in year three of the planning horizon. With seven firms and two choices, there are $2^7=128$ possible combinations of firms' decisions.

Thus in year five of the planning horizon there are 14 possible industry states; the total number of machines added by all firms in the model will be between 0 and 13 (since there are 13 firms considered in the model). (The capacity of all other firms in the industry, i.e, fringe firms, is exogenously forecast for all years, and is netted out of the industry demand function.)

For years six to 15 then, there are many paths that the growth of capacity could take, starting from these 14 original states in year five. It is, however, reasonable to assume that over time, industry capacity will remain in balance with demand, despite short-term deviations from this path. If we estimate a demand function for each year, assume an average industry operating rate, and a reasonable long term price growth, we can determine the long run capacity growth of the industry such that this price growth will occur. We assume that the industry capacity levels after five years, in years 11 to 15, will be the same, no matter which state the industry is in year five. We are assuming that industry capacity will adjust, in time, to industry demand. These capacity projections are used to calculate the V_i for each possible firm capacity choice z_i, given the choices of other firms, z_j, $j \neq i$. For a given z_i and z_j, $j \neq i$, we can calculate $\sum_{j=1}^{n} k_{jT}$ (where $k_{jt}=k_{jt-1} + z_{jt}$, k_{j0} given). The capacity projection used to calculate V_i for this combination of firm capacity choices for firm i has $K_{T+1} = \sum_{j=1}^{n} k_{jT}$.

There are a number of probabilistic demand scenarios that represent different futures in terms of demand growth. For a given industry demand scenario, there will be an anticipated industry capacity growth level in years 11 to 15, and in years 6 to 11 capacity will grow at different rates depending upon the number of machines added in the short run. Again, this growth will be based on some assumptions about average industry operating rate and long term price growth, (that may differ by demand scenario).

4.4 Solving the model

4.4.1 The capacity problem

To solve the capacity problem, we need to find the matrix Z^* (equation 4.2, without uncertainty or 4.7, with uncertainty), i.e., the matrix of capacity choices z_i^*, for firms $i=1,\ldots,n$, such that $\pi_i(z_i^*,z_{-i}^*,P,K) \geq \pi_i(z_i, z_{-i}^*,P,K)$ for all i, where $z_{-i}=(z_1,z_2,\ldots,z_{i-1},z_{i+1},\ldots,z_n)$, and $z_i=z_{i1},\ldots,z_{iT}$. (Note, we need to first solve for the $\tilde{q}_{it}$, $i=1,..,n$, $t=1,\ldots,T$, for each possible Z [see below]).

The model is solved by an enumerative search algorithm. A variant of the backtrack algorithm is used. The algorithm is as follows:

i. For each firm i, find the best (e.g., highest expected profit) capacity option choice z_i^* for each possible combination of all other firms' capacity options excluding firm i, $z_{-i} =(z_1, z_2, ..,z_{i-1},z_{i+1},\ldots, z_n)$, where firm 1's capacity option is z_1, firm 2's option is z_2 , etc. (I.e., solve problem 4.1 (4.6 with uncertainty)). Do for all firms and capacity combinations (i.e., capacity matrices).

ii. For firm 1, for $z_1^* \in Z$, check if $z_2 = z_2^*$ for capacity combination Z.

iii. If yes, then check if $z_3 = z_3^*$ for capacity combination Z. Continue checking for each firm i=3,n.

If not, go to next capacity combination Z' and repeat ii for $z_1'^* \in Z'$.

iv. If $Z=(z_1^*, z_2^*, ..,z_n^*)$, then capacity combination Z is an equilibrium solution.

This algorithm finds all pure-strategy equilibria. Note that because of the integer nature of the problem, there is no guarantee of an equilibrium solution.

4.4.2 The production problem

To solve the production problem, we first determine the Kuhn-Tucker conditions for the problem for each firm. The Lagrangean for the problem 4.4 (or 4.8 with uncertainty) (ignoring time subscripts) for a given firm i is:[10]

$$L(q_i, \alpha_i, P, \lambda_i) = P \cdot q_i - C_i(q_i) + \alpha_i \cdot (k_i - q_i) + \lambda_i \cdot (D(P) - Q_{-i} - q_i)$$

where $Q_{-i} = \sum_{j \neq i} q_j$

The Kuhn-Tucker conditions are as follows:

1. a) $q_i \geq 0$

   b) $\partial L/\partial q_i = L_1 = P - C'(q_i) - \alpha_i - \lambda_i - \lambda_i \cdot (\partial Q_{-i}/\partial q_i) \leq 0$

   c) $q_i \cdot L_1 = 0$

2. a) $\alpha_i \geq 0$

   b) $\partial L/\partial \alpha_i = L_2 = k_i - q_i \leq 0$

   c) $\alpha_i \cdot L_2 = 0$

3. a) $P \geq 0$

   b) $\partial L/\partial P = L_3 = q_i + \lambda_i \cdot D'(P) \leq 0$

   c) $P \cdot L_3 = 0$

4. a) $\partial L/\partial \lambda_i = D(P) - Q_{-i} - q_i$

We can simplify (1) and (2) as follows.

If $q_i = 0$

then from 2(b) and 2(c) we know that $\alpha_i=0$ (since $L_2 = k_i$).

[10] Note that the constraint $q_i=D(P) - Q_{-i}$ is not really required, and could be directly incorporated into equation 4.4 (4.8). However, the solution algorithm requires its explicit inclusion.

Thus we know that 1(b) is $P - C'(q_i) - \lambda_i - \lambda_i \cdot (\partial Q_{-i}/\partial q_i) \leq 0$.

If $q_i = k_i$

Then from 2(b) and 2(c) we know that $\alpha_i \geq 0$ (since $L_2 = 0$)

and since $q_i > 0$ we know that $L_1 = 0$

thus 1(b) is $P - C'(q_i) - \lambda_i - \lambda_i \cdot (\partial Q_{-i}/\partial q_i) = \alpha_i$,

and thus $P - C'(q_i) - \lambda_i - \lambda_i \cdot (\partial Q_{-i}/\partial q_i) \geq 0$.

If $0 < q_i < k_i$

Then $\alpha_i = 0, L_2 > 0, L_1 = 0$ (since $q_i > 0$)

thus $P - C'(q_i) - \lambda_i - \lambda_i \cdot (\partial Q_{-i}/\partial q_i) = 0$

So we have

$$P - C'(q_{i,}) - \lambda_i - \lambda_i \cdot (\partial Q_{-i}/\partial q_i) \begin{cases} \leq 0 \text{ if } q_i = 0 \\ = 0 \text{ if } 0 < q_i < k_i \\ \geq 0 \text{ if } q_i = k_i \end{cases}$$

Also in equilibrium, $P > 0$ therefore $L_3 = 0$ and thus

$$q_i + \lambda_i \cdot D'(P) = 0$$

or $\lambda_i = -q_i/D'(P)$

Thus we have in equilibrium, for each firm,

$$(4.11)\quad P + q_i/D'(P) + (q_i/D'(P)) \cdot (\partial Q_{-i}/\partial q_i) - C'(q_i) \begin{cases} \leq 0 \text{ if } q_i = 0 \\ = 0 \text{ if } 0 < q_i < k_i \\ \geq 0 \text{ if } q_i = k_i \end{cases}$$

and

$$(4.12)\quad D(P) = \sum_{j=1}^{n} q_j$$

Equation 4.11 can be restated as marginal revenue equals marginal cost, when $0<q_i<k_i$. Marginal revenue equals the industry price, plus the change in price as a result of the firm's production quantity, plus the change in price as a result of the change in production quantity of the rest of the firms as a result of a change in the firm i's production. We then have marginal revenue minus marginal cost ($C'(q_i)$) equals zero.

These conditions (equations 4.11 and 4.12) can be used to solve for the equilibrium solutions $\tilde{q}_{it}$ (equation 4.5 or 4.9), where $\pi_{it}(\tilde{q}_{it},\tilde{q}_{-it},P_t,k_{it}) \geq \pi_{it}(q_{it},\tilde{q}_{-it},P_t,k_{it})$ for all i, i=1..n, and $\tilde{q}_{-it}=(\tilde{q}_{1t},\tilde{q}_{2t},\ldots,\tilde{q}_{i-1t},\tilde{q}_{i+1t},\ldots,\tilde{q}_{nt})$.

A bisecting search algorithm (adapted from Salant (1982)) is used to determine the solution of the Kuhn -Tucker conditions for the production problem as follows:

i Set upper and lower bounds on price, $P_{UB}= B$ and $P_{LB}=L$, where $L<B$

ii. Determine a price $P=(P_{UB}+P_{LB})/2$.

iii. Relax equation (4.12).

iv. Solve equation (4.11) for each q_i independently, i=1,...n.

If $q_i > k_i$, $q_i = k_i$. If $q_i < 0$, $q_i = 0$.

v. If $\Sigma_i q_i > D(P)$, then $P_{UB}=P$, $P_{LB}=L$ and go back to ii.

If $\Sigma_i q_i < D(P)$, then $P_{UB}=B$, $P_{LB}=P$ and go back to ii.

If $\Sigma_i q_i = D(P)$, (within some tolerance limits) then stop.

We start with a price P. Each firm then determines how much it would produce at that price. We then sum up the quantities that would be produced at that price. If the sum is greater than demand at that price, then the price must be lower. If the sum is lower than demand at that price, then the price must be increased. We iterate to find the market clearing, equilibrium price. This procedure is repeated for each year t=1 to T, given the demand function in that year.

This algorithm finds only one equilibrium. As noted earlier, the solution to the production problem exists and is unique under certain conditions that are fulfilled in the implementation of the model (see Appendix I).

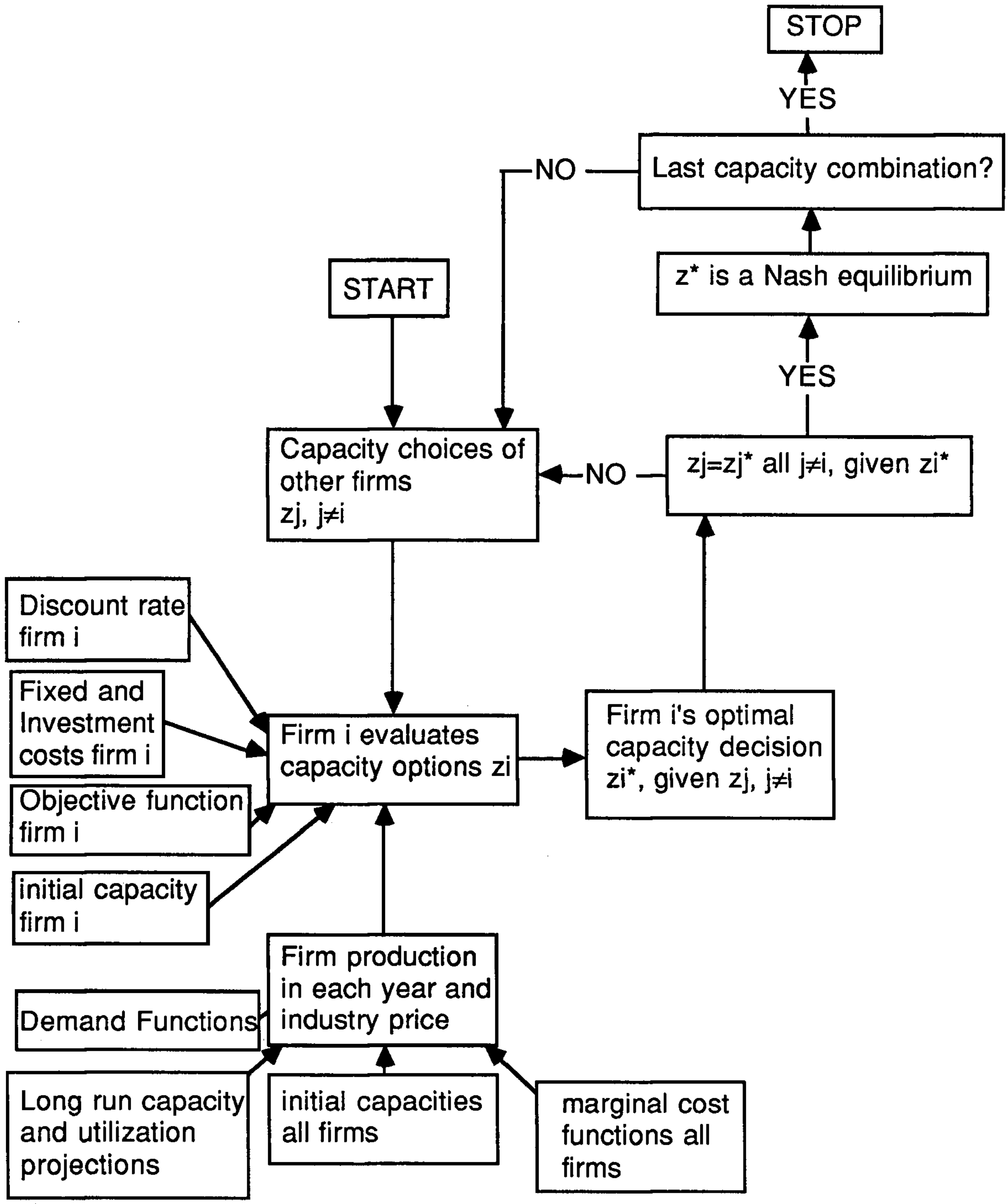
4.5 Computational aspects

With 7 firms (n=7), a five year short run horizon (T=5), a 15 year planning horizon (R=15), two capacity choices per firm, and one demand scenario, the CPU time required to solve the model on an IBM 3081 K mainframe is about 16.3 seconds; with three demand scenarios, the CPU time required is about 41 seconds. With three capacity choices and one demand scenario, the CPU time required is about 200 seconds. The model was written in FORTRAN 77. (See Appendix IV for a listing of the program).

4.6 Summary

Figure 4.2 shows a schematic outline of the model. Firms first choose their capacity levels for all years, and then knowing each others' capacity levels, they determine their production levels in each year. For any given capacity level, firms are assumed to "see through" to the production equilibrium. The basic solution concept is the Nash equilibrium. The Nash equilibrium solution for the capacity problem is determined as the set of firm capacity options such that each firm is using its preferred option, given the preferred options of all other firms, and no firm has an incentive to change its option choice. For each year, there is also a Nash equilibrium in production for each possible set of capacity decisions for all firms, for a given demand function. Figure 4.1 shows the decision time line for the model.

FIGURE 4.2: Outline of model



CHAPTER V

DATA AND PRODUCTION COMPONENT VALIDATION

5.1. Introduction

The time period chosen for the implementation is 1979 to 1983. During this time period, a large number of firms expanded capacity. Thirteen firms are included in the model: Abitibi-Price, International Paper, Bowater, MacMillan Bloedel and Consolidated Bathurst are modelled individually and there are two groups of four firms each. These 13 firms represent 80% of the capacity in 1979. The actions of the remaining 20% are forecast exogenously to the model.

This chapter summarizes the development of the database for the model, and component validation carried out to test the production and pricing estimation procedure. For this validation, we wanted to determine if, given the actual capacity decisions of firms and the cost and demand functions estimated from "observed" demand conditions, we could reproduce the production decisions and pricing outcomes using the model.

In order to validate the production portion of the model we needed the following information:

1. Individual firm capacities for 1979 to 1983
2. The residual demand function faced by the firms in the model from 1979 to 1983
3. Firm marginal cost functions for 1979-83 for capacity that existed in 1979 as well as cost functions for new capacity added.
4. Industry production and price (and firm production if available) to be used for comparison with model predictions.

The derivation of these items is discussed in the next four sections. This is followed by the presentation and discussion of the validating of the production and pricing component of the model.

5.2. Estimation of firm capacities

The capacities of each firm had to be estimated for each year in the five year period. The capacities needed were the actual capacity in place, thus reflecting any capacity decisions undertaken in this time period. The primary source of capacity data for Canada was the Canadian Pulp and Paper Association (CPPA) Annual Newsprint Supplement, and for the U.S. was the American Newspaper Publishers Association (ANPA) Newsprint Statistics. However, actual mill capacities of standard grade newsprint are less than those reported by the CPPA for some Canadian mills. This is because other grades of groundwood papers inflate the statistics for standard newsprint, and there is very little information on the extent of the problem.

Standard newsprint paper is defined predominantly by chief end-use, i.e., those papers used primarily in the printing of newspapers. There are also specifications with regard to basis weight (46 to 57 g/m^2), thickness (not more than 1.067 mm), amount of ash, sizing, size, colour and finish, that correspond to the U.S. Treasury Department's specifications for duty-free standard newsprint. As of 1980, all groundwood printing papers also enter the U.S. duty-free. However, prior to this date, Canadian producers were believed to classify what might be considered groundwood printing papers as standard newsprint in order to avoid the duty. Industry sources confirm that even today Canadian producers classify some of their groundwood printing papers as standard newsprint for a couple of reasons. One is to avoid revealing how much they actually produced in the past; the other is to avoid possible trade actions from groundwood printing paper producers in the U.S., because of the large market share that they actually have relative to their "reported" market share.

The problem is compounded by the close relationship between newsprint and other groundwood papers. They are often produced on the same machines,[1] and usually have only slightly different furnishes (e.g., groundwood specialties have more chemical pulp to improve brightness). The rotogravure newsprint (or rotonews) grade is an only slightly improved newsprint. It is machine finished which means it is smoother, and sells at about a $30 premium above standard newsprint. However, it is so similar to standard newsprint that most sources identify this grade as the primary cause of newsprint reporting difficulties.

Different sources report different newsprint capacities for mills as a result of this problem of grades. For example, while the CPPA reported Abitibi's mill in Sault Ste. Marie to be producing 92,000 tonnes of newsprint in 1979, Abitibi reported in its annual report of that year that the mill produced 100% groundwood specialty grades. Because these groundwood papers command a higher price than newsprint, they can be profitably produced on machines that are not profitable for newsprint production. (This is in fact why the machines have been converted from newsprint to groundwood specialties). Thus if these machines are included in the newsprint model, their high cost will mean that they will not be used to produce newsprint.

The basic mill capacities we used were primarily from the CPPA Annual Newsprint Supplement for Canadian firms and from the ANPA Newsprint Statistics for U.S. firms but an attempt was made where possible to adjust these basic capacities for groundwood specialties capacity as given in the firm's annual report. Actual newsprint capacity is thus less than that reported in the CPPA Annual Newsprint Supplement for some firms.

Table 5.1 shows the capacities of the firms in the model for each year. These capacities have been adjusted from CPPA data for GWS papers, as well as strikes, and changes in ownership. Appendix II outlines the adjustments made for each firm. These capacities also reflect any changes as a result of capacity expansions, conversions or shut-downs over the five year period, and thus reflect actual capacity decisions by the firms.

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[1] For example, a firm might use a machine for 10 months to produce newsprint, and for two months to produce groundwood specialty papers.

TABLE 5.1 Standard newsprint capacity by firm, 1979-1983. (1,000 tonnes)

	1979	1980	1981	1982	1983
1. Abitibi-Price	1,698	1,416	1,808	1,893	1,823
2. International Paper	985	999	1,023	744	809
3. Bowater	1,165	1,285	1,308	1,333	1,266
4. MacMillan Bloedel	775	1020	856	732	694
5. Consolidated Bathurst	700	640	700	636	639
6. Kimberly Clark	683	693	691	694	703
Ontario Paper	635	637	632	590	672
St. Regis	584	591	680	736	736
Boise Cascade	519	602	707	700	714
Group I Average	605.25	630.75	677.5	680	706.25
7. Kruger	409	405	450	475	450
Crown Zellerbach	393	406	406	529	413
Great Lakes Forest Products	372	372	388	394	396
Publishers Paper	350	354	488	526	518
Group II Average	381	384.25	420	481	444.25
Total All Firms in Model	9,268	9,792	10,274	9,982	9,831
All Other Newsprint Firms	2,483	2,908	3,166	4,044	4,372
TOTAL INDUSTRY	11,751	12,700	13,440	14,026	14,203

SOURCES: CPPA Newsprint Supplement and ANPA Newsprint Statistics, various years. Annual reports of firms, newspaper clippings, Pulp and Paper Journal (various years).

NOTE: See Appendix II for derivation of capacities.

5.3. Estimating firm's marginal cost curves

5.3.1. Introduction

In order to model the quantity decision of a firm (how much a firm produces in a given year), we needed to estimate its cost curve, i.e., its cost of producing various quantities of newsprint. Because fixed costs are dependent only upon total capacity for the firm (which is fixed in the short run), at this stage we only need to consider variable costs. The main components of variable cost in the newsprint industry are: furnish material (i.e., roundwood, chips, pulp, recycled fibre, chemicals, etc.), labour, transportation, energy, and other materials and supplies (i.e., maintenance materials, operating materials, etc.). The importance of these component costs varies by firm and by region.

We know that there are major cost differences between firms. However, several factors account for a large part of these differences. The first is the location of a firm's mills. Location has a major impact on costs of inputs, as well as transportation costs. The second is the age and size of its paper machines. This has an impact on labour productivity (number of finished tonnes of newsprint per manhour) because larger machines substitute capital for labour.[2] There are also lower maintenance costs for newer, larger machines. Thirdly, the furnish mix affects wood costs, since wood requirements per tonne of newsprint vary depending upon the pulping process. Chemical costs and energy costs are also affected by pulping process and furnish mix. Lastly, the proportion of energy purchased as opposed to self-generated is a major cost difference between firms.

The method for determining the distribution of a firm's costs assumed that these were the only factors differing between firms. Table 5.2 summarizes the major variable cost components and the main factors affecting them. The regions used were British Columbia (B.C.) Coast,

[2] This substitution of capital for labour means that while labour costs may be lower, capital costs may be higher. However, capital costs are fixed and thus independent of quantity produced.

TABLE 5.2: Major factors assumed to influence a mill's average variable cost.

Cost component	Factors influencing
Wood	region, pulp processes
Chemicals	region, pulp processes
Energy	region, pulp processes, percent of power purchased
Transportation	region
Labour	region, machine size
Materials and supplies	region

Canada East, U.S. Northwest, and U.S. South. The procedure that was used to estimate the firms' cost curves and its underlying assumptions are outlined below. Wood, chemical, energy and transportation costs per tonne were determined on a mill by mill basis. Labour cost per tonne was determined on a per machine basis. Component costs were estimated individually and then summed. This will facilitate the incorporation of improved information and more detail as it becomes available.

The firm cost curves had to be estimated for each year in the short-run planning horizon (i.e., 1979 to 1983 inclusive).

5.3.2. Labour costs

First, the capacity of all paper machines for a firm, by region, was determined. Then, the average labour cost per tonne for each machine size was determined, based on labour requirements and regional labour costs.

Distribution of machine sizes. Information on the speed, width and trim[3] of individual paper machines, 1979 to 1983, by mill was collected from Post's Pulp and Paper Directory and

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[3] Trim is the width of paper after the edges have been trimmed off.

Lockwood's Directories of the Paper and Allied Trades. The annual capacities of some paper machines were collected from Canadian Paper Analyst (1984). The capacities of other machines were estimated by comparing their speed and trim with those of machines with known capacities.[4]

Once machine capacities were estimated, these were summed for each mill and compared to total mill capacities from the CPPA and ANPA (CPPA Annual Newsprint Supplement and ANPA Newsprint Statistics, various years). Large discrepancies were investigated further (e.g., by looking at earlier or later directories). Because annual capacity is not an exact measure (e.g., it is dependent upon the number of days worked), discrepancies of up to 15% were allowed.

As noted earlier, the definition of newsprint grades as opposed to groundwood specialty (GWS) paper grades is not clearcut. We found, for example, that some firms reported producing much higher amounts of GWS in their annual reports as opposed to what they reported to the CPPA. (Abitibi Price and CIP were two firms that had significant differences between these two sources). Since GWS generally command a higher price than newsprint, firms can produce GWS on more costly machines than newsprint and still make a profit. (Some machines can produce both grades; others have been upgraded from newsprint to produce only GWS). We chose the CPPA mill capacities as the basic estimate of standard newsprint capacity for calculating cost curves. The estimated machine capacities were thus scaled so that the sum of the machine capacities for a mill equaled the CPPA capacity in that year for that mill.[5] See Figure 5.1 for an example of the distribution of machine sizes for a firm.

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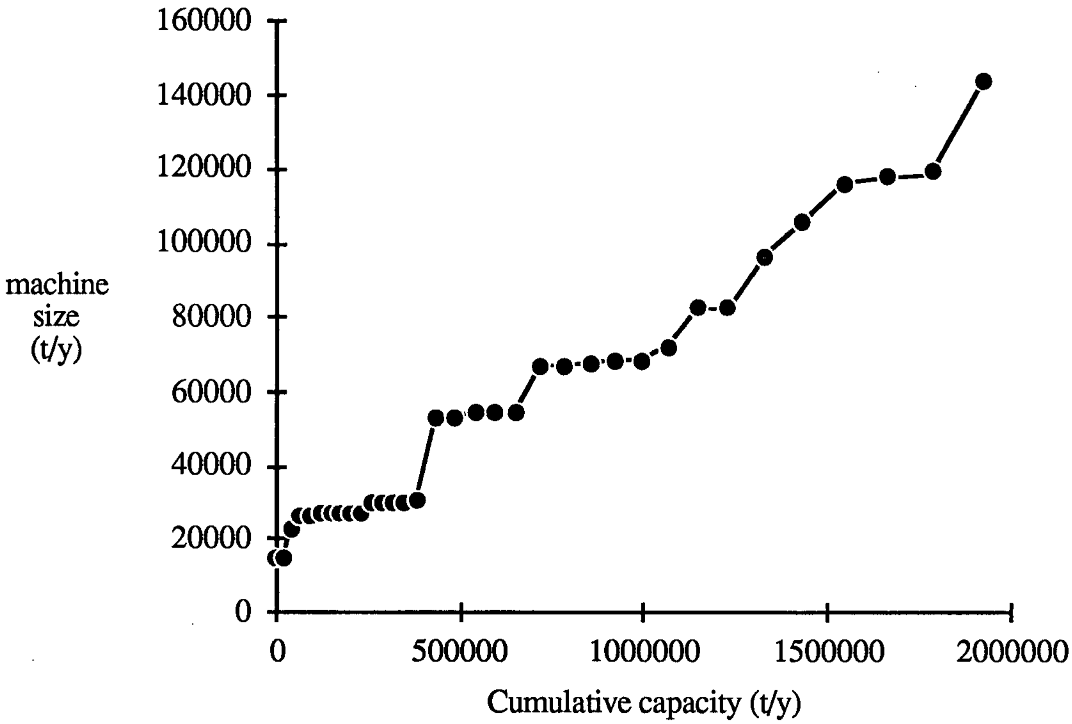
[4] As might be expected, there was a strong linear relationship between machine capacity (t/year) and a variable representing speed times width (i.e., m2/min). The equation of the line was Capacity=7616.13+17.734 (s·w). This was used to help estimate machine capacities, with some rounding off of estimates.

[5] If the estimated mill capacity was greater than the CPPA's estimate, we assumed that the difference was attributable to GWS papers, and thus reduced the capacity by reducing the mill's capacity of the highest cost machines first . If the estimated mill capacity was less than the CPPA's estimate, we inflated each machine's capacity equally.

FIGURE 5.1: Abitibi-Price capacity by machine size, 1979.



Machine size and costs. While other variable factors are affected by machine capacity or size, the major component affected is labour. A machine requires a crew, regardless of machine size.[6] Larger machines represent a substitution of capital for labour.

Information on the relationship between manhours required per unit of output and machine size was obtained from several sources. Firstly, the FSAC Newsprint Cost Study (1987) reported average machine size (capacity) and average number of manhours required per tonne for five countries, for 1982 to 1987. If we assume that the technology of paper machines is similar between countries, and that the productivity of other factors (e.g., capital, wood) are also similar, then we can pool the data and derive a relationship between manhours per tonne and machine size. However, this data was for mean machine size and mean manhours per tonne for each country, and the manhours per tonne of a machine of mean size does not necessarily correspond to the mean manhours per tonne of the country. Anderson and Bonsor (1981) report average manhours per unit of output for three different machine sizes. In addition, manhours per tonne for various machine sizes were derived for some sample points in Post's and Lockwood's directories. Only mills that produced only newsprint and no other products, that had only one size of paper machine(s), and that had information on total number of employees, were included in the sample. This led to 10 more data points.[7]

A plot of these data (see Figure 5.2) shows a fairly linear trend with some indication of nonlinearity for lower machine sizes. There were no data points for machine sizes less than 40,000 t/y. The estimated equation of the line is:

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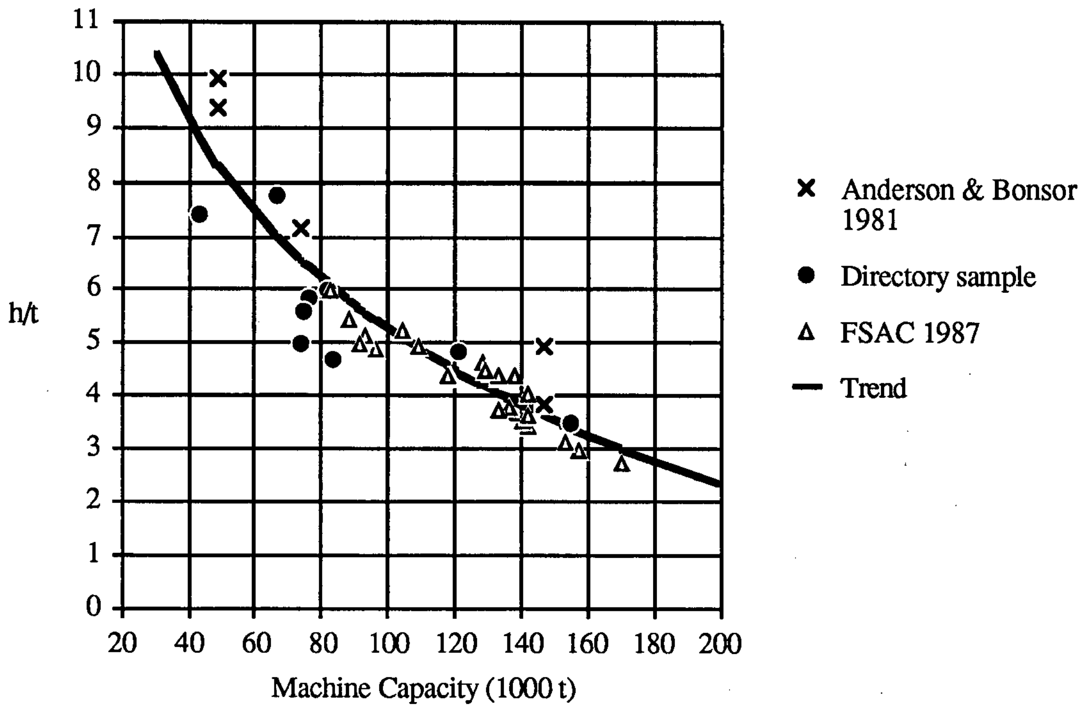
[6] Some references indicated that, as a result of both union agreements and industry practice, the size of crew for a paper machine was independent of its width or speed (Gray 1981).

[7] Given the number of employees at a mill site, we estimated the total number of hours worked in a year, and divided that by the total annual capacity of the mill. This gave us the average manhours required per tonne of output of the mill, and thus for the machine size used at that mill. (Total number of hours worked per year per employee=40h/wk · 49 wk/yr).

FIGURE 5.2: Labour productivity and machine size
(Y=a+logX)



$$\text{LABREQ} = 24.83 - 4.252\ \text{LN(CAPACITY)} \qquad \text{Adj. } R^2 = 0.81$$

(16.3) (13.0) (t-statistic)

(manhours/t) (t/year)

This equation was used to estimate the quantity of labour required per tonne of output for each paper machine.

Labour cost per hour. From RISI, we had wages ($/hr) by region. From the FSAC study (1987) we had estimates of the percentage of labour cost from "nonwage" costs, (e.g., benefits, dollars for time not worked) also by region.[8] From these, we determined the total labour cost ($/hr) by region.

Labour cost per tonne. Given the information in (2) and (3) above, we determined the labour cost per tonne for each machine size in each region.[9]

5.3.3. Fibre costs

The fibre cost per tonne of newsprint depends upon a number of factors. The percentage of high yield mechanical pulps (yield of 95%),[10] as opposed to sulphite (yield of 65%) or kraft pulp (yield of 45%), determines the total amount of wood required per tonne of newsprint. The density of wood will also affect the amount of wood required; this can be assumed to be region dependent. Southern pine, for example, is much denser than Eastern Canada species. The cost of fibre per unit input depends on such factors as region and type of fibre (e.g., roundwood, chips or recycled paper). We assumed that the mix of fibre type inputs differed only on a regional basis, thus basic fibre input cost varied only by region.

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[8] The earliest year reported is 1982, so we assume this percentage holds for previous years.

[9] Note that wages per hour for an employee may increase with increasing machine speed and trim (Gray 1981). We assume that this increase is not large and ignore it for simplicity.

[10] I.e., for 100 tonnes of wood input, 95 tonnes of fibre are made into pulp.

The basic idea used to determine wood costs per tonne of newsprint by mill was to take the regional estimate for wood cost (from RISI) and then adjust the individual mill level wood cost to account for differences between that mill's furnish mix and that of the "average" mill in that region. For most mills, we determined the percentage of each type of pulp used to produce newsprint from Post's Directory, which has volumes of pulp produced per day by type. This information was supplemented by Canadian Paper Analyst (1984).[11] Sandwell (1977) reports average percentage of each type of pulp used to produce newsprint by region. Given an average wood cost per tonne of newsprint (by region from RISI), we used these average percentages, plus the information on pulp yields given above, to derive a cost per tonne of fibre input for that region. (This is the average cost per tonne of input fibre, which is a weighted average of the costs of logs, chips, etc). Then this cost per tonne of fibre input divided by the average yield (output per unit of input fibre) of a mill is an estimate of the wood cost per tonne of newsprint for that mill. An example for a B.C. mill with 90% groundwood pulp and 10% kraft pulp follows.

B.C. fibre cost=63 \$/t of newsprint

B.C. average pulp mix= 75% groundwood, 25% kraft

Yield of groundwood pulp=95%

Yield of kraft pulp=45%

Average yield= $0.75 \cdot 0.95 + 0.25 \cdot 0.45 = 0.825$ units wood output per unit wood input

Input wood cost in \$/t =(63 \$/t output) * 0.825 units wood output/ unit wood input

= 52 \$/t wood input.

Thus the input fibre cost for the B.C. Coast is 52\$/t.

For a B.C. mill with 90% groundwood and 10% kraft,

average yield= $0.9 \cdot 0.95 + 0.1 \cdot 0.45 = 0.9$

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[11] In some cases, firms purchase chemical pulp instead of producing it. We assumed that the costs of purchasing the pulp were equal to the costs of producing it in these cases. If no information was available on furnish mix, we assumed the firm's furnish mix was the same as that of the region's average.

Therefore the mill's wood cost per tonne of newsprint= 52$/t /0.9=58$/t

Since information about furnish mix by mill is not exact, we specified two to five representative furnish mixes per region, and mills were assigned the furnish mix that most closely represented their specific mix.

