A Comparison of Price-Cost Margins in the Canadian and U.S. Petroleum Refining Industries

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for the Degree of

MASTER OF ARTS

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A COMPARISON OF PRICE-COST MARGINS IN THE CANADIAN AND U.S. PETROLEUM REFINING INDUSTRIES

BY

BRENT DEPAPE

A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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ABSTRACT

This thesis compares industrial concentration and profitability in the Canadian and U.S. refining industries. The approach taken is an eclectic one; in its focus on a single industry it is reminiscent of the case study approach which first dominated the literature until the late fifties and has been recently rejuvenated in the literature. But it also relies heavily on the empirical methods of analysis which developed during the sixties and seventies.

The performance measure employed in the analysis is the price-cost margin which is a proxy for the so-called Lerner Index of monopoly power. Using national aggregate data and aggregate product revenue, the study period extends from the 1973 oil crisis through to 1991. The study includes a discussion of measurement issues and an empirical analysis of the primary determinants of price-cost margins. The variables examined include average cost and its relationship to marginal cost, capacity utilization, economies of scale, x-inefficiency, capital intensity, technology, market demand growth and demand elasticity.

The analysis concludes that the refining industry in the two markets is similar in many respects and that the observed aggregate price-cost margins in the two countries are of a similar order of magnitude. This latter finding contradicts the *a priori* expectation that the Canadian refining margin would be lower than that of its U.S. counterpart because of the lower proportion of high-value products in the Canadian product slate. The evidence suggests that the higher than expected Canadian margin is consistent with the higher level of industry concentration in Canada, which is expected to facilitate collusion. Because capital costs could not be dealt with adequately, only tentative conclusions were drawn regarding industry profitability.

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I am deeply indebted to so many members of the faculty of the University of Manitoba who have, in one way or the other, contributed to the successful completion of this thesis. I remain particularly grateful for the kindness and guidance offered by Professor Ralph Harris (retired), for without his encouragement I would not have continued with my graduate studies. I am also particularly indebted to my thesis advisor, Professor Costas Nicolaou, who has, over many years, guided, encouraged, and frequently prodded me into action and has always remained an unwavering pillar of support. Special thanks are due to my family, especially Karen and Jo, for the many sacrifices they have made in support of my efforts.

INTRODUCTION

The traditional view in the field of industrial economics holds that the behaviour and performance of business firms is significantly influenced by the structure of the particular industry in which the firms operate. This structure-conduct-performance paradigm is derived from the theory of the firm which distinguishes (in the theoretically limiting cases) between monopoly and perfectly competitive markets - and suggests a link between these market structures to the firms' conduct which is ultimately reflected in its performance. Because a monopolist is inclined to make price and output decisions which result in a misallocation of resources, it is expected to be a sub-optimal performer. Between the dichotomy of monopoly and competition lies the bulk of market reality, where observed market structures tend to vary between the two limiting cases of competition and monopoly and in general, allocative efficiency is expected to decline as market structure deviates from the competitive norm.

As a key indicator of performance[1], allocative efficiency has remained a principle focus of empirical research in industrial economics. The theoretical criteria for allocative efficiency is articulated within the perfectly competitive model in which

[1] Other dimensions of performance measures have also been considered, including product innovation and the level of research and development, but short-run price or profit performance has been the main pre-occupation of empiricists.

firms are driven by the competitive forces of the market environment to expand output and establish prices at levels consistent with the optimal allocation of resources. It was against this benchmark performance criteria that A.P. Lerner (1934) first proposed a simple measure of monopoly power: the ability of the firm to raise price above marginal cost. The so-called Lerner index is the theoretical underpinning to the price-costs margin, a tool employed by empiricists as a barometer of allocative efficiency.

Criticism of the use of price-cost margin arises not because it offends underlying theory, but because it is poorly suited for the research design in which it has been most frequently employed, namely, the statistical analysis of industry cross-sections. This research method dominated the literature throughout the sixties and seventies but fell out of favour as the weaknesses of the approach became apparent. There were essentially two such weaknesses. The first was that cross-section studies could not account for idiosyncratic determinants of profit sources in individual industries, nor the varying degree to which a particular structural determinant may be relevant to individual industries. The second problem identified was that because of data limitations, certain determinants of price-cost margins were not included in these studies, thereby introducing bias of an unknown magnitude. An obvious determinant of the price-cost margin which was infrequently discussed and never included in cross-sectional industry models is the price-elasticity of demand[2]. The inclusion of demand elasticities covering a wide range of products in a cross-section of industries is virtually an impossible task, and in some sense the inability to correct for this weakness spelled the end of the industry cross-section research design. By the mid-seventies there was a growing consensus that the generalizations sought after through the statistical analyses of a large number of industries had been taken as far as it could go. In his review and assessment of the accumulation of empirical work conducted in this tradition, Weiss (1974) suggested that researchers abandon this approach and return to the industry study, taking with them the knowledge and techniques which had been improved upon over the intervening decades.

The present research study is a comparative study of petroleum refining in Canada and the United States. An international comparison of a single industry represents a different approach to the study of structure-performance relationships. Like the traditional cross-section studies its focus is on the role of market structure as a determinant of price-cost margins. But rather than comparing margins across many industries, this time-series study compares the margins of a single industry operating in different geographic markets. There are a number of advantages to using the price-cost margin in a time-series study of a single industry. First, a time-series analysis is preferable over static analysis because the latter may only reflect

[2] International comparisons attempt to handle this through the matching of industries in the country sample. The approach is rather crude because elasticities apply to goods, and many industries - even at the four-digit level - produce many individual products.

temporary disequilibrium conditions. Second, the influence of demand characteristics on the price-cost margin can be better handled in a single industry study. In the present case, the usual implicit assumptions underlying the industry cross-section analysis are discarded in favour of an explicit treatment of the relevant price-elasticities of demand.

The petroleum refining industry represents a particularly suitable application of the price-cost margin for a number of reasons. First, because of the nature of the industry's cost function and the similarity of the technology employed by the industry in the two markets, the comparison of price-cost margins in different markets are not seriously biased. Third, refinery outputs are relatively homogeneous products for which demand characteristics can be reasonably compared across different markets and there is a substantial body of data which facilitates an analysis of the demand characteristics for major refinery outputs. The availability of detailed information on the shape of the demand curve is relatively rare and makes this industry a particularly suitable[3] one in which to apply the price-cost margin as the performance indicator.