5.3.4. Chemical costs

Again, we compared a mill's furnish mix to the regional average furnish mix to determine how a mill's chemical costs per tonne should be adjusted relative to the RISI estimate of regional costs. For example, a mill with more chemical pulp than an average mill in that region would have a higher chemical cost per tonne of newsprint. Chemical costs include not only the cost of chemicals for the chemical pulp part of the furnish, but also groundwood brightening chemicals, colours, defoamers, alum, etc. Thus chemical costs are not directly proportional to the amount of chemical pulp used.

5.3.5. Energy costs

The cost of energy per unit of newsprint produced depends upon a number of factors, the most important of which are region and proportion of power purchased. Region affects unit input costs, which vary dramatically between regions, as well as energy requirements per tonne of newsprint. Energy requirements vary as a result of species differences and climate (e.g., lower heat requirements in the southern U.S.). The pulping process used also affects energy costs, since for example, stone groundwood pulp requires about 2,000 kwh/t compared to 2,400–3,000 kwh/t for thermomechanical pulp (TMP) (Tillman 1985).

Energy costs per tonne of newsprint were derived for each mill by adjusting the RISI regional energy cost per tonne of newsprint for differences in the percentage of purchased power between the mill and an average mill in the region. A number of assumptions were made in order to derive these mill costs. Firstly, the proportion of total energy cost attributed to each of steam and electricity was assumed to be constant for each region and equal to the proportion in 1982 (FSAC 1987).[12] Thus all the mills in a region were assumed to have the same steam cost per tonne of newsprint. Only the power portion of the energy cost varies by mill. Secondly, the cost of purchased power relative to the cost of generated power was assumed to be constant by region and equal to the factor as calculated in 1982 (FSAC 1987).

Given the percentage of power that an average mill purchases in a region (Sandwell 1977), the relative cost of purchased power and generated power in that region, and the average power cost in that region (from RISI and FSAC 1987), we determined the cost of 100% generated power or 100% purchased power per tonne of newsprint. Then, given a mill with purchased electricity differing from the regional average, we could determine its total energy cost. (Post's directory gives percent of electricity purchased for most mills. We assumed regional average costs for those mills for which we did not know the percentage of purchased electricity). An example for a B.C. Coast mill follows.

B.C. energy cost= 32 $ /t newsprint

% of energy cost attributed to electrical power=55%

B.C. power cost=$0.55 \cdot 32=17.6$\$/t

B.C. steam cost=$0.45 \cdot 32=14.4$ \$/t

Relative cost of purchased power to generated power in B.C.=2.25

Average % of power purchased in B.C.=71%

Total power cost $0.71 \cdot 2.25 \cdot y+0.29 \cdot y=17.6$

$y=9.3$\$/t=cost of generated power per tonne of newsprint

cost of purchased power=9.3*2.25=21.0\$/t newsprint

[12] The consumption of steam is higher in the chemical pulp process than in mechanical processes. Steam costs may also be higher for older machines (FSAC 1987). Steam costs are also affected by the proportion of steam generated from hog fuel as opposed to other fuels such as natural gas, oil or coal (Anderson and Bonsor 1981). These factors are not captured except on a regional basis.

Total energy cost per tonne of newsprint for a mill on the B.C. Coast that purchases 90% of its electrical power

= steam cost + purchased energy cost + generated energy cost

$= 14.4 + 0.9 \cdot 21 + 0.1 \cdot 9.3 = 34.2$ \$/t

Differences in furnish mix between mills also result in different power costs. We assumed that TMP required on average 36% more energy than stone groundwood pulp. Mills with TMP replacing groundwood pulp were assumed to have higher energy requirements in proportion to the amount of TMP in their pulp furnish.

5.3.6. Transportation costs

Transportation costs were determined by the location of the mill relative to the closest U.S. major market area. We used average transportation cost by region from RISI.

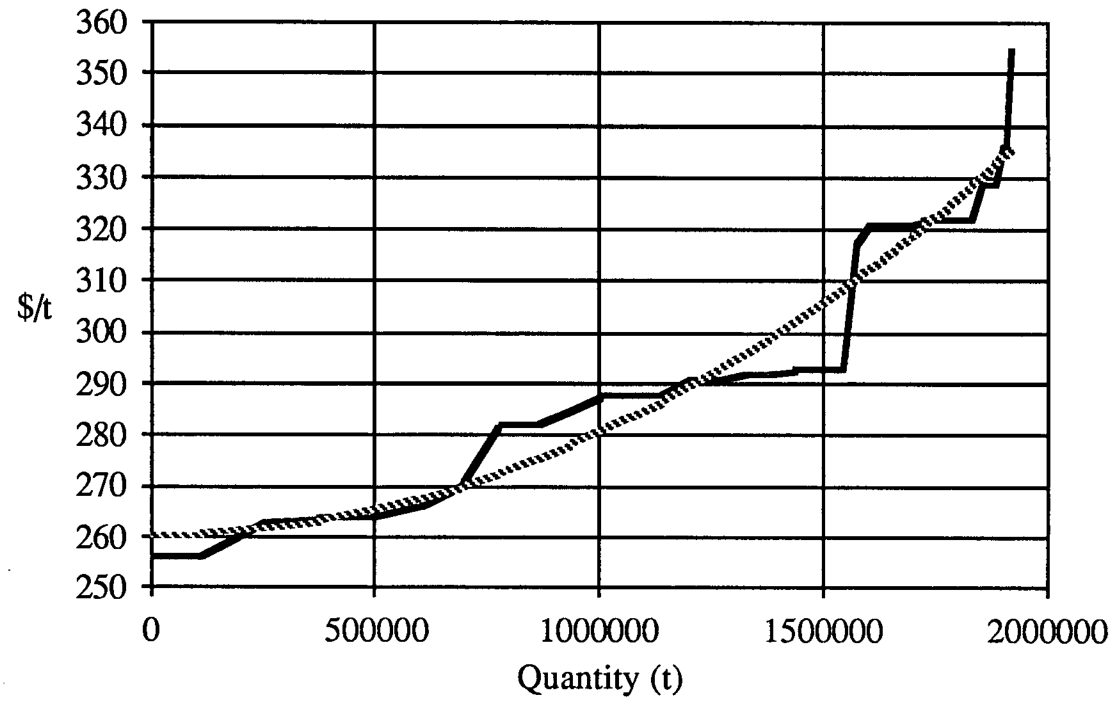
5.3.7. Other materials and supplies

All mills within a region were assumed to have the same costs for "other materials and supplies". We used average materials and supplies costs from RISI.

5.3.8. Derivation of marginal cost functions

For each mill, we calculated the average energy, wood, chemicals, transportation and materials and supplies cost per tonne. For each machine at each mill, we calculated labour cost per tonne. Then average variable cost per machine was calculated by adding on all "mill-level" costs for each machine. Then for each firm, we sorted the machines by cost and plotted this "marginal cost" against cumulative capacity (Figure 5.3).

FIGURE 5.3: Abitibi-Price 1979 marginal cost curve
(1979 US$/t)



If we assume that firms shut down their highest cost machines first, then this curve approximates the firm's marginal cost curve.[13] (Marginal cost (MC) is the cost per tonne of producing the last tonne of newsprint). Since a firm can shut down a machine for a length of time less than a year, the curve can be made piecewise linear. The equation of the marginal cost curves were estimated using regression analysis (MC=f(Q,Q2)) (Figure 5.3). Table 5.3 reports the estimated coefficients of the marginal cost curves for each firm and year. (Note that the cost curves were estimated in nominal U.S. dollars. The coefficients were then converted into 1979 U.S. dollars using the U.S. GNP deflator.)

The cost curves were estimated for each year (1979 to 1983) for Abitibi-Price, Consolidated Bathurst, International Paper, Bowater, MacMillan Bloedel, and the two firm groups. Group one is Boise Cascade, St. Regis, Ontario Paper, and Kimberly Clark and group two is Crown Zellerbach, Publishers Paper, Great Lakes and Kruger. An "average" marginal cost curve was derived for each group, by estimating the individual piecewise linear cost curves for each firm from the data, and then using all four firms' data in the regression analysis to determine the coefficients of the equation.

5.4. Estimating the industry demand function

An industry demand function for North American newsprint needed to be estimated for the model. Over eighty percent of North American newsprint production is consumed in the U.S., so the U.S. demand for newsprint was estimated econometrically, and then Canadian demand and adjustments for imports and exports were made to the estimated function. The U.S. demand for

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[13] Industry experts confirm that, in most cases, firms will shut down their highest cost machines first. However, it is sometimes more economical for a firm to shut down an entire mill for a week than to shut down a machine for a month, for example. In cases where a firm owns multiple mills, there may also be pressure from communities and unions to spread the "down time" between mills. A firm will determine the best way to cut down on production subject to constraints imposed. However, the assumption that high cost machines are shut down first is a reasonable approximation to reality.

TABLE 5.3: Estimated coefficients of the firm marginal cost curves, 1979 to 1983. (1979 US$/1000 t).

		Intercept	Q	Q^2	R^2 (%)
1979	ABITIBI	260.2	0.0	2.032E-05	93
	BOWATER	246.2	0.03425	0.0	94
	CONBATH	270.4	0.0	8.942E-05	86
	CIP/IP	228.3	0.07897	0.0	93
	MB	252.0	0.0	4.838E-05	92
	GRP 1	226.6	0.12072	0.0	62
	GRP2	270.5	0.0	3.651E-05	43
1980	ABITIBI	269.8	0.0	1.826E-05	92
	BOWATER	265.1	0.02154	0.0	90
	CONBATH	277.2	0.0	8.536E-05	86
	CIP/IP	241.8	0.07251	0.0	92
	MB	266.6	0.0	5.950E-05	93
	GRP 1	255.7	0.0	1.649E-04	52
	GRP2	289.8	0.0	4.082E-04	32
1981	ABITIBI	266.1	0.0	1.710E-05	92
	BOWATER	260.5	0.02249	0.0	92
	CONBATH	274.7	0.0	8.386E-05	86
	CIP/IP	234.6	0.07538	0.0	96
	MB	264.0	0.0	5.026E-05	95
	GRP 1	251.9	0.0	1.385E-04	53
	GRP2	272.7	0.0	3.583E-04	68

TABLE 5.3 – Continued

		Intercept	Q	Q^2	R^2 (%)
1982	ABITIBI	256.3	0.0	1.633E-05	91
	BOWATER	247.1	0.03016	0.0	94
	CONBATH	270.7	0.0	8.724E-05	86
	CIP/IP	267.0	0.0	6.479E-05	94
	MB	267.3	0.0	6.7889E-05	92
	GRP 1	241.2	0.0	1.2169E-04	48
	GRP2	266.5	0.0	2.908E-04	67
1983	ABITIBI	256.0	0.0	1.908E-05	90
	BOWATER	239.5	0.04109	0.0	92
	CONBATH	275.2	0.0	8.512E-05	86
	CIP/IP	264.9	0.0	6.478E-05	96
	MB	236.9	0.0	7.055E-05	91
	GRP 1	239.5	0.0	1.144E-04	52
	GRP2	260.2	0.0	2.506E-04	47

NOTE: All coefficients are significant at the 99% level of confidence.

newsprint (C) is assumed to be a linear function of newsprint price (P), U.S. GDP, and price of printing and writing papers (PS).[14] A dummy variable is also included for the 1975 manufacturers' strike (ST).

In 1974, most producers reduced the basis weight (g/m^2) of newsprint, which resulted in a reduction in total tonnage consumed (for a given number of sheets of newsprint, the tonnage went down). Consumption prior to 1974 was thus adjusted to correspond to the tonnage that would have been consumed at this lower basis weight (based on estimates from the CPPA Annual Newsprint Supplement). Thus all consumption figures are in 48.8 g/m^2 equivalent. (We also tested the price effect of the basis weight shift by including a dummy variable for pre and post 1974, and a price times the dummy variable, but neither were significant).

The U.S. consumption function was estimated assuming a linear functional form.[15]

(5.1) $C=b_0+b_1 P+b_2 GDP+b_3 PS+b_4 ST.$

Using data for 1966 to 1986, the U.S. consumption function was estimated to be:

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14 U.S. apparent consumption was estimated from data in the CPPA Newsprint Supplement. The newsprint price we used was based on the Bureau of Labour Statistics (BLS) Producer price index for newsprint. We transformed it into the actual transaction price by taking the known actual price in one year (1970), and adjusting each year's price index accordingly. The price used for the closest substitute product was the BLS producer price index for uncoated book paper, no. 3 offset. In reality, the closest substitute for newsprint is uncoated groundwood papers (UGW) (of various grades), since these will compete for the newspaper insert market. Since only partial time-series data were available for UGW, we compared regressions using book paper and UGW over the partial time periods available and found that the results were similar. This gave us confidence in the use of uncoated book paper as the closest substitute. U.S. GDP is from the National Income and Product Accounts of the U.S., U.S. Department of Commerce, Bureau of Economic Analysis. All dollar figures are in U.S. dollars, deflated to 1979 constant dollars by the U.S. GNP implicit price deflator, also from the National Income and Product Accounts of the U.S.

15 We estimate consumption as apparent consumption which equals production–exports+imports–inventory changes.

(5.2) $C = 1065.93 - 8.5150\,P + 4.1770\,GDP + 9.9406\,PS - 336.93\,ST$

(1.18) (-5.56) (27.3) (2.27) (-2.07) (t-statistic)

Adjusted R^2=99%

All parameter estimates except the intercept are significant at the 95% level or better. We substituted in the values for GDP, price of printing and writing papers and the strike dummy (equals 1 in 1975, and zero otherwise) to obtain the U.S. consumption function as a function of price of newsprint only. For example, in 1979 the adjusted intercept is 13489.72 (b_1 remains at -8.5150).

However, we are concerned with the total production of firms. We must therefore also consider exports, imports, Canadian demand,[16] and inventories.

Total North American production= U.S. consumption – imports to N.A. + exports from N.A. + Canadian consumption + change in inventories.

The total industry demand curve is a function of all these variables. Assuming that all variables are exogenous except U.S. consumption, the observed values for each year can be substituted in. From (5.1) and (5.2):

(5.3) Demand for NA newsprint= (b_0 – imports + exports + Canadian consumption + change in inventories) + b_1 P+ b_2 GDP + b_3 PS + b_4 ST

We also had to make some assumptions about the quantity produced by the fringe (i.e., firms not explicitly in the model), and subtract this quantity to get the residual demand faced by the

[16] Note that a demand function for Canadian newsprint could have been estimated. However, total Canadian consumption is only about 10% of total North American consumption, so it was assumed to be exogenous for simplicity.

13 firms in the model. We took the total capacity of the fringe as calculated from the CPPA Annual Newsprint Supplements and multiplied by the average operating rate of the U.S. for that year. This gave us fringe production for that year, which we then subtracted from the intercept of the demand function.[17]

(5.4) Demand for NA newsprint= $(b_0 + b_2\ GDP + b_3\ PS + b_4\ ST$ – imports + exports + Canadian consumption + change in inventories – fringe quantity) $+ b_1 P$

or

$D = b_0' + b_1 P$

where, for example, in 1979 $b_0 = 13{,}323.21$ and $b_1 = -8.5150$.

This is the demand function used in the model. b_0 shifts over time as we substitute in the actual values of GDP, imports, exports, Canadian consumption and inventory changes, but b_1 stays the same.

As with the capacity numbers, there was a problem with the consumption figures for newsprint. Apparent consumption includes some groundwood printing papers since Canadian figures for production and exports of newsprint are flawed.[18] The capacity correction for each firm was converted to a production figure by multiplying by the operating rate for that firm. The industry demand function for newsprint was then adjusted by subtracting off from b_0' the total firm production that was groundwood specialty papers but had been classified as newsprint.[19]

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[17] This method is a proxy for estimating the individual marginal cost curves of each firm in the fringe, summing them, and subtracting the resulting fringe supply curve from the industry demand curve by assuming that fringe firms will produce where MC=P.

[18] ANPA estimates of U.S. consumption are equal to apparent U.S. consumption, within +/- 1000 tonnes, suggesting that this is the method they use to calculate total consumption.

[19] We assumed that the only firms producing groundwood specialties that were reclassified as newsprint were those in the model.

Thus in 1979, the capacity misclassified as newsprint was about 850 thousand tonnes. This implies GWS production of 850 thousand tonnes. Thus b_0 = 13,323.21 – 850.0 = 12,473.21.

Table 5.4 reports the estimated demand functions for 1979 to 1983. These were calculated by taking the demand equation above, and substituting in the actual values of GDP, price of printing and writing papers, imports, exports, Canadian demand, inventory changes and fringe production for each year.

5.5. Industry production and prices

In order to assess the model output, actual industry prices and firm and industry production numbers were required for validation purposes.

We used a newsprint price based on the Bureau of Labour Statistics Producer price index and transformed it into the actual transaction price by taking the known price in one year (1970), and adjusting each year's price accordingly. Prices were deflated to 1979 dollars using the U.S. implicit GNP price deflator. (Note that these are the same prices used in the estimation of the demand function.) See Table 5.5.

Industry production figures were obtained from the CPPA Annual Newsprint Supplement. We then subtracted off the production of the fringe (as calculated for the demand function), and the production of GWS papers misclassified as newsprint, to obtain the standard newsprint production of the firms in the model.[20] See Table 5.5.

[20] Note that the production numbers for 1979 to 1983 were not adjusted for the change in grammage to 48.8g/m^2. However, by 1979, newsprint consumption as reported was within one percent of consumption at 48.8g/m^2, since most production was at the lower grammage.

TABLE 5.4: Derivation of North American demand function for newsprint, 1979–1983. All quantities in thousands of tonnes.

U.S. Consumption Function Intercept

	U.S. GDP (1979 billion US$)	Price Index for Printing Papers (1979$)	U.S. Demand Function Intercept
1979	2,464.40	214.10	13,489.72
1980	2,462.01	219.11	13,529.54
1981	2,508.93	222.67	13,760.95
1982	2,448.23	194.38	13,226.14
1983	2,538.73	204.71	13,706.91

Production of Fringe Firms

	Fringe Capacity	Fringe Operating Rate (%)	Fringe Production
1979	2,483.0	97	2,408.51
1980	2,908.0	96	2,791.68
1981	3,166.0	96	3,039.36
1982	4,044.0	89	3,599.16
1983	4,372.0	90	3,934.80

TABLE 5.4 – Continued

Intercept for North American newsprint demand function faced by the firms in the model

	Fringe Production (–)	Imports (–)	Exports (+)	Canadian Demand (+)	Inventory Change (+)	GWS Papers (–)	Adjusted Intercept
1979	2,408.51	132.0	1,523.0	971.0	-120.0	850	12,473.21
1980	2,791.68	125.0	1,700.0	980.0	220.0	850	12,662.86
1981	3,039.36	37.0	2,092.0	1,045.0	434.0	949	13,306.59
1982	3,599.16	42.0	1,799.0	934.0	-109.0	810	11,398.98
1983	3,934.80	67.0	1,701.0	970.0	-19.0	830	11,527.11

TABLE 5.5: Industry production and prices, 1979-1983.

Production (1000 tonnes)	1979	1980	1981	1982	1983
CPPA Industry	12,441	12,863	13,698	12,683	13,174
Fringe Firms (–)	2,409	2,792	3,039	3,599	3,935
GWS Papers (–)	850	850	949	810	830
All firms in model	9,182	9,221	9,710	8,274	8,409
Industry Price ($US)	391	436	481	493	473
Industry Price (1979 $US)	391	400	402	388	358

TABLE 5.6: Approximate operating rates by firm, 1979-1983. (In percent)·

	1979	1980	1981	1982	1983
Abitibi Price	100	100	98	80	78
CIP	n/a	100	n/a	79	91
Bowater	100	100	100	91	92
MacMillan Bloedel	95	95	100	67	79
Consolidated Bathurst	100	100	100	83	85
Group 1	n/a	n/a	n/a	95	96
Group 2	n/a	n/a	n/a	90	96

NOTE: n/a means not available

Operating rates for each firm were estimated where possible (see Table 5.6). Information from the Pulp and Paper Journal and newspaper articles on down-time and strikes were used in addition to comments and data from annual reports. The operating rates are for strike-adjusted capacity; i.e., if the only down-time a firm took was for strikes, then the operating rate for that firm would be 100%. This is because capacity figures for each firm have been adjusted for strikes (see Appendix II). Since much of the information was on a mill by mill basis, adjustments for differences in GWS and standard newsprint operating rates were taken into account as much as possible for each firm.

Unfortunately, it was impossible to reconcile the industry production numbers with the industry production as inferred from the firm-by-firm operating rates, partly because of incomplete firm data. Even for 1982 and 1983 where we had almost complete data, the production implied by the operating rates was 375,000 (1982) and 423,000 (1983) tonnes too high relative to the industry production level reported by the CPPA (adjusted for the fringe and GWS). Part of this difference stemmed from differences in how capacity is determined. For example, for their annual reports firms may estimate their annual capacity by excluding times that a machine is down for regular maintenance, or times when machines are down for conversions. The other major source of uncertainty in the calculations is the fringe production.

5.6. Production validation

The model was run to validate the production/pricing part of the model. Given the actual capacity decisions of the firms and the demand and cost conditions of the time period, we wanted to see if we could reproduce the industry price, industry production and individual firm production strategies. We used the marginal cost functions for each firm as developed in Section 5.3, where the function differs in each year to reflect changes in capacity. (See Appendix V for the database).

The conjectural variation terms were first set to zero for all firms (i.e., the Cournot Nash assumption) (see Section 4.2.1). The model underestimated total quantities and overestimated prices under these assumptions (see Figures 5.4 and 5.5). In particular, the model underestimated the quantities produced by the largest firms (in particular Abitibi and Bowater), and overestimated the quantities produced by the other firms in the industry. There are several possible reasons for these results. One is that these large firms exert some influence over the smaller firms to reduce production when, on a myopic one-period profit maximization basis, it may not be the smaller firms' best strategy (i.e., they should be producing more).[21]

We can adjust the "zero" conjectural variations term for each firm so that predicted firm outcomes are closer to reality (i.e., by increasing (making positive) the smaller firms' term and decreasing (making negative) the larger firms' term). Figures 5.4 and 5.5 show the industry prices

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[21] However, if more than one period is considered, it may be in the smaller firms' best interests to produce less, if these larger firms can punish them for producing too much, e.g., by driving the price down.

FIGURE 5.4: Industry quantities for various values of the conjectural variation term, 1979-1983 (1000 t).

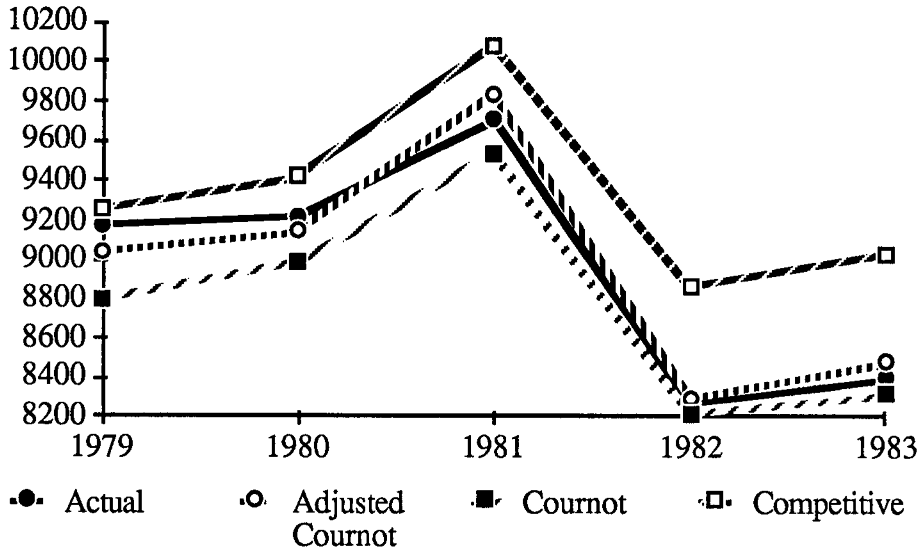
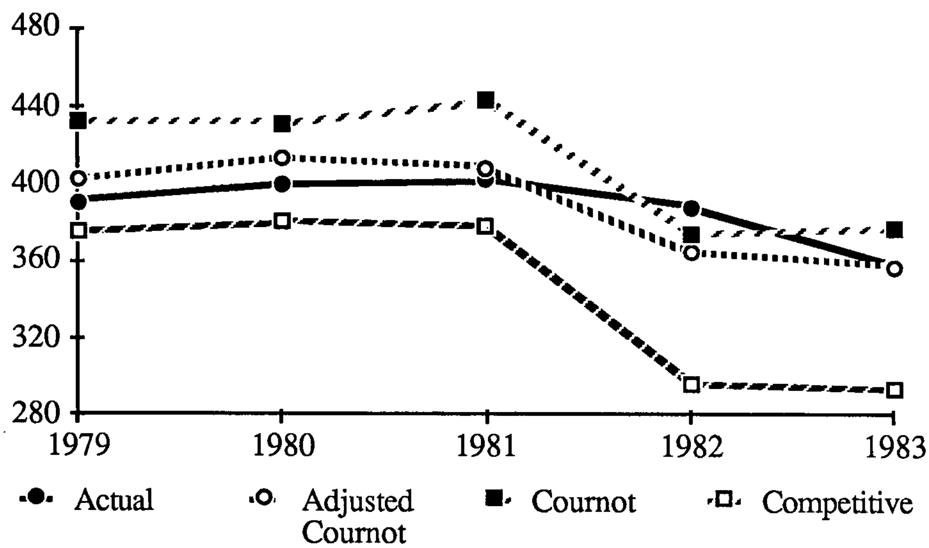


FIGURE 5.5: Industry prices for various values of the conjectural variation term, 1979-1983 (1979 US$).



and quantities for various conjectural variation terms and Table 5.7 shows the actual and predicted operating rates by firm. The "competitive" solution assumes that the conjectural variations term for all firms is -1; the resulting prices and quantities are what would be predicted for perfect competition.

If we assign Abitibi-Price and Bowater conjectural variations of -0.5 and all other firms conjectural variations of zero, then the industry quantities, industry prices and firm quantities are close to those actually observed. Abitibi-Price and Bowater produce more than predicted under Cournot, and the rest of the firms produce less.

5.7. Sensitivity analysis

The firm production levels and thus industry price were highly sensitive to a number of factors. The obvious one, as outlined above, is the assumption made about the conjectural variation terms for each firm. As has been mentioned many times in the development of oligopolistic industry models, industry outcomes from the competitive to the monopolistic can be derived depending upon the assumptions made. We chose to get around this problem by deriving the conjectural variation terms by calibrating the model to actual data.

The results were also, not surprisingly, sensitive to the demand function used, in particular the coefficient on price. The demand function faced by a firm, is a residual demand function, the value of which depends upon the firm's assumptions about its competitors. The demand curve faced by a firm is as follows:

$$q_j = b_0 - Q_{-j} + b_1 * P,$$

where Q_{-j} is the quantity produced by the rest of the industry. Q_{-j} may be a function of q_j, if a firm anticipates that other firms will react to its quantity decision. The industry demand curve is $D = q_j + Q_{-j} = b_0 + b_1 \cdot P$.

TABLE 5.7: Actual and predicted operating rates (% of capacity) by firm, 1979-1983, for Cournot and adjusted Cournot conjectural variation terms (CV).

<u>Actual</u>	1979	1980	1981	1982	1983
Abitibi Price	100	100	98	80	78
CIP	n/a	100	n/a	79	80
Bowater	100	100	100	91	92
MacMillan Bloedel	95	95	100	67	79
Consolidated Bathurst	100	100	100	83	85
Group 1	n/a	n/a	n/a	95	96
Group 2	n/a	n/a	n/a	90	96
Industry Quantity (1000 t)	9,182	9,227	9,710	8,274	8,409
Industry Price (1979$US/t)	391	400	402	388	358

<u>Cournot</u>	CV	1979	1980	1981	1982	1983
Abitibi Price	0	72	82	70	48	49
CIP	0	100	99	100	91	85
Bowater	0	100	93	99	65	68
MacMillan Bloedel	0	100	93	100	91	100
Cons. Bathurst	0	100	100	100	97	94
Group 1	0	100	100	100	100	100
Group 2	0	100	100	100	92	100
Industry Quantity (1000 t)		8,794	8,986	9,534	8,218	8,320
Industry Price (1979$US/t)		432	431	443	374	377

TABLE 5.7 – Continued

Adjusted Cournot	CV	1979	1980	1981	1982	1983
Abitibi Price	-0.5	93	100	92	69	69
CIP	0	90	89	89	80	75
Bowater	-0.5	100	100	100	96	95
MacMillan Bloedel	0	100	84	100	81	100
Cons. Bathurst	0	100	100	100	85	81
Group 1	0	100	100	100	88	88
Group 2	0	100	100	100	83	98
Industry Quantity (1000 t)		9,050	9,148	9,831	8,300	8,483
Industry Price (1979$US/t)		402	413	408	364	356

The price elasticity is the percentage change in quantity given a one percent change in price. The price elasticity of the industry demand curve is $P \cdot D'(P)/D(P) = P \cdot b_1/D$. (Linear demand curves imply quantity dependent price elasticities). The price elasticity of the demand function faced by an individual firm, under Cournot assumptions, is $P^* b_1/q_j$. The higher the price elasticity faced by a firm, the more it will produce, <u>ceteris paribus</u>. Thus larger firms will tend to have lower operating rates than smaller firms, because the elasticity of the demand curve they face is higher.

This means that production decisions of firms are highly dependent on the value of b_1 used in the model. The 99% confidence intervals for b_1 were as follows:[22]

$$-12.99 \leq b_1 \leq -4.04$$

Figures 5.6 and 5.7 show the effects on industry prices and quantities of varying the coefficient on price between the confidence limits. While the effect on quantities was not dramatic, the effect on prices was, particularly for $b_1 = -4.04$. This reflects the impact of the much lower price elasticity of demand.

Another factor that affects the results is the assumed operating rate of the fringe firms. These firms comprise 20% of total capacity and thus have an effect on industry outcomes. The base case assumption is that fringe firms produce at the average operating rate of U.S. firms in that year. Figures 5.8 and 5.9 show the effects on quantities and prices of increasing and decreasing the operating rate by 5%, which was considered to be a reasonable range. Thus if the base case operating rate was 92%, plus 5% would be 97%. (The maximum operating rate was assumed to

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[22] Confidence intervals were estimated as $b_1 \pm (t_{\alpha/2,d.f.} \cdot \text{standard error})$, or $8.5150 \pm 2.921 \cdot 1.5321$, with 16 degrees of freedom. The intercept term was adjusted as well, so that the function would still go through the mean of the data. The intercept for $b_1 = -4.04$ is -528.1, and for $b_1 = -13.0$ is 2660.3.

FIGURE 5.6: Changes in the demand function coefficient on price and effect on industry quantities, 1979-1983 (1000 t).

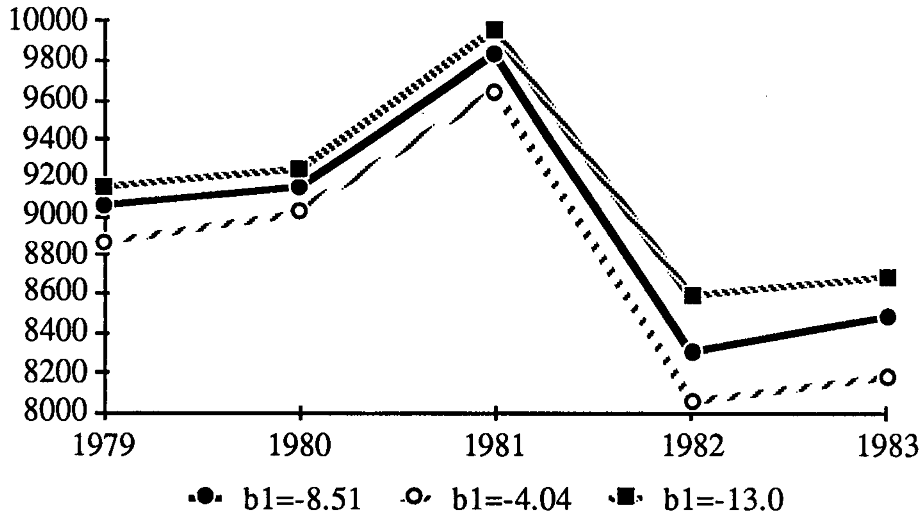


FIGURE 5.7: Changes in the demand function coefficient on price and effect on industry prices, 1979-1983 (1979 $US).

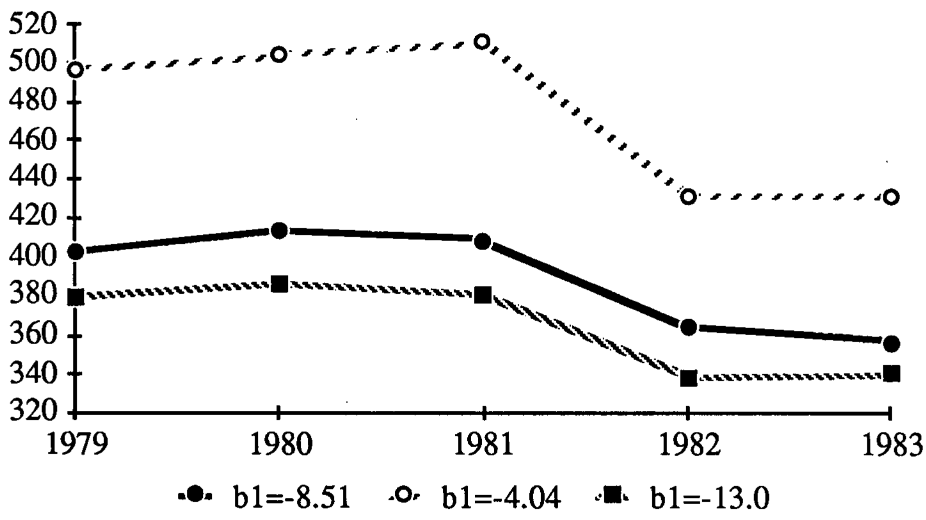


FIGURE 5.8: Changes in fringe operating rate and effect on industry quantities, 1979-1983 (1000 t).