Besides its suitability which derives from the associated cost and demand characteristics, the oil refining industry is an interesting subject for study in its own right. As the world's biggest industry, and the subject of numerous anti-trust

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[3] Given the integrated nature of the industry and the resultant absence of any other performance indicators (refinery profits - for what they are worth - are not reported separately), this match is fortuitous.

investigations in a variety of jurisdictions, the oil industry has been studied extensively since the turn of the century. But the vast majority of the oil industry analyses appearing in the literature have been focused on upstream operations - particularly exploration and extraction. Little attention has been paid to downstream operations because historically, oil industry profitability was largely determined at the production stage. Since the events which led to the oil embargo of 1973, the entire industry has undergone a significant period of change which has resulted in a greater proportion of the oil industry's profitability (in the West at least) shifting away from production to operations further downstream, i.e. refining and marketing. For reasons which are explored in greater detail in Chapter one, profitability in the refining sector became of paramount interest during this period, and the process of rationalization which took place in the two markets makes this historical period an interesting one in which to explore the comparative dynamics of the price-cost margin.

The thesis is organized as follows: Chapter one provides a brief overview of the historical setting to put the evolution of the industry in context and to explain why the post-embargo period was chosen for study. A thumbnail sketch of refining technology as well as an overview of some of the changes that have been introduced over the period of study are also discussed. Chapter two discusses the economic concept of markets and the geographic delineation of markets.

The national boundaries of Canada and the U.S. are tested for market "separateness" using a well-known anti-trust indicator of market delineation known as the Elzinga-Hogarty Test.

Chapter three first discusses the empirical uses of the price-cost margin as an indicator of performance. A more detailed theoretical discussion of the margin follows. The analysis focuses on those factors which impact on margins, and others which may introduce bias in its use as a measure of performance. The factors examined include marginal cost and average cost, and the implications with respect to capacity utilization, economies of scale, x-inefficiency, capital intensity, demand growth and demand elasticity.

In Chapter four, the price-cost margin is constructed and the data is analyzed over the 1973-1990 period for Canada and the U.S. The remainder of the chapters are devoted to an analysis of the factors outlined in Chapter three to establish the extent to which they may account for differences in the observed margin. Chapter five examines elements of demand for refined petroleum products. Two dimensions of demand growth are discussed - the aggregate growth in demand for oil products and the relative shift in demand for major components of the "product slate". The second half of Chapter five discusses the demand elasticities for oil products and a review of some of the estimated elasticities is presented.

Chapter six begins with a theoretical discussion of the concept of capacity. An acceptable measure of capacity is chosen and the rates of capacity utilization in the refining industries of Canada and the U.S. are compared. The available evidence regarding the comparability of refining technology employed in the two countries is also examined. The chapter ends with an examination of concentration ratios as an indicator of market structure. Chapter seven examines some issues relating to the measurement of capital cost. Because of the difficulties in measuring the rental value of capital, the analysis examines the scope for economies of scale and examines the extent to which these are exploited in the two markets, with the assumption that these measures can act as a rough proxy to the per-unit cost of capital. A summary and some concluding remarks are presented in Chapter eight.

1. OVERVIEW OF THE INDUSTRY

Introduction

The purpose of this chapter is to first sketch the historical development of the modern international oil industry. These historical developments are of significance to us here because of the role they played in shaping the North American response to the change of control in Mid-East oil which took place in the early seventies. The ownership structure of oil reserves in the pre-OPEC[4] era, together with the prevalence and influence of integrated operators, has been pivotal in shaping downstream developments, notably the structure and conduct of refiners and marketers. This discussion is intended to put the rationalization period of the refining industry into historical perspective, and points to the significance of this era as an interesting period in which to study the refining industry.

The latter half of the chapter provides a brief description of the refining industry, and some of the major technologies and processes adopted by the industry. A basic understanding of these elements will be useful in dealing with the material presented in later chapters, particularly the discussion of refining technology.

[4] Organization of Petroleum Exporting Countries.

Historical Development of International Oil

The scope of the petroleum industry begins with successful drilling activity and ends with the delivery of refined products to consumers, and involves a myriad of activity in between. Taxonomically, the petroleum industry can be divided into four basic functional levels, beginning with the "upstream" activity of crude oil exploration and production, and progressing "downstream" to include refining, marketing and transportation. There is a traditional distinction made in the industry between the "integrated" firms or "majors" and the so-called "independents" or "non-integrated" firms. The former terms refer to those firms which have vertically integrated into crude production, refining and marketing and the latter refer to firms who limit their operations largely to one stage of the production chain. The existence of the large integrated companies has had a profound impact on the historical development of the industry, from the discovery and ownership of reserves, to the development of the transportation infrastructure, to the retail marketing of petroleum products. The rivalry between the independents and the majors has been pivotal in shaping the history of the industry (Blair: 1976).

The Pre-OPEC Era

The emergence of the modern international oil industry is associated with two significant events, both of which date back to 1912: the first shipments of crude out of the Persian Gulf, and the introduction of the Model T Ford (Adelman: 1989). The major international players were also established by this time, and while the ownership structure would continue to evolve, the major players remain largely unchanged up to this day. In 1911, for example, the Standard Oil "trust" had been dissolved into a number of separate companies, but three of the reformed companies would eventually come to rank among the "seven sisters" about which so much has been written.

Although the Middle East was endowed with vast reserves of crude, crude oil production would remain dominated by North America and Europe, until it was finally overtaken by the Middle East in 1968 (Blair: 1976, p.52). But gaining and maintaining control of Middle East reserves had long been a preoccupation of the international majors. By 1930, the development and production of Middle East oil had become almost entirely controlled by the "seven sisters", who sought to effectively limit competition at the production stage. Their control over Middle East oil was secured through a complex series of jointly owned operating companies established in the principal producing countries, namely Iraq, Iran, Saudi Arabia, and Kuwait.

At the same time that control over the world's oil supplies were being consolidated, the majors pursued other avenues to limit the degree of global competition at all levels of the industry, from crude production through to final marketing. The so-called Arachnacarry Agreement and subsequent related agreements between the majors would be the predominant influence guiding the development of world petroleum markets until the eventual upset caused by the emergence of OPEC in 1973.

The control over world crude reserves - particularly low-cost producers like those found in the Middle East - was a critical element to the strategy of the integrated refiner. The key to this strategy lay in the basing point pricing system which prevailed through much of the "pre-OPEC" era of the industry. During the first half of this century, the price of oil sold in world markets was set at a level consistent with the prevailing production costs in Texas - that is, all oil was priced "as if" it were produced in Texas. For those who held control of cheap foreign crude, this provided every incentive to expand market share sufficiently to absorb upstream production capacity. The so-called "Texas Gulf system" became increasingly fragile as production in the Middle East began to represent an increasingly larger proportion of world production. As the Middle East became a significant supplier, some of its more influential (and geographically proximate) customers became increasingly irate about paying oil prices which reflected the higher production and transportation costs of Texas crude. In response to the protestations of some customers, particularly government interests in the U.K., a second "base price" was eventually established at the Persian Gulf. The Persian Gulf base price reflected the same price prevailing at the Texas Gulf but was exclusive of the related transport costs. This development eliminated the phantom freight charges from Texas and allowed the relative "stability" of the world market to be maintained; the price changes originating in the U.S. Texas Gulf would continue to rapidly lead to global price adjustments through the basing point system.

The structure of the North American industry over this period was influenced substantially by legal and institutional factors which, combined with the concentrated control of integrated activities and access to cheap Middle East crude, led to the development of an industry whose profitability was determined by essentially two factors: the ability to access inexpensive crude, and the market share necessary to dispose of the finished products. Under this regime, the economics of refining or marketing were of little interest. The central objective of the marketing function for the major integrated oil companies was to maximize the volume of sales, and hence market share was the industry bellwether. As long as crude was cheap, the costs associated with both refinery and marketing outlet installations would be more than compensated. This led to the construction of a large number of gasoline stations and extensive inland distribution networks which could only exist under cross-subsidization from upstream profitability. While the economics of this proliferation were unattractive, they furthered the objective of increasing volume and market share (Jones: 1988).

This evolutionary direction of the petroleum industry was encouraged in the U.S. and elsewhere through a number of import quotas, special tax regulations and prorationing[5].

The Emergence of OPEC

Until 1973, when a host of governments began to exercise varying degrees of influence over the disposition of mineral wealth, control of Mid-east oil remained almost entirely under the control of the "seven sisters". Although some erosion in their position took place during the 1960's, by 1972 the seven international majors were still producing 91% of the Middle East's crude oil and 77 percent of the free world's supply outside the U.S. (Blair: 1976, p. 31).

While the majors continued to control the supply of Middle-East oil until 1973, they had been losing effective control over the profits associated with crude production for a number of years as producing countries were increasingly able to extract and maintain a larger proportion for themselves. At the same time, the OPEC countries gradually increased their ownership interest of crude reserves during this period. Increased OPEC ownership resulted in a declining proportion of "equity" oil held by the international majors. Hereafter, the majors would hold an increasing proportion of "participation" oil which was under the firm control of OPEC members. By 1970,

[5] Federal Trade Commission (1973) 'The Petroleum Industry: Structure and Conduct', in *Monopoly Power and Economic Performance*. Ed. Edwin Mansfield. (1978).

when the majors still retained significant ownership of Middle East concessions, producing country governments were already getting up to 80% of the profits (Adelman: 1989). By 1973, most of the OPEC countries had more or less secured full ownership of their crude reserves (Blair: 1974). This transfer of control of the world's largest reserves of crude oil marked a radical change in the industry, with significant impacts on the major integrated companies. Prior to 1973, the majors were virtually the only vendors of crude oil, and their dealings were largely restricted to their affiliated companies and with third party buyers through contract sales. After 1973, while some international majors continued to have access to crude at better than market prices, they no longer had access to crude at the cost of production[6]. This put the international majors in the same position as the independents had found themselves prior to 1973 (Measday& Martin 1986). Another change evoked by the events of 1973 is that many independents have since been able to deal directly with producer governments, with independent oil traders, or have developed their own production capacity. Consequently the number of both buyers and sellers in the international crude market has increased in the OPEC era, a factor which (in the short term at least) could only be viewed as positive for the independent refiners.

Furthermore, the large increase in established global reserves has substantially

[6] The majors have increased equity ownership outside of OPEC, particularly within OECD countries. As a result, the majors and large independents continued to have access to large volumes of oil at prices well below official OPEC prices.

reduced the requirement to retain access to oil through long term contracts, and many refiners rely more and more on spot markets or contract purchases tied to spot price-related indices.

The oil shocks of the seventies and the new structure of crude ownership which was associated with it were the most immediate cause of the reorganization of refining that subsequently took place throughout the world. The majors' loss of control over the price of crude, and their lost control or ownership of large reserves of oil in the Mid-East, ended the era of "lifting" cheap oil and pumping it through the system. The majors now had to compete with large international companies which had been more selective in the markets in which they entered, and with independent marketers on much more equal terms with respect to the price of the crude. This required an extensive reorientation of the majors' marketing objectives: no longer could upstream profitability be expected to subsidize an inefficient marketing sector. The viability of the majors would require a rationalization of downstream operations, with refining and marketing now expected to serve as profit centres.

Refining and marketing operations the world over have struggled with the adjustments imposed by the "energy crisis", and these adjustments have been manifest most obviously in a massive shedding of excess capacity in both refining and marketing operations. Although the process is largely complete, the Canadian industry has lagged in the adjustment process compared to Europe and the United States, and it continues to grapple with a proliferation of retail capacity.

An Overview of the Refining Industry

Petroleum refining is the technical linchpin in the petroleum industry, linking the crude producer with the end user through the transformation of oil into usable products. Refiners in the U.S. and Canada produce a relatively homogeneous mix of products from a similarly homogeneous input. A "typical" product slate includes gasoline, a range of distillate fuels and residual products. Although this has not always been the case historically, gasoline and distillates now account for about two-thirds of the yield from a barrel of crude. The industry is technologically intensive and relies, in conjunction with a small labour force[7], almost entirely on crude as a sole material input. In the refining industry, labour is relatively fixed (or quasi-fixed as it is sometimes referred), and process specific (Dahl: 1981).

Prior to the Second World War, refineries were generally constructed at the point of crude extraction, largely because such a small proportion of the end product could be marketed that the value-added in relation to the cost of transportation prohibited other location choices (Molle & Wever: 1984). In 1939 for example, when total world capacity was about 85 million tonnes per year, 60 million tonnes were refined within

[7] The refining industry generates far less direct employment than most other industries. Drouet (1984) notes that a refinery built after 1965 employs only about 300 workers.

producing countries (Drouet 1984). But political instability throughout the Middle East, together with the increased consumption of petroleum products in consumer countries, combined with the higher cost of transporting finished products in relation to the bulk transport of crude, all contributed to the migration of refineries from the producer countries to the consumer countries[8]. As a result, most countries, even those with little or no indigenous crude reserves, meet their requirements for refined products through domestic refineries. This is certainly true for Canada and the U.S. as we shall see in Chapter two.