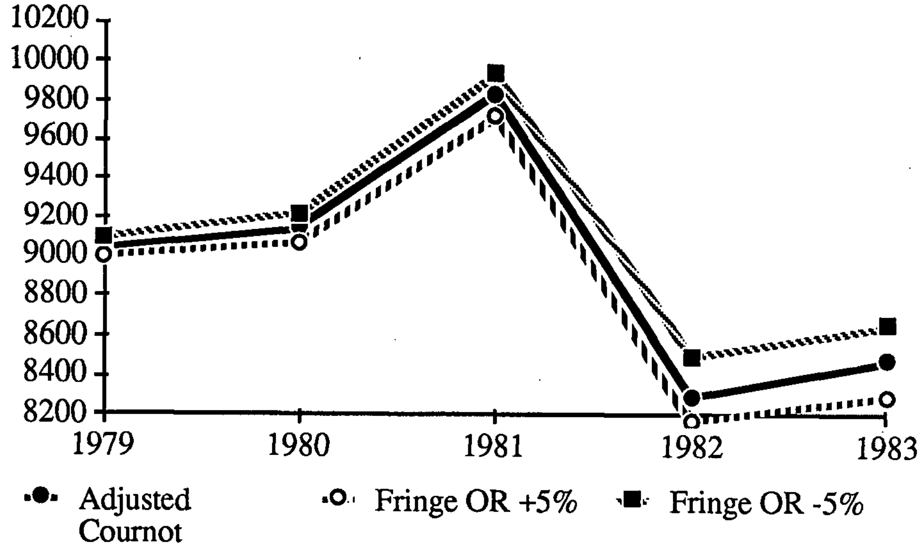
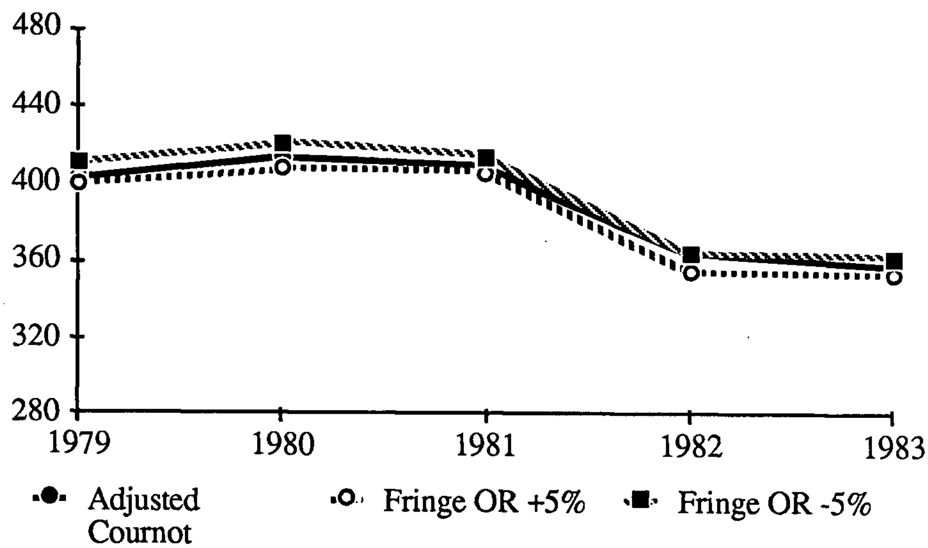


FIGURE 5.9: Changes in fringe operating rate and effect on industry prices, 1979-1983 (1979 $US).



be 100%). The results were within 3% of base case prices and quantities, thus within reasonable limits the operating rate of the fringe is not a highly sensitive factor.

The production decisions of firms were sensitive to the value of the marginal cost functions. Reducing all firms' marginal cost curve intercepts by $25 increased output so that prices were reduced, particularly in 1982 and 1983 when demand was down. Increasing marginal cost curves by $25 reduced output and increased prices, again with the main effect in years 1982 and 1983. Results are shown in Figures 5.10 and 5.11.

5.8. Summary

The production and pricing portion of the model described in Chapter IV was implemented and tested for the 1979 to 1983 time period for the North American newsprint industry. Results indicated that the model was a reasonable predictor of industry prices and quantities, as well as individual firm quantities. Results were sensitive to the conjectural variations term used, as well as the price coefficient of the demand function, and marginal cost estimates.

The next step is to validate the capacity decision portion of the model, and compare the capacity decisions predicted by the model to those actually taken by firms. This will be addressed in the next chapter.

FIGURE 5.10: Changes in marginal costs and effect on industry quantities, 1979-1983 (1000 t).

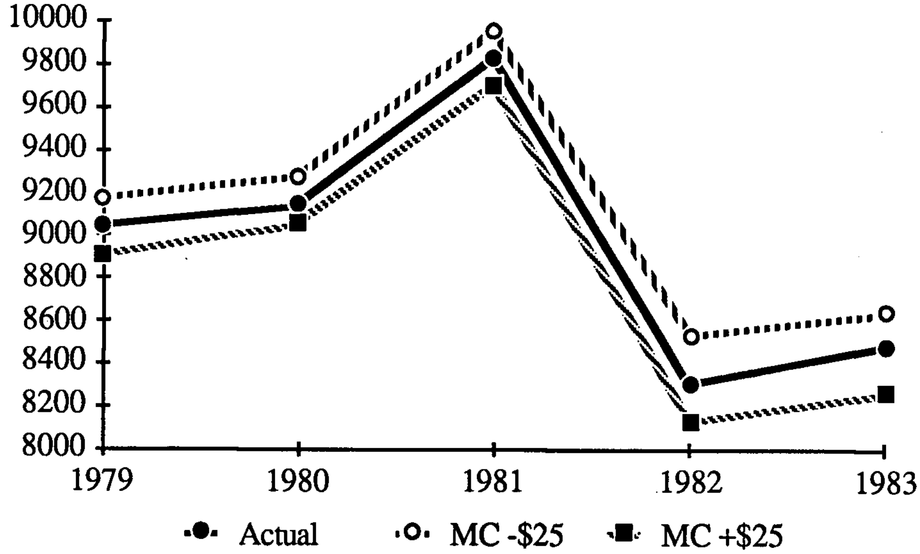
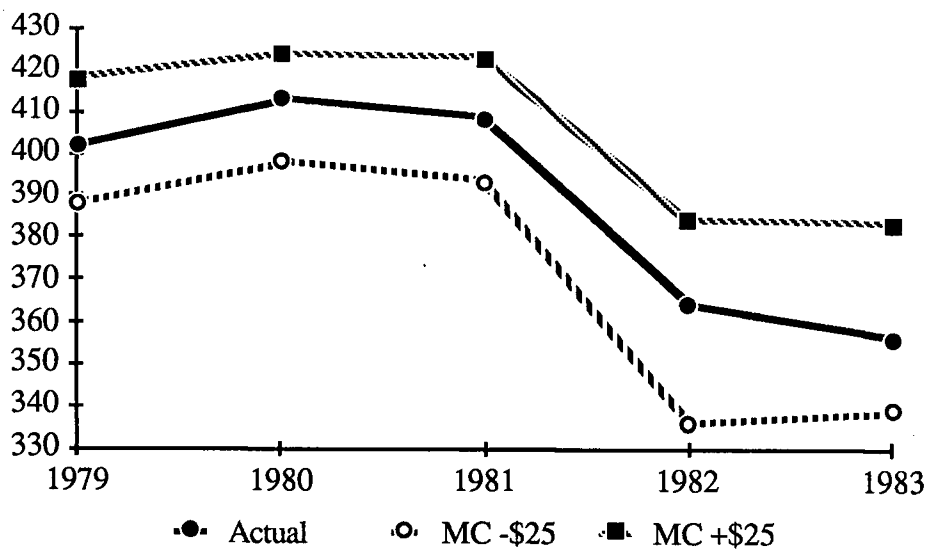


FIGURE 5.11: Changes in marginal costs and effect on industry prices, 1979-1983 (1979 $US).



CHAPTER VI

MODEL VALIDATION AND RESULTS

6.1 Introduction

We can differentiate between two major types of models: descriptive and prescriptive. Descriptive models describe the behaviour of a system, without attempting to prescribe how the participants should behave. The purpose of these models is to help understand the solution choice that has been made, or to predict future behaviour of the system. Prescriptive models examine what participants should do under various circumstances. They prescribe the best courses of action, given the goals of the participants.

Prescriptive models can be further differentiated into stylized normative models, and decision-making models. The former deals with an abstracted reality, and allows one to gain insight from theoretical exercises. Normative models are used as benchmarks for behaviour, to evaluate an industry's performance, for example, relative to a rational actor model (Allison 1971). They can also be used to explain, in an abstract way, why events unfolded in a certain way. Classical economic models of the firm employ the normative rational actor model and use it to explain and predict changes, for example, in observed prices as a result of various conditions. While it is recognized that firms may not actually act rationally, the outcome of their decision processes result in predictable consequences using the rational actor model (Machlup 1967).

Prescriptive decision-making tools, on the other hand, deal with real problems, and attempt to determine optimal decisions for participants under realistic conditions.

The required validation procedure depends upon the type of model. Validation of a descriptive model would require the comparison of the data predicted by the model to historical data. A stylized normative model would require the validation of the underlying assumptions, and confirmation of internal consistency (i.e., does the model make sense). A prescriptive decision-making model would require the validation of its assumptions, as well as the examination of whether decisions are improved with the use of the model.

The rational actor model underlies the framework of the newsprint model. For an individual firm, the model determines the capacity decision or action that would be reasonable, given the firm's objectives. The model is thus prescriptive; it prescribes how rational firms should behave. The interdependencies between firms lead to actions that are dependent on other firms' actions, and the solution for rational firms must be an equilibrium, where each firms' decision is optimal given the decisions of all other firms, and no firm would unilaterally wish to change its decision.

The model, however, can also be used as a descriptive model. If the assumptions of rationality reasonably describe behaviour in the industry and the information is available to calibrate the model, then the model can be used to predict firm and industry behaviour.[1] It is also possible that the rationality assumption, even without providing an accurate description of firm behaviour, may provide robust predictions for aggregate long term industry behaviour (Machlup 1967).

Raiffa (1982) describes a third type of model, the asymmetric prescriptive/descriptive model, where the model is prescriptive from the point of view of one party and descriptive from the points of view of the competing parties. As a decision-making tool, we want to use the model as a prescriptive/descriptive model, where the model is prescriptive for the individual firm being considered, and descriptive of the behaviour of the rest of the industry.[2] Thus while all firms in

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[1] The model can also be used in a normative manner, to test structural assumptions about the industry. Thus numerical experiments or simulations can be run to determine industry outcomes under various assumptions.

[2] If the model is used prescriptively by all firms, and the firms follow the prescribed actions, then the model would also be descriptive.

the newsprint industry may have market share maximization goals, an individual firm may want to determine what its best action would be if it wanted to maximize profits.

In addition, while the model is prescriptive in terms of the firms' capacity decisions, we want it to be descriptive of the production decision. Production and prices are needed in order to determine the profitability of alternative capacity decisions, but this subcomponent of the model is not likely to be used at an operational level to determine production levels because of its simplicity. We really just want a good approximation to what is really a much more complex and ongoing decision process, and to do this we again assume the rational actor model, assuming firms maximize short run (annual) profits. As the component validation showed in Chapter V, this approximation appears to reasonably describe actual industry outcomes.

Validation is the process of assessing whether the model does what it is supposed to do. In terms of the validation procedure for the newsprint model then, we need to first of all check its underlying structural assumptions, as well as its data assumptions. Once we are assured that the assumptions used in the building of the model and the model structure are reasonable, and that the input data are reasonable, we need to look at the results of the model. To validate the model as a descriptive model, we need to compare the predictions of the model with historical data, given the actual objectives of firms. We also need to confirm, for a prescriptive model, that the decisions chosen by the model are an improvement over current decisions.

The implications of model assumptions and structure were discussed on a component by component level during the description of model development and will not be repeated here. Chapter V described the development of the database, and the validation of the production and pricing component. As noted above, the production/pricing component is assumed to be descriptive of actual industry behaviour. Given the actual capacity decisions of firms, the cost functions, and the demand function estimated from "observed" demand conditions, we attempted to reproduce the production decisions and pricing outcomes using the model. We used this step to calibrate the production decision part of the model, by adjusting the conjectural variations term. The initial hypothesis of Cournot was tested first (i.e., no industry reaction to a change in a firm's production). Under these assumptions, the model underestimated total quantities and overestimated prices. In particular, the model underestimated the quantities produced by the largest firms (predominantly Bowater and Abitibi-Price) and overestimated quantities produced by the rest of the industry. Abitibi-Price's and Bowater's conjectural variation terms were set at -0.5, indicating the exercising of some influence on smaller firms through preemption of some of the available market; this resulted in predicted outcomes closely corresponding to actual firm production levels. The production decisions were validated for the 1979 to 1983 time period.

We wanted the model to be prescriptive for a firm's capacity decision. Given a firm's objectives, the model determines optimal decisions, contingent on other firms' decisions. To validate the model then, we assign each firm an objective function that is a reasonable representation of its actual objective and compare the outcomes to historical behaviour. The model should then be descriptive of industry behaviour.

Information and forecasts that were available in late 1978, i.e., industry demand forecasts, reasonable cost estimates, etc., were used as the input, and then, given the assumed objective functions for firms, the model was run with these forecasts to determine optimal firm capacity additions. Thus we used only information that was actually available at the beginning of the planning horizon since this is the information available to firms when they made their decisions about how much capacity to add. The time horizon used was 15 years (1979 to 1993), with a newly added machine coming on line in 1981.

As noted above, in order to test the descriptive validity of the model, we make some assumptions about the objectives of firms. The common economic assumption is that of profit maximization, which seems reasonable as a first approximation. There is some evidence, however, that firms in the newsprint industry do not maximize profits (e.g., Guthrie 1972), and certainly there could be a number of other objectives that firms pursue besides profit maximization such as market share or sales maximization (Scherer 1980). However, the profit maximization case provides a useful benchmark for comparison, even if it does not provide a good description of industry behaviour. Market share maximization subject to a profitability constraint is a closer approximation to reality according to industry sources, so this objective was also assumed for all firms and the results compared to the profit maximization case.

Section 6.2 reports the results of the validation of the model. The data assumptions are first presented for the validation analysis followed by a comparison of the model predictions to historical data for both profit-maximizing firms and for market share maximizing firms. The results of the sensitivity analysis to determine critical factors are then presented. This is followed by a discussion of the implications of multiple equilibria to the validity of the model. Section 6.3 introduces the subject of uncertainty and the effects of risk/return attitudes are examined. Finally, the use of the model as a prescriptive tool for strategic experiments is illustrated in Section 6.4.

6.2 Validation

6.2.1 Description of the base case data

The following sections outline the basic demand and cost data for the "base case". All costs are in real (1979) U.S. dollars and all quantities are in metric tonnes.

Demand scenarios. We used the same U.S. demand function as described in Chapter V, calculated from 1966 to 1986 data. However, forecasted values for GDP and price of substitutes were substituted in to get U.S. demand as a function of price only. The demand function for North American production was then calculated by adjusting for exports, imports and Canadian demand, using reasonable forecasts for these as well. We assumed that the underlying U.S. demand function was "known" by the industry, that they could experiment and determine the price elasticity since they were actually within the market. We, on the other hand, had to estimate the demand function from annual data. We also assumed that the underlying demand function was relatively stable over time (i.e., the coefficients on the parameters remained constant) although it shifts as a result of shifts in GDP and substitute prices.

We used widely held views of demand forecasts, found in industry trade journals in late 1978 and early 1979 (Pulp and Paper 1978a, 1978b). Most forecasts were for newsprint demand increases of between 2.5 and 3% increase on average per year and economic growth of between 2 and 3% per year. A major newsprint consumption study (Michaels 1978) forecasted average GNP growth of 3% per year from 1978 to 1985. For the base case, we assumed economic growth (i.e., U.S. GDP growth) of 3% per year for Demand Scenario I, starting at a 1978 GDP level of $2,415.8 billion. This was similar to the average growth rate of GDP from 1950 to 1978 of 3.1%, but was a bit below the rate of the most recent 10 years, from 1968 to 1978, of 3.5%.

The price of substitutes, printing and writing papers, was assumed to remain at the 1978 price index level of 205. The amount of standard newsprint misclassified as groundwood specialties was also assumed to remain constant at 850 thousand tonnes.

Canadian demand increased at an average rate of 3.6% per year from 1950 to 1978. From 1969 to 1978 it increased at a rate of 7.4% per year. Industry demand forecasts for the U.S. were in the range of 3% per year, so we assumed a more conservative 3% per year increase for Canadian demand from 1979 to 1993.

Since about 1955, exports from North America have accounted for between 10 and 15% of total North American shipments. The level varies primarily with world demand and exchange rates of both buyers and other sellers. Exports of newsprint from North America (other than to the U.S.) increased at a rate of 4.5% per year on average from 1950 to 1978, but during the last 10 years of that period there was no significant upward trend. Exports have averaged about 14% of total shipments over those last 10 years. North American exports (predominantly Canada) supply about 30% of non-North American demand. Increases in developing country self-sufficiency would imply that exports would increase at less than the rate of non-North American demand. We assumed that exports rise at rate of 2% per year, starting from a base of 1,642 thousand tonnes in 1978.

Newsprint is imported by the U.S. primarily from Canada, but a small percentage of U.S. demand is filled each year by imports from overseas. The percentage varies from zero to four percent, and is highly variable from year to year. Exchange rates and the strength of the market are the major determining factors in the amount of non-North American supply used in the U.S. Imports of newsprint into the U.S. have averaged about 178,000 tonnes from 1950 to 1978 (as well as from 1968 to 1978). We assumed that imports of newsprint continue to average about 178,000 tonnes from 1979 to 1994. While the actual level fluctuates from year to year, the volume is small relative to overall demand and therefore can be assumed to be constant in the future.

The capacity expansion of the fringe and its production also needed to be forecast. Capacity of the fringe was forecast to expand at three percent per year, about the same rate as demand. Three mills (Weyerhaueser's North Pacific Paper, Southeast Paper and Bear Island Paper), already under construction in 1978, were added to the fringe capacity in 1979 and 1980. Average operating rate was assumed to be 95%.

Table 6.1 shows the derivation of the intercepts for the demand functions for 1979 to 1993 for Demand Scenario I. The coefficient on price remained at 8.5150 in all years.

Costs. A firm's marginal cost curve for capacity existing in 1979 was assumed to remain constant in real terms (1979 $US) at the 1979 level, as estimated in Chapter V for each firm (see Table 5.3). The firm's capacity is assumed to remain at the 1979 level, except if a new machine is added (i.e., there is no depreciation or deterioration over time). The production cost of new capacity was assumed to be the same for all firms ($250/tonne). Overhead, which can, in the model, differ for new and old capacity, was assumed to remain constant over time at $24/tonne .

Investment costs. The cost of new investment was assumed to be the same for all firms, for a given capacity option. The capacity options considered were "do nothing" and "add one machine". The addition of a machine to an existing complex will always dominate that of building a greenfield mill, unless there is a constraint on a firm. For now, we assumed that a firm can add a machine if it wants to. The cost of US$140 million (spread equally over the first two years of the planning horizon) includes the cost of installing new TMP pulping capacity and a 180,000 tonne per year newsprint machine. Costs were estimated from costs of installations reported in Pulp and Paper Journal (1977–1979).

Conjectural variations. The values of the conjectural variations term were as determined in Chapter V. Abitibi-Price and Bowater have conjectural variations equal to -0.5, and all other firms have conjectural variations equal to 0. (See Section 5.6 for discussion).

TABLE 6.1: Deriving demand function intercept for Demand Scenario I, 1979 to 1993 (GDP 3% per year).

	U.S. GDP (1979 billion $U.S.)	Price Index for Printing Papers	Fringe Capacity (1000 t)	Fringe Production (1000 t) (–)	Imports (1000 t) (–)	Exports (1000 t) (+)	Canadian (1000 t) (+)	Inventory Change (1000 t) (+)	GWs Papers (1000 t) (–)	Intercept for NA Demand Function
1979	2488.3	205.0	2683.0	2548.9	178.0	1674.8	951.7	0.0	850.0	12548.8
1980	2562.9	205.0	2983.0	2833.9	178.0	1708.3	980.3	0.0	850.0	12637.7
1981	2639.8	205.0	3018.0	2867.1	178.0	1742.5	1009.7	0.0	850.0	12989.2
1982	2719.0	205.0	3108.5	2953.1	178.0	1777.4	1040.0	0.0	850.0	13299.2
1983	2800.6	205.0	3201.8	3041.7	178.0	1812.9	1071.2	0.0	850.0	13618.1
1984	2884.6	205.0	3297.9	3133.0	178.0	1849.2	1103.3	0.0	850.0	13946.3
1985	2971.1	205.0	3396.8	3226.9	178.0	1886.1	1136.4	0.0	850.0	14283.9
1986	3060.3	205.0	3498.7	3323.8	178.0	1923.9	1170.5	0.0	850.0	14631.3
1987	3152.1	205.0	3603.6	3423.5	178.0	1962.3	1205.6	0.0	850.0	14988.7
1988	3246.6	205.0	3711.8	3526.2	178.0	2001.6	1241.8	0.0	850.0	15356.5
1989	3344.0	205.0	3823.1	3632.0	178.0	2041.6	1279.0	0.0	850.0	15734.9
1990	3444.4	205.0	3937.8	3740.9	178.0	2082.5	1317.4	0.0	850.0	16124.2
1991	3547.7	205.0	4055.9	3853.1	178.0	2124.1	1356.9	0.0	850.0	16524.8
1992	3654.1	205.0	4177.6	3968.7	178.0	2166.6	1397.6	0.0	850.0	16937.1
1993	3763.8	205.0	4302.9	4087.8	178.0	2209.9	1439.6	0.0	850.0	17361.3

Discount rates. In order to determine the net present value of profits or expected profits of a particular capacity choice, profits in future years must be discounted to the present. All costs and prices are in constant prices, so inflation can be ignored. Clearly, however, a dollar earned today is worth more than a dollar earned ten years from now, since a dollar today can be invested to start earning interest immediately. The discount rate used by a firm to determine the present value of an investment is the rate of return offered by comparable investment alternatives. Because cashflows are in real terms, we used a real discount rate (net of inflation).

Although the discount rate used to evaluate investments may differ between firms, we assumed that all firms use a real rate of 10% (Sandwell Swan Wooster Inc. 1987).

Taxes. All firms were assumed to have the same tax rate of 0.46 and to have no current outstanding capital cost allowances. Capital cost allowances are calculated for new investments. A 20% rate was assumed (Breeley et al. 1986), which is the rate for machines in Canada.[3] Taxable income is calculated as revenues less expenses (excluding investment costs) less the capital cost allowance (CCA). After tax cashflows equals taxable income times (1–tax rate) minus CCA minus investment costs. The CCA is calculated as follows for an investment of $10 million:

Year 1: CCA=0.2·10=2

Year 2: CCA=0.2·(10–2)= 1.6

Year 3: CCA=0.2·(8–1.6)=1.28, etc.

All investments were assumed to be financed through equity.

Objective functions. All firms were assumed to maximize after tax profits (actually aftertax cashflow, since we do not consider depreciation except through its effects on taxes). This is the most common economic assumption for firm behaviour. The results are also presented for the assumption that firms maximize market share subject to a profitability constraint, which is more in line with observed industry behaviour.

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3 Note that we are using the Canadian tax system for all firms.

Long run projections. The model is divided into the short run and the long run. For computational reasons, individual firm actions (capacity and production levels) are determined only for the short run. While only the immediate capacity expansion decision is examined, we know that, in the long run, more capacity may be added. Thus we must make some assumptions about what the supply/demand balance will be like in the future. Thus long run aggregate industry production, prices and capacity levels are determined exogenously. A firm then determines the profitability of a particular capacity choice, given the capacity choices of all other firms in the model, and given that the short run capacity level of all firms in the model is consistent with an hypothesized long run capacity level. This long run industry capacity level (in years 1984 to 1993) is determined based on assumptions about future demand and long run price conditions, and by the total capacity added by all firms by 1983.[4]

The base case scenario assumed zero long run price growth. In other words, long run capacity levels for the industry were assumed to increase so that demand and supply remained balanced with no long run increase in price. This was consistent with the long run price development since 1950. Figure 6.1 shows that prices have varied in real terms from $330 to $425 in real terms ($1979) but there is not really a discernible trend. Since we assumed that marginal costs of production remained constant over time, and that sufficient capacity could be built to fill future demand, then this seemed to be a reasonable assumption for decision-makers in 1979 to have made for their calculations. (Sandwell Swan Wooster (1987) assumed constant real prices of $381 ($1979) for their newsprint mill feasibility study.)

The capacity levels in years 10 to 15 of the planning horizon for the capacity projections are dependent upon the demand scenario, since the industry is assumed to "adjust" its capacity to demand over time. For a given demand scenario, industry capacity levels were assumed to adjust

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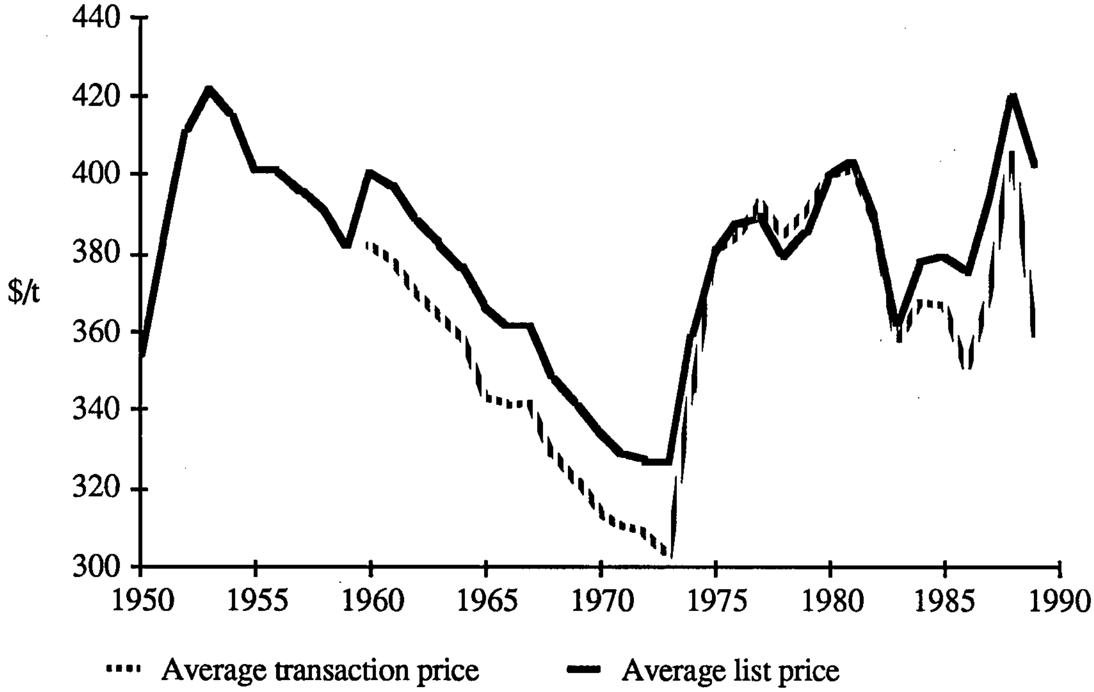
[4]Note that the capacity projections are for the 13 firms in the model only. Capacity projections are also made for the rest of the firms in the industry (i.e., the fringe), but these are converted to production quantities and subtracted from the industry demand function.

FIGURE 6.1: Newsprint Prices (1979 U.S. $/t)



to a certain level by year 10; in other words, no matter how many machines were added in years one to five, by year 10, the industry capacity would be the same for all capacity projections for a given demand scenario.

For each demand scenario, there were 14 possible capacity projections, reflecting the addition of between zero and 13 machines by the industry from 1979 to 1983. Tables 6.2 and 6.3 show the capacity levels and price development for the capacity projections for Demand Scenario I, assuming average industry operating rates of 95%. Figure 6.2 shows three of the long run capacity projections for Demand Scenario I, as well as the historical development of capacity since 1960 for the 13 firms in the model. The three projections reflect the growth of industry capacity over time (from 1984 to 1993) for the case of zero, six and 13 machines added from 1979 to 1983.

6.2.2 Descriptive validity 1979–1983

The major factors characterizing the base case run can be summarized as follows. GDP was assumed to grow at a rate of 3% per year, with no uncertainty. Prices were assumed to remain relatively constant in real terms up to 1993. The operating rate of the firms in the model was assumed to average 95% from 1984 to 1993. (See Appendix VI for a listing of the database).

Profit maximization. There was only one equilibrium solution to the model given the above data and assuming profit maximization for all firms. The solution was for Consolidated Bathurst to add one machine, and for all other firms not to add any machines. Figure 6.3 shows the capacity added and the long run capacity growth projection consistent with this solution. Figure 6.4 shows the prices predicted by the model. Actual historical prices and capacities are also shown from 1960 to 1989.

The "no add" option was dominant for all other firms, regardless of the choices made by the rest of the firms in the industry. The reason for this was that prices were too low relative to the marginal costs of existing capacity, and adding a new machine resulted in even lower prices that affect all of a firm's capacity. Consolidated Bathurst is small enough that the effect on price of adding a new machine still allowed an increase in profitability, given its cost functions.

TABLE 6.2: Long run capacity projection levels for Demand Scenario I (3% GDP growth per year, 0% price growth).

CAPACITY (1000 t)

Number of machines added by 1983

	0	1	2	3	4	5	6	7	8	9	10	11	12	13
1984	9483	9663	9843	10023	10203	10383	10563	10743	10923	11103	11283	11463	11643	11823
1985	10242	10339	10532	10674	10815	10954	11091	11226	11360	11492	11621	11807	11992	12178
1986	11061	11063	11269	11368	11464	11557	11646	11732	11814	11894	11970	12161	12352	12543
1987	11946	11838	12058	12107	12152	12192	12228	12260	12287	12310	12329	12526	12723	12919
1988	12902	12666	12902	12894	12881	12863	12839	12811	12778	12741	12699	12902	13080	13080
1989	13080	13080	13080	13080	13080	13080	13080	13080	13080	13080	13080	13080	13080	13080
1990	13472	13472	13472	13472	13472	13472	13472	13472	13472	13472	13472	13472	13472	13472
1991	13877	13877	13877	13877	13877	13877	13877	13877	13877	13877	13877	13877	13877	13877
1992	14293	14293	14293	14293	14293	14293	14293	14293	14293	14293	14293	14293	14293	14293
1993	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722

TABLE 6.3: Long run prices for Demand Scenario I (3% GDP growth per year, 0% price growth).

PRICES (1979$US)

Number of machines added by 1983

	0	1	2	3	4	5	6	7	8	9	10	11	12	13
1984	580	560	540	520	500	479	459	439	419	399	379	359	339	319
1985	535	524	502	487	471	455	440	425	410	395	381	360	340	319
1986	484	484	461	450	439	429	419	409	400	391	383	362	340	319
1987	427	440	415	409	405	400	396	392	389	387	385	363	341	319
1988	364	390	364	365	366	368	371	374	378	382	387	364	344	344
1989	389	389	389	389	389	389	389	389	389	389	389	389	389	389
1990	391	391	391	391	391	391	391	391	391	391	391	391	391	391
1991	392	392	392	392	392	392	392	392	392	392	392	392	392	392
1992	394	394	394	394	394	394	394	394	394	394	394	394	394	394
1993	396	396	396	396	396	396	396	396	396	396	396	396	396	396

FIGURE 6.2: Actual capacity 1960-78, and 3 capacity projections for Demand Scenario I (for 0, 6 and 13 machines added by 1983)

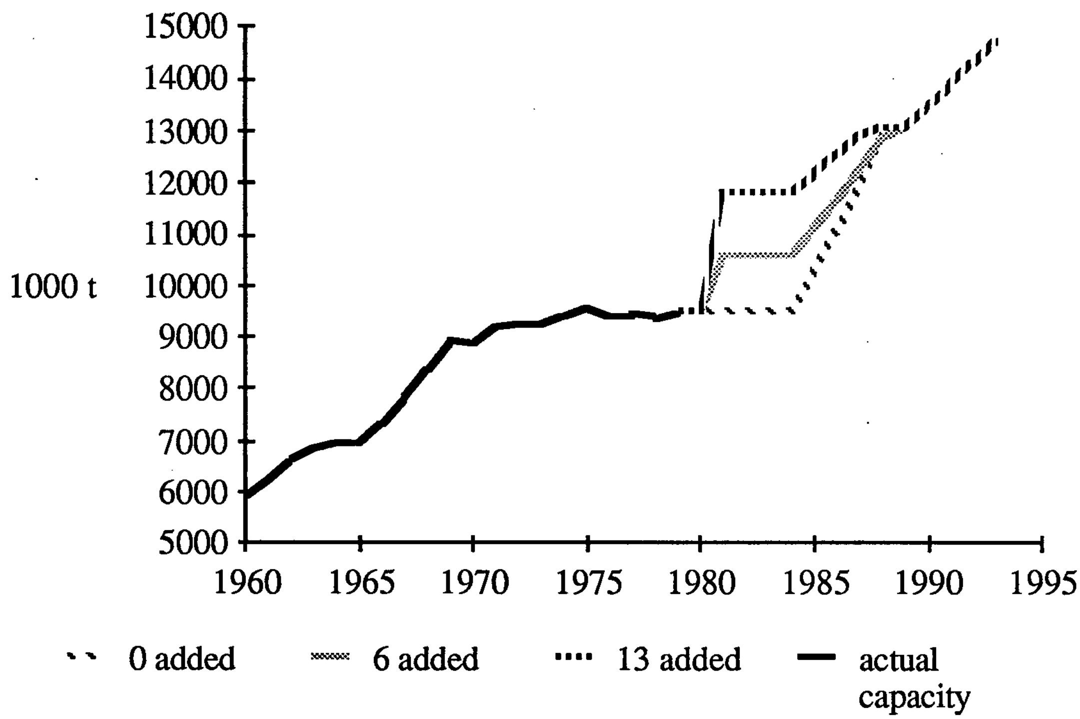


FIGURE 6.3: 13 firm and total industry capacity – actual and predicted under profit maximization hypothesis

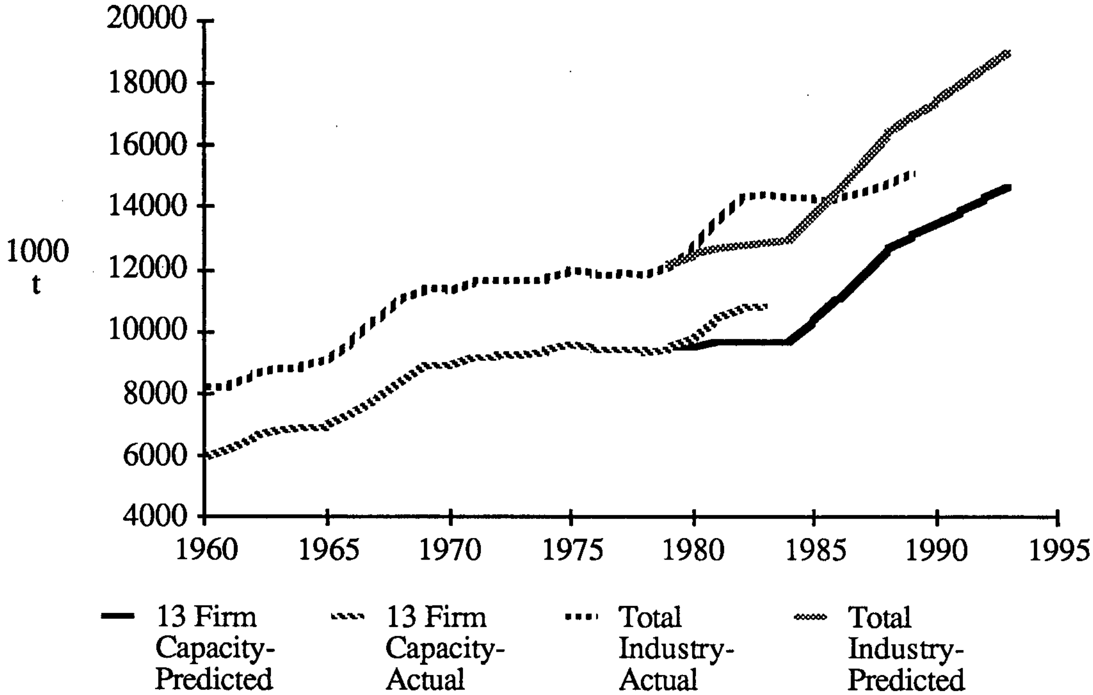
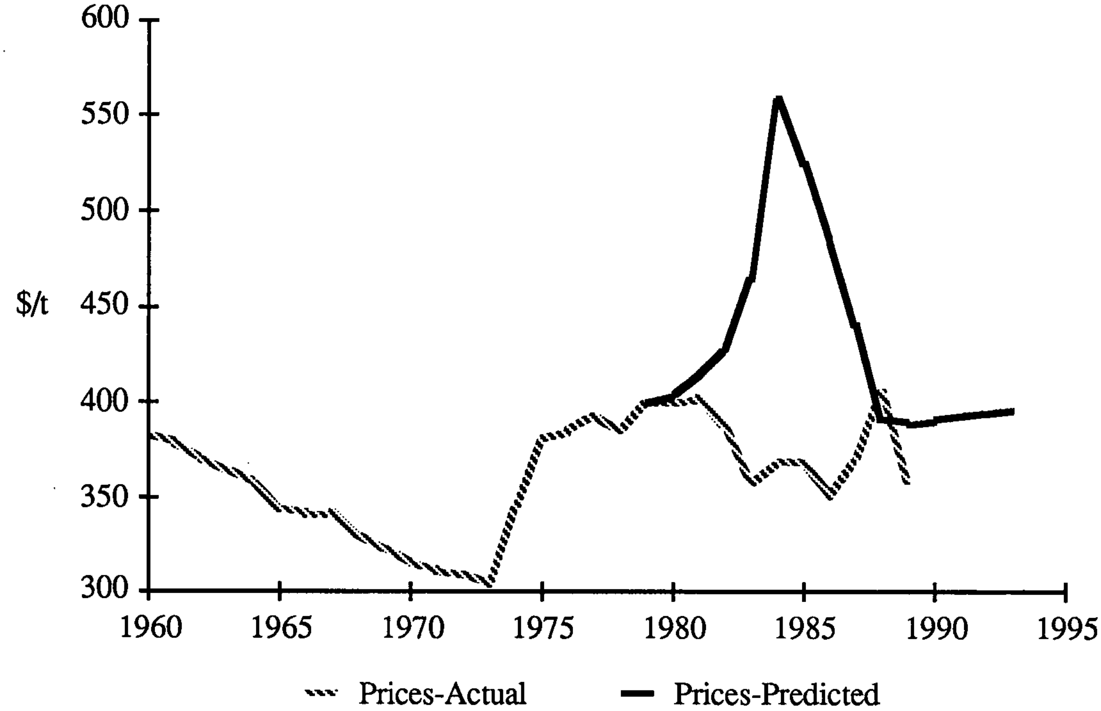


FIGURE 6.4: Actual and predicted prices under profit maximization hypothesis (1979$US/t)



From 1979 to 1983, North American capacity expanded by a net of 2,322 thousand tonnes. Of this, 1,224 thousand tonnes, or 53%, was added by the 13 firms included in the model. This represents seven machines averaging 148,000 tonnes plus a net increase of 190,000 tonnes from speedups and conversions or shutdowns. Some capacity was also replaced over this time period, without any increase in capacity. Table 6.4 summarizes the actual capacity changes carried out by each of the 13 firms in the model from 1979 to 1983.