The refining sector is represented by both the majors and independents, although unlike the other sectors of oil industry, the role of the independents in refining is relatively small and has declined in importance since 1973 (Jones: 1988). The declining role of independents can be attributed to the high entry barriers which characterize the industry. Capital cost and secure access to crude are the two primary barriers faced by potential entrants. The independents, especially the smaller producers, may suffer from an inability to gain access to competitively priced and secure crude supplies[9], increasing both risk and immediate cost. For example, the small scale of operation typical of independent refiners dictates the purchase of crude

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[8] This trend slowed somewhat during the period after 1974 as OPEC nations reinvested petrodollars into additional refining capacity in the producing countries (Drouet: 1984).

[9] The international majors have always been concerned with the competitive threat of the independent refiners. One method of controlling this threat was through actively limiting the independents access to crude, as one clause of the so-called "as-is" agreement read "except as herebefore provided, no participant shall ben free to sell to outsiders [i.e. independents] either crude oil or finished products..." (Blair: 1976, p.76).

supplies from nearby sources in order to avoid burdensome transportation costs. Unlike upstream production, the capital costs associated with refining represent a substantial entry barrier. Refineries are subject to economies of scale and today can only be profitable with the flexibility of expensive secondary conversion units. Capital barriers have been especially onerous in the changing environment of the past twenty years in which more sophisticated refining techniques, changing demand patterns, and new environmental regulations have demanded that refiners undertake high levels of investment in technologies, some of which are economical at scales of production greater than those of many independents. Furthermore, this period has been of uncharacteristic excess capacity, and because of their weaker capital base, it has largely been the independents that have borne the brunt of plant closures brought about by industry rationalization (Jones: 1988).

The majors, by contrast, have been able to benefit from economies of scale through their international networks. They have also enjoyed more secure access to competitively priced crude which was gained through both equity ownership in production and the large quantities of crude purchased (Reid and Fesharaki: 1989). The majors are also able to benefit from their joint ownership of pipeline networks which can work to the disadvantage of the independents.

The Refining Process

The objective of refining is the addition of value: unprocessed crude oil is a substance of little intrinsic value to the consumer. Crude oil is a feedstock which, through the refining process, can be manufactured into a whole range of fuels including propane gas, liquid gasolines, distillates and residual fuel oils. Through additional processing, an array of consumer products arise from crude, including lubricants, waxes, solvents, bitumen and an vast array of petrochemicals.

Petroleum refining consists of treating crude oil physically and chemically to separate its various components and reblending them to obtain the range of products desired. Crude oil is not a chemical compound but rather a mixture of chemical compounds. The refining process[10] comes down to the following operations: fractionation of the crude by atmospheric distillation, desulphurization, conversion of the products obtained to increase the quantities of distillate and improve the octane number of gasoline, or fractionation of crude oil and heavy fuels by more intense vacuum distillation to produce thermal or catalytic cracking and enable the heavy fractions to be desulphurized (Drouet: 1984).

[10] For a detailed discussion of refining technologies and processes see: Gary & Handwerk (1984), a more technical discussion is found in Leffler (1985).

The basic process in all refineries is distillation, which separates crude oil into its constituent parts (i.e. separates the various compounds). The other processes listed above can be categorized generally as conversion activities. Conversion processes are undertaken to change the product mix produced by the distillation process. The major drawback to the distillation process is that it doesn't yield a great proportion of lighter products (i.e. fuels). As we discuss in greater detail later, the growth in demand for refined products has been most significant in the transportation sector, but distillation does not produce a large proportion of these "lighter" products. To address this, the industry has gradually introduced a number of processes which increase the yields of lighter products from a barrel of crude.

In its early years, refining technology was limited entirely to distillation. Because kerosene was the primary refined product prior to the advent of the automobile, this technology was sufficient to meet demand in an economical fashion. One of the earliest technological advances was the development of Partial Vacuum Distillation, a process which boils off a greater proportion of lighter fractions than is possible under atmospheric conditions. Today it is a well-established and low-cost technology.

With the introduction of the automobile, gasoline quickly became the primary refinery product and the value of gasoline grew rapidly relative to kerosene. The need for a higher yield of lighter products, and the limitations of vacuum distillation, led to the introduction of commercial thermal "cracking" processes. The introduction of thermal cracking not only allowed for a higher yield of light products, it also allowed the refiner some control over the relative proportions in the slate of products produced from the middle distillates, i.e. kerosene & oil (Copp: 1976). A number of cracking processes were developed over a number of decades beginning in the inter-war years: thermal cracking is a relatively old process which improves the yield of light distillate products. It is no longer regarded as a viable technology where, as is now universally the case, major improvements in the yield pattern are sought. Today the technology is confined to two specialist forms of the process called visebreaking and coking.

Visebreaking is a rather mild form of thermal cracking and is used to reduce the viscosity of some residual fractions so that less middle distillate is required as a cutter stock to blend them to meet fuel oil viscosity specifications. Visebreaking is relatively inexpensive in terms of capital investment and operating costs, providing only moderate changes in the yield pattern are sought. Coking is a more severe form of thermal cracking in which heavy residues are heated to 500 degrees Celsius in a coking drum. Lighter fractions are vaporized, leaving a solid residue called petroleum coke. There are few plants in the industry configured for this process.

Catalytic cracking was the technological successor to thermal cracking. It involves the use of a catalyst to remove from the feedstock a proportion of the atoms of carbon, thereby reducing the molecular size of the components and thus increasing the proportion of lighter components. Hydrocracking serves the same role as catalytic cracking but requires the use of hydrogen in the process. Although it is a more costly technology compared to catalytic cracking, it offers greater flexibility.

Alkylation is, in effect, the opposite of catalytic cracking. Generally, its purpose is to take small, volatile molecules and transform them into larger and more stable ones. Thermal reforming, visebreaking, and catalytic cracking were all introduced prior to the Second World War. This technology really advanced in the 1960's with the development of zeolite catalysts. While relatively expensive to construct and operate, the construction of these units in combination with other secondary units such as HF alkylation units has been widespread in the eighties and has made it possible to adjust the yield pattern of hydroskimming refineries to one much more close to the market demand pattern.

Hydrocracking allows for a very high rate of upgrading and conversion and can be used over a wide variety of feedstock. It is a very flexible process and a unit can be designed to produce a wide variation in the relative proportions of gasolines and middle distillates from the same feedstock, which is particularly valuable for a refinery located in a market subject to heavy seasonal fluctuations. It does, however, require high pressures and temperatures together with a considerable input of hydrogen. Today, refineries consisting of atmospheric distillation units, reforming and hydrotreating units are characterized as hydroskimming refineries. Those with any substantial catalytic or hydrocracking units are characterized as complex refineries or conversion refineries.