The remaining 1,098 thousand tonnes was added by the fringe, which increased its capacity share from 20% to 24% over this time period. This represents four new mills, plus two new machines and 155,000 tonnes from net speedups and shutdowns. Average machine size was 170,000 tonnes. Table 6.5 reports the major changes in the fringe firms.

The capacity expansion of the fringe firms was estimated exogenously to the model, and estimated production subtracted from the industry demand function. Capacity of the fringe was assumed to increase at three percent per year (after previously announced projects were completed). This resulted in an estimated 519,000 tonnes added over the five year time period, as opposed to the 1,098,000 tonnes actually added. Under a profit maximization hypothesis for firms in the model, correction for this underestimation of actual behaviour would, if anything, result in less capacity being added for the 13 firms.

The model clearly underestimated firm capacity additions, under these assumptions. It is possible that firms only consider the estimated return on investment (ROI) of the machine (i.e., the net present value of revenues and costs for the incremental capacity only), and not the effect on overall profits. The ROI is positive (for all firms) until five machines are added. In fact if we run the model assuming that firms seek only to maximize the ROI on the machine, and ignore the impact of their decision on the profitability of existing capacity, then there are six resulting equilibrium solutions – all possible combinations of four of the 13 firms adding one machine. (See Section 6.2.5 for a discussion of multiple equilibria).

TABLE 6.4: Actual changes in capacity for the 13 firms in the model.

Firm	1979 Capacity[a] (1000 t)	1983 Capacity[a] (1000 t)	Net Change[a] (1000 t)	Description
Abitibi-Price[a]	1,926	2,040	+114	+130 new Stephensville mill (conversion from linerboard) -16 net other changes
International Paper[b]	1,281	1,364	+83	net of speedups/shut downs
Bowater	1,165	1,266	+101	+140 at Bowater Southern Mill (machine addon) -39 net other changes
MacMillan Bloedel[c]	1,107	1,238	+131	+127 at Powell River mill (machine addon) +4 net other changes
Consolidated Bathurst	909	908	-1	-1 net changes
Kruger	409	450	+41	+41 net changes
Crown Zellerbach[d]	393	552	+159	+161 at Campbell River (machine addon) -2 net other changes
Great Lakes F.P.	372	396	+24	+24 net changes
Publishers	350	518	+168	+181 at Newberg mill (machine addon) -13 net other changes
Kimberly Clark	683	703	+20	+20 net changes
Ontario Paper	635	672	+37	+37 net changes
Boise Cascade	519	714	+195	+157 at DeRidder mill (machine addon) +38 net other changes
St. Regis	584	736	+152	+138 at Houston mill (machine converted from linerboard) +14 net other changes
TOTAL	10,333	11,557	+1,224	7 machines added (average capacity 148), plus net other changes of +190

TABLE 6.4 – Continued

[a] Capacity figures include groundwood specialty papers that are misclassified as newsprint (see Chapter V). Sources: CPPA Newsprint Supplements, ANPA Newsprint Statistics, and annual reports.
[a] Abitibi-Price also replaced four machines at its Iroquois Falls mill in 1982, with no increase in capacity.
[b] In 1981, IP sold its CIP division to CP, leaving IP with only 268,000 tonnes of newsprint capacity. We include both IP and CIP capacity in the the 1983 figure.
[c] In 1981, MacMillan Bloedel sold its MacMillan Rothesay mill to Irving. We include Rothesay mill in the 1983 figure.
[d] In 1983, Crown Zellerbach sold off its Canadian holdings. We include all 3 mills in the 1983 figure.

TABLE 6.5: Actual major changes in capacity for the fringe firms (not explicitly in the model).

Firm	1979 Capacity (1000 t)	1983 Capacity (1000 t)	Net Change (1000 t)	Description
Bear Island Paper[a]	0	165	+165	New mill
Weyerhaueser[a]	73	419	+347	New mill 73+117=+190 2nd machine added (+229)
Donohue Normick	227	370	+143	New mill (Donohue Normick)
BCFP	255	433	+178	New machine
SWFI	144	249	+105	Conversion of linerboard machine
SEPM[a]	68	185	+117	New mill 68+117=185
Georgia Pacific	23	0	-23	Mill closure
Ocean Falls	88	0	-88	Mill closure
Other firms	1,662 (14 mills)	1,817 (14 mills)	+155	Net of minor speedups/ shutdowns
TOTAL	2,540	3,638	+1,098	4 new mills, 2 mill closures, 2 new machines, +155 other net changes

[a] Bear Island Paper Mill, Southeast Paper Mill, and Weyerhauser's (North Pacific Paper Mill) first machine were announced in 1977, and so in the model were assumed to be known additions to fringe capacity.

Market share maximization. The model, assuming profit maximization, underestimated the actual amount of capacity added between 1979 and 1983. Interviews with industry experts suggested that firms were not profit-maximizers, and that market share and growth were important considerations in a firm's expansion decision. There is obviously some tradeoff between profits and market share, and we approximate this behaviour by assuming that when firms evaluate capacity options, they seek to maximize market share, subject to a minimum constraint on profitability.[5]

There are several rationales for market share or sales maximization as an objective for a firm. One is the search for market power that is usually associated with large market shares. A manager's prestige or renumeration may be linked more closely to sales than to profits in situations where ownership is divorced from control (e.g., Baumol 1967, Williamson 1966). The desire to make some profit (i.e., a profit constraint) usually enters into the decision-maker's objective since profits may be required to achieve some other objective (i.e., maximizing sales may require growth, which requires profits), plus there is usually a requirement for a minimum return to the owners of the firm (e.g., dividends), in order for managers to retain control (Scherer 1980). In addition, being the largest firm, or one of the top ten firms, may be perceived as important in terms of managerial prestige, or importance to customers. Another rationale for sales or market share maximization is the learning or experience curve effect (e.g., Hax and Majluf 1984). With more production, learning increases so that costs are decreased. There may also be some scale economies that reduce costs as well. (This effect is more important in fast growing, new markets).

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[5] Other ways of incorporating multiple objectives are as follows. Firms may choose to satisfice, that is, to achieve minimum levels for all goals. Thus an alternative is chosen that satisfies a set of minimum criteria. Or they may choose to priorize goals and maximize each one sequentially (constraining the various levels of objectives below). Another method is to weight each objective is some way, and then maximize the weighted sum or product. A firm could attempt to maximize its expected utility. Multiattribute utility functions could be estimated that explicitly consider a person's tradeoffs between objectives and incorporate the risk preferences of the individual for each objective. Each of these is relatively straightforward to implement in a quantitative model.

The nature of uncertainty and its interaction with time may also affect the type of objective in a firm. The difficulty arises when one cannot determine the possible states, or one cannot with confidence estimate probabilities, over the possible outcomes. In a closed system, the states are identifiable and probabilities estimable. In an open system, risk is unmeasurable since the possible states cannot be identified. Thus long planning periods increase the possibility of unforecastable states. Under these circumstances, the explicit maximization of expected profit is not meaningful. If firms realize this extreme uncertainty, they may pursue other objectives that they believe will help them face an uncertain future, by building their capabilities and ensuring flexibility. For example, managers may consider the best hedge against an unknowable future to be a strong investment level (Scherer 1980) or large market share to give them market power. Although the underlying objective may be long term profit maximization, the pursuit of this goal is by way of other objectives. This provides a further rationale for sales or market share objectives.

In addition, maintenance of market share may be used as as a form of investment coordination (e.g., Osborne 1976, Spence 1978a,1978b, Friedman 1978, Brock and Scheinkman 1985).

There are indications from statements in annual reports that some newsprint firms may place importance on market share and their size. For example, Abitibi-Price seeks to be a market leader (Abitibi-Price Annual Report 1987); "Our policy is to expand when there are opportunities" (Great Lakes Forest Products Annual Report 1987); "Our strength in newsprint comes in part from our size...Strategy of growth and investment" (Bowater Annual Report 1984). Other statements indicate the importance of low costs, and high quality.

"To be the lowest cost, highest quality newsprint producer and maintain mills as the most modern in the industry " (Bowater Annual Report 1984).

"To maximize the value of the Company to its investors" by being the market leader, providing top quality and service, controlling costs, and being a leader in adopting technological innovations (Abitibi-Price Annual Report 1987).

"To move the Company toward its objective of being a low-cost, quality producer with emphasis on value-added...Ensure it is a low-cost, competitive environmentally-aware producer" (MacMillan Bloedel Annual Report 1988).

"Major capital program aimed at strengthening Consolidated Bathurst's position as low-cost producer and increasing its potential to enter promising new markets" (Consolidated Bathurst Annual Report 1981).

These statements indicate that while "value maximization" may be a common objective, other goals are also stressed. For example, striving to be a low cost producer is often cited. This often implies investment in new capacity (or replacement of older capacity with new). This also tends to be synonymous with a high volume, production orientation, since high capacity utilization rates are needed to minimize average costs (because of high fixed costs). Thus sales or market share maximization can be considered a proxy for cost minimization.

The objective function of all firms was thus set to maximize the capacity share of a firm in year five (1983) subject to an average minimum return on sales (ROS) of 10%. (The ROS in each year is calculated as after tax cashflows as a percentage of total sales, and then the average ROS calculated by averaging the ROS in 1979 to 1993). The resulting equilibrium solution was for all firms to add a machine except those firms in group II. This resulted in nine machines being added to the industry, which is much closer to reality (where seven machines are added) than the results under profit maximization assumptions. Figure 6.5 shows the capacity added and the long run capacity growth projection consistent with this solution. Figure 6.6 shows the prices predicted by the model. Actual historical prices and capacities are also shown from 1960 to 1989.

The model predicts that Abitibi-Price, International Paper, Bowater, MacMillan Bloedel, Consolidated Bathurst and all firms in group I (Kimberly Clark, Ontario Paper, St. Regis and Boise Cascade) each add one machine. As shown in Table 6.4, Abitibi-Price, Bowater, MacMillan Bloedel, Crown Zellerbach (Group II), Publishers (Group II), Boise Cascade (Group I) and St. Regis (Group I) actually added machines over the time period. The predicted total capacity added by the 13 firms is 1,690,000 tonnes. The fringe capacity was exogenously forecast to increase by 519,000 tonnes, thus total industry capacity added was 2,208,000 tonnes. Actual total capacity added was 2,322,000 tonnes, a difference of only 114,000 tonnes. (See Figure 6.5).

It is possible that firms had better information on fringe capacity expansion than we have assumed. If the actual fringe capacity is substituted for the forecast fringe capacity in the estimate of the residual demand function, then a total of eight machines are added: Abitibi-Price, International Paper, Bowater, MacMillan Bloedel and all firms in group I, for total industry capacity added of 2,538,000 tonnes (216,000 more than was actually added).[6] The number of machines actually added was seven, but these averaged 148,000 tonnes, plus there was another 190,000 tonnes added through speedups and upgrades of existing capacity.

Because of the grouping of firms in the model, it is impossible for the model to correctly predict the historical capacity behaviour, i.e., it cannot predict that group I adds two machines and group II adds two machines, since the groups can only add zero or four machines. The firms in a particular group are assumed to be identical – they have identical cost functions, capacities, and objectives – and are assumed to behave the same way under the same circumstances. Clearly, no firm is identical to another. There are always differences and these differences are important to firm behaviour. The grouping was done to allow more firms to be explicitly included in the model, and yet not cause the model to become too big to be solved in a reasonable length of time. This simplification may reduce the utility of a management tool that seeks to predict individual firm behaviour, not just industry behaviour.

In addition, firms have a certain amount of flexibility that is not reflected in the model. Actual machine sizes added in the 1979 to 1983 period ranged from 130,000 tonnes to 230,000 tonnes. Firms also have the option of shutting down old capacity, and possible replacing it with new capacity. The model allows production to be curtailed on high cost machines (during the 1979

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[6] The minimum profitability constraint was modified to be ROS≤9.8%, since with ROS≤10% there was no equilibrium solution.

FIGURE 6.5: 13 firm and total industry capacity–
actual and predicted under
constrained market share maximization hypothesis

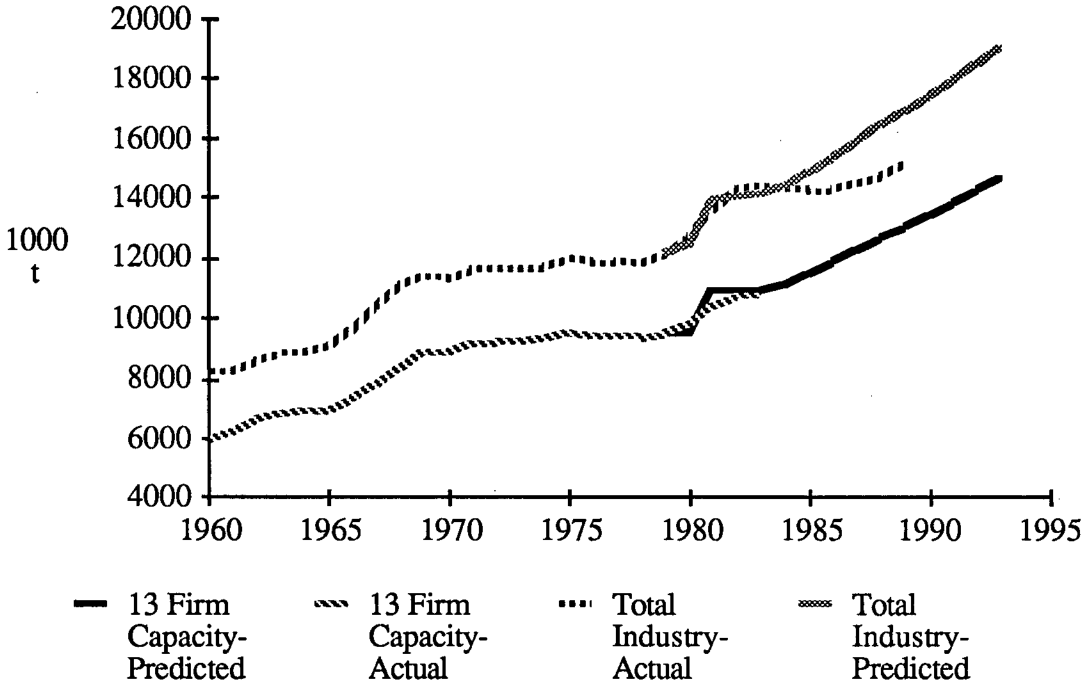
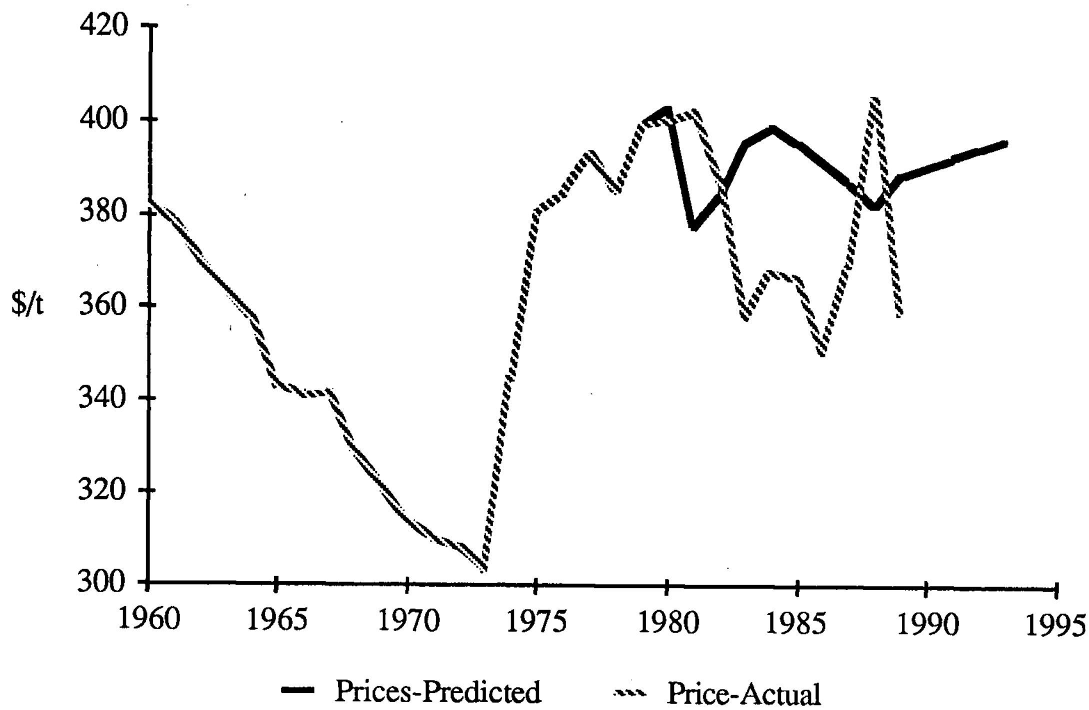


FIGURE 6.6: Actual and predicted prices under constrained market share maximization hypothesis (1979$US/t)



to 1983 time period), but firms are assumed to still pay the fixed cost for this capacity. They cannot permanently shut down a machine or mill. Many firms over this time period also upgraded their old capacity by relatively low investment cost machine speedups. This increases the capacity of a given machine and thus reduces its labour cost.

6.2.3 Mixed objectives between firms

Up to now, all firms have been assumed to have the same objectives; either all profit maximization or all constrained market share maximization. The pursuit of market share maximization or maintenance may be more likely in firms that already possess significant market shares than in smaller firms. What happens to the model's predictions if we assume some firms maximize market share subject to a profit constraint and some firms maximize profits?

If the top five firms maximize market share (subject to a 10% ROS constraint) and all others maximize profits, then the equilibrium solution is for the five firms to each add a machine. Similarly, if only the top four maximize market share, the equilibrium solution is for these four firms to each add a machine. If we assume that only Abitibi-Price maximizes market share, then it adds a machine, and no others are added.

As before, we can see that market share maximization increases the amount of capacity added to the industry, and the market share maximizing firms preempt the profit-maximizing firms, since market share maximizing firms are willing to forego some profits to maintain or increase market share. All firms are assumed to know each others' objectives (and costs, etc.), so other firms will expect that under any situation where the market share maximizing firm gets at least a 10% ROS, it will add new capacity.

6.2.4 Sensitivity analysis

Effect of long run price assumptions. Expectations with regard to the supply and demand balance and industry prices in the long run will have an important influence on the results of the model. All firms are assumed to have the same outlook on these.

The effects of the long run supply and demand assumption was tested by assessing the results for various price assumptions, given the Demand Scenario I assumption of GDP growth of 3% per year.

Under profit maximization, the base case long run price assumption was 0.2% average compound growth in price per year, from 1978 to 1993, and the equilibrium solution was for Consolidated Bathurst to add one machine. If we assume a long run price increase of 1% per year, the equilibrium solution is for no new additions to capacity. A long run price increase of 1.78% per year results in 15 equilibria; all possible combinations of two of the top five firms adding one machine each, and all possible combinations of four of the top five firms adding one machine each. A long run price increase of 2% per year results in the equilibrium solution of Consolidated Bathurst adding one machine (same as the base case). A long run price increase of 2.46% per year results in eight equilibria; all possible combinations of Consolidated Bathurst plus one other of the top five firms adding one machine each, and all possible combinations of Consolidated Bathurst plus three of the other top five firms adding one machine each.

These results were not as expected. Increasing long run price expectations did not lead to a monotonic or predictable change in equilibrium solutions. The main reason for this is likely the discontinuous nature of the decision variable. Firms can only add an entire machine, or none at all. As the long run prices increase, it becomes more profitable for an individual firm to add a new machine, but there is not necessarily an equilibrium solution where each firm's decision is optimal given the decisions of all other firms. For example, with a 2.46% long run price increase, the ROI is positive for all firms, no matter what other firms decide to do.

Under market share maximization and assuming a 10% ROS constraint, the results for a one percent price increase are the same as for a zero percent price increase. For a two percent price increase and above, all firms add a machine (i.e., 13 machines are added).

<u>Effect of investment cost estimate</u>. When the investment cost was increased to $154 million from $140 million, no machines were added under profit maximization. When it was decreased to $126 million, only one machine was added (as with the base case), but that machine

was added by either one of Bowater, Consolidated Bathurst, International Paper or MacMillan Bloedel (i.e., there were four possible equilibria).

Changing the investment cost did not change the results under constrained market share maximization.

Effect of discount rate. The real discount rate was increased to 12.5% from 10% for all firms. Under profit maximization, the equilibrium solution was for no machines to be added. When it was reduced to 7.5%, there were four equilibria: one machine was added by one of Bowater, Consolidated Bathurst, International Paper or MacMillan Bloedel.

Changing the discount rate did not change the results under constrained market share maximization.

Effect of marginal cost estimates. Marginal costs for all firms were first shifted downward by $25/tonne (i.e., the intercept term of the function was reduced by 25). Under these assumptions, no firms added; the most profitable solution was for all firms to do nothing. When marginal costs were shifted up by $25/tonne, there were two equilibria: one was the same as under the base case assumptions (Consolidated Bathurst adds one machine), the other was for Bowater to add a machine.

Reducing marginal costs by $25/tonne did not affect the solution under market share maximization. Increasing them by $25/tonne however resulted in no equilibrium solution, since some firms could not now meet the 10% ROS constraint.

Changing the ROS constraint on market share maximization. Under market share maximization, the constraint on ROS is what determines whether a machine is added or not. A return on sales of 10% is reasonable, but it is of interest to see how sensitive the decisions of firms are to the level. Below a constraint level of 5.7% (i.e., ROS≤5.7%), all firms added a machine, for a total of 13 machines. Thus, if all firms added, the minimum ROS achieved was 5.7% (for Group II). For ROS between 5.8% and 10.4%, all firms except those in group II added a machine. For ROS of 12.5% and 14% there was no equilibrium solution, and for ROS≥15%, there was no feasible solution, since Group II only achieved a maximum ROS of 14.5%.

Summary of sensitivity analysis. The model is highly sensitive to the assumptions made about long run price expectations, particularly under the profit maximization hypothesis. The solution also changed when changes were made in investment costs, discount rates, or marginal cost functions, but not to the same degree. The equilibrium still was to add one machine or in some cases none. The model is not as sensitive under the market share maximization hypothesis, but changes in the ROS constraint caused some shifts in the results. Under different sets of assumptions, no equilibria and multiple equilibria were found. The implications of this will be discussed next.

6.2.5 Implications of multiple equilibria for model validity

A noted earlier in Chapter IV, there is no guarantee that there will be an equilibrium, or that there will be a unique equilibrium, because of the integer nature of the capacity decision. As we can see from the results, the model often predicts multiple equilibria. What are the implications of multiple equilibria? In order for the model to be used for prescribing behaviour, one needs to determine a unique equilibrium.

If there is more than one Nash equilibrium solution, then there is not necessarily a convincing argument that one of the equilibria will in fact occur. If there is a reasonable outcome in the game, then all players should be able to predict it and predict that their rivals will predict it, etc. If players cannot coordinate their expectations in this manner, then there is no reason to expect observed actions to correspond to one of the equilibrium points (Fudenburg and Tirole 1989). The idea is that the Nash equilibria provide a set of candidates for rational play. Some logic or custom suggests one Nash equilibrium is " the way to go"; this logic or custom must be evident to everyone playing the game. There is nothing to guarantee that an "obvious way" exists, only that if it does, it must be Nash.

We are assuming no communication between firms, however they need "to coordinate predictions, to read the same message in the same situation, to identify the one course of action that their expectations of each other can converge on. They must 'mutually recognize' some unique signal that coordinates their expectations of each other" (Schelling 1960). There may, for example, be more information, e.g., on history, than that contained in the game specification. This information may help define focal points for coordination, or perhaps indicate some common sense choice based on past behaviour (Schelling 1960).

Another coordinating mechanism for expectations could be the payoffs to the alternative equilibria; if all firms have higher payoffs with one of the equilibria points compared to the other equilibria, then it seems reasonable that this Pareto optimal point would be the equilibrium. This is a fairly stringent set of conditions, and as such not a useful method for choosing an equilibrium.[7]

In the context of the newsprint industry, we need to identify the possible focal points that could provide a coordinating mechanism for choosing a unique equilibrium from a set of possibilities. Participants in the industry can more readily identify the more likely equilibria, because they have private information and experience that is not available to outsiders. We can identify, however, some likely possibilities for focal points. For example, given historical behaviour, if the equilibria were to add 0, 2 or 4 machines, we could assume that 4 machines would be added (i.e., the most possible). In terms of choosing which combination of firms add, the largest ones could likely be identified as those that would add first. Alternatively, it may be that all firms that have an equilibrium choice that includes adding a machine may add a machine, in which case you would get more than the equilibrium capacity (but this would not be rational behaviour).

The equilibrium that provides a focal point could perhaps be the one that most closely provides a maintenance of the current market share distribution. If firms recognize that sharing the

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[7] A "strong equilibrium" (Aumann 1959) requires that no subset of players, taking the actions of all other players as given, could profitably deviate from the Nash equilibrium. This concept must also hold for the grand coalition of all players, hence a strong equilibrium must be Pareto optimal (Fudenburg and Tirole 1989). Coalitions could exist if there was pre-play communication. Bernheim, Peleg and Whinston (1985) suggested the idea of "coalition-proof" equilibrium, which places less stringent conditions than strong equilibrium (See Fudenburg and Tirole 1989).

market will lead to an orderly and predictable capacity expansion process then this could be appropriate.

If some firms are willing to trade off some profits for market share (e.g., maximize market share subject to a 10% ROS constraint), then they will preempt the market (since others also know that this is their objective). This reduces but does not totally solve the multiple equilibria problem.

Finally, there may be constraints on firms that are not included in the model; for example, there may not be enough room or enough fibre supply for a firm to add a machine at an existing mill, and it must, if it wants to add capacity, build a greenfield mill. This would change its costs and timeframe for expansion relative to other firms. It may also face financial constraints. Users of the model in industry would also have better information on objectives, constraints and costs, and by incorporating this information into the model, would likely reduce the number of equilibria. Industry users would also have more information that could lead to identification of focal points.

6.2.6 Summary of validation

The assumption of profit maximization resulted in total industry profits of 5.73 billion dollars, compared to 3.67 billion dollars for the maximization of market share subject to a 10% ROS constraint (and assuming forecast, not actual, fringe expansion). This is a reduction of 2.06 billion dollars, or 36%. Individual firms' profits were also all lower than under the profit maximization hypothesis, with reductions of between 44% (Consolidated Bathurst) to 32% (Bowater). Thus there is a major tradeoff in profitability between market share and profit maximization. As expected, pursuing a market share maximization strategy also resulted in more capacity being added than under profit maximization. When firms were assumed to maximize their ROI, a total of four machines were added, still less than what actually was added, but closer than under strict profit maximization. Market share maximization resulted in more stable equilibria when the various factors were varied in the sensitivity analysis.

While neither hypothesis resulted in predicted individual firm capacity additions exactly, the results for the market share maximization hypothesis were much closer to reality than those for the profit maximization hypothesis. Thus in terms of descriptive validity, the constrained market share maximization hypothesis seems to result in reasonable predictions. The profit maximization assumption results provide a benchmark of behaviour that can be compared with outcomes under other objectives.

As a prescriptive model, the results are limited in their applicability unless a reasonable method of choosing between multiple equilibria can be identified. Further work is needed to identify focal points in the industry that are recognizable as such to all firms. The inclusion of better information on firms' objectives and additional constraints on behaviour would also aid in producing more realistic results. The constrained market share maximization assumption provides a reasonable description of industry behaviour, but more insight could be gained with more accurate objectives for each firm.

6.3 Results under uncertainty

The model assumes that firms are rational, which means that a firm will choose from among a set of possible alternatives the alternative that has consequences which are preferred relative to all others. The firm must therefore rank alternatives by assigning their consequences some value that relates to the firm's preferences. Firms have so far been assumed to maximize either profits or market share, with all forecasted conditions known with certainty.

However, firms must compete and make choices in an environment of uncertainty. They face uncertainty, for example, in future demand levels and elasticities, labour costs, political regulatory changes and interest rates. Uncertainty exists when there is a set of possible events or states of the world, each of which could occur or exist, but only one of which will do so. "To say that a decision is affected by uncertainty is to say that the outcomes of at least one of the courses of action being considered is different according to which state of the world occurs" (Sugden and Williams 1978, P. 52). This section deals with the question of how one can incorporate uncertainty into the decision-making framework, and what effects this has on the outcomes predicted by the model.

6.3.1 Dealing with uncertainty

One method of dealing with uncertainty is to estimate probability distributions over uncertain events. Cumulative distributions can then be compared to determine which course of action dominates the others. In many cases, there will not be a clear conclusion over which action is preferred, so expectations of returns can be calculated and used to rank consequences. The difficulty in using expectations to compare alternatives is that individuals have different risk preferences. There is a trade-off between expected or average returns and the risk of that return, and individuals differ in what value they place on this tradeoff. Only individuals that place no value on risk avoidance (i.e., they are risk neutral) would strictly choose the alternative that maximized expected profits. In general, decision-makers are assumed to prefer larger expected returns to smaller ones, and smaller risk to larger risk, all other things being equal.

First of all, how is risk defined? While the dictionary definition is " the possibility of incurring misfortune or loss" (Collins 1986), classical decision theorists generally conceive of risk as reflecting the variation of possible outcomes and the probabilities and values of those outcomes (March and Shapira 1987). In order for a situation to be risky, there is a need for there to be a potential loss of some amount, and there must be some uncertainty or chance of loss. There must also be some way for the decision-maker to affect the magnitude or chance of loss by his actions. Decision models for comparing distributions of returns often rely on comparisons of some measure of returns (usually expected returns) and a risk parameter measured from the distribution (e.g., variance or probability of loss). The most common of these parametric models is the mean-variance model. Risk can also be measured as the premium a decision-maker would be willing to pay to remove the risk which is a function of the nonlinearities in a decision-maker's utility function for money. Utility models are based on comparisons of expected utility between distributions (Keeney and Raiffa 1976). There is some overlap between the two types of models, since some parametric models correspond to expected utility models.

The method that will be used to incorporate risk into the model is to compare probability distributions of outcomes based on expected utility. We can define a utility function as a measure of the desirability of the alternative, where the decision-maker prefers the alternative with the greatest expected utility. Utility is invariant through transformation of origin and unit of scale. A decision maker's attitude towards risk can be explicitly incorporated in a utility function. Nonlinear utility functions for monetary payoffs indicate the decision-maker is not risk neutral for all values; if a decision-maker is strictly risk averse, his utility function will be concave; if a decision-maker is strictly risk seeking, his utility function will be strictly convex.

One form of utility function is the exponential. This function is as follows:

$$U(r)=-e^{-br} \text{ for } b>0 \text{ and } U(r)=e^{-br} \text{ for } b<0$$

where b is the Pratt-Arrow measure of risk aversion (Pratt 1964). The risk aversion of a decision-maker is thus constant and is not a function of his wealth.[8] If $b>0$, the function is concave everywhere, indicating risk-avoiding behaviour. The larger the value of b, the more conservative the decision-maker. For $b<0$, the function is convex everywhere, indicating risk-seeking behaviour.

The maximization of a decision-maker's expected utility for profits (for exponentially distributed utility function) is approximately equal to the maximization of the mean-variance model

$$\text{Maximize } \mu - 1/2\, \sigma^2\, b,$$

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[8] Other utility functions permit decreasing risk aversion with increasing wealth levels (e.g., logarithmic, double exponential, special exponential). This is intuitively appealing, since as an individual's assets increase, he may be willing to pay less of a risk premium for a given risk (Keeney and Raiffa 1976). A risk-averse decision-maker will attach a positive risk premium to any risk, but will attach a smaller premium to any given risk the larger his wealth. That is, they become better able to afford a specific risk.

where μ is the mean profit, σ^2 its variance and b is a measure of risk aversion[9] (see Appendix III for derivation).