Because of the economics of oil which prevailed prior to 1973, refineries were frequently based on simple hydroskimming refineries which were more oriented to a high volume of output and gave much less emphasis to maximizing value-added. As a result they produced relatively low quantities of light products and the large proportion of residual fuel in the product slate was almost a "disposal product" which was sold to power generating utilities (Jones: 1988 Ch. 11). This would change after 1973, when profitability became the dominant objective. In the years prior to 1960, refineries were often designed to handle a fairly narrow band of differing crude types. In the post-OPEC era, the availability of any given crude type became less certain, and refineries were designed with greater flexibility in terms of the scope of crude types which it could deal with. The desirability of the more complex refinery lies in its flexibility, and therefore ability to produce a higher total value of products from a given crude oil (Jones: 1988, Ch. 9). Since 1973, refineries have become more complex through the addition of upgrading facilities which have been undertaken in an effort to adjust the product mix to changing market demand.

Although the literature is sparse, there is some evidence indicating that refineries are able to respond to changes in petroleum product prices in a stable fashion by making changes to the refinery product mix. For example Dahl (1981) has examined the share of a barrel of crude going to gasoline as a function of the price of distillate and residual fuel oil, and has concluded that refinery mix has been price responsive in both Canada and the U.S. with Canadian refiners being even more price responsive than their U.S. counterparts. Using data covering the period 1936-1975, Dahl further found that a 1 percent price increase in gasoline led to a 0.4 percent increase in gasoline's share of a crude barrel. The corresponding figure for U.S. refineries was exactly half at 0.2. This difference is explained at least in part by the fact that while Canada has a substantial amount of cracking capacity, the proportion of gasoline in the product slate is lower than in the U.S. Thus an increase in the price of gasoline should result in a larger increase in gasoline production in Canada than in the U.S. because of the relative availability of productive capacity. This is a significant finding as the demand elasticity of gasoline is among the lowest of all petroleum products, and as such the proportion of gasoline in the product slate is a critical determinant of refinery profitability.

Summary

Prior to 1973, the ownership structure of crude supplies and the dominance of the integrated oil companies molded the structure of the petroleum industry in such a way that growth in market share was the predominant occupation of the industry. Running cheap crude through the system remained a profitable strategy until OPEC countries began to take control of both crude supply and the profits derived from its production.

At this time the marketing system, which was characterized by a proliferation of retail outlets and a refinery system designed to maximize a low-cost throughput, could no longer be subsidized by the profitability of upstream activity, and this in turn led to significant changes to both refining economics and marketing strategies. As a result, the profitability of the refining sector has gained in importance. The refining industry is characterized as a capital intensive industry with significant entry barriers. In the post-OPEC era, independents have enjoyed greater access to crude supplies but have faced a number of financial challenges which have been more difficult for the smaller-scale independents to deal with.

The purpose of refining is to convert low-value crude into high-value products. This is achieved by separating the crude into its constituent parts. Secondary processing involves converting large molecules into smaller ones through various "cracking" processes, or joining small molecules to form larger ones through "reforming" processes. Of course the technology employed to do so has evolved over the years. The process of technological innovation in refining has been largely driven by the need to extract higher yields of light products for use in the transportation sector and, more recently, by the need to meet more stringent environmental regulations. The adoption of new technologies has led to more efficient and flexible refineries which are more able to act as profit centres by maximizing the value-added generated from a barrel of crude.

2. DEFINING PETROLEUM PRODUCT MARKETS

Introduction

The extent of the market has long been recognized as an important element of industry structure. The framework for the present analysis of the petroleum industry is predicated on the assumption that the national "markets" are distinctive in some sense and that such a comparative analysis is warranted. In this chapter we examine the concept of the "market", and employ a technique, well recognized in the anti-trust literature, to establish the degree to which Canada and the U.S can be considered separate markets for petroleum products.

The "Market"

In its every day usage, the term "market" may refer to a number of things, including: (1) the place where buyers and sellers meet to exchange goods; (2) looking at the supply side, the "market" may refer to the suppliers of a particular product or group of products; (3) on the demand side, the "market" may refer to a particular group of buyers; (4) the demand, actual or potential, for a product or service; (5) in economics, the concept of a single market refers to a group of buyers and sellers exchanging goods or services that are highly substitutable. It is the last definition which is of interest here.

The literature identifies two components which together sufficiently parameterize a single market. The first relates to the nature, or scope, of "the product", while the second deals with the geographic dimension of the market. As a matter of practice, it is common to first delineate the product, or group of products, which is associated with a potential group of suppliers. The market includes the suppliers of the defined product who, by geography, are able to profitably supply a given consuming point[11]. In some cases, defining the relevant product line and delineating the geographic market area may be interdependent (Elzinga: 1973).

In practice, markets do not operate in isolation from one another. In fact it is surely the case that market boundaries have become increasingly blurred by both the proliferation of products and transportation technologies which, by lowering the cost of moving goods, have effectively expanded markets and increased the opportunity for arbitrage to take place between markets. Clearly then, a perfect delineation of markets - in the vast majority of cases at least - will be less than perfect.

[11] Weiss (1972) 'The Geographic Size of Markets in Manufacturing', The Review of Economics and Statistics, Vol 61 No. 4:245-254.

As Alfred Marshall summarized the situation:

> "... at the one extreme are world markets in which competition acts directly from all parts of the globe; and at the other those secluded markets in which all direct competition from afar is shut out, though indirect and transmitted competition may make itself felt even in these; and about midway between these extremes lie the great majority of the markets which the economist and the businessman have to study[12]."

Although markets are rarely, if ever, defined with perfect accuracy, the practical objective involves a measure which is broad enough to encompass all firms which are truly competing with one another while excluding superfluous entries.

Defining the Product

For a good many products, market definition must take into account the possibility of product substitutability both with respect to production and consumption. On the consumption side, all products which are substitutes for a specific product should be included in the market for that product. In many markets the identification of close substitutes is not a trivial matter[13], and where there exists a continuum from very close substitutes to far substitutes, the empiricist is compelled to choose a cut-off point. This cut-off point is ultimately arbitrary, and inevitably leads to an imperfect market delineation which introduces a measure of bias into the analysis. Although the exact degree of bias may remain unknown, it is clear that it will be minimized in cases where the opportunity for substitution is highly restricted or where there is a

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[12]Marshall, A. (1949), p. 274.

[13]Stigler (1968) addresses this problem at some length.

clear demarcation of viable product substitutes.

A third dimension of the market involves substitution in production processes. If the technology employed by a firm is dedicated to one line of production, but the firm may easily convert the process toward the production of another product, the task of market delineation becomes further complicated. As we shall see subsequently, the production of petroleum products involves uniquely configured technologies which allow for virtually no possibility for substitution.

The foregoing discussion outlines the issues to be addressed in defining the product or class of products which constitute the market. The second stage in defining a market involves proper delineation of the geographic area within which producers of a commodity can be said to be truly competing. This is the subject of the following section.

The Extent of the Market

Alfred Marshall persuasively argued that a market encompasses the primary demand and supply forces that determine a product's price, and the geographic market area is the area that encompasses these buyers and sellers. The more a market reflects the perfectly competitive ideal, the greater is the tendency toward uniform pricing. Thus a market may be defined as that area in which prices of standardized goods are equalized, given due allowance for transportation costs (Marshall: 1959, 270-271) This emphasis on price as the relevant observable variable has been referred as the "price uniformity criterion" in the anti-merger literature.

From the above definition it would appear that an examination of the spatial distribution of prices would be sufficient to delineate geographic markets, but this approach has a number of shortcomings. For example, while the presence of uniform prices may indicate a single market, it is also conceivable that there are in fact two markets which concurrently operate under the same supply and demand conditions. Alternatively, where a monopolist can discriminate among spatially separated customers, the price uniformity criterion would lead to the conclusion that more than one geographical market existed. This argument notwithstanding, the difficulties in establishing *the* price and *the* transportation costs typically prohibit the practical application of the method[14].

Clearly the price uniformity criterion is problematic when applied to industries which operate in markets which do not fit the perfectly competitive model. A definition of markets - one that is to be empirically useful - should be independent of the various market structure models, and this precludes undue emphasis on price as a criterion. Consequently the uniform price criterion is rejected for empirical purposes, but the Marshallian conception of a market area remains instructive in highlighting the dual

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[14]Elzinga & Hogarty: (1973) p. 45.

role of the supply and demand "scissors", and the scope of their influence, in the delineation of geographic markets.

While the delineation of markets has been of concern to economists studying a wide range of issues, it has received little serious attention in structure-performance studies. In fact there have been few attempts to empirically measure geographic market areas from an economic perspective outside of the judicial setting. Lacking direct measures, most economic studies have relied on either a crude classification of geographical market size - usually defined broadly as local, regional or national - or alternatively, have relied on an output dispersion index or estimates of actual transportation costs[15]. More recently, the problem of market delineation has been given considerable attention in the anti-merger literature. Over the past few decades, a number of approaches - many rather eclectic and theoretically incomplete - have emerged[16]. The approach adopted here and described below was developed by Elzinga and Hogarty[17] (1973) and while it remains imperfect, the approach avoids many of the pitfalls of its predecessors.

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[15] See Collins and Preston (1969) Appendix 1, for a calculation of a geographic dispersion index.

[16] For a critique of eclectic approaches and the use of transportation cost data see Elzinga and Hogarty (1973). For a critique of dispersion indices see Weiss (1972).

[17] Although their definition bears some resemblance to that developed by Weiss (1973) it differs in that Weiss is concerned with establishing a geographic measure of a market in which plants supply or could *hypothetically* supply a given consuming point. The focus is on potential rather than actual competition.

Elzinga and Hogarty begin their analysis by addressing the question: "Why are all markets not global in scope?". In reply to this question, they note that there are basically two factors that restrict the size of market areas and together they explain why all markets are not simply world-wide in scope. The first is the existence of tariffs, quotas or other legal barriers which inhibit the mobility of either buyers or products. Products facing these barriers will, ceteris paribus, have smaller market areas than those unhampered by such barriers.

The second factor limiting the size of the market is transaction costs, in which transportation costs typically dominate[18]. In most cases, the relative cost of shipping a product relative to its market value may prohibit its distribution from a given location to all potential buyers. Conversely, it may be prohibitively expensive for buyers to become informed of more distance suppliers and/or to travel to the location where the product is made available. In general then, products that would incur significant transportation/transaction costs relative to their value will have smaller markets than those whose associated costs are relatively low.

Note that it is the relative, as opposed to the absolute cost of transportation which is relevant. This is so because transportation costs represent a barrier to a distant supplier because it is not a cost incurred by a "local" supplier. Thus if transportation

[18]Elzinga and Hogarty restrict their discussion to transportation costs, but in following their suggestion, the discussion is broadened here to incorporate other elements of transaction costs.

costs represent only a small fraction of the product price - say 2 percent, then the local seller has only a 2 percent cost advantage (locational rent) over the distant supplier. In this case transportation costs borne by a distant rival may well be more than offset by other cost advantages - such as proximity to raw materials, lower prevailing wages, superior technology, and the relative absence of x-inefficiency.

The Elzinga-Hogarty Test

The Elzinga-Hogarty approach gives recognition to the idea proposed by Marshall that the contours of a market are determined by supply and demand elements. The simplicity of their test derives from the fact that these forces, without being made explicit, are ultimately reflected in the delivered prices of products. Furthermore, supply and demand conditions establish both an equilibrium price and quantity, and while the use of price data has proven problematic in market delineation, shipments data are much more readily available and less problematic, both conceptually and operationally.

The Elzinga-Hogarty test actually melds two separate tests of market delineation known as LIFO (little in from outside) and LOFI (little out from inside), both of which have been used independently in anti-trust litigation. The main contribution of the Elzinga-Hogarty test is the recognition that LIFO and LOFI are each an independently necessary, but insufficient, condition in delineating a geographic market. Satisfaction of both the LIFO and LOFI tests however, is both necessary and sufficient to define a market area in which goods are actually traded.

The use of shipments data allows the market to be delineated in term of exports and imports. The only data required to estimate a market area are the destination and origin of shipments (measured in physical terms). A geographic market is defined as a region where there are few imports of a given product (LIFO) and few exports (LOFI). This approach incorporates those factors known to limit the scope of the market in that they are reflected in shipments data on exports and imports. This is so because any legal or transactional (particularly transportation) costs high enough to limit the movement of goods will ultimately be mirrored in the shipments data.

The LOFI test addresses the "supply side" in posing the question: "What geographic region accounts for nearly all shipments from a given producing area?". The LOFI test ensures that exports to other regions are adequately accounted for in defining the scope of the market. The LIFO test addresses the demand side and poses the question: "Of the total quantity sold in the region defined in the LOFI test, does nearly all of the product sold originate from the same region?".