The assumption of constant risk aversion is a useful simplification, and some researchers think that the exponential function is a reasonable approximation to decision-makers' actual preference levels (Howard 1971, Savage 1971). Because it can be expressed as a mean variance model, it provides a description of behaviour that is relatively simple, computationally efficient, readily calculable and easily understood by others (Libby and Fishburn 1977). The exponential distribution is most appropriate when catastrophic risks are not considered (e.g., risk of ruin). It permits useful comparisons when the distribution of outcomes for the alternatives do not result in large changes in wealth relative to initial wealth. These conditions are met for capacity expansion decisions in the newsprint industry.

There are some indications that newsprint firms' objectives are aimed at the maximization of monetary values, e.g., "Our primary objective continues to be to enhance the underlying value of the Company for our shareholders" (Bowater Annual Report 1987); "To maximize the value of the Company to its investors" (Abitibi-Price Annual Report 1987). It is reasonable to assume that while firms may strive to achieve "value maximization", they may differ in their risk preferences and this will affect their decisions. Thus we can investigate the impact of differences in risk aversion on the model solutions, by assigning different measures of risk aversion to firms and evaluating decisions assuming the exponential utility function. These risk aversion measures (i.e., the values of b) must be inferred from the behaviour of firms and published statements. We examine the sensitivity of the solution to various values, and infer some general conclusions from the results.

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9 Freund (1956) has shown that this maximization equivalence is exact if the random variable is normally distributed.

6.3.2 Uncertainty and objectives in the model

There are two levels of decisions in the model: production decisions and capacity decisions. Production decisions are contingent on capacity decisions. The objectives for production decisions and capacity decisions may differ because of the time horizon differences and degree of uncertainty. The production decision is made for the short run; capital (capacity) is assumed to be fixed. Because the horizon for the production decision is one year, we assume that there is no uncertainty : firms know the demand function for that year. With a short planning horizon and no uncertainty, the assumption of profit maximization is reasonable. Thus for the production decision, firms are assumed to maximize one year profits.

In the longer term planning horizon of 15 years or so, there is considerable uncertainty about future events, particularly demand function levels. This uncertainty points to the need for explicit incorporation of risk attitudes for firms. Section 4.2.2 shows how uncertainty is incorporated into the model framework. The only uncertain element is assumed to be demand. A series of scenarios are specified, with associated probabilities. Firms are assumed to have the same probability forecasts for the demand scenarios.[10] A scenario consists of estimates of the elements affecting the demand function for each year over the entire planning horizon. In particular, estimates are made of U.S. GDP in each year, as well as forecasts of fringe capacity, substitute prices, etc. (See Section 5.4).

Because it is difficult to infer the objectives of firms, we would like to determine the robustness of the model solution under different assumptions. Thus in the validation section, we tested the hypothesis of maximization of profits. Maximization of profit serves as a useful starting point in the absence of any further information about objectives and provides a benchmark. We

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[10] The assumption that all firms have similar forecasts of demand functions and probabilities is probably reasonable given the high degree of information exchange in trade journals and newspapers. While the model could easily be modified to allow differences between firms, the input data and space requirements would be significantly increased. It would also be difficult to determine what each individual firm's forecast was.

also examined the consequences and predictive ability of the hypothesis of market share maximization subject to a profitability constraint, which provided results that corresponded more closely to observed behaviour.

Now we investigate the results under the assumption of maximization of expected utility. The impact of risk attitudes is investigated by assuming that all firms have an exponential utility function for profits and thus maximize $\mu-\sigma^2 b/2$. The assumption of an exponential utility function with constant risk aversion is reasonable since the size of the investment decision is small relative to the assets of the firms, so there is no risk of ruin from a poor investment choice.

Clearly firms may have other objectives beyond those discussed here (see, e.g., Scherer 1980). While these could be incorporated in various ways into the model, the range of objectives tested here provides a reasonable base for determining the robustness of the model to objectives. Industry users of the model would use their private information to better infer individual firm objectives.

6.3.3 Results of runs

In Section 6.2, firms were assumed to have no uncertainty about the future demand function. They were assumed to maximize profits or market share, subject to an assumed commonly viewed demand function. Unfortunately, demand is not perfectly forecastable. There is a certain amount of uncertainty as a result of uncertainty in the growth rate of the economy, among other factors. The base case demand scenario is described in Section 6.1. U.S. GDP is assumed to increase at a rate of 3% per year, and all other factors remain constant. We assume that this demand scenario occurs with a probability of 34%, and there is a 33% probability that the economy grows at each of 2.5% and 3.5% per year. The growth rate of real price is assume to stay at 0% per year. (In other words, by 1989, capacity and demand will be in balance such that no matter what the assumed growth in the economy, price will not increase in the long run. In the short run however, the differences in growth rates will have a significant impact on prices). Figure

6.7 shows three capacity projections (0, 6 and 13 machines added by 1983) for the three demand scenarios. All other factors (e.g., price of substitutes) remain the same as the base case scenario.

All firms same risk aversion. The equilibrium solution for the assumption of maximization of expected profits (i.e., b=0) is for no new capacity to be added. The results are the same when the probabilities are changed to (0.5,0.25,0.25). If a long run price increase of one percent is assumed, results remain the same: no machines are added (under both sets of probabilities).[11] The equilibrium solutions assuming other values of the risk aversion term b for all firms can be compared to the expected profit maximization case, assuming firms maximize $E(\pi)-b\ \sigma^2/2$.

Increasing the b value increases the risk aversion of the firm – firms will trade off some profit for a reduction in variability of outcomes, where the variability results from the uncertainty in demand scenarios. A value of b=0.00005[12] did not change the solution from the expected profit maximization solution. For values of b above 0.00005, multiple equilibria resulted. There were eight to 24 equilibria, ranging from adding 0 to various combinations of firms adding a total of eight machines (see Table 6.6), as b was increased to infinity (i.e., minimization of variance).

The model was also run assuming all firms were risk prone, i.e., with b<0. Again there were multiple equilibria, ranging from a total of one to nine machines being added (see Table 6.6).

There is a U-shaped trend to Table 6.6. As risk aversion increased or decreased, the maximum number of machines added increased. (Note there is still a range of number of machines

[11] The results for market share maximization were the same as the base case when we assumed a probability distribution over the three demand scenarios of (0.34,0.33,0.33) (for both the zero percent and one percent price increase in the long run). For the base case with no uncertainty, the equilibrium solutions assuming firms maximize solely their return on the new investment was all possible combinations of four of the top five firms adding one machine, or group I adding four machines. The results for maximization of expected ROI are similar - four of the top five firms add one machine each, resulting in five different equilibria. Under an assumption of 1% price increase in the long run (and keeping the probabilities of demand scenarios at 0.34, 0.33 and 0.33), we obtain 15 equilibria. A total of seven, eight or five machines are added.

[12] Note that profits are in thousands of dollars; the value of b depends upon the units of wealth used.

FIGURE 6.7 Three capacity projections
(for 0, 6 and 13 machines added by 1993) for the three demand scenarios
(D 1=3%GDP/yr, D 2=3.5% GDP/yr, D 3=2.5% GDP/yr)

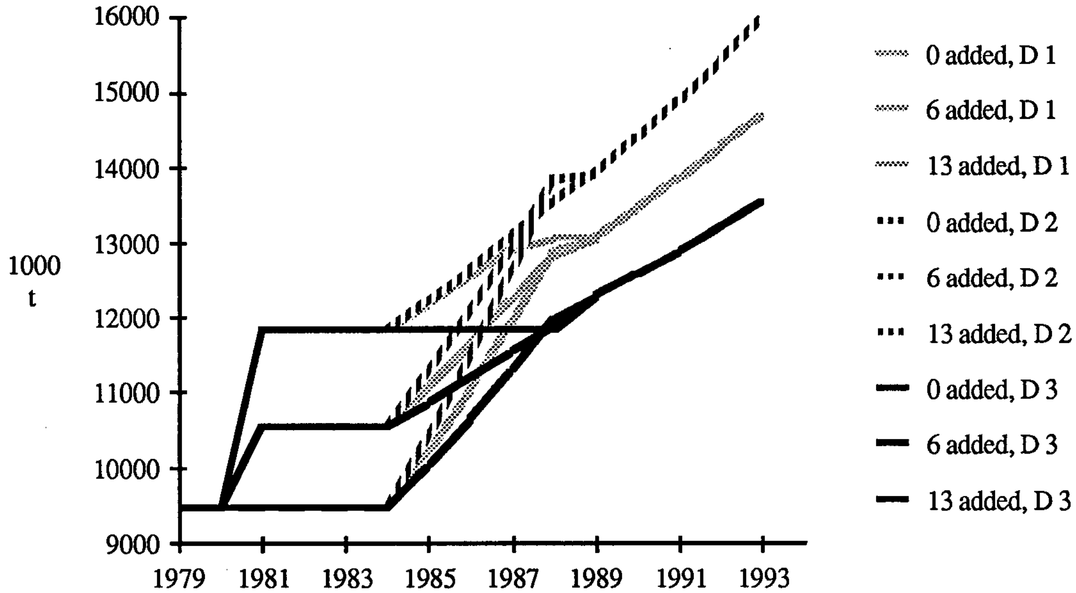

TABLE 6.6: Number of equilibrium solutions and total number of machines added for various values of b.

No. of machines added	Value of b ($x10^{-4}$) -10	-5	-1	-0.5	0.0	0.5	1	5	10	100	∞	Industry Profits (billions $)
0					1	1	1	1				5.91
1	5	5	5	5								5.66
2							6	10	10			5.34
3	10	10	10	10								5.07
4							1	5	6	7	7	4.74
5			1									4.61
6										13	17	4.32
7												
8												
9	7	7										3.59
10												
11	10	7										3.19
TOTAL	32	22	16	15	1	1	8	16	16	20	24	

added because of the multiple equilibria, but as noted earlier, an assumption of the maximum capacity equilibrium is probably reasonable for the newsprint industry).

Total industry expected profits decreased with increasing number of machines added (see Table 6.6). The approximate level of total profits remained the same independent of which firms added, but the distribution of profits varied (i.e., which firms received how much profit).

Modifying the assumptions slightly to assume a one percent annual price increase in the long run did not materially change the results.

Differing risk aversions between firms. Clearly, not all firms will necessarily have the same risk attitudes. What happens if some firms are risk-prone and others risk-averse?

Table 2.2 lists the firms in the model, the volume of sales for all products and the percentage of sales attributable to newsprint. The differences in size, diversity of product mix and exposure to newsprint market, will influence the risk attitude of the firm. Because of the high percentage of newsprint sales for Abitibi-Price and Bowater (46% and 72% respectively), these two firms were assumed to be risk averse (b=0.0005) and all others risk neutral. This resulted in two equilibria: zero added (the same as when all firms had b=0), or Abitibi-Price and Bowater each add one. (The results remained the same for b=0.001 and b=0.01). If we assume that all other firms are risk-taking, then there is no equilibrium solution (for various values of b). If we assume that other firms are also risk averse, but less so than Abitibi-Price and Bowater, then we obtain more multiple equilibria. If b=0.001 for Abitibi-Price and Bowater, and b=0.0005 for other firms, there are 16 equilibria, the same ones as if all firms had b=0.0005. Similarly, if b=0.001 for Abitibi-Price and Bowater, and b=0.0001 for other firms, there are 8 equilibria, the same as if all firms had b=0.0001.

6.3.4 Conclusions for results under uncertainty

It is difficult to infer any general behaviour given the results of the tests with various risk attitudes. There are some combinations of assumptions that result in capacity expansions similar to what happened over the 1979 to 1983 time period, but the mechanism for choosing this equilibrium over others is not clear.

In order to use the model as a prescriptive tool, a mechanism for choosing between multiple equilibria is needed, as discussed in Section 6.2.5. The plethora of equilibria under most of the risk attitude assumptions tested here underlines this point.

6.4 Strategic Experiments

The model has been developed as a decision-making tool. A firm would likely use it in the descriptive/prescriptive manner described by Raiffa (1982). It would want the model to be descriptive of the behaviour of other firms, and prescriptive for itself. It could also use the model as a "what -if" simulation framework, and test out strategic implications of various assumptions about industry structure. For the following examples of how the model could be used, the user firm was assumed to be MacMillan Bloedel.

We assumed that market share maximization was a reasonable approximation to the objective functions for all other firms in the industry. Then, if MacMillan Bloedel wanted to maximize its profits, it should not add a new machine. (The equilibrium solution was for a total of 8 machines to be added, not including MacMillan Bloedel). If however, it wished to maximize market share subject to a 10% constraint on profitability, i.e., the same as other firms in the industry, then it should add a machine, for a total of 9 machines in the industry. This analysis is predicated on the assumption that the other firms know its objective. However, because MacMillan Bloedel's decision does not cause the decisions of the other firms to change, we can look at the difference in profits from the two possibilities. Its profits if it adds a machine are $384 million, versus $435 million if it doesn't. Thus there is over 51 million dollars difference between the two decisions. This reflects both the reduction in prices as a result of more capacity being added, as well as the increase in costs to MacMillan Bloedel (i.e., through the investment costs). MacMillan Bloedel would have to look at that $51 million dollar difference and determine if market share was that important to it.

We can also look at MacMillan Bloedel's profits for the option of adding or not adding a machine, given the approximate actual capacity decisions from 1979 to 1983 (i.e., Abitibi-Price, Bowater and Group I all adding machines). MacMillan Bloedel's profits would be $467 million if they did not add and $421 million if they added. The most profitable decision would thus have been to not add, assuming that their decision did not impact the decisions of other firms in the industry. Thus assuming that Abitibi-Price, Bowater and Group I maximize market share subject to 10% ROS constraint, and that the others including MacMillan Bloedel maximize profits, the equilibrium solution was for MacMillan Bloedel not to add, and for Abitibi-Price, Bowater and Group I to all add machines.

What happens if MacMillan Bloedel reduces its marginal cost for existing capacity by $25 per tonne (i.e., it shifts its marginal cost curve down by $25)? The equilibrium solutions do not change, under profit maximization or market share maximization for all firms, but MacMillan Bloedel's profits increase significantly. Assuming market share maximization for other firms, MacMillan Bloedel's profits increase from $383 to $505 million if it adds a machine, and from $435 to $553 million if it doesn't.

Under uncertainty, if MacMillan Bloedel is very risk averse, i.e., it wants to minimize the variability of its returns, and all other firms are market share maximizers, then MacMillan Bloedel's optimal decision is not to add a machine. The decisions of all other firms remain the same independent of MacMillan Bloedel's decision, and are the same as if MacMillan Bloedel also had a market share maximization objective. MacMillan Bloedel's expected profit is also higher if it does not add: $430 million versus $380 million if it adds.

Thus we can use the model to look at tradeoffs for an individual firm under different objectives, or under different cost assumptions. All firms are assumed to have full information about each other, so one can't assume that a firm switches its objective from day to day, however the model does provide some strategic insights into the impacts of various assumptions and goals on profits.

CHAPTER VII

CONCLUSIONS AND FUTURE RESEARCH

7.1 Introduction

A strategic capacity planning model has been developed for a firm in the newsprint industry in North America. The model was tested for the 1979 to 1983 time period, and its predictions compared to historical data. The sensitivity of the model to various assumptions was tested, and its performance under different objective functions evaluated. This chapter summarizes the conclusions and recommendations from this research.

7.2 Evaluation of model

The model's explicit depiction of the largest firms in the industry and their interaction in terms of both production and capacity decisions makes it a useful tool for strategic planning. The model is prescriptive for an individual firm, and if appropriate assumptions are made about firm objectives, it is also descriptive of industry behaviour. Under assumptions of market share maximization subject to profitability constraints, the model predicted total industry expansion reasonably well, although because of various simplifications, the model could not accurately predict actual behaviour of individual firms. The firms within groups were assumed to be identical, and to behave identically under the same circumstances. This, combined with the simplification of allowing only machine add-ons and not machine speed-ups, shut downs or new mills, reduced the predictive ability of the model. While the model is intended to be prescriptive for an individual firm, it must also provide a good description of the behaviour of other firms if it is to be useful for planning.

The model can be used to gain some insight into the structure of the industry, and its development under different conditions. The reduction in industry profits as result of market share maximization instead of profit-maximization, and the changes in outcomes for differing risk attitudes offer some insight into tradeoffs.

The rational profit-maximizing model for firm behaviour does not appear to fit firms in the newsprint industry. Even with the limitations of the data and the model, it seems clear that rational profit-maximizing firms would have added much less capacity than that actually added over the study time period. The profit maximization assumption provides a useful benchmark for comparison of behaviour under other objectives. One explanation for its poor predictive ability is that firms have other objectives (e.g., market share); another is that firms do not fully take into consideration the impact of their decisions and their competitors' decisions on profits. They may believe, for example, that their adding a machine will not have much impact on future prices. There may also be a tendency for firms to overinvest because of the agency reward structure problem. If a decision is made to invest in a machine when all other firms are investing, then if the worst case demand scenario occurs, the manager can always blame industry factors (Porter and Spence 1982). However, if the decision is made not to invest when others are investing, and the best case demand scenario occurs, then it is difficult for a manager to explain his decision.

The prescriptive validity of the model is dependent on the validity of the underlying assumptions and input data. The rational actor model requires consistency in behaviour, which seems to provide a reasonable approximation to actual behaviour. The model leads to improved decision-making by compelling firms to consider firm interdependencies explicitly. A feature of this model that is both a drawback and a strength is the requirement of detailed information about all major competitors in the industry. While information on costs, strategies and objectives may be difficult to determine, it is crucial for effective competitor analysis and strategic planning (see

Porter 1980). The inclusion of improved information on objectives, financial constraints, costs, etc., will improve the validity of the model as a decision-making tool

Multiple equilibria (as well as no equilibria) were a problem with the model, resulting in large part from the integer nature of the capacity decision variable. The problem was not significant when some or all firms were assumed to maximize market share; market-share maximizing firms willing to trade off profit for market share would then preempt the market. There are some logical ways to choose from among equilibria, but focal points and decision rules for equilibrium choice need to be identified for the industry. Interviews or questionnaires with industry experts could shed more insight on this problem.

The results were, not surprisingly, sensitive to assumptions made about long run prices, although the profit-maximizing hypothesis results were more sensitive than the market share results. This was true of all the sensitivity tests, and perhaps this stability indicates a reason why constrained market share maximization may be pursued by firms.

The integer nature of the capacity decision was considered to be crucial to the problem in the newsprint problem. It is the coordination of the lumpy capacity additions that causes overcapacity problems. This decision to use integer values for capacity decisions limited the design of the model, as well as the size of it in terms of number of firms and number of strategic choices per firm, because of the burdensome nature of large integer problems. It effectively precluded the use of a dynamic model, because of the number of state variables (i.e., number of machines added by each firm) and number of possible states in each year. This problem could probably be somewhat alleviated if the pricing portion of the model was less detailed, or modelled in some way that did not require the knowledge of each firm's capacity. The state variables could then be just total number of machines added to date by the industry and total number of machines added by the particular firm. This would reduce the computational effort substantially.

The newsprint model described here uses an open loop solution.[1] The open loop model is very tractable compared to the computational requirements of a feedback model. The model is also more flexible and easier to modify. We assume that a firm makes a decision about adding capacity in the first time period. The capacity is added after a lag of two years, and then we assume that the firm's capacity does not increase over the rest of the planning horizon. Given the assumed demand functions and an assumed rate of price increase, we determine the total industry capacity increase required to result in those prices. This approximates an orderly long run expansion of capacity that keeps pace with demand, according to some long run price trend.

What are the implications of using an open loop as opposed to a feedback solution? There has been little research done to determine the magnitude of the differences between the two types of solutions (Salant 1982). The question we are interested in is whether a firm's decision would differ under the two solution types. Firms are assumed to commit to their decisions under the open loop assumption and this seems reasonable given that we are looking at only a short (five year) time horizon. With longer planning horizons, precommitment is less realistic. However, a more myopic horizon is probably appropriate in the case of the newsprint industry.

One could approximate a feedback systm by implementing the current model using a "rolling plan" approach. Thus a decision-maker would face a finite planning horizon of the same

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[1] For any game in extensive form, there are three possible Nash solution types: the closed-loop, the open-loop and the feedback (or subgame perfect) solutions, where the latter two are a subset of the closed loop type (Salant 1982). Under the closed loop solution, each firm has a set of decision rules that are a function of the vector of state variables at each period; in other words, the trajectories can be revised after the game is started. This sequence of decision rules is optimal given the sequences of decision rules of the other players. If each firm takes the time-dated sequence of decisions of other firms as completely prespecified (though able to depend on state variables), this is the open loop solution. Under a feedback solution concept, each firm determines its optimal decision rule given the vector of state variables in each period and the expectation that all firms continue to make optimal decisions in subsequent periods. Thus at any period in the game, the decision rule of each firm is optimal given the decision rules of other firms. The feedback and open loop formulations correspond to two extremes with regard to the ability of firms to make commitments about future actions. The open loop corresponds to the assumption that firms commit over the entire planning horizon; the feedback or decision rule formulation corresponds to the assumption that no commitment at all is possible (Reinganum and Stokey 1985).

length in each period, and would implement the "first period decision" in each period, depending upon the actual observed state.

A dynamic model would allow a more strategic long term planning tool, in the sense that each firm would base its decision on the assumption that all firms act optimally in the future, and its future decisions would be contingent on what decisions had been made up to that time (i.e., a closed loop model). Again, there would be no guarantee of an equilibrium solution, and multiple equilibria could also be a problem. However, this is perhaps a useful area to pursue in terms of a capacity planning tool. While one can use the current model to examine the implications of alternative production and pricing decisions, it is not likely that firms would use this part of the model for operational production planning, because of its lack of detail. Thus simplifying this component even more, to permit more detailed modelling of the capacity decision, might be in order.

Game theory type models have intuitive appeal for strategic planning, because of the interdependence of firms' decisions. However, the application of this methodology to real empirical problems is not straightforward. Real problems have many firms with asymmetries in costs, objectives and sizes. In addition, economic conditions do not remain constant over time. This causes computational problems in actually solving the model. The assumptions of rationality of firms, complete information and simultaneous decision-making are also strong, and the solution concept of the Nash equilibrium is weakened by the existence of multiple equilibria and the problems of choosing a logical one from these. Despite these drawbacks, there is still value in further pursuing this line of research. The modelling exercise could help a firm think more strategically, and to consider more explicitly the interdependence of its decision with those of its competitors. This type of model can also provide valuable insights into tradeoffs between decisions.

7.3 Possible modifications and other applications

As noted above, the possibilities for expansion of the model are limited by the high computation cost. The model currently solves in about 42 seconds of CPU time with two capacity options and three demand scenarios, and in about 200 seconds of CPU time with three capacity options and one demand scenario, on an IBM 3081 K mainframe. However, if these difficulties could be overcome, either through a further simplification of the model, or improvement in algorithms, there are a number of possible modifications and applications that are of interest.

The number of possible capacity alternatives should be increased to improve the realism of the model. Firms, in addition to adding a machine to an existing plant, can also build a greenfield mill (although this would be dominated by a machine addition if feasible), permanently shut down an uneconomical machine, speedup (increase the capacity) of some existing machines, or in some cases convert a machine to another product.[2] In particular, firms in recent years have converted some older newsprint machines to groundwood specialty papers that command higher prices. If the GWS industry (i.e., firms and demand) were also included in the model, then the choice of converting to GWS could be made endogenous.

Similarly, the increasing demand for recycled content in newsprint is creating a new market. Thus one could have separate demand functions for virgin and recycled newsprint, and firms could choose to invest in recycling equipment to meet recycled newsprint demand, or to invest in virgin newsprint capacity. Decisions will depend upon what others do in both markets.

A further modification to the model would be the explicit incorporation of the Canadian-U.S. exchange rate. This has a major influence on the profitability of firms in Canada, and will impact their investment decisions. Currently all costs are in U.S. dollars in the model. The incorporation of exchange rates is complicated by the fact that most firms have capacity in both the

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[2]In some cases firms convert machines from other products (e.g., linerboard) to newsprint. For example, both Abitibi Price and St. Regis converted linerboard machines to newsprint during the time period of the study.

U.S. and Canada. In addition, any aggregation of firms into groups would have to account somehow for the geographical distribution of capacity between the two countries.

This framework is suitable for other strategic decisions besides those of capacity expansion in the newsprint industry. Further research into this and similar methodologies should prove useful to the strategic planning field.

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APPENDIX I

PROOF OF EXISTENCE AND UNIQUENESS OF NASH EQUILIBRIUM IN PRODUCTION QUANTITIES

Consider an n-player normal form game whose strategy spaces S_i are compact convex subsets of an Euclidean space. If the payoff functions $\pi^i(s)$ are continous in s and quasiconcave in s_i (quasi concavity in own actions implies that reactions are convex valued), there exists a pure-strategy Nash equilibrium (Fudenburg and Tirole 1989).

We would like to determine the existence and uniqueness characteristics of the production problem of the model. The general conditions for the existence of Nash are fulfilled. We have a linear demand function, and convex or linear marginal cost functions thus payoffs are continous and concave in q_i . The maximization is over a convex set (linear constraints).

The proof of uniqueness of the Nash equilibrium for the production problem follows (from Salant [1982])

As described in Section 4.4.2, the first order conditions that define the Nash equilibrium in production quantities (ignoring corners for simplicity) are:

$$P+q_i /D'(P) + (q_i/D'(P))\cdot(\partial Q_{-i}/\partial q_i) - C_i'(q_i) = 0 \text{ if } 0<q_i<k_i \qquad i=1,\dots,n$$

where $Q_{-i}=\sum_{j\neq i} q_j$

If $P=a-bQ$ where $b,a>0$ then we have

$$a-bQ-bq_i - bq_i\cdot(\partial Q_{-i}/\partial q_i) - C_i'(q_i)= 0 \quad i=1,\dots,n$$

Now consider the following artificial problem

$$\underset{\{q\}}{\text{Maximize}}\ M(q_1,\ldots q_n)$$

subject to $q_i \geq 0$

$q_i \leq k_j \quad i=1,..,n$

where $M = a\Sigma q_i - b/2\cdot(\sum_{i=1}^{n} q_i)^2 - b/2\cdot(\sum_{i=1}^{n} q_i^2) - \sum_{i=1}^{n} C_i(q_i)$.

Now the first order conditions for maximization of M are

$$a - bq - bq_i - bq_i\cdot(\partial Q_{-i}/\partial q_i) - C_i'(q_i) = 0 \quad i=1,\ldots,n$$

The necessary conditions for a maximum to this constrained-optimization problem are identical to the conditions defining the Nash equilibrium. Note that M is concave. The first term is linear, the second, and third[1] are strictly convex so their negatives are strictly concave, and the last term is convex by assumption (and its negative is thus concave). The sum of concave functions is a concave function. The function M is thus strictly concave over a convex set (the constraints are linear so the constraint set is convex), so only one maximum exists. Since the conditions for a maximum for M also fill the conditions for a Nash equilibrium, there is only one Nash equilibrium to the original problem.

---

[1] $\partial Q_{-i}/\partial q_i$ is the conjectural variation term, which is assumed to be a constant (between -1 and +1).

APPENDIX II

CALCULATING NET STANDARD NEWSPRINT CAPACITY BY FIRM
(THOUSAND METRIC TONS)

	Capacity	1979	1980	1981	1982	1983
1. Abitibi-Price[a]	CPPA News	1,926	1,976	2,053	2,120	2,040
	GWS (–)	228	248	245	227	217
	Strikes (–)	0	312	0	0	0
	Net News	1,698	1,16	1,808	1,893	1,823
2. CIP[b]	CPPA News	1,281	1,284	1,307	1,026	1,084
	GWS (–)	296	285	284	282	275
	Strikes (–)	0	0	0	0	0
	Net News	985	999	1023	744	809
3. Bowater	CPPA News	1,165	1,285	1,308	1,333	1,266
	GWS (–)	0	0	0	0	0
	Strikes (–)	0	0	0	0	0
	Net News	1,165	1,285	1,308	1,333	1,266
4. MacMillan Bloedel[c]	CPPA News	1,107	1,108	1,221	976	923
	GWS (–)	117	88	228	244	231
	Strikes (–)	215	0	137	0	0
	Net News	775	1,020	856	732	694

APPENDIX II – Continued

	Capacity	1979	1980	1981	1982	1983
5. Cons. Bathurst[d]	CPPA News	909	929	943	922	908
	GWS (–)	209	229	243	286	269
	Strikes (–)	0	60	0	0	0
	Net News	700	640	700	636	639
Group I Avg per firm	CPPA News	605.3	630.8	677.5	680	706.3
	GWS (–)	0	0	0	0	0
	Strikes (–)	0	0	0	0	0
	Net News	605.3	630.8	677.5	680	706.3
Group II Avg per firm[e]	CPPA News	381	384.3	433	481	444.3
	GWS (–)	0	0	0	0	0
	Strikes (–)	0	0	13	0	0
	Net News	381	384.3	420	481	444.3
Total for Model Firms	CPPA News	10,333	10,642	11,274	11,021	10,823
	GWS (–)	850	850	1000	1039	992
	Strikes (–)	215	372	189	0	0
	Net News	9,268	9,420	10,085	9,982	9,833
Fringe Firms	CPPA News	2,540	2,908	3,166	4,044	4,372
	GWS (–)	0	0	0	0	0
	Strikes (–)	57	0	0	0	0
	Net News	2,483	2,908	3,166	4,044	4,372

APPENDIX II – Continued

	Capacity	1979	1980	1981	1982	1983
Total Industry	CPPA News	12,873	13,550	1,440	15,065	15,195
	GWS (–)	850	850	1,000	1,039	992
	Strikes (–)	272	372	189	0	0
	Net News	1,1751	12,328	1,351	14,026	14,205

SOURCES: CPPA Newsprint Supplements and ANPA Newsprint Statistics for mill capacities and industry capacity by year. Annual reports and Pulp and Paper journal for information on strikes and groundwood specialty capacity.

NOTE: Strike quantities are adjusted for GWS if applicable (depends on mill struck).

[a] GWS produced at Sault Ste. Marie and Kenogami

[b] GWS produced at Trois Riviere. 1982–83 excludes U.S. mills (CIP sold to CP)

[c] GWS produced at Powell River and Port Alberni. 1982–83 excludes MacMillan Rothesay (sold to Irving)

[d] GWS produced at Trois Riviere, Grandmere, Port Alfred

[e] 1983 excludes Crown's U.S. mills (Canadian mills sold)

APPENDIX III

DERIVATION OF MEAN-VARIANCE MODEL OF EXPONENTIAL UTILITY

One form of utility function is the exponential which implies constant risk aversion. This function is as follows:

$U(r)=-e^{-br}$ for $b>0$ and $U(r)=e^{-br}$ for $b<0$.

The Pratt-Arrow measure of risk aversion r(x) (Pratt 1964) is

$$r(x)=-U''(x)/U'(x).$$

In the case of the exponential utility function $r(x)=b$. Thus the risk aversion of a decision-maker is constant and is not a function of his wealth. If $b>0$, the decision maker is risk avoiding; if $b<0$, the decision-maker is risk-seeking.

The risk premium is the amount that the decision-maker is willing to give up to avoid the risk associated with the choice. In general, the risk premium π is defined such that the decision-maker is indifferent to receiving ß and the non-random amount $E(ß)-\pi$ (Pratt 1964). That is,

$$U[x+E(ß)-\pi(x,ß)] = E[U(x+ß)]$$

In general the risk premium is equal to

$$\pi(x,ß)=1/2\ \sigma^2_ß\ r(x+E(ß)) + o(\sigma^2_ß),$$

for ß with small variance $\sigma^2_ß$ where r(x) is the Pratt-Arrow measure of risk aversion. (o( ) means "terms of smaller order than"). Thus the risk aversion index $r(x+E(ß))$ is approximately equal to twice the risk premium per unit of variance for infinitisimal risk. And

$$E[U(x+ß)]=U(x+E(ß)-\pi)\approx U[x+E(ß)-1/2\ \sigma^2_ß\ r(x+E(ß))]$$

If a firm is assumed to maximize its expected utility for profits, and has an exponential utility function for profits, then its maximization problem can be expressed in terms of a mean-variance tradeoff. Assume that ß is the level of profits and is distributed with mean μ and variance σ^2, and a firm's initial wealth level is x. Then a firm wishes to

Maximize E(U(x+ß))

This is equivalent to

Maximize $U[x+E(ß)-\pi]$ =Maximize $U(x+E(ß)-1/2\,\sigma^2\, r(x+E(ß)+o(\sigma^2)))$

For exponential utility functions this is approximately equal to

a) Maximize $U[x+E(ß)-1/2\,\sigma^2\, b]$

$= -\,e^{-b[x+\mu-1/2\,\sigma^2\, b]}$ for b>0

or

b) Maximize $e^{-b[x+\mu-1/2\,\sigma^2\, b]}$ for b<0

For case a), where b>0, this is equivalent to minimizing the exponent or

Maximize $bx+\mu b-1/2\,\sigma^2\, b^2$.

or

Maximize $x+\mu-1/2\,\sigma^2\, b$.

For case b), where b<0, this is equivalent to maximizing the exponent or

Maximize $-bx-\mu b+1/2\,\sigma^2\, b^2$.

or

Maximize $x+\mu-1/2\,\sigma^2\, b$.

Since x is the initial wealth of the firm, this will remain constant between choices and the function becomes:

Maximize $\mu-1/2\,\sigma^2\, b$

Thus in order to (approximately) maximize its expected utility for profits, a firm should choose the alternative that maximizes $\mu-1/2\,\sigma^2\, b$, where μ is the mean profit, σ^2 its variance and b the Pratt–Arrow risk aversion measure.[1]

---

[1] Freund (1956) has shown that this maximization equivalence is exact if ß is normally distributed.