Concerns may be raised over the term "nearly all" in the delineation of markets, however the alternative of using the maximum distance shipped as the measure of market size is not practical for a test of market size because most commodities have some shipments in all distance classes including the very longest. As Weiss (1972) has pointed out, it is likely that the longest shipping distance of any commodity represents something of an anomaly. It is preferable therefore, to define a geographical market as that area which encompasses a large proportion of shipments. The choice of which percentage of shipments to use is inherently arbitrary, but it appears that most researchers employing shipments data to delineate markets have opted for a percentage between 75-90%. Elzinga and Hogarty have suggested that a figure of 90% is sufficient to define a "strong" market, and 75% for a "weak" market.[19]

A final element of concern relating to the LIFO/LOFI method, and one which differentiates it from the method proposed by Weiss, is that the former takes no account of *potential* competition. While this criticism is valid, the focus of the present work is on *actual* competition. Furthermore, in delineating potential markets, the approach proposed by Weiss makes a number of implicit assumptions regarding the free flow of goods, both with respect to legal barriers and transportation infrastructure.

[19] Elzinga and Hogarty, 1978, p. 2.

The "Petroleum Market" Defined

Petroleum products lend themselves to a strong market definition both in terms of the production side and the demand side. Petroleum refineries use a limited range of technology to transform crude oil into a range of refined petroleum products. The specific range of products produced at a given refinery are referred to as the refinery's "product slate". The majority of refineries produce a product slate comprised of transportation fuels, heating fuel and other residuals. Crude oil is the overwhelmingly dominant raw material in these general refineries. Of considerably lesser significance (in terms of industry output) are specialty refineries. These refineries are usually of a smaller scale and produce a narrow range of product, and often use intermediate goods from a general refinery as its major input.

As both the inputs and the outputs of a refinery are limited in scope, so too is the technology employed. Beyond the limited scope for changes in the relative quantities of the product slate produced, a petroleum refinery is "fixed" in its production applications and the potential for production substitutability over the lifetime of the facility is limited to the use of a narrow range of crude inputs to produce a relatively narrow range of petroleum products. Furthermore, refining technology is highly specialized and has no practical alternative uses. Hence from the point of view of substitutability in production, the petroleum industry is well defined.

The potential for substitution in consumption is particularly narrow in the short run (with the exception of "belt-tightening"), although for some product classes there is more flexibility for substitution given a sufficiently long adjustment period. The demand for petroleum can be broken down by looking at the broad categories of uses and consumers. The largest component of refined product is represented by transportation fuels including gasoline (the largest), jet fuels, and diesel fuels. The demand for these fuels is derived from the demand for transportation services, for which technology (over the period of study at least) has remained extremely limited in terms of fuel substitutability. Not only has transportation fuel remained almost entirely petroleum based, the various transportation technologies (e.g. jets, cars, locomotives) exhibit almost no scope for fuel substitutability[20].

A second major demand component of petroleum refineries is found in heating applications. The question of substitution here is more complex and requires analysis in both the short and long-run over the period in question. Heating fuels have two basic applications: space heating (i.e. home and industrial space heating), and as a fuel for electrical generation. Except for unusual applications, the substitutability of heating fuels in the short-run is virtually non-existent.

[20] One notable exception is the use of electric trains and buses whose application has been extremely limited over the scope of the study.

For many heating fuel applications, the potential for product substitution increases in the long-run. Indeed during the seventies, when oil prices skyrocketed and remained high over a significant period, there was a marked shift away from oil-based heating fuels into alternative sources - particularly natural gas and to a lesser extent, electricity and coal[21]. This dramatic shift in the price of alternative fuel sources led to a significant and more or less permanent shift in technology applications on the demand side. It also initiated a more-or-less one-time shift in the refining technology as producers adapted techniques to reflect the new composition (e.g. lower production of heating fuels) of the product slate. Note however, that the substitution away from heating fuels required considerable investment in technology on behalf of consumers, and given the eventual adoption of these technologies, the scope for fuel substitution in the short run is again virtually nil.

The "heavy" components of the refinery slate have not yet been discussed. Although fuels comprise the bulk of refinery output from a value perspective, both lubricants and asphalts are significant products. As the subsequent analysis makes clear, there was little change in the relative production of these components and this likely reflects the low possibility for substitution with other products.

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[21] Substitution toward coal as a heating fuel was limited almost entirely to generating facilities.

Delineation of the Geographic Markets

As was mentioned in a previous section, markets are frequently defined rather arbitrarily as being local, regional or national in scope. From an empirical perspective, markets defined nationally are attractive because much of the available data is collected, made available, or calculated, on a national basis. In cases where data is made available at the regional level, it is often only coincidental that these regions would correspond in any meaningful way with the "relevant market". For example in the U.S., data collection conducted by the U.S. Energy Administration is gathered on a district basis, with the nation somewhat arbitrarily divided into five broad districts. This delineation was motivated for purposes of supply security, and it is not at all clear that these districts would reflect the actual scope of markets in practice. In other countries - including Canada - much of the data necessary for the foregoing analysis is only available at the national level. But the defensibility of delineating markets nationally remains an important question.

Calculation of LIFO and LOFI

The "little in from outside" theory (LIFO) posits that if little product is imported from outside a region, this is supporting evidence of a geographic market.

Calculation of LIFO is a three step process:

1) For a given a hypothetical geographic market, determine the total consumption (in physical units, in this case volume) of petroleum products within the region.

2) Calculate the volume of petroleum products produced within the region which are consumed within the region.

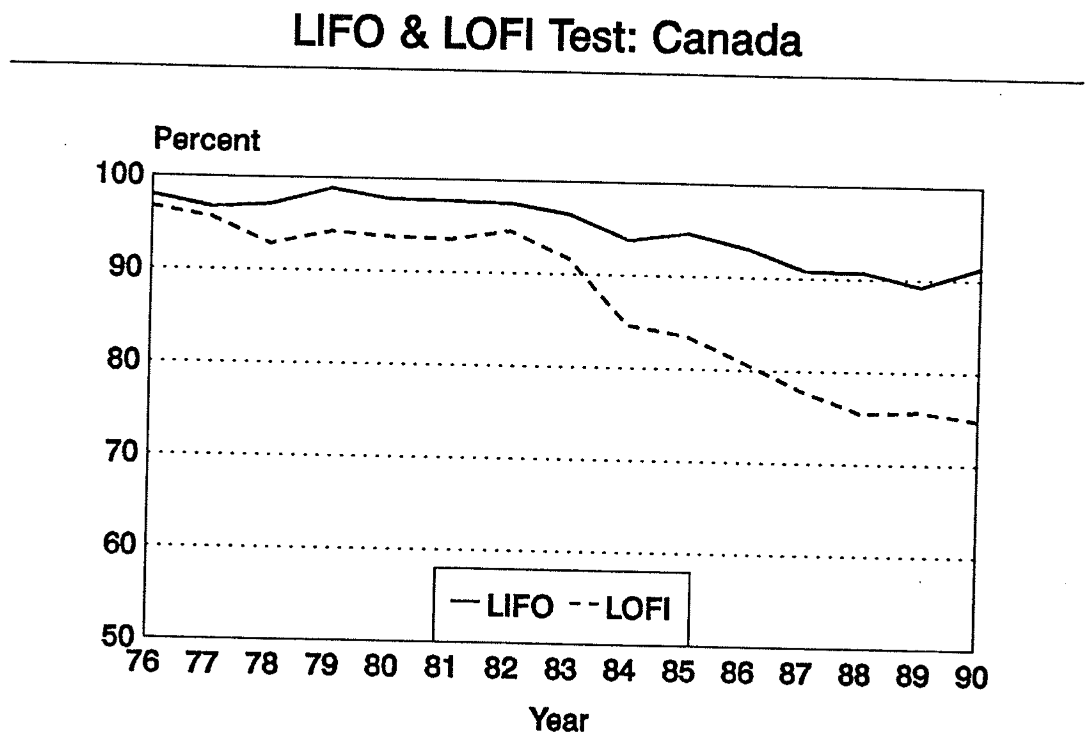
3) The greater the degree to which the ratio of (2)/(1) approaches unity - that is, the less the region's internal demand is met by imports - the greater support for considering the region as a geographic market area.

It was mentioned previously that the LIFO test was designed to address the "demand" side of the Marshallian scissors. The "little out from inside" (LOFI) theory addresses the "supply" side. The calculation proceeds as follows:

1) For a given hypothetical geographic market, determine the total sales (in physical units, in this case volume) of petroleum products within the region.

2) Calculate the volume of petroleum products produced within the region which are consumed both within and outside the region.

3) The greater the degree to which the ratio of (2)/(1) approaches unity - that is, the less the regions internal production is exported - the greater support for considering the region as a geographic market area.



Source: IEA, International Energy Annual, various editions.
See text for data definintions and calculations.

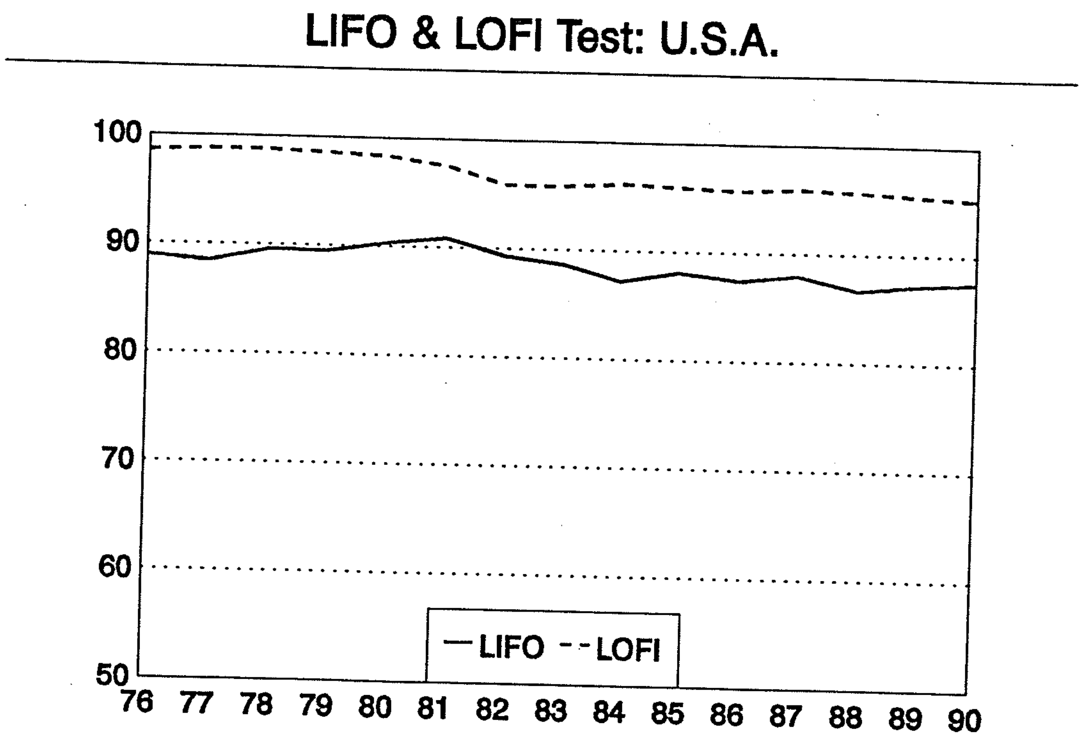
Figure 1

Using data from International Energy Agency, both LIFO and LOFI were calculated for Canada and the United States for the periods 1976-1990[22]. The results appear in Figures 1 and 2 respectively. In 1976 the calculated value of LIFO for Canada was 0.98, indicating that domestic demand was met almost entirely by domestic production. The value of LIFO remained in this same vicinity until beginning a gradual and modest decline in 1983. Only in 1989 did LIFO decline below a value of 90 and then just marginally. According to this test then, the Canadian market for petroleum products is a "strong" one.

The LOFI test results exhibit markedly different behaviour. Although the value of LOFI remained near 95 until 1983 when domestic demand dropped off sharply. The value of LOFI shows a marked decline thereafter, suggesting perhaps, that Canadian petroleum refiners sought new markets for their surplus production. In any event, the Combined LIFO and LOFI tests indicate that Canada was a "strong" market until 1983 and then - primarily owing to increased exports - became an increasingly "weaker" market. In spite of this it remains a defensible geographic market by the criteria set out earlier.

The U.S.A. data relating to LIFO and LOFI demonstrate less variation and relatively higher values. In 1976 the value of LIFO in the U.S. was 0.88 and remains above

[22] IEA data was employed because similar treatment of data from the two countries may reduce discrepancies in data collection and treatment practices across international boundaries. The data was not available for the 1973-75 period.



Source: EIA, International Energy Annual, various editions.
See text for data definitions and caclulations.

0.86 throughout the period. Similarly the value of LOFI in the U.S. was 0.98 in 1976, and although it shows a marginal decline after 1982, remains above 0.95 until 1990. Thus by the results of both tests taken together, the U.S. market for petroleum products remains a relatively "strong" one. Notably, the increased Canadian exports to the U.S. after 1983 had an insignificant impact on the U.S. LOFI test, a result which reflects the relatively large size of the U.S. market in relation to the Canadian market.

Summary

There are two main elements which together parameterize a market. The first relates to the product, and the extent to which market boundaries may be blurred by product and technology substitution