APPENDIX IV

LISTING OF MODEL

```
C*********************************************************************
C  A Strategic Capacity Expansion Model for the Newsprint Industry
C
C                             FORTRAN program
C*********************************************************************
C
C  Exogenous Data
C
      IMPLICIT REAL (A-H,O-Z)
      COMMON /EXODAT/ DEMAND(2,20,3),DPROB(3),KOPTS(5,3),
     +                KCOST(20,3),PCOST(20,8),CAPLR(20,3,27),CULR(3,27),
     +                INITK(8,5),VCOST(3,20,8),
     +                OHOLD(20,8),OHNEW(20,8),DISCNT(8),BCOEFF(8),
     +                ROSMIN(8),OBJTYP(8),FRCAP(20),
     +                TAXRTE,CCARTE,
     +                IBASE,NYEARS,NYRSR,NDEM,NKOPTS,NCAP,
     +                NFIRMS, LAG, NTYPE, NDTAIL
      REAL KOPTS,KCOST,INITK
      INTEGER OBJTYP
C
      COMMON /CHARS/ TITLE,KNAME(3),FNAME(8),CAPNAM(27),OBJNAM(7)
      CHARACTER*80 TITLE
      CHARACTER*50 FNAME
      CHARACTER*20 KNAME,OBJNAM
      CHARACTER*10 CAPNAM
C
      EXTERNAL FUNCA
C
      COMMON /SIMEQ/ COEFF1(8),COEFF2(8),COEFF3(8),D1,PPRICE,DV(8),
     +               CAP(8),DEMNDQ,NEQ,NFGRP(8),IFIRM
C
C  Endogenous Variables
C
      REAL Q(8),DEMNDQ,CU(8),FPROF(8,7000)
      REAL PRISR(5,3,7000),FIRMD(8,5,3,7000),
     +     PRILR(20,3,27),OBJFNC(8,7000),Q1(2)
      REAL INVEST,MSINIT(8),MS(8,7000),MAXLSS,EXPRET(8,7000),LOSS
      REAL MAXPR
      INTEGER KCOMB(8,7000),BESTOP(8,3000),INDEX(8)
      CHARACTER*15 FILE1,FILE2,FILE3,FILE4,            FILE7,FILE8
C    + ,FILE9, FILE10
C
C  Endogenous variable dimensions:
C
C     KCOMB(NFIRMS,NKCOMB)
C     BESTOP(NFIRMS,NOPTS)
C     INDEX(NFIRMS)
C     PRISR(NYRSR,NDEM,NKCOMB)
C     PRILR(NYEARS,NDEM,NCAP)
```

```
C     FIRMD(NFIRMS,NYRSR,NDEM,NKCOMB)
C     OBJFNC(NFIRMS,NKCOMB)
C
C  Endogenous variable definitions:
C
C     KCOMB  the capacity option combinations.
C     BESTOP the best capacity option for each firm given the
C            combination of capacity options for every other firm
C            (one NOPTS array for each firm, each element containing
C            a number from 1 to KCOMB)
C     INDEX  an array used for holding combinations of capacity
C            options and industry scenarios.
C     PRISR  the average short-run industry price for each capacity
C            combination, demand scenario and year.
C     PRILR  the average long-run industry price for each capacity
C            scenario, demand scenario and year.
C     FIRMD  the short-run optimal CU strategy for each firm,
C            each capacity combination, demand scenario and year.
C     OBJFNC the expected value of the objective function
C            for each firm and each capacity combination.
C
C  Define the I/O units
C  Input
C
C     FILE10='DB/NP5.D791S'
C     FILE9='DB/DEM.DAT1S'
C
C     OPEN(10,FILE=FILE10,STATUS='OLD')
C     OPEN(9,FILE=FILE9,STATUS='OLD')
C
C  Output
C
      FILE1='-FPROD          '
      FILE2='-INDPRSR        '
      FILE3='-INDPRLR        '
      FILE4='-NPV            '
C     FILE6='-MESSAGES       '
      FILE7='-OBJFNS         '
      FILE8='-EQUIL          '
C
      OPEN(1,FILE=FILE1)
      OPEN(2,FILE=FILE2)
      OPEN(3,FILE=FILE3)
      OPEN(4,FILE=FILE4)
C     OPEN(6,FILE=FILE6)
      OPEN(7,FILE=FILE7)
      OPEN(8,FILE=FILE8)
C
C  Read in the industry and individual firm data.
C
      CALL INPUT
C
C  NKCOMB = total # of possible capacity combinations per year
C  NOPTS = # of capacity combinations to be evaluated when
C          determining the "best" capacity option for each firm
C
      NKCOMB=NKOPTS**NFIRMS
      NOPTS=NKOPTS**(NFIRMS-1)
      NEQ=NFIRMS
C
```

```
      DO 5 L=1,NKCOMB
      DO 5 K=1,NDEM
      DO 5 J=1,NYRSR
      PRISR(J,K,L)=0.0
      DO 5 I=1,NFIRMS
      FIRMD(I,J,K,L)=0.0
    5 CONTINUE
      DO 10 J=1,NFIRMS
         DO 15 I=1,NKCOMB
         OBJFNC(I,J)=0.0
   15    CONTINUE
         DO 20 I=1,NOPTS
         BESTOP(I,J)=0
   20    CONTINUE
   10 CONTINUE
      DO 30 K=1,NCAP
      DO 30 J=1,NDEM
      DO 30 I=1,NYEARS
      PRILR(I,J,K)=0.0
   30 CONTINUE
C
C  Generate the capacity combinations.
C
       IF(NTYPE.EQ.1) THEN
          DO 35 IFIRM=1,NFIRMS
          KCOMB(IFIRM,1)=1
   35     CONTINUE
       ELSE
      DO 50 J=1,NKCOMB
C
      IF(J.EQ.1) THEN
         DO 55 I=1,NFIRMS
         INDEX(I)=1
   55    CONTINUE
      ELSE
         DO 60 I=NFIRMS,1,-1
         INDEX(I)=INDEX(I)+1
         IF(INDEX(I).LE.NKOPTS) GO TO 65
         INDEX(I)=1
   60    CONTINUE
      ENDIF

   65    DO 70 I=1,NFIRMS
         KCOMB(I,J)=INDEX(I)
   70    CONTINUE
C
   50 CONTINUE
      ENDIF
C read in the capacity combination to be evaluated if run type=3
      IF(NTYPE.EQ.3) THEN
      WRITE(6,6001)
6001  FORMAT(1X,' ENTER CAPACITY COMBINATION NUMBER TO BE RUN (I4)')
      READ(5,5002) KAPTST
5002  FORMAT(I4)
      ENDIF
C
      WRITE(1,6000) TITLE, NTYPE
 6000 FORMAT('1','>>>>>  ',A80,'  <<<<<', 2X,'RUN TYPE= ',I1//)
C
      WRITE(2,6000) TITLE, NTYPE
```

```
      WRITE(3,6000) TITLE, NTYPE
      WRITE(4,6000) TITLE, NTYPE
      WRITE(7,6000) TITLE, NTYPE
      WRITE(8,6000) TITLE, NTYPE
C
      WRITE(2,2000)
 2000 FORMAT(1X,'*** Industry Prices and Quantities for the',
     +          ' Short-run ***'//
     +       1X,'IKCOMB',1X,'IDEM',1X,'YEAR',1X,'PRICE',4X,
     +          'SUMQ',1X,'SUMCAP',2X,'CU',1X,'NITER')
C
C  Stage 1 ::  Find the optimal production strategy for each firm
C        for each capacity combination, demand scenario and year.
C
C  For each year IYR in the short-run planning horizon NYRSR, each
C  demand scenario IDEM, each capacity combination IKCOMB and each
C  firm IFIRM, find the production quantity that maximizes profit.
C
      DO 100 IYR=1,NYRSR
C
      IYEAR=IBASE+(IYR-1)
      WRITE(2,2001)
 2001 FORMAT(1X)
C
      DO 100 IDEM=1,NDEM
C
      D0=DEMAND(1,IYR,IDEM)
      D1=DEMAND(2,IYR,IDEM)
C
      IF(NTYPE.EQ.1) THEN
         NSTART=1
         NEND=1
      ELSEIF(NTYPE.EQ.2) THEN
         NSTART=1
         NEND=NKCOMB
      ELSEIF(NTYPE.EQ.3) THEN
         NSTART=KAPTST
         NEND=KAPTST
      ENDIF
C
      DO 100 IKCOMB=NSTART,NEND
C
C
C Use an iterative procedure to find an equilibrium solution to
C the simultaneous solution of MR=MC (subject to capacity constraints)
C for all firms
C
      NITER=0
      PRUB=1000.0
      PRLB=200.0
104   PPRICE=PRLB+((PRUB-PRLB)/2.0)
      DEMNDQ=D0+D1*PPRICE
      ELAIND=PPRICE*D1/DEMNDQ
      SUMQ=0.0
C
         DO 105 IFIRM=1,NFIRMS
C
C All capacity combinations are the same in the first n=LAG
C years of the short run, so you don't need to recalculate Prices etc.
C
```

```
            IF((NTYPE.EQ.2)
     +      .AND.(IYR.LE.LAG).AND.(IKCOMB.GT.1)) THEN
               FIRMD(IFIRM,IYR,IDEM,IKCOMB)=FIRMD(IFIRM,IYR,IDEM,1)
               GO TO 105
            ENDIF
C
C  Determine firm's capacity
C  (Note that if run type =1, then KCOMB=1 and IOPT=1 so CAPNEW=0)
C
            IOPT=KCOMB(IFIRM,IKCOMB)
            CAPNEW=KOPTS(IYR,IOPT)
            CAP(IFIRM)=INITK(IFIRM,IYR)+CAPNEW
C
C
C  Determine each firm's total cost coefficients
C
            C0=VCOST(1,IYR,IFIRM)
            C1=VCOST(2,IYR,IFIRM)
            C2=VCOST(3,IYR,IFIRM)
C
C  Marginal cost coefficients
C
            COEFF1(IFIRM)=C0-(2.0*C1*CAPNEW)+(3.0*C2*CAPNEW*CAPNEW)
            COEFF2(IFIRM)=(2.0*C1)-(6.0*C2*CAPNEW)
            COEFF3(IFIRM)=3.0*C2
C
C Initialize firm elasticity to 99.99 (if Q1=0 then ELAST=99.99)
C
            ELAST=99.99
C
C  NR = # of roots to search for
C
            IF(COEFF3(IFIRM).EQ.0.0) THEN
               NR=1
            ELSE
               NR=2
            ENDIF
            DO 6 IR=1,NR
            Q1(IR)=0.0
    6       CONTINUE
C
C If price is greater than the minimum MC then Q=0
C
            Q(IFIRM)=0.0
            IF(PPRICE.LE.COEFF1(IFIRM)) GO TO 7
            CALL RZFUN(FUNCA,NR,50,Q1,IND,0.001,0.001,0.001,0.001)
C
C  Firm's production (Q1) cannot be found
C
            IF(IND.NE.0) THEN
               WRITE(6,6020) IFIRM,IKCOMB,IYEAR
 6020          FORMAT(1X,'*** WARNING - Q1 was not successfully ',
     +                   'found by RZFUN'/
     +               15X,'last incorrect estimate is used for ',
     +                   'firm',1X,I1,1X,
     +                   'capacity combination',1X,I2,1X,
     +                   'year',1X,I4/)
               STOP
            ENDIF
            IF(NR.EQ.1) THEN
```

```
                  Q(IFIRM)=Q1(1)
               ELSE
                  Q(IFIRM)=AMAX1(Q1(1),Q1(2))
               ENDIF
    7          IF(Q(IFIRM).NE.0.0) THEN
                        ELAST=PPRICE*D1/Q(IFIRM)
               ELSE
                        ELAST=0.0
               ENDIF
               IF(Q(IFIRM).GT.CAP(IFIRM)) Q(IFIRM)=CAP(IFIRM)
               IF(Q(IFIRM).LT.0.0) Q(IFIRM)=0.0
               SUMQ=SUMQ+Q(IFIRM)*NFGRP(IFIRM)
               CU(IFIRM)=Q(IFIRM)*100.0/CAP(IFIRM)
 105        CONTINUE
            IF((NTYPE.EQ.2).AND.(IYR.LE.LAG).AND.(IKCOMB.GT.1)) THEN
               PRISR(IYR,IDEM,IKCOMB)=PRISR(IYR,IDEM,1)
               GO TO 100
            ENDIF
            PRICE=(-D0+SUMQ)/(D1)
            IF((ABS(SUMQ-DEMNDQ)/DEMNDQ).LE.0.005) GO TO 107
            IF((SUMQ-DEMNDQ).GT.0.0) PRUB=PPRICE
            IF((SUMQ-DEMNDQ).LT.0.0) PRLB=PPRICE
            NITER=NITER+1
            IF(NITER.GT.50) THEN
               WRITE(6,6002) IKCOMB,IDEM,IYEAR
               STOP
            ENDIF
 6002       FORMAT(1X,'WARNING - number of iterations exceeds 50 for',
     +               ' capacity combination ',I4,' demand scenario ', I1,
     +               ' year ',I4)
            GO TO 104
C
  107       SUMCAP=0.0
            DO 116 IFIRM=1,NFIRMS
               IOPT=KCOMB(IFIRM,IKCOMB)
               CAPNEW=KOPTS(IYR,IOPT)
               FCAP=INITK(IFIRM,IYR)+CAPNEW
               SUMCAP=SUMCAP+FCAP*NFGRP(IFIRM)
  116       CONTINUE
            CUIND=SUMQ*100/SUMCAP
            IF(NDTAIL.EQ.1)
     +      WRITE(2,2012) IKCOMB,IDEM,IYEAR,PRICE,SUMQ,SUMCAP,CUIND,NITER
 2012       FORMAT(2X,I4,4X,I1,1X,I4,1X,F6.2,1X,
     +             F6.0,1X,F6.0,1X,F4.0,4X,I2)
C
C  Save the short-run price and firm production data for Stage 2.
C
            PRISR(IYR,IDEM,IKCOMB)=PRICE
            DO 120 I=1,NFIRMS
            FIRMD(I,IYR,IDEM,IKCOMB)=Q(I)
  120       CONTINUE
C
  100 CONTINUE
C
C  Warning if short-run prices are missing for any year.
C
C
         IF(NTYPE.EQ.1) THEN
            NSTART=1
            NEND=1
```

```
      ELSEIF(NTYPE.EQ.2) THEN
         NSTART=1
         NEND=NKCOMB
      ELSEIF(NTYPE.EQ.3) THEN
         NSTART=KAPTST
         NEND=KAPTST
      ENDIF
      DO 170 IKCOMB=NSTART,NEND
      DO 170 IDEM=1,NDEM
      DO 170 IYR=1,NYRSR
         IYEAR=IBASE+(IYR-1)
         IF(PRISR(IYR,IDEM,IKCOMB).NE.0.0) GO TO 170
         WRITE(6,6003) IYEAR,IDEM,IKCOMB
 6003    FORMAT(1X,'WARNING - missing price in year ',I4,' demand',
     +              ' scenario ',I1,' capacity combination ',I4,
     +              ', a price of 0.0 is used')
         STOP
  170 CONTINUE
C
C  Find long-run prices if the number of years in the planning
C  horizon is greater than the number of years in the short-run.
C
      IF(NYEARS.GT.NYRSR) THEN
         WRITE(3,3006)
 3006    FORMAT(1X,'** Industry Prices and Quantities for the Long-',
     +           'run **'//
     +   1X,'ICAP',1X,'IDEM',1X,'YEAR',1X,'PRICE',4X,'SUMQ',
     +   1X,'SUMCAP',1X,'CU')
         NY1LR=NYRSR+1
C
         SUMCAP=0.0
         DO 172 I=1,NFIRMS
         SUMCAP=SUMCAP+INITK(I,NYRSR)*NFGRP(I)
 172     CONTINUE

C
         DO 175 ICAP=1,NCAP

         DO 175 IDEM=1,NDEM
C
         WRITE(3,2001)
C
         DO 175 IYR=NY1LR,NYEARS
C
            IYEAR=IBASE+(IYR-1)
C
            D0=DEMAND(1,IYR,IDEM)
            D1=DEMAND(2,IYR,IDEM)
C
            PROD=CAPLR(IYR,IDEM,ICAP)*CULR(IDEM,ICAP)
            PRICE=(PROD-D0)/D1
            CULRIN=CULR(IDEM,ICAP)*100.0
C
            IF(NDTAIL.EQ.1)
     +      WRITE(3,3007) ICAP,IDEM,IYEAR,PRICE, PROD,
     +      CAPLR(IYR,IDEM,ICAP), CULRIN
 3007       FORMAT(2X,I2,4X,I1,1X,I4,1X,F8.2,1X,F6.0,1X,F6.0,1X,F4.0)
C
            PRILR(IYR,IDEM,ICAP)=PRICE
C
```

```
  175    CONTINUE
      ENDIF
C
C
C
C
C  Stage 2 ::  Find the optimal capacity option for each firm
C              such that the capacity option for every other firm
C              is optimal, according to some objective function.
C
      WRITE(1,1001)
 1001 FORMAT(1X,'** Annual Firm Production, Costs, Profits **'//
     + 1X,'IKCOMB',1X,'IDEM',1X,'YEAR',1X,'FIRM',1X,'IOPT',
     + 1X,'FCAP',2X,'FPROD',2X,'CU',1X,'VAR COST',2X,'FIX COST',2X,
     + 'TOTAL COST',1X,'REVENUES',1X,'BT PROFIT',1X,'PRICE',2X,'AVC',
     + 3X,'ROI NEW',8X,'CCA'//)
C
      WRITE(4,4001)
 4001 FORMAT(1X,'** OBJECTIVE FUNCTION VALUES BY DEMAND SCENARIO **'//
     + 1X,'IKCOMB',1X,'ICAP',1X,'IDEM',1X,'FIRM',1X,'IOPT',1X,
     + 'ATAX PROF',1X,'NPV SALES',4X,'ROS',2X,'MS','BTAX PROF',1X,
     + 'ROI NEW'//)
C
      WRITE(7,7001)
 7001 FORMAT(1X,'** EXPECTED VALUE OF FIRM OBJECTIVE FUNCTIONS **'//
     + 1X,'IKCOMB',1X,'ICAP',1X,'FIRM',1X,'IOPT',1X,'AT PROF',11X,
     + 'VAR PROF',2X,'EXP UTIL FN',1X,'EX SALES',2X,'EX ROS',2X,
     + 'MS',3X,'MAX LOSS',5X,'EX ROI',3X,'BCOEFF',1X,'OBJ TYPE'//)
C
C Assign names of possible objective functions for firms
C
      OBJNAM(1)='Profit max'
      OBJNAM(2)='Utility max'
      OBJNAM(3)='Minimax'
      OBJNAM(4)='MS st profit'
      OBJNAM(5)='Sales st profit'
      OBJNAM(6)='Profit st MS'
      OBJNAM(7)='Max ROI'
C
C Calculate market share in year one.
C
      SUMCAP=0.0
      DO 178 IFIRM=1,NFIRMS
         SUMCAP=SUMCAP+INITK(IFIRM,1)*NFGRP(IFIRM)
  178 CONTINUE
      DO 179 IFIRM=1,NFIRMS
         MSINIT(IFIRM)=INITK(IFIRM,1)*100.0/SUMCAP
  179 CONTINUE
C
C  Find the equilibrium capacity options
C
C  Calculate the outputs for each firm and each capacity option.
C
      DO 205 IFIRM=1,NFIRMS
C
      IF(NTYPE.EQ.1) THEN
         NSTART=1
         NEND=1
      ELSEIF(NTYPE.EQ.2) THEN
         NSTART=1
```

```
            NEND=NKCOMB
         ELSEIF(NTYPE.EQ.3) THEN
            NSTART=KAPTST
            NEND=KAPTST
         ENDIF
         DO 205 IKCOMB=NSTART,NEND
         IOPT=KCOMB(IFIRM,IKCOMB)
         EXPROF=0.0
         EXBPRF=0.0
         EXROI=0.0
         EXSALE=0.0
         EXROS=0.0
         VAR=0.0
         MAXLSS=1.0E10
C
C Calculate market share of each firm in last year of short run
C and the number of machines added (ICAP-1) for KCOMB
C
         SUMCAP=0.0
         ICAP=1
         DO 206 J=1,NFIRMS
                  IOPTN=KCOMB(J,IKCOMB)
                  CAPNEW=KOPTS(NYRSR,IOPTN)
                  FCAP=INITK(J,NYRSR)+CAPNEW
                  SUMCAP=SUMCAP+FCAP*NFGRP(J)
                  ICAP=ICAP+(IOPTN-1)*NFGRP(J)
                  IF(J.EQ.NFIRMS) THEN
                    DO 207 I=1,NFIRMS
                    IOPTN=KCOMB(I,IKCOMB)
                    CAPNEW=KOPTS(NYRSR,IOPTN)
                    FCAP=INITK(I,NYRSR)+CAPNEW
                    MS(I,IKCOMB)=FCAP*100.0/SUMCAP
 207                CONTINUE
                  ENDIF
 206     CONTINUE
C
            DO 210 IDEM=1,NDEM
            ATPROF=0.0
            BTPROF=0.0
            TSALES=0.0
            ROS=0.0
            ROI=0.0
C
               DO 215 IYR=1,NYEARS
C
               C0=VCOST(1,IYR,IFIRM)
               C1=VCOST(2,IYR,IFIRM)
               C2=VCOST(3,IYR,IFIRM)
               CNEW=PCOST(IYR,IFIRM)
               INVEST=KCOST(IYR,IOPT)
               OHO=OHOLD(IYR,IFIRM)
               OHN=OHNEW(IYR,IFIRM)
C
               IF(IYR.GT.NYRSR) THEN
                  CAPNEW=KOPTS(NYRSR,IOPT)
                  FCAP=INITK(IFIRM,NYRSR)+CAPNEW
                  FPROD=FCAP*CULR(IDEM,ICAP)
                  PRICE=PRILR(IYR,IDEM,ICAP)
               ELSE
                  CAPNEW=KOPTS(IYR,IOPT)
```

```
               FCAP=INITK(IFIRM,IYR)+CAPNEW
               FPROD=FIRMD(IFIRM,IYR,IDEM,IKCOMB)
               PRICE=PRISR(IYR,IDEM,IKCOMB)
            ENDIF
C
C  Calculate the firm's total revenues.
C
            REV=PRICE*FPROD
C
C  Calculate the firm's total costs.
C
            CSTNEW=AMIN1(FPROD,CAPNEW)*CNEW
            CAPOLD=AMAX1(FPROD-CAPNEW,0.0)
            CSTOLD=C0*CAPOLD + C1*CAPOLD**2 + C2*CAPOLD**3
            VARCST=CSTNEW+CSTOLD
            AVC=VARCST/FPROD
            IF(IYR.GT.NYRSR) THEN
               OHO1=OHO*INITK(IFIRM,NYRSR)
            ELSE
               OHO1=OHO*INITK(IFIRM,IYR)
            ENDIF
            FIXCST=OHO1+OHN*CAPNEW
            COST=VARCST+FIXCST+INVEST*1000.0
C
C CALCULATE CAPITAL COST ALLOWANCE ON NEW CAPACITY
C
         CCANEW=0.0
         DO 213 J=1,IYR
         CCANEW=CCANEW+1000.0*CCARTE*KCOST(J,IOPT)*(1-CCARTE)**(IYR-J)
 213     CONTINUE
            ROINEW=(CAPNEW*PRICE-CSTNEW-OHN*CAPNEW-CCANEW)
     +             *(1-TAXRTE)-INVEST*1000.0+CCANEW
            FCU=FPROD*100/FCAP
            PI=REV-COST
            IYEAR=IBASE+(IYR-1)
         IF(NDTAIL.EQ.2) GO TO 214
            IF(IYR.LE.NYRSR)
     +      WRITE(1,1002)
     +         IKCOMB,IDEM,IYEAR,IFIRM,IOPT,FCAP,FPROD,FCU,VARCST,
     +         FIXCST,COST,REV,PI,PRICE,AVC,ROINEW,CCANEW
 1002       FORMAT(2X,I4,4X,I1,1X,I4,4X,I1,4X,I1,1X,F5.0,1X,F5.0,
     +             1X,F4.0,5(1X,F9.0),2(1X,F6.2),2(1X,F10.0))
C
C  Compute discounted profits
C
  214       BTPROF=BTPROF+((REV-COST)/((1.0+DISCNT(IFIRM))**(IYR-1)))
            AFTERT=(REV-FIXCST-VARCST-CCANEW)*
     +             (1-TAXRTE)-INVEST*1000.0+CCANEW
            ATPROF=ATPROF+AFTERT/
     +             ((1.0+DISCNT(IFIRM))**(IYR-1))
            SALES=(REV/((1.0+DISCNT(IFIRM))**(IYR-1)))
            ROI=ROI+ROINEW/((1.0+DISCNT(IFIRM))**(IYR-1))
            TSALES=TSALES+SALES
            ROS=ROS+ AFTERT*100/REV
  215       CONTINUE
C
         ROS=ROS/NYEARS
C
         IF(NDTAIL.EQ.1)
     +   WRITE(4,4004)IKCOMB,ICAP,IDEM,IFIRM,IOPT,ATPROF,TSALES,ROS,
```

```
     +    MS(IFIRM,IKCOMB),BTPROF,ROI
 4004     FORMAT(2X,I4,2X,I2,3X,I1,4X,I1,3X,I1,2(1X,F10.0),2X,F5.1,
     +            1X,F5.1,2(F10.0))
          BP=BTPROF*DPROB(IDEM)
          AP=ATPROF*DPROB(IDEM)
          S=TSALES*DPROB(IDEM)
          R=ROS*DPROB(IDEM)
          RI=ROI*DPROB(IDEM)
          EXPROF=EXPROF+AP
          EXBPRF=EXBPRF+BF
          EXSALE=EXSALE+S
          EXROS=EXROS+R
          EXROI=EXROI+RI
          LOSS=AMIN1(ATPROF,MAXLSS)
          MAXLSS=LOSS
          VAR=VAR+AP*ATPROF
  210     CONTINUE
C
C  Determine the value of the objective function:
C
C
C     Firm objective function type for the long run capacity decision
C      1. maximize expected profit
C      2. maximze expected utility (exponential utility function)
C      3. Minimax (minimize the maximum loss)
C      4. maximize market share (in last year of short run horizon)
C         subject to a constraint on profits (return on sales)
C      5. Maximize sales subject to a constraint on profits
C      6. Maximize expected profits subject to a constraint on market
C         share (MS in year 5 >= MS in year 1).
C      7. Maximize ROI (return on investment for new capacity)
C
C
C     OBJFNC(IFIRM,IKCOMB)
C
C
      VAR=VAR-(EXPROF*EXPROF)
         EXUTIL=EXPROF-BCOEFF(IFIRM)*VAR/2.0
      FPROF(IFIRM,IKCOMB)=EXPROF
      EXPRET(IFIRM,IKCOMB)=EXROS
      IF((OBJTYP(IFIRM).EQ.1).OR.(OBJTYP(IFIRM).EQ.6)) THEN
         OBJFNC(IFIRM,IKCOMB)=EXPROF
      ELSEIF(OBJTYP(IFIRM).EQ.2) THEN
         OBJFNC(IFIRM,IKCOMB)=EXUTIL
      ELSEIF(OBJTYP(IFIRM).EQ.3) THEN
         OBJFNC(IFIRM,IKCOMB)=MAXLSS
      ELSEIF(OBJTYP(IFIRM).EQ.4) THEN
         OBJFNC(IFIRM,IKCOMB)=MS(IFIRM,IKCOMB)
      ELSEIF(OBJTYP(IFIRM).EQ.5) THEN
         OBJFNC(IFIRM,IKCOMB)=EXSALE
      ELSEIF(OBJTYP(IFIRM).EQ.7) THEN
         OBJFNC(IFIRM,IKCOMB)=EXROI
      ENDIF
C
      IF(NDTAIL.EQ.1)
     +WRITE(7,7004) IKCOMB,ICAP,IFIRM,IOPT,EXPROF,VAR,EXUTIL,
     +      EXSALE,EXROS,MS(IFIRM,IKCOMB),MAXLSS, EXROI,
     +      BCOEFF(IFIRM),OBJTYP(IFIRM)
 7004 FORMAT(1X,2X,I4,2X,I2,4X,I1,3X,I1,1X,F10.0,1X,F18.0,1X,F18.0,
     +1X,F10.0,2X,F4.1,2X,F5.1,2(1X,F10.0),2X,F4.1,4X,I1)
```

```
C
  205 CONTINUE
C
C If runtype=2 (full solution of model) then continue; if ntype=3
C (one capacity combo) recalculate for next capacity scenario;
C if runtype=1, then stop
C
      IF(NTYPE.EQ.3) STOP
      IF(NTYPE.EQ.1) STOP
C
C  For each firm, find the best capacity option
C  by maximizing the objective function (OBJTYP 1,2 or 3)
C  or maximizing the objective function subject to a constraint
C  (OBJTYP 4,5,6)
C
      DO 225 IFIRM=1,NFIRMS
      NF=NFIRMS-IFIRM
      INC=NKOPTS**NF
      NK=0
C
         DO 230 KBASE=1,NKCOMB
         IF(NK.EQ.NOPTS) GO TO 225
         IF(KCOMB(IFIRM,KBASE).NE.1) GO TO 230
         NK=NK+1
         MAXPR=-1.0E6
C
            DO 235 IK=1,NKOPTS
            IPTR=KBASE+INC*(IK-1)
            IBEST=BESTOP(IFIRM,NK)
C
C  Maximize the objective function
C
            IF((OBJTYP(IFIRM).LE.3).OR.(OBJTYP(IFIRM).EQ.7)) THEN
            IF(IBEST.EQ.0.OR.OBJFNC(IFIRM,IPTR).GT.MAXPR) THEN
               BESTOP(IFIRM,NK)=IPTR
               MAXPR=OBJFNC(IFIRM,IPTR)
            ENDIF
            ELSEIF((OBJTYP(IFIRM).EQ.4).OR.(OBJTYP(IFIRM).EQ.5))THEN
            IF((OBJFNC(IFIRM,IPTR).GT.MAXPR).AND.
     +         (EXPRET(IFIRM,IPTR).GE.ROSMIN(IFIRM)))THEN
               BESTOP(IFIRM,NK)=IPTR
               MAXPR=OBJFNC(IFIRM,IPTR)
            ENDIF
            ELSEIF(OBJTYP(IFIRM).EQ.6) THEN
            IF((OBJFNC(IFIRM,IPTR).GT.MAXPR).AND.
     +         (MS(IFIRM,IPTR).GE.MSINIT(IFIRM)))THEN
               BESTOP(IFIRM,NK)=IPTR
               MAXPR=OBJFNC(IFIRM,IPTR)
            ENDIF

            ENDIF
  235       CONTINUE
C
  230    CONTINUE
C
  225 CONTINUE
C
C  Finally, search for equilibria
C
      WRITE(8,6000) TITLE, NTYPE
```

```
      WRITE(8,8003)
 8003 FORMAT(1X,'***  Equilibrium Solutions '//
     + 1X,'FIRM',4X,'FIRM NAME',31X,'IOPT',5X,'CAPACITY OPTION',
     + 4X,'OBJ FN',14X,'AT PROFIT')
      NEQUIL=0
      JOPTS=0
C
  255 JOPTS=JOPTS+1
      IF(JOPTS.GT.NOPTS) GO TO 240
      IPTR=BESTOP(1,JOPTS)
      IF(IPTR.EQ.0) GO TO 255
C
      DO 245 I=2,NFIRMS
         DO 250 J=1,NOPTS
         IF(BESTOP(I,J).EQ.IPTR) GO TO 245
  250    CONTINUE
C
C  There can be no equilibrium if there are no capacity combinations
C  in each firm I that match a capacity combination in firm 1.
C
         GO TO 255
  245 CONTINUE
C
C  An equilibrium is found else we would have branched to statement
C  255 by now
C
      WRITE(8,2001)
      SUMCAP=0.0
      SUMPRF=0.0
      ICAP=1
      DO 260 I=1,NFIRMS
         IOPT=KCOMB(I,IPTR)
         WRITE(8,8004) I,FNAME(I),IOPT,KNAME(IOPT),OBJNAM(OBJTYP(I))
     +   ,FPROF(I,IPTR)
 8004    FORMAT(2X,I2,5X,A40,4X,I1,2X,'==>',2X,A20,1X,A20,1X,F18.0)
         FCAP=INITK(I,NYRSR)+KOPTS(NYRSR,IOPT)
         SUMCAP=SUMCAP+FCAP*NFGRP(I)
         SUMPRF=SUMPRF+NFGRP(I)*FPROF(I,IPTR)
         ICAP=ICAP+(IOPT-1)*NFGRP(I)
  260 CONTINUE
      NEQUIL=NEQUIL+1
      WRITE(8,8006) NEQUIL,ICAP,SUMCAP,CAPLR(NYRSR+1,1,ICAP),SUMPRF,
     +  IPTR
 8006 FORMAT('0','EQUIL',I3,' LR CAP SCENARIO',I3,' ESTIMATED CAP=',
     +          F9.0,' LR SCENARIO CAP=',F9.0,/
     + 'INDUSTRY PROFITS=',F20.0,   1X,'CAPACITY COMBINATION=',I5)
C
C  Find next equilibrium
C
      GO TO 255
C
C  Equilibrium search is complete
C
  240 IF(NEQUIL.EQ.0) THEN
         WRITE(8,8005)
 8005    FORMAT(1X,'>>>>>  No Equilibrium Found  <<<<</')
      ENDIF
C
      STOP
      END
```

```
C
C  Subroutine INPUT reads the control information and firm data.
C
      SUBROUTINE INPUT
C
      IMPLICIT REAL (A-H,O-Z)
      COMMON /EXODAT/ DEMAND(2,20,3),DPROB(3),KOPTS(5,3),
     +                KCOST(20,3),PCOST(20,8),CAPLR(20,3,27),CULR(3,27),
     +                INITK(8,5),VCOST(3,20,8),OHOLD(20,8),
     +                OHNEW(20,8),DISCNT(8),BCOEFF(8),
     +                ROSMIN(8),OBJTYP(8),FRCAP(20),
     +                TAXRTE,CCARTE,
     +                IBASE,NYEARS,NYRSR,NDEM,NKOPTS,NCAP,
     +                NFIRMS, LAG, NTYPE, NDTAIL
      REAL KOPTS,KCOST,INITK
      INTEGER OBJTYP
C
      COMMON /CHARS/ TITLE,KNAME(3),FNAME(8),CAPNAM(27),OBJNAM(7)
      CHARACTER*80 TITLE
      CHARACTER*50 FNAME
      CHARACTER*20 KNAME,OBJNAM
      CHARACTER*10 CAPNAM
C
      COMMON /SIMEQ/ COEFF1(8),COEFF2(8),COEFF3(8),
     +D1,PPRICE,CV(8),
     +   CAP(8),DEMNDQ, NEQ, NFGRP(8)
     + ,IFIRM
C
C
      CHARACTER*280 BUF
C
C Number of inputs to be read in (not by firm)
      MAXINP=14
C Number of inputs to be read in for each firm
      MAXF=8
C
C Read in demand data from file 9 using subroutine DEMINP
C
       CALL DEMINP
C
      NREC=0
C
C  Read in the control information
C
  100 READ(10,5000) BUF
 5000 FORMAT(A280)
      IF(BUF(1:1).EQ.'*') GO TO 100
      NREC=NREC+1
C
C  Run description
C
      IF(NREC.EQ.1) THEN
         DO 101 I=1,280
         IF(BUF(I:I).NE.' ') GO TO 102
  101    CONTINUE
         I=1
  102    IS=I
         IE=(IS-1)+80
         TITLE=BUF(IS:IE)
C
```

```
C Run type.  If run type=1, then capacity is given for each
C year of short run planning horizon and only production and prices
C are calculated.  If run type=2, then model is run for full solution.
C If runtype=3, then one capacity combo is specified (interactively)
C and only output is calculated for that combination.
C If NDTAIL=1 then write all information to files.
C if NDTAIL=2 then only write final solution (to file 8).
C
         ELSEIF(NREC.EQ.2) THEN
            READ(BUF,*) NTYPE, NDTAIL
C
C  Starting year of the analysis
C
      ELSEIF(NREC.EQ.3) THEN
         READ(BUF,*) IBASE
C
C  Total number of years in the planning horizon, and the number
C  of years in the short-run planning horizon.
C
      ELSEIF(NREC.EQ.4) THEN
         READ(BUF,*) NYEARS,NYRSR
C
C  Number of short-run capacity options and number of years
C  from present before new capacity is added
C
      ELSEIF(NREC.EQ.5) THEN
         READ(BUF,*) NKOPTS, LAG
C
C  Description of each short-run capacity option
C
      ELSEIF(NREC.EQ.6) THEN
         DO 115 I=1,280
         IF(BUF(I:I).NE.' ') GO TO 120
  115    CONTINUE
         I=1
  120    IS=I
         DO 125 I=1,NKOPTS
         IE=(IS-1)+20
         KNAME(I)=BUF(IS:IE)
         IS=IE+1
  125    CONTINUE
C
C  New short-run capacity options
C
      ELSEIF(NREC.EQ.7) THEN
         READ(BUF,*) (KOPTS(1,J),J=1,NKOPTS)
         DO 130 I=2,5
         READ(10,*) (KOPTS(I,J),J=1,NKOPTS)
  130    CONTINUE
C
C  Long-run new capacity investment costs (includes short-run)
C
      ELSEIF(NREC.EQ.8) THEN
         READ(BUF,*) (KCOST(1,J),J=1,NKOPTS)
         DO 135 I=2,20
         READ(10,*) (KCOST(I,J),J=1,NKOPTS)
  135    CONTINUE
C
C  Number of long-run capacity scenarios
C
```

```
      ELSEIF(NREC.EQ.9) THEN
         READ(BUF,*) NCAP
C
C  Description of long-run capacity scenarios
C
      ELSEIF(NREC.EQ.10) THEN
         DO 140 I=1,280
         IF(BUF(I:I).NE.' ') GO TO 145
  140    CONTINUE
         I=1
  145    IS=I
         DO 150 I=1,NCAP
         IE=(IS-1)+10
         CAPNAM(I)=BUF(IS:IE)
         IS=IE+1
  150    CONTINUE
C
C  Long run capacity scenarios (total capacity of the 13 firms in the
C  model, by year and demand scenario
C
      ELSEIF(NREC.EQ.11) THEN
         READ(BUF,*) NY,(CAPLR(1,1,J),J=1,NCAP)
         DO 155 K=1,NDEM
         IF(K.EQ.1)GO TO 154
         READ(10,*) NY,(CAPLR(1,K,J),J=1,NCAP)
154      DO 155 I=2,20
         READ(10,*) NY,(CAPLR(I,K,J),J=1,NCAP)
  155    CONTINUE
C
C  Long run average industry capacity utilization, by demand scenario
C
      ELSEIF(NREC.EQ.12) THEN
         READ(BUF,*) (CULR(1,J),J=1,NCAP)
         DO 160 I=2,3
         READ(10,*) (CULR(I,J),J=1,NCAP)
  160    CONTINUE
C
C  Number of firms in the industry
C
      ELSEIF(NREC.EQ.13) THEN
         READ(BUF,*) NFIRMS
C
C  Taxrate, capital cost allowance rate, depreciation rate/yr
C
      ELSEIF(NREC.EQ.14) THEN
         READ(BUF,*) TAXRTE,CCARTE
      ENDIF
      IF(NREC.LT.MAXINP) GO TO 100
C
C  Firm data - input by firm
C
      DO 200 IFIRM=1,NFIRMS
      NREC=0
  205 READ(10,5000) BUF
      IF(BUF(1:2).EQ.'**') GO TO 205
      NREC=NREC+1
C
C  Name of firm
C
      IF(NREC.EQ.1) THEN
```

```
        DO 201 I=1,280
        IF(BUF(I:I).NE.' ') GO TO 202
 201    CONTINUE
        I=1
 202    IS=I
        IE=(IS-1)+50
        FNAME(IFIRM)=BUF(IS:IE)
C
C  Number of firms in firm group
C
      ELSEIF(NREC.EQ.2) THEN
        READ(BUF,*) NFGRP(IFIRM)
C
C  Initial firm capacity (equals average firm capcity if more than
C  one firm in firm group).   If runtype=1 then enter capacity for
C each year of short run planning horison.  If run type=2 or 3,
C enter capacity of first year in planning horizon, for each
C year in short run.  (i.e., the same number 5 times).
C
      ELSEIF(NREC.EQ.3) THEN
        READ(BUF,*) (INITK(IFIRM,J),J=1,NYRSR)
C
C  Conjectural variation term
C
      ELSEIF(NREC.EQ.4) THEN
           READ(BUF,*) CV(IFIRM)
C
C  Long-run total variable cost function coefficients
C
      ELSEIF(NREC.EQ.5) THEN
        READ(BUF,*) (VCOST(I,1,IFIRM),I=1,3)
        DO 230 J=2,20
        READ(10,*) (VCOST(I,J,IFIRM),I=1,3)
 230    CONTINUE
C
C  Production cost of new capacity, overhead cost for new
C  capacity, overhead cost for old capacity
C
      ELSEIF(NREC.EQ.6) THEN
        READ(BUF,*) PCOST(1,IFIRM),OHNEW(1,IFIRM),OHOLD(1,IFIRM)
        DO 235 I=2,20
        READ(10,*) PCOST(I,IFIRM),OHNEW(I,IFIRM),OHOLD(I,IFIRM)
 235    CONTINUE
C
C  Annual discount rate
C
      ELSEIF(NREC.EQ.7) THEN
        READ(BUF,*) DISCNT(IFIRM)
C
C  Firm objective function type for the long run capacity decision
C  1. maximize expected profit
C  2. maximze expected utility (exponential utility function)
C  3. Minimax (minimize the maximum loss)
C  4. maximize market share (in last year of short run horizon)
C     subject to a constraint on profits (return on sales)
C  5. Maximize sales subject to a constraint on profits
C  6. Maximize expected profits subject to a constraint on market
C     share (MS in year 5 >= MS in year 1).
C  7. maximize ROI (return on investment for new capacity added)
C
```

```
C  OBJTYP=1 to 7.  If OBJTYP=2, then assign value of risk aversion
C  index BCOEFF, else set BCOEFF=0. If OBJTYPE=4 or 5, then set
C  minimum value for return on sales (ROSMIN), else set = 0.
C
      ELSEIF(NREC.EQ.8) THEN
         READ(BUF,*) OBJTYP(IFIRM),BCOEFF(IFIRM),ROSMIN(IFIRM)
C
      ENDIF
      IF(NREC.LT.MAXF) GO TO 205
C
  200 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE DEMINP
C
      IMPLICIT REAL (A-H,O-Z)
      COMMON /EXODAT/ DEMAND(2,20,3),DPROB(3),KOPTS(5,3),
     +                KCOST(20,3),PCOST(20,8),CAPLR(20,3,27),CULR(3,27),
     +                INITK(8,5),VCOST(3,20,8),OHOLD(20,8),
     +                OHNEW(20,8),DISCNT(8),BCOEFF(8),
     +                ROSMIN(8),OBJTYP(8),FRCAP(20),
     +                TAXRTE,CCARTE,
     +                IBASE,NYEARS,NYRSR,NDEM,NKOPTS,NCAP,
     +                NFIRMS, LAG, NTYPE, NDTAIL
      REAL KOPTS,KCOST,INITK
      INTEGER OBJTYP
      REAL RGDP(20),RPRSUB(20),FROR(20),IMPORT(20),EXPORT(20),
     + CANDEM(20),INVCH(20),GWS(20),INTCEP
C
      CHARACTER*255 BUF
C
C This subroutine reads in demand information and calculates
C the intercept to be used in the model
C
      NREC=0
 100  READ(9,9000) BUF
9000  FORMAT(A255)
      IF(BUF(1:1).EQ.'*') GO TO 100
      NREC=NREC+1
C
C Read in number of demand scenarios (NDEM). Maximum is 3.
C
      IF(NREC.EQ.1) THEN
           READ(BUF,*) NDEM
C
C Read in probabilities of demand scenarios.
C
      ELSEIF(NREC.EQ.2) THEN
            READ(BUF,*) (DPROB(I),I=1,NDEM)
C
C Read in demand function information for each demand scenario.
C
      ENDIF
      IF(NREC.EQ.1) GO TO 100
      DO 200 K=1,NDEM
      NREC=0
  205 READ(9,9000) BUF
      IF(BUF(1:2).EQ.'**') GO TO 205
```

```
      NREC=NREC+1
C
C Read in coefficients of the US demand function
C (intercept, price of newsprint, Real GDP, Real price of substitutes)
C
      IF(NREC.EQ.1) THEN
      READ(BUF,*) INTCEP, CPNEWS, CGDP, CPSUB
C
C Read in values of real US GDP, and real price of substitutes
C for each year (20 years)
C
      ELSEIF(NREC.EQ.2) THEN
      READ(BUF,*) YEAR, RGDP(1), RPRSUB(1)
      DO 235 I=2,20
      READ(9,*) YEAR, RGDP(I), RPRSUB(I)
 235  CONTINUE
C
C Read in values of fringe capacity (1000 metric tons) and operating rate (%)
C
      ELSEIF(NREC.EQ.3) THEN
      READ(BUF,*) YEAR, FRCAP(1), FROR(1)
      DO 240 I=2,20
      READ(9,*) YEAR, FRCAP(I),FROR(I)
  240 CONTINUE
C
C Read in quantities
C (1000 metric tons) of imports, exports, canadian demand,
C change in inventories and quantity
C of groundwood specialty papers misclassified as newsprint.
C
      ELSEIF(NREC.EQ.4) THEN
      READ(BUF,*) YEAR,IMPORT(1),EXPORT(1),CANDEM(1),INVCH(1),GWS(1)
      DO 245 I=2,20
      READ(9,*)YEAR, IMPORT(I),EXPORT(I),CANDEM(I),INVCH(I),GWS(I)
  245 CONTINUE
      ENDIF
      IF(NREC.LT.4) GO TO 205
C
C Calculate intercept term for North American production in each year
C
      DO 250 I=1,20
      DEMAND(1,I,K)=INTCEP+CGDP*RGDP(I)+CPSUB*RPRSUB(I)
     +  -(FRCAP(I)*FROR(I)/100.0)
     +  -IMPORT(I)+EXPORT(I)+CANDEM(I)+INVCH(I)-GWS(I)
      DEMAND(2,I,K)=CPNEWS
  250 CONTINUE
  200 CONTINUE
      RETURN
      END
C
C
C  Function FUN determines the value of each continuous reaction
C  function.  Called by the MTS subroutine RZFUN.
C
      FUNCTION FUNCA(Q1)
C
      IMPLICIT REAL (A-H,O-Z)
C
      COMMON /SIMEQ/ COEFF1(8),COEFF2(8),COEFF3(8),
     +D1,PPRICE,CV(8) ,
```

```
     +  CAP(8),DEMNDQ, NEQ, NFGRP(8)
     + ,IFIRM
C
      IF(IFIRM.EQ.3) THEN
        DUMMY=1.0
        ELSE
        DUMMY=1.0
      ENDIF
      FUNCA=PPRICE+Q1*DUMMY/D1-COEFF1(IFIRM)-COEFF2(IFIRM)*Q1
     +       -COEFF3(IFIRM)*Q1*Q1 + Q1*CV(IFIRM)/D1
C
      RETURN
      END
```

APPENDIX V

LISTING OF DATABASE FOR PRODUCTION VALIDATION RUNS

NOTE: There are two files containing data to be read in. The first is the general run information and firm data; the second is the demand data.

FILE 10

```
** A Strategic Capacity Expansion Model for the Newsprint Industry **
**
** Control Information **
**
** 1. Run Identification (max. 80 chars)
**
Validation - Production (Abitibi,bowater CV=-0.5)
**
** 2. Run type/detail. If run type=1, then model is run only for
**  short run horizon and actual capacititis are input for each year.
**    For run type 2, the model is run with all years and capacity
**   combinations.  For run type 3, a specific capcaity combination
** is specified interactively, and model is evaluated for that one
** combination only. For full detail output NDTAIL=1.For solution only
** NDTAIL=2.
**
     1  1
**
** 2. Starting year of analysis
**
      1979
**
** 3. Total number of years in the planning horizon (max. 20) and
**    number of years in the short-run planning horizon (max. 5)
**
      5  5
**
**
** 9. Number of short-run firm capacity options (max. 3) and
**    number of years before first capacity can be installed (LAG)
**
      2   2
**
** 10. Description of each short-run firm capacity option
**      (max. 20 chars)
**
**      Option 1            Option 2            Option 3
**
       Do nothing           Add 1 machine
**
** 11. Short-run, new firm capacity (in M tonnes) by year
**      (max. 5 years)
**
**      Option 1            Option 2         Option 3
```

```
**
      0.0                 0.0
      0.0                 0.0
      0.0                 180.0
      0.0                 180.0
      0.0                 180.0
**
** 12. Long-run new capacity investment costs (in MM U.S. dollars)
**     by year
**
**    Option 1            Option 2            Option 3
**
      0.0                  70.0
      0.0                  70.0
      0.0                 0.0
      0.0                 0.0
      0.0                 0.0
      0.0                 0.0
      0.0                 0.0
      0.0                 0.0
      0.0                 0.0
      0.0                 0.0
      0.0                 0.0
      0.0                 0.0
      0.0                 0.0
      0.0                 0.0
      0.0                 0.0
      0.0                 0.0
      0.0                 0.0
      0.0                 0.0
      0.0                 0.0
      0.0                 0.0
**
**
** 14. Number of long-run industry capacity scenarios (max. 4)
**
      4
**
** 15. Description of long-run industry capacity scenarios (max. 20 chars)
**
**    Scenario 1          Scenario 2          Scenario 3          Scenario 4
**
      Add 0 machines      Add 4 machines      Add 8 machines      Add 11
machines
**
** 16. Long-run industry capacity scenario by year (in M tonnes)
**     (total new capacity added)
**
**    Scenario 1          Scenario 2          Scenario 3          Scenario 4
**
         0.0                 0.0                 0.0                 0.0
         0.0                 0.0                 0.0                 0.0
         0.0                 0.0                 0.0                 0.0
         0.0                 0.0                 0.0                 0.0
         0.0                 0.0                 0.0              0.0
          0.0              720.0              1440.0             1980.0
        341.0             1067.0              1789.0             2335.0
        695.0             1426.0              2150.0             2701.0
       1061.0             1797.0              2522.0             3079.0
       1441.0             2180.0              2907.0             3469.0
```

```
       1834.0              2577.0              3303.0              3870.0
       2241.0              2987.0              3712.0              4284.0
       2664.0              3410.0              4134.0              4711.0
       3101.0              3848.0              4570.0              5151.0
       3554.0              4302.0              5020.0              5604.0
          0.0                 0.0                 0.0                 0.0
          0.0                 0.0                 0.0                 0.0
          0.0                 0.0                 0.0                 0.0
          0.0                 0.0                 0.0                 0.0
          0.0                 0.0                 0.0                 0.0
**
** 17. Long-run industry capacity utilization for each capacity
**     scenario (columns) and demand scenario (rows).
**
**     Scenario 1          Scenario 2          Scenario 3          Scenario 4
**
       .95                 .95                 0.95                0.95
       .95                 .95                 0.95                0.95
       .95                 .95                 0.95                0.95
**
** 18. Number of firms in the industry (max. 8)
**
       7
**
** 19. Corporate tax rate and capital cost allowance.
**
      0.46  0.20
**
** Firm Data - Firm 1 **
**
** 1. Name of firm or firm group (max. 50 chars)
**
Abitibi-Price
**
** 2. Number of firms represented by firm group
**
      1
**
** 3. Initial newsprint capacity (M tonnes) (av. firm capacity
**    if number of firms in group > 1)
**
      1698.0 1416.0 1808.0 1893.0 1823.0
**
** 4. Value of conjectural variation term
**
     -0.5
**
** 5. Long-run total variable cost function coefficients (a0, a1
**    and a2) by year, where TC is in M U.S. dollars and Q is in
**    M tonnes (includes transportation costs):
**
**    TC = a0 * Q + a1 * Q**2 + a2 * Q**3
**
**    a0                  a1                  a2
**
      260.219             0.0             0.00000677193
      269.814             0.0             0.00000608699
      266.077             0.0             0.00000569970
      256.265             0.0             0.00000544171
      255.967             0.0             0.00000636133
```

```
     243.79              0.0096275         0.000003633
     243.79              0.0096275         0.000003633
     243.79              0.0096275         0.000003633
     243.79              0.0096275         0.000003633
     243.79              0.0096275         0.000003633
     243.79              0.0096275         0.000003633
     243.79              0.0096275         0.000003633
     243.79              0.0096275         0.000003633
     243.79              0.0096275         0.000003633
     243.79              0.0096275         0.000003633
     243.79              0.0096275         0.000003633
     243.79              0.0096275         0.000003633
     243.79              0.0096275         0.000003633
     243.79              0.0096275         0.000003633
     243.79              0.0096275         0.000003633
**
** 6. Other costs (U.S. dollars per tonne) by year
**
**    Production cost     Overhead cost   Overhead cost
**     (new capacity)      (new capacity)  (existing capacity)
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
**
** 7. Annual discount rate (0.10 = 10%)
**
     0.10
**
** 8. Firm objective function type for the long run capacity decision
**      1. maximize expected profit
**      2. maximze expected utility (exponential utility function)
**      3. Minimax (minimize the maximum loss)
**      4. maximize market share (in last year of short run horizon)
**         subject to a constraint on profits (return on sales)
**      5. Maximize sales subject to a constraint on profits
**      6. Maximize expected profits subject to a constraint on market
**         share (MS in year 5 >= MS in year 1).
**
** OBJTYP=1 to 6.  If OBJTYP=2, then assign value of risk aversion
** index BCOEFF, else set BCOEFF=0.0. If OBJTYPE=4 or 5, then set
** minimum value for return on sales (%) (ROSMIN), else set = 0.0.
**
** OBJTYP BCOEFF ROSMIN
```

```
**
  1 0.0 0.0
**
**
** Firm Data - Firm 2 **
**
** 1. Name of firm or firm group (max. 50 chars)
**
International Paper
**
** 2. Number of firms represented by firm group
**
      1
**
** 3. Initial newsprint capacity (M tonnes) (av. firm capacity
**    if number of firms in group > 1)
**
      985.0 999.0 1023.0 744.0   809.0
**
**
** 4. Value of conjectural variation term
**
    0.0
**
** 5. Long-run total variable cost function coefficients (a0, a1
**    and a2) by year, where TC is in M U.S. dollars and Q is in
**    M tonnes (includes transportation costs):
**
**    TC = a0 * Q + a1 * Q**2 + a2 * Q**3
**
**    a0                   a1                  a2
**
      228.345              0.039486        0.0
      241.821              0.036256        0.0
      234.617              0.037688        0.0
      267.015              0.0             0.0000215959
      264.862              0.0             0.0000215944
      247.26               0.013825        0.0000067159
      247.26               0.013825        0.0000067159
      247.26               0.013825        0.0000067159
      247.26               0.013825        0.0000067159
      247.26               0.013825        0.0000067159
      247.26               0.013825        0.0000067159
      247.26               0.013825        0.0000067159
      247.26               0.013825        0.0000067159
      247.26               0.013825        0.0000067159
      247.26               0.013825        0.0000067159
      247.26               0.013825        0.0000067159
      247.26               0.013825        0.0000067159
      247.26               0.013825        0.0000067159
      247.26               0.013825        0.0000067159
      247.26               0.013825        0.0000067159
**
** 6. Other costs (U.S. dollars per tonne) by year
**
**    Production cost      Overhead cost    Overhead cost
**     (new capacity)      (new capacity)   (existing capacity)
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
```

```
     250.0              24.0          24.0
     250.0              24.0          24.0
     250.0              24.0          24.0
     250.0              24.0          24.0
     250.0              24.0          24.0
     250.0              24.0          24.0
     250.0              24.0          24.0
     250.0              24.0          24.0
     250.0              24.0          24.0
     250.0              24.0          24.0
     250.0              24.0          24.0
     250.0              24.0          24.0
     250.0              24.0          24.0
     250.0              24.0          24.0
     250.0              24.0          24.0
     250.0              24.0          24.0
     250.0              24.0          24.0
**
** 7. Annual discount rate (0.10 = 10%)
**
      0.10
**
** 8. Firm objective function type for the long run capacity decision
**      1. maximize expected profit
**      2. maximze expected utility (exponential utility function)
**      3. Minimax (minimize the maximum loss)
**      4. maximize market share (in last year of short run horizon)
**         subject to a constraint on profits (return on sales)
**      5. Maximize sales subject to a constraint on profits
**      6. Maximize expected profits subject to a constraint on market
**         share (MS in year 5 >= MS in year 1).
**
** OBJTYP=1 to 6.  If OBJTYP=2, then assign value of risk aversion
** index BCOEFF, else set BCOEFF=0.0. If OBJTYPE=4 or 5, then set
** minimum value for return on sales (%) (ROSMIN), else set = 0.0.
**
** OBJTYP BCOEFF ROSMIN
**
  1 0.0 0.0
**
**
** Firm Data - Firm 3 **
**
** 1. Name of firm or firm group (max. 50 chars)
**
Bowater
**
** 2. Number of firms represented by firm group
**
      1
**
** 3. Initial newsprint capacity (M tonnes) (av. firm capacity
**    if number of firms in group > 1)
**
      1165.0  1285.0 1308.0 1333.0 1266.0
**
**
** 4. Value of conjectural variation term
**
**
```

```
     -0.5
**
** 5. Long-run total variable cost function coefficients (a0, a1
**    and a2) by year, where TC is in M U.S. dollars and Q is in
**    M tonnes (includes transportation costs):
**
**    TC = a0 * Q + a1 * Q**2 + a2 * Q**3
**
**    a0                  a1                  a2
**
      246.181             0.017123        0.0
      265.145             0.010771        0.0
      260.459             0.011243        0.0
      247.053             0.015081        0.0
      239.549             0.020543        0.0
      225.92              0.024843        0.0
      225.92              0.024843        0.0
      225.92              0.024843        0.0
      225.92              0.024843        0.0
      225.92              0.024843        0.0
      225.92              0.024843        0.0
      225.92              0.024843        0.0
      225.92              0.024843        0.0
      225.92              0.024843        0.0
      225.92              0.024843        0.0
      225.92              0.024843        0.0
      225.92              0.024843        0.0
      225.92              0.024843        0.0
      225.92              0.024843        0.0
      225.92              0.024843        0.0
**
** 6. Other costs (U.S. dollars per tonne) by year
**
**    Production cost     Overhead cost   Overhead cost
**    (new capacity)      (new capacity)  (existing capacity)
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
**
** 7. Annual discount rate (0.10 = 10%)
**
      0.10
**
```

```
** 8. Firm objective function type for the long run capacity decision
**      1. maximize expected profit
**      2. maximze expected utility (exponential utility function)
**      3. Minimax (minimize the maximum loss)
**      4. maximize market share (in last year of short run horizon)
**         subject to a constraint on profits (return on sales)
**      5. Maximize sales subject to a constraint on profits
**      6. Maximize expected profits subject to a constraint on market
**         share (MS in year 5 >= MS in year 1).
**
** OBJTYP=1 to 6.  If OBJTYP=2, then assign value of risk aversion
** index BCOEFF, else set BCOEFF=0.0. If OBJTYPE=4 or 5, then set
** minimum value for return on sales (%) (ROSMIN), else set = 0.0.
**
** OBJTYP BCOEFF ROSMIN
**
  1 0.0 0.0
**
**
** Firm Data - Firm 4 **
**
** 1. Name of firm or firm group (max. 50 chars)
**
MacMillan Bloedel
**
** 2. Number of firms represented by firm group
**
      1
**
** 3. Initial newsprint capacity (M tonnes) (av. firm capacity
**    if number of firms in group > 1)
**
        775.0 1020.0 856.0 732.0 694.0
**
**
** 4. Value of conjectural variation term
**
**
     0.0
**
** 5. Long-run total variable cost function coefficients (a0, a1
**    and a2) by year, where TC is in M U.S. dollars and Q is in
**    M tonnes (includes transportation costs):
**
**    TC = a0 * Q + a1 * Q**2 + a2 * Q**3
**
**    a0                  a1                  a2
**
      251.953             0.0                0.0000161261
      266.561             0.0                0.0000198328
      263.971             0.0                0.0000167521
      267.342             0.0                0.0000226277
      236.889             0.0                0.0000235180
      248.41            -0.0152055           0.00002297
      248.41            -0.0152055           0.00002297
      248.41            -0.0152055           0.00002297
      248.41            -0.0152055           0.00002297
      248.41            -0.0152055           0.00002297
      248.41            -0.0152055           0.00002297
      248.41            -0.0152055           0.00002297
```

```
    248.41              -0.0152055        0.00002297
    248.41              -0.0152055        0.00002297
    248.41              -0.0152055        0.00002297
    248.41              -0.0152055        0.00002297
    248.41              -0.0152055        0.00002297
    248.41              -0.0152055        0.00002297
    248.41              -0.0152055        0.00002297
    248.41              -0.0152055        0.00002297
**
** 6. Other costs (U.S. dollars per tonne) by year
**
**    Production cost      Overhead cost   Overhead cost
**    (new capacity)       (new capacity)  (existing capacity)
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
    250.0                 24.0            24.0
**
** 7. Annual discount rate (0.10 = 10%)
**
    0.10
**
** 8. Firm objective function type for the long run capacity decision
**     1. maximize expected profit
**     2. maximze expected utility (exponential utility function)
**     3. Minimax (minimize the maximum loss)
**     4. maximize market share (in last year of short run horizon)
**        subject to a constraint on profits (return on sales)
**     5. Maximize sales subject to a constraint on profits
**     6. Maximize expected profits subject to a constraint on market
**        share (MS in year 5 >= MS in year 1).
**
** OBJTYP=1 to 6.  If OBJTYP=2, then assign value of risk aversion
** index BCOEFF, else set BCOEFF=0.0. If OBJTYPE=4 or 5, then set
** minimum value for return on sales (%) (ROSMIN), else set = 0.0.
**
** OBJTYP BCOEFF ROSMIN
**
  1 0.0 0.0
**
**
** Firm Data - Firm 5 **
**
** 1. Name of firm or firm group (max. 50 chars)
```

```
**
Consolidated Bathurst
**
** 2. Number of firms represented by firm group
**
     1
**
** 3. Initial newsprint capacity (M tonnes) (av. firm capacity
**    if number of firms in group > 1)
**
     700.0 640.0  700.0 636.0 639.0
**
**
** 4. Value of conjectural variation term
**
**
     0.0
**
** 5. Long-run total variable cost function coefficients (a0, a1
**    and a2) by year, where TC is in M U.S. dollars and Q is in
**    M tonnes (includes transportation costs):
**
**    TC = a0 * Q + a1 * Q**2 + a2 * Q**3
**
**    a0                  a1                  a2
**
     270.424              0.0             0.0000298058
     277.183              0.0             0.0000284551
     274.667              0.0             0.0000279526
     270.681              0.0             0.0000290804
     275.157              0.0             0.0000283744
     262.12               0.0             0.000025158
     262.12               0.0             0.000025158
     262.12               0.0             0.000025158
     262.12               0.0             0.000025158
     262.12               0.0             0.000025158
     262.12               0.0             0.000025158
     262.12               0.0             0.000025158
     262.12               0.0             0.000025158
     262.12               0.0             0.000025158
     262.12               0.0             0.000025158
     262.12               0.0             0.000025158
     262.12               0.0             0.000025158
     262.12               0.0             0.000025158
     262.12               0.0             0.000025158
     262.12               0.0             0.000025158
**
** 6. Other costs (U.S. dollars per tonne) by year
**
**    Production cost     Overhead cost   Overhead cost
**    (new capacity)      (new capacity)  (existing capacity)
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
    250.0                24.0            24.0
```

```
     250.0                  24.0            24.0
     250.0                  24.0            24.0
     250.0                  24.0            24.0
     250.0                  24.0            24.0
     250.0                  24.0            24.0
     250.0                  24.0            24.0
     250.0                  24.0            24.0
     250.0                  24.0            24.0
     250.0                  24.0            24.0
     250.0                  24.0            24.0
     250.0                  24.0            24.0
**
** 7. Annual discount rate (0.10 = 10%)
**
      0.10
**
** 8. Firm objective function type for the long run capacity decision
**      1. maximize expected profit
**      2. maximze expected utility (exponential utility function)
**      3. Minimax (minimize the maximum loss)
**      4. maximize market share (in last year of short run horizon)
**         subject to a constraint on profits (return on sales)
**      5. Maximize sales subject to a constraint on profits
**      6. Maximize expected profits subject to a constraint on market
**         share (MS in year 5 >= MS in year 1).
**
** OBJTYP=1 to 6.  If OBJTYP=2, then assign value of risk aversion
** index BCOEFF, else set BCOEFF=0.0. If OBJTYPE=4 or 5, then set
** minimum value for return on sales (%) (ROSMIN), else set = 0.0.
**
** OBJTYP BCOEFF ROSMIN
**
  1 0.0 0.0
**
** Firm Data - Firm 6 **
**
** 1. Name of firm or firm group (max. 50 chars)
**
Group #1 (KC,ONT,STREGIS,BOISE)
**
** 2. Number of firms represented by firm group
**
      4
**
** 3. Initial newsprint capacity (M tonnes) (av. firm capacity
**    if number of firms in group > 1)
**
      605.25 630.75 677.5 680 706.25
**
**
** 4. Value of conjectural variation term
**
**
      0.0
**
** 5. Long-run total variable cost function coefficients (a0, a1
**    and a2) by year, where TC is in M U.S. dollars and Q is in
**    M tonnes (includes transportation costs):
**
**    TC = a0 * Q + a1 * Q**2 + a2 * Q**3
```

```
**
**    a0                  a1                  a2
**
      226.639              0.060358      0.0
      255.749              0.054951      0.0
      251.890              0.046152      0.0
      241.165              0.040550      0.0
      239.452              0.038133      0.0
      237.44               0.04191       0.0
      237.44               0.04191       0.0
      237.44               0.04191       0.0
      237.44               0.04191       0.0
      237.44               0.04191       0.0
      237.44               0.04191       0.0
      237.44               0.04191       0.0
      237.44               0.04191       0.0
      237.44               0.04191       0.0
      237.44               0.04191       0.0
      237.44               0.04191       0.0
      237.44               0.04191       0.0
      237.44               0.04191       0.0
      237.44               0.04191       0.0
      237.44               0.04191       0.0
**
** 6. Other costs (U.S. dollars per tonne) by year
**
**    Production cost     Overhead cost   Overhead cost
**    (new capacity)      (new capacity)  (existing capacity)
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
     250.0                24.0            24.0
**
** 7. Annual discount rate (0.10 = 10%)
**
      0.10
**
** 8. Firm objective function type for the long run capacity decision
**     1. maximize expected profit
**     2. maximze expected utility (exponential utility function)
**     3. Minimax (minimize the maximum loss)
**     4. maximize market share (in last year of short run horizon)
**        subject to a constraint on profits (return on sales)
**     5. Maximize sales subject to a constraint on profits
```

```
**      6. Maximize expected profits subject to a constraint on market
**         share (MS in year 5 >= MS in year 1).
**
** OBJTYP=1 to 6.  If OBJTYP=2, then assign value of risk aversion
** index BCOEFF, else set BCOEFF=0.0. If OBJTYPE=4 or 5, then set
** minimum value for return on sales (%) (ROSMIN), else set = 0.0.
**
** OBJTYP BCOEFF ROSMIN
**
 1 0.0 0.0
**
**
** Firm Data - Firm 7 **
**
** 1. Name of firm or firm group (max. 50 chars)
**
Group #2 (KRUGER,CZ,GLFP,PUB)
**
** 2. Number of firms represented by firm group
**
     4
**
** 3. Initial newsprint capacity (M tonnes) (av. firm capacity
**    if number of firms in group > 1)
**
     381.0 384.25 420.0 481.0 444.25
**
**
** 4. Value of conjectural variation term
**
**
     0.0
**
** 5. Long-run total variable cost function coefficients (a0, a1
**    and a2) by year, where TC is in M U.S. dollars and Q is in
**    M tonnes (includes transportation costs):
**
**    TC = a0 * Q + a1 * Q**2 + a2 * Q**3
**
**    a0                  a1                  a2
**
     270.501             0.0             0.000121683
     289.821             0.0             0.000136068
     272.735             0.0             0.000119415
     266.506             0.0             0.000096920
     260.211             0.0             0.000083523
     260.65              0.0             0.000101896
     260.65              0.0             0.000101896
     260.65              0.0             0.000101896
     260.65              0.0             0.000101896
     260.65              0.0             0.000101896
     260.65              0.0             0.000101896
     260.65              0.0             0.000101896
     260.65              0.0             0.000101896
     260.65              0.0             0.000101896
     260.65              0.0             0.000101896
     260.65              0.0             0.000101896
     260.65              0.0             0.000101896
     260.65              0.0             0.000101896
     260.65              0.0             0.000101896
```

```
      260.65                0.0             0.000101896
**
** 6. Other costs (U.S. dollars per tonne) by year
**
**    Production cost      Overhead cost   Overhead cost
**    (new capacity)       (new capacity)  (existing capacity)
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
     250.0                 24.0            24.0
**
** 7. Annual discount rate (0.10 = 10%)
**
      0.10
**
** 8. Firm objective function type for the long run capacity decision
**      1. maximize expected profit
**      2. maximze expected utility (exponential utility function)
**      3. Minimax (minimize the maximum loss)
**      4. maximize market share (in last year of short run horizon)
**         subject to a constraint on profits (return on sales)
**      5. Maximize sales subject to a constraint on profits
**      6. Maximize expected profits subject to a constraint on market
**         share (MS in year 5 >= MS in year 1).
**
** OBJTYP=1 to 6.  If OBJTYP=2, then assign value of risk aversion
** index BCOEFF, else set BCOEFF=0.0. If OBJTYPE=4 or 5, then set
** minimum value for return on sales (%) (ROSMIN), else set = 0.0.
**
** OBJTYP BCOEFF ROSMIN
**
  1 0.0 0.0
**
```

<u>FILE 9</u>

```
**Base data for demand function for validating
** production part of Newsprint Model (1979 base year)
**
**Revised July 10/89 and OCT.10/89
**
** 1. Number of demand scenarios NDEM (maximum of 3).
**
```

```
1
**
** 2. Probability of demand scenarios (DPROB)
**
    1.0  0.0  0.0
**
** Demand Function information for demand scenario ** 1 **
**
**1. Coefficients of the US demand function
**  Intercept (INTCEP), real price of newsprint (CPNEWS), real GDP (CRGDP),
** real price of substitutes (CPRSUB), strike dummy
**
1065.925 -8.5150   4.1777 9.94059 -336.93
**
** 2. Values of real GDP and real price of substitutes in each year (RGDP and
RPRSUB)
**
1979 2464.40 214.10
1980 2462.01 219.11
1981 2508.93 222.67
1982 2448.23 194.38
1983 2538.73 204.71
1984 0.00 0.00
1985 0.00 0.00
1986 0.00 0.00
1987 0.00 0.00
1988 0.00 0.00
1989 0.00 0.00
1990 0.00 0.00
1991 0.00 0.00
1992 0.00 0.00
1993 0.00 0.00
1994 0.00 0.00
1995 0.00 0.00
1996 0.00 0.00
1997 0.00 0.00
1998 0.00 0.00
**
** 3. Values of Fringe Capacity FRCAP ('000 m t) and operating rate FROR (%)
**
1979 2483.00  97.00
1980 2908.00  96.00
1981 3166.00  96.00
1982 4044.00 89.00
1983 4372.00 90.00
1984 0.00 0.00
1985 0.00 0.00
1986 0.00 0.00
1987 0.00 0.00
1988 0.00 0.00
1989 0.00 0.00
1990 0.00 0.00
1991 0.00 0.00
1992 0.00 0.00
1993 0.00 0.00
1994 0.00 0.00
1995 0.00 0.00
1996 0.00 0.00
1997 0.00 0.00
1998 0.00 0.00
```

```
**
** 4. Quantities of imports, exports, Canadian demand, changes in inventory,
**  and quantity of groundwood specialty papers misclassified as newsprint
('000 m t).
**
1979 132.00 1523.00 971.00 -120.00 850
1980 125.00 1700.00 980.00 220.00 850
1981 37.00 2092.00 1045.00 434.00 949
1982 42.00 1799.00 934.00 -109.00 810
1983 67.00 1701.00 970.00 -19.00 830
1984 0.00 0.00 0.00 0.00 0
1985 0.00 0.00 0.00 0.00 0
1986 0.00 0.00 0.00 0.00 0
1987 0.00 0.00 0.00 0.00 0
1988 0.00 0.00 0.00 0.00 0
1989 0.00 0.00 0.00 0.00 0
1990 0.00 0.00 0.00 0.00 0
1991 0.00 0.00 0.00 0.00 0
1992 0.00 0.00 0.00 0.00 0
1993 0.00 0.00 0.00 0.00 0
1994 0.00 0.00 0.00 0.00 0
1995 0.00 0.00 0.00 0.00 0
1996 0.00 0.00 0.00 0.00 0
1997 0.00 0.00 0.00 0.00 0
1998 0.00 0.00 0.00 0.00 0
```

APPENDIX VI

LISTING OF DATABASE FOR THE MODEL

NOTE: There are two files containing data to be read in. The first is the general run information and firm data; the second is the demand data.

FILE 10

```
** A Strategic Capacity Expansion Model for the Newsprint Industry **
**
** Control Information **
**
** 1. Run Identification (max. 80 chars)
**
NP5.D79 MAX ex PROFIT(dem 3%,3.5%,2.5%/.34,.33,.33)/0.2% PR GR
**
** 2. Run type/detail. If run type=1, then model is run only for
**  short run horizon and actual capacititis are input for each year.
**    For run type 2, the model is run with all years and capacity
**   combinations.  For run type 3, a specific capcaity combination
** is specified interactively, and model is evaluated for that one
** combination only. For full detail output NDTAIL=1.For solution only
** NDTAIL=2. (for run types 1 or 3, use detail=1)
**
     2  1
**
** 2. Starting year of analysis
**
      1979
**
** 3. Total number of years in the planning horizon (max. 20) and
**    number of years in the short-run planning horizon (max. 5)
**
     15  5
**
**
** 9. Number of short-run firm capacity options (max. 3) and
**    number of years before first capacity can be installed (LAG)
**
      2   2
**
** 10. Description of each short-run firm capacity option
**     (max. 20 chars)
**
**     Option 1            Option 2            Option 3
**
       Do nothing          Add 1 machine       Add 2 machines
**
** 11. Short-run, new firm capacity (in M tonnes) by year
**     (max. 5 years)
**
**     Option 1            Option 2         Option 3
**
       0.0                 0.0                0.0
       0.0                 0.0                0.0
```

```
      0.0                 180.0           180.0
      0.0                 180.0           360.0
      0.0                 180.0           360.0
**
** 12. Long-run new capacity investment costs (in MM U.S. dollars)
**     by year
**
**     Option 1            Option 2            Option 3
**
      0.0                  70.0                70.0
      0.0                  70.0               140.0
      0.0                 0.0                  70.0
      0.0                 0.0                   0.0
      0.0                 0.0                   0.0
      0.0                 0.0                   0.0
      0.0                 0.0                   0.0
      0.0                 0.0                   0.0
      0.0                 0.0                   0.0
      0.0                 0.0                   0.0
      0.0                 0.0                   0.0
      0.0                 0.0                   0.0
      0.0                 0.0                   0.0
      0.0                 0.0                   0.0
      0.0                 0.0                   0.0
      0.0                 0.0                   0.0
      0.0                 0.0                   0.0
      0.0                 0.0                   0.0
      0.0                 0.0                   0.0
      0.0                 0.0                   0.0
**
**
** 14. Number of long-run industry capacity scenarios (max. 14)
**
      14
**
** 15. Description of long-run industry capacity scenarios (10 chars)
**
**
**
      Add 0     Add 1     Add 2     Add 3     Add 4     Add 5     Add 6     Add 7     Add 8
Add 9     Add 10    Add 11    add 12    add 13
**
** 16. Long-run industry capacity scenario by year (in M tonnes)
**     (new capacity added)
**
**     Scenarios ADD 0 1 2 3 4 5 6 7 8 9 10 11 12 13
**
1979 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1980 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1981 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1982 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1983 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1984 9483 9663 9843 10023 10203 10383 10563 10743 10923 11103 11283 11463 11643 11823
1985 10242 10339 10532 10674 10815 10954 11091 11226 11360 11492 11621 11807 11992 12178
1986 11061 11063 11269 11368 11464 11557 11646 11732 11814 11894 11970 12161 12352 12543
1987 11946 11838 12058 12107 12152 12192 12228 12260 12287 12310 12329 12526 12723 12919
1988 12902 12666 12902 12894 12881 12863 12839 12811 12778 12741 12699 12902 13080 13080
1989 13080 13080 13080 13080 13080 13080 13080 13080 13080 13080 13080 13080 13080 13080
1990 13472 13472 13472 13472 13472 13472 13472 13472 13472 13472 13472 13472 13472 13472
1991 13877 13877 13877 13877 13877 13877 13877 13877 13877 13877 13877 13877 13877 13877
1992 14293 14293 14293 14293 14293 14293 14293 14293 14293 14293 14293 14293 14293 14293
1993 14722 14722 14722 14722 14722 14722 14722 14722 14722 14722 14722 14722 14722 14722
1994 15163 15163 15163 15163 15163 15163 15163 15163 15163 15163 15163 15163 15163 15163
1995 15618 15618 15618 15618 15618 15618 15618 15618 15618 15618 15618 15618 15618 15618
1996 16087 16087 16087 16087 16087 16087 16087 16087 16087 16087 16087 16087 16087 16087
1997 16569 16569 16569 16569 16569 16569 16569 16569 16569 16569 16569 16569 16569 16569
```

```
1998 17067 17067 17067 17067 17067 17067 17067 17067 17067 17067 17067 17067 17067 17067
1979 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1980 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1981 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1982 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1983 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1984 9483 9663 9843 10023 10203 10383 10563 10743 10923 11103 11283 11463 11643 11823
1985 10431 10533 10729 10825 11019 11110 11302 11388 11578 11658 11847 11922 12109 12237
1986 11474 11481 11694 11691 11901 11887 12094 12071 12273 12241 12440 12398 12593 12665
1987 12622 12514 12747 12626 12853 12720 12940 12795 13009 12853 13061 12894 13097 13108
1988 13884 13640 13894 13636 13881 13610 13846 13563 13790 13496 13715 13410 13621 13567
1989 13925 13925 13925 13925 13925 13925 13925 13925 13925 13925 13925 13925 13925 13925
1990 14412 14412 14412 14412 14412 14412 14412 14412 14412 14412 14412 14412 14482 14412
1991 14917 14917 14917 14917 14917 14917 14917 14917 14917 14917 14917 14917 15061 14917
1992 15439 15439 15439 15439 15439 15439 15439 15439 15439 15439 15439 15439 15664 15439
1993 15979 15979 15979 15979 15979 15979 15979 15979 15979 15979 15979 15979 16290 15979
1994 16539 16539 16539 16539 16539 16539 16539 16539 16539 16539 16539 16539 16942 16539
1995 17117 17117 17117 17117 17117 17117 17117 17117 17117 17117 17117 17117 17620 17117
1996 17716 17716 17716 17716 17716 17716 17716 17716 17716 17716 17716 17716 18324 17716
1997 18337 18337 18337 18337 18337 18337 18337 18337 18337 18337 18337 18337 19057 18337
1998 18978 18978 18978 18978 18978 18978 18978 18978 18978 18978 18978 18978 19820 18978
1979 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1980 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1981 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1982 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1983 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1984 9483 9663 9843 10023 10203 10383 10563 10743 10923 11103 11283 11463 11643 11823
1985 10052 10243 10335 10524 10611 10798 10880 11012 11196 11381 11509 11578 11759 11823
1986 10655 10857 10852 11050 11036 11230 11206 11287 11476 11665 11739 11693 11877 11823
1987 11294 11509 11395 11603 11477 11679 11542 11569 11763 11957 11974 11810 11996 11823
1988 11972 12199 11964 12183 11936 12147 11889 11858 12057 12256 12213 11928 12116 11823
1989 12285 12285 12285 12285 12285 12285 12285 12285 12285 12285 12285 12285 12285 12285
1990 12592 12592 12592 12592 12592 12592 12592 12592 12592 12592 12592 12592 12592 12592
1991 12907 12907 12907 12907 12907 12907 12907 12907 12907 12907 12907 12907 12907 12907
1992 13230 13230 13230 13230 13230 13230 13230 13230 13230 13230 13230 13230 13230 13230
1993 13560 13560 13560 13560 13560 13560 13560 13560 13560 13560 13560 13560 13560 13560
1994 13899 13899 13899 13899 13899 13899 13899 13899 13899 13899 13899 13899 13899 13899
1995 14247 14247 14247 14247 14247 14247 14247 14247 14247 14247 14247 14247 14247 14247
1996 14603 14603 14603 14603 14603 14603 14603 14603 14603 14603 14603 14603 14603 14603
1997 14968 14968 14968 14968 14968 14968 14968 14968 14968 14968 14968 14968 14968 14968
1998 15342 15342 15342 15342 15342 15342 15342 15342 15342 15342 15342 15342 15342 15342
**
** 17. Long-run industry capacity utilization for each capacity
**     scenario (columns) and demand scenario (rows).
**
**     0 1 2 3 4 5 6 7 8 9 10 11 12 13
**
   .95  .95   .95  .95  .95  .95  .95  .95  .95  .95  .95  .95 .95 .95
   .95  .95   .95  .95  .95  .95  .95  .95  .95  .95  .95  .95 .95 .95
   .95  .95   .95  .95  .95  .95  .95  .95  .95  .95  .95  .95 .95 .95
**
** 18. Number of firms in the industry (max. 8)
**
       7
**
** 19. Corporate Tax rate and capital cost allowance
**
       0.46  0.20
**
** Firm Data - Firm 1 **
**
** 1. Name of firm or firm group (max. 50 chars)
**
Abitibi-Price
**
** 2. Number of firms represented by firm group
```

```
**
     1
**
** 3. Initial newsprint capacity (M tonnes) (av. firm capacity
**    if number of firms in group > 1)
**
     1698.0   1698.0 1698.0 1698.0 1698.0
**
** 4. value of conjectural variation term
**
       -0.5
**
** 5. Long-run total variable cost function coefficients (a0, a1
**    and a2) by year, where TC is in M U.S. dollars and Q is in
**    M tonnes (includes transportation costs):
**
**    TC = a0 * Q + a1 * Q**2 + a2 * Q**3
**
**    a0                  a1                  a2
**
     260.219             0.0              6.77193E-6
     260.219             0.0              6.77193E-6
     260.219              0.0              6.77193E-6
     260.219              0.0              6.77193E-6
     260.219             0.0              6.77193E-6
     260.219              0.0              6.77193E-6
     260.219              0.0              6.77193E-6
     260.219              0.0              6.77193E-6
     260.219              0.0              6.77193E-6
     260.219              0.0              6.77193E-6
     260.219              0.0              6.77193E-6
     260.219              0.0              6.77193E-6
     260.219              0.0              6.77193E-6
     260.219              0.0              6.77193E-6
     260.219              0.0              6.77193E-6
     260.219              0.0              6.77193E-6
     260.219              0.0              6.77193E-6
     260.219              0.0              6.77193E-6
     260.219              0.0              6.77193E-6
     260.219              0.0              6.77193E-6
**
** 6. Other costs (U.S. dollars per tonne) by year
**
**    Production cost      Overhead cost   Overhead cost
**    (new capacity)       (new capacity)  (existing capacity)
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
    250.0                 24.0           24.0
**
```

```
** 7. Annual discount rate (0.10 = 10%)
**
      0.10
**
** 8. Firm objective function type for the long run capacity decision
**      1. maximize expected profit
**      2. maximze expected utility (exponential utility function)
**      3. Minimax (minimize the maximum loss)
**      4. maximize market share (in last year of short run horizon)
**         subject to a constraint on profits (return on sales)
**      5. Maximize sales subject to a constraint on profits
**      6. Maximize expected profits subject to a constraint on market
**         share (MS in year 5 >= MS in year 1).
**      7. maximize ROI for new investment
**
** OBJTYP=1 to 7.  If OBJTYP=2, then assign value of risk aversion
** index BCOEFF, else set BCOEFF=0.0. If OBJTYPE=4 or 5, then set
** minimum value for return on sales (%) (ROSMIN), else set = 0.0.
**
** OBJTYP BCOEFF ROSMIN
**
  1 0.0 0.0
**
** Firm Data - Firm 2 **
**
** 1. Name of firm or firm group (max. 50 chars)
**
International Paper
**
** 2. Number of firms represented by firm group
**
      1
**
** 3. Initial newsprint capacity (M tonnes) (av. firm capacity
**    if number of firms in group > 1)
**
      985.0 985.0 985.0 985.0 985.0
**
** 4. value of conjectural variation term
**
         0.0
**
** 5. Long-run total variable cost function coefficients (a0, a1
**    and a2) by year, where TC is in M U.S. dollars and Q is in
**    M tonnes (includes transportation costs):
**
**    TC = a0 * Q + a1 * Q**2 + a2 * Q**3
**
**    a0                  a1                  a2
**
      228.345             0.039486        0.0
      228.345              0.039486        0.0
      228.345              0.039486        0.0
      228.345              0.039486        0.0
      228.345              0.039486        0.0
      228.345              0.039486        0.0
      228.345              0.039486        0.0
      228.345              0.039486        0.0
      228.345              0.039486        0.0
      228.345              0.039486        0.0
      228.345              0.039486        0.0
      228.345              0.039486        0.0
      228.345              0.039486        0.0
      228.345              0.039486        0.0
      228.345              0.039486        0.0
      228.345              0.039486        0.0
```

```
      228.345              0.039486        0.0
      228.345              0.039486        0.0
      228.345              0.039486        0.0
      228.345              0.039486        0.0
**
** 6. Other costs (U.S. dollars per tonne) by year
**
**    Production cost     Overhead cost   Overhead cost
**    (new capacity)      (new capacity)  (existing capacity)
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
     250.0               24.0           24.0
**
** 7. Annual discount rate (0.10 = 10%)
**
      0.10
**
**
** 8. Firm objective function type for the long run capacity decision
**     1. maximize expected profit
**     2. maximze expected utility (exponential utility function)
**     3. Minimax (minimize the maximum loss)
**     4. maximize market share (in last year of short run horizon)
**        subject to a constraint on profits (return on sales)
**     5. Maximize sales subject to a constraint on profits
**     6. Maximize expected profits subject to a constraint on market
**        share (MS in year 5 >= MS in year 1).
**     7. maximize ROI for new investment
**
** OBJTYP=1 to 7.  If OBJTYP=2, then assign value of risk aversion
** index BCOEFF, else set BCOEFF=0.0. If OBJTYPE=4 or 5, then set
** minimum value for return on sales (%) (ROSMIN), else set = 0.0.
**
** OBJTYP BCOEFF ROSMIN
**
  1 0.0 0.0
**
** Firm Data - Firm 3 **
**
** 1. Name of firm or firm group (max. 50 chars)
**
Bowater
**
** 2. Number of firms represented by firm group
**
      1
**
** 3. Initial newsprint capacity (M tonnes) (av. firm capacity
**    if number of firms in group > 1)
```

```
**
     1165.0  1165.0 1165.0 1165.0 1165.0
**
** 4. valud of conjectural variation term
**
       -0.5
**
** 5. Long-run total variable cost function coefficients (a0, a1
**    and a2) by year, where TC is in M U.S. dollars and Q is in
**    M tonnes (includes transportation costs):
**
**    TC = a0 * Q + a1 * Q**2 + a2 * Q**3
**
**    a0                   a1                   a2
**
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
     246.181            0.017123         0.0
**
** 6. Other costs (U.S. dollars per tonne) by year
**
**    Production cost     Overhead cost   Overhead cost
**    (new capacity)      (new capacity)  (existing capacity)
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
   250.0                 24.0              24.0
**
** 7. Annual discount rate (0.10 = 10%)
**
     0.10
**
**
```

```
** 8. Firm objective function type for the long run capacity decision
**      1. maximize expected profit
**      2. maximze expected utility (exponential utility function)
**      3. Minimax (minimize the maximum loss)
**      4. maximize market share (in last year of short run horizon)
**         subject to a constraint on profits (return on sales)
**      5. Maximize sales subject to a constraint on profits
**      6. Maximize expected profits subject to a constraint on market
**         share (MS in year 5 >= MS in year 1).
**      7. maximize ROI for new investment
**
** OBJTYP=1 to 7.  If OBJTYP=2, then assign value of risk aversion
** index BCOEFF, else set BCOEFF=0.0. If OBJTYPE=4 or 5, then set
** minimum value for return on sales (%) (ROSMIN), else set = 0.0.
**
** OBJTYP BCOEFF ROSMIN
**
  1 0.0 0.0
**
** Firm Data - Firm 4 **
**
** 1. Name of firm or firm group (max. 50 chars)
**
MacMillan Bloedel
**
** 2. Number of firms represented by firm group
**
      1
**
** 3. Initial newsprint capacity (M tonnes) (av. firm capacity
**    if number of firms in group > 1)
**
       990.0   990.0 990.0 990.0 990.0
**
** 4. value of conjectural variation term
**
         0.0
**
** 5. Long-run total variable cost function coefficients (a0, a1
**    and a2) by year, where TC is in M U.S. dollars and Q is in
**    M tonnes (includes transportation costs):
**
**    TC = a0 * Q + a1 * Q**2 + a2 * Q**3
**
**    a0                  a1                  a2
**
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
      251.953             0.0              1.61261E-5
```

```
**
** 6. Other costs (U.S. dollars per tonne) by year
**
**     Production cost      Overhead cost   Overhead cost
**     (new capacity)       (new capacity)  (existing capacity)
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
     250.0                  24.0              24.0
**
** 7. Annual discount rate (0.10 = 10%)
**
      0.10
**
**
** 8. Firm objective function type for the long run capacity decision
**      1. maximize expected profit
**      2. maximze expected utility (exponential utility function)
**      3. Minimax (minimize the maximum loss)
**      4. maximize market share (in last year of short run horizon)
**         subject to a constraint on profits (return on sales)
**      5. Maximize sales subject to a constraint on profits
**      6. Maximize expected profits subject to a constraint on market
**         share (MS in year 5 >= MS in year 1).
**      7. maximize ROI for new investment
**
** OBJTYP=1 to 7.  If OBJTYP=2, then assign value of risk aversion
** index BCOEFF, else set BCOEFF=0.0. If OBJTYPE=4 or 5, then set
** minimum value for return on sales (%) (ROSMIN), else set = 0.0.
**
** OBJTYP BCOEFF ROSMIN
**
  1 0.0 0.0
**
** Firm Data - Firm 5 **
**
** 1. Name of firm or firm group (max. 50 chars)
**
Consolidated Bathurst
**
** 2. Number of firms represented by firm group
**
      1
**
** 3. Initial newsprint capacity (M tonnes) (av. firm capacity
**    if number of firms in group > 1)
**
      700.0 700.0 700.0 700.0 700.0
**
** 4. value of conjectural variation term
```

```
**
         0.0
**
** 5. Long-run total variable cost function coefficients (a0, a1
**    and a2) by year, where TC is in M U.S. dollars and Q is in
**    M tonnes (includes transportation costs):
**
**    TC = a0 * Q + a1 * Q**2 + a2 * Q**3
**
**    a0                   a1                  a2
**
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
      270.424               0.0              2.98058E-5
**
** 6. Other costs (U.S. dollars per tonne) by year
**
**    Production cost      Overhead cost   Overhead cost
**    (new capacity)       (new capacity)  (existing capacity)
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
      250.0                24.0              24.0
**
** 7. Annual discount rate (0.10 = 10%)
**
      0.10
**
**
** 8. Firm objective function type for the long run capacity decision
**     1. maximize expected profit
**     2. maximze expected utility (exponential utility function)
**     3. Minimax (minimize the maximum loss)
```

```
**      4. maximize market share (in last year of short run horizon)
**         subject to a constraint on profits (return on sales)
**      5. Maximize sales subject to a constraint on profits
**      6. Maximize expected profits subject to a constraint on market
**         share (MS in year 5 >= MS in year 1).
**      7. maximize ROI for new investment
**
** OBJTYP=1 to 7.  If OBJTYP=2, then assign value of risk aversion
** index BCOEFF, else set BCOEFF=0.0. If OBJTYPE=4 or 5, then set
** minimum value for return on sales (%) (ROSMIN), else set = 0.0.
**
** OBJTYP BCOEFF ROSMIN
**
 1 0.0 0.0
**
** Firm Data - Firm 6 **
**
** 1. Name of firm or firm group (max. 50 chars)
**
Group #1 (KC,ONT,STREGIS,BOISE)
**
** 2. Number of firms represented by firm group
**
     4
**
** 3. Initial newsprint capacity (M tonnes) (av. firm capacity
**    if number of firms in group > 1)
**
     605.25 605.25 605.25 605.25 605.25
**
** 4. valud of conjectural variation term
**
     0.0
**
** 5. Long-run total variable cost function coefficients (a0, a1
**    and a2) by year, where TC is in M U.S. dollars and Q is in
**    M tonnes (includes transportation costs):
**
**    TC = a0 * Q + a1 * Q**2 + a2 * Q**3
**
**    a0                  a1                  a2
**
     226.639              0.060358      0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
     226.64               0.060358       0.0
**
** 6. Other costs (U.S. dollars per tonne) by year
**
**    Production cost     Overhead cost   Overhead cost
```

```
**    (new capacity)       (new capacity)  (existing capacity)
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
       250.0                 24.0            24.0
**
** 7. Annual discount rate (0.10 = 10%)
**
      0.10
**
**
** 8. Firm objective function type for the long run capacity decision
**      1. maximize expected profit
**      2. maximze expected utility (exponential utility function)
**      3. Minimax (minimize the maximum loss)
**      4. maximize market share (in last year of short run horizon)
**         subject to a constraint on profits (return on sales)
**      5. Maximize sales subject to a constraint on profits
**      6. Maximize expected profits subject to a constraint on market
**         share (MS in year 5 >= MS in year 1).
**      7. maximize ROI for new investment
**
** OBJTYP=1 to 7.  If OBJTYP=2, then assign value of risk aversion
** index BCOEFF, else set BCOEFF=0.0. If OBJTYPE=4 or 5, then set
** minimum value for return on sales (%) (ROSMIN), else set = 0.0.
**
** OBJTYP BCOEFF ROSMIN
**
  1 0.0 0.0
**
** Firm Data - Firm 7 **
**
** 1. Name of firm or firm group (max. 50 chars)
**
Group #2 (KRUGER,CZ,GLFP,PUB)
**
** 2. Number of firms represented by firm group
**
      4
**
** 3. Initial newsprint capacity (M tonnes) (av. firm capacity
**    if number of firms in group > 1)
**
      381.0 381.0 381.0 381.0 381.0
**
** 4. value of conjectural variation term
**
         0.0
**
** 5. Long-run total variable cost function coefficients (a0, a1
```

```
**    and a2) by year, where TC is in M U.S. dollars and Q is in
**    M tonnes (includes transportation costs):
**
**    TC = a0 * Q + a1 * Q**2 + a2 * Q**3
**
**    a0                    a1                   a2
**
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
      270.501                0.0               1.21683E-4
**
** 6. Other costs (U.S. dollars per tonne) by year
**
**    Production cost     Overhead cost    Overhead cost
**    (new capacity)      (new capacity)   (existing capacity)
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
      250.0               24.0               24.0
**
** 7. Annual discount rate (0.10 = 10%)
**
      0.10
**
**
** 8. Firm objective function type for the long run capacity decision
**      1. maximize expected profit
**      2. maximze expected utility (exponential utility function)
**      3. Minimax (minimize the maximum loss)
**      4. maximize market share (in last year of short run horizon)
**         subject to a constraint on profits (return on sales)
**      5. Maximize sales subject to a constraint on profits
**      6. Maximize expected profits subject to a constraint on market
```

```
**       share (MS in year 5 >= MS in year 1).
**     7. maximize ROI for new investment
**
** OBJTYP=1 to 7.  If OBJTYP=2, then assign value of risk aversion
** index BCOEFF, else set BCOEFF=0.0. If OBJTYPE=4 or 5, then set
** minimum value for return on sales (%) (ROSMIN), else set = 0.0.
**
** OBJTYP BCOEFF ROSMIN
**
  1 0.0 0.0
```

FILE 9

```
**Base data for demand function for validating capacity part of Newsprint Model (1979 base
year)
**db/np5.d79
**Feb. 12, 1990
**
** 1. Number of demand scenarios NDEM (maximum of 3). (GDP3.0%, GDP 3.5%, GDP 2.5%)
**
       3
**
** 2. Probability of demand scenarios (DPROB)
**
0.34 0.33 0.33
**
** Demand Function information for demand scenario ** 1 **
**
**1. Coefficients of the US demand function
**  Intercept (INTCEP), real price of newsprint (CPNEWS), real GDP (CRGDP),
** real price of substitutes (CPRSUB), strike dummy
**
1065.92 -8.51496 4.1777 9.94059 -336.93
**
**
** 2. Values of real GDP and real price of substitutes in each year (RGDP and RPRSUB)
**    (3%/yr)
1979   2488.28   205.00
1980   2562.93   205.00
1981   2639.82   205.00
1982   2719.02   205.00
1983   2800.59   205.00
1984   2884.60   205.00
1985   2971.14   205.00
1986   3060.28   205.00
1987   3152.08   205.00
1988   3246.65   205.00
1989   3344.05   205.00
1990   3444.37   205.00
1991   3547.70   205.00
1992   3654.13   205.00
1993   3763.75   205.00
1994   3876.67   205.00
1995   3992.97   205.00
1996   4112.75   205.00
1997   4236.14   205.00
1998   4363.22   205.00
**
** 3. Values of Fringe Capacity FRCAP ('000 m t) and operating rate FROR (%)
** (3%/yr except 1st 3 years)
1979 2683.00 95.00
1980 2983.00 95.00
1981 3018.00 95.00
1982 3108.54 95.00
1983 3201.80 95.00
```

```
1984 3297.85 95.00
1985 3396.79 95.00
1986 3498.69 95.00
1987 3603.65 95.00
1988 3711.76 95.00
1989 3823.11 95.00
1990 3937.81 95.00
1991 4055.94 95.00
1992 4177.62 95.00
1993 4302.95 95.00
1994 4432.03 95.00
1995 4565.00 95.00
1996 4701.95 95.00
1997 4843.00 95.00
1998 4988.29 95.00
**
** 4. Quantities of imports, exports, Canadian demand, changes in inventory,
**  and quantity of groundwood specialty papers misclassified as newsprint ('000 m t).
**  (2%/yr) (3%/yr)
1979 178.00 1674.84 951.72 0.00 850
1980 178.00 1708.34 980.27 0.00 850
1981 178.00 1742.50 1009.68 0.00 850
1982 178.00 1777.35 1039.97 0.00 850
1983 178.00 1812.90 1071.17 0.00 850
1984 178.00 1849.16 1103.30 0.00 850
1985 178.00 1886.14 1136.40 0.00 850
1986 178.00 1923.86 1170.50 0.00 850
1987 178.00 1962.34 1205.61 0.00 850
1988 178.00 2001.59 1241.78 0.00 850
1989 178.00 2041.62 1279.03 0.00 850
1990 178.00 2082.45 1317.40 0.00 850
1991 178.00 2124.10 1356.93 0.00 850
1992 178.00 2166.58 1397.63 0.00 850
1993 178.00 2209.92 1439.56 0.00 850
1994 178.00 2254.11 1482.75 0.00 850
1995 178.00 2299.20 1527.23 0.00 850
1996 178.00 2345.18 1573.05 0.00 850
1997 178.00 2392.08 1620.24 0.00 850
1998 178.00 2439.93 1668.85 0.00 850
**
** Demand Function information for demand scenario ** 2 **
**
**1. Coefficients of the US demand function
**  Intercept (INTCEP), real price of newsprint (CPNEWS), real GDP (CRGDP),
** real price of substitutes (CPRSUB), strike dummy
**
1065.92 -8.51496 4.1777 9.94059 -336.93
**
** 2. Values of real GDP and real price of substitutes in each year (RGDP and RPRSUB)
** (3.5%/yr)
1979  2500.36  205.00
1980  2587.88  205.00
1981  2678.45  205.00
1982  2772.20  205.00
1983  2869.22  205.00
1984  2969.65  205.00
1985  3073.58  205.00
1986  3181.16  205.00
1987  3292.50  205.00
1988  3407.74  205.00
1989  3527.01  205.00
1990  3650.45  205.00
1991  3778.22  205.00
1992  3910.46  205.00
1993  4047.32  205.00
1994  4188.98  205.00
```

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1995  4335.60  205.00
1996  4487.34  205.00
1997  4644.40  205.00
1998  4806.95  205.00
**
** 3. Values of Fringe Capacity FRCAP ('000 m t) and operating rate FROR (%)
** (3%/yr except 1st 3 years)
1979 2683.00 95.00
1980 2983.00 95.00
1981 3018.00 95.00
1982 3108.54 95.00
1983 3201.80 95.00
1984 3297.85 95.00
1985 3396.79 95.00
1986 3498.69 95.00
1987 3603.65 95.00
1988 3711.76 95.00
1989 3823.11 95.00
1990 3937.81 95.00
1991 4055.94 95.00
1992 4177.62 95.00
1993 4302.95 95.00
1994 4432.03 95.00
1995 4565.00 95.00
1996 4701.95 95.00
1997 4843.00 95.00
1998 4988.29 95.00
**
** 4. Quantities of imports, exports, Canadian demand, changes in inventory,
**  and quantity of groundwood specialty papers misclassified as newsprint ('000 m t).
**  (2%/yr) (3%/yr)
1979 178.00 1674.84 951.72 0.00 850
1980 178.00 1708.34 980.27 0.00 850
1981 178.00 1742.50 1009.68 0.00 850
1982 178.00 1777.35 1039.97 0.00 850
1983 178.00 1812.90 1071.17 0.00 850
1984 178.00 1849.16 1103.30 0.00 850
1985 178.00 1886.14 1136.40 0.00 850
1986 178.00 1923.86 1170.50 0.00 850
1987 178.00 1962.34 1205.61 0.00 850
1988 178.00 2001.59 1241.78 0.00 850
1989 178.00 2041.62 1279.03 0.00 850
1990 178.00 2082.45 1317.40 0.00 850
1991 178.00 2124.10 1356.93 0.00 850
1992 178.00 2166.58 1397.63 0.00 850
1993 178.00 2209.92 1439.56 0.00 850
1994 178.00 2254.11 1482.75 0.00 850
1995 178.00 2299.20 1527.23 0.00 850
1996 178.00 2345.18 1573.05 0.00 850
1997 178.00 2392.08 1620.24 0.00 850
1998 178.00 2439.93 1668.85 0.00 850
**
** Demand Function information for demand scenario ** 3 **
**
**1. Coefficients of the US demand function
**  Intercept (INTCEP), real price of newsprint (CPNEWS), real GDP (CRGDP),
** real price of substitutes (CPRSUB), strike dummy
**
1065.92 -8.51496 4.1777 9.94059 -336.93
**
**
** 2. Values of real GDP and real price of substitutes in each year (RGDP and RPRSUB)
**  (2.5%/yr)
1979  2476.21  205.00
1980  2538.11  205.00
1981  2601.56  205.00
```

```
1982  2666.60  205.00
1983  2733.27  205.00
1984  2801.60  205.00
1985  2871.64  205.00
1986  2943.43  205.00
1987  3017.02  205.00
1988  3092.44  205.00
1989  3169.75  205.00
1990  3249.00  205.00
1991  3330.22  205.00
1992  3413.48  205.00
1993  3498.81  205.00
1994  3586.28  205.00
1995  3675.94  205.00
1996  3767.84  205.00
1997  3862.04  205.00
1998  3958.59  205.00
**
** 3. Values of Fringe Capacity FRCAP ('000 m t) and operating rate FROR (%)
** (3%/yr except 1st 3 years)
1979 2683.00 95.00
1980 2983.00 95.00
1981 3018.00 95.00
1982 3108.54 95.00
1983 3201.80 95.00
1984 3297.85 95.00
1985 3396.79 95.00
1986 3498.69 95.00
1987 3603.65 95.00
1988 3711.76 95.00
1989 3823.11 95.00
1990 3937.81 95.00
1991 4055.94 95.00
1992 4177.62 95.00
1993 4302.95 95.00
1994 4432.03 95.00
1995 4565.00 95.00
1996 4701.95 95.00
1997 4843.00 95.00
1998 4988.29 95.00
**
** 4. Quantities of imports, exports, Canadian demand, changes in inventory,
**  and quantity of groundwood specialty papers misclassified as newsprint ('000 m t).
**   (2%/yr) (3%/yr)
1979 178.00 1674.84 951.72 0.00 850
1980 178.00 1708.34 980.27 0.00 850
1981 178.00 1742.50 1009.68 0.00 850
1982 178.00 1777.35 1039.97 0.00 850
1983 178.00 1812.90 1071.17 0.00 850
1984 178.00 1849.16 1103.30 0.00 850
1985 178.00 1886.14 1136.40 0.00 850
1986 178.00 1923.86 1170.50 0.00 850
1987 178.00 1962.34 1205.61 0.00 850
1988 178.00 2001.59 1241.78 0.00 850
1989 178.00 2041.62 1279.03 0.00 850
1990 178.00 2082.45 1317.40 0.00 850
1991 178.00 2124.10 1356.93 0.00 850
1992 178.00 2166.58 1397.63 0.00 850
1993 178.00 2209.92 1439.56 0.00 850
1994 178.00 2254.11 1482.75 0.00 850
1995 178.00 2299.20 1527.23 0.00 850
1996 178.00 2345.18 1573.05 0.00 850
1997 178.00 2392.08 1620.24 0.00 850
1998 178.00 2439.93 1668.85 0.00 850
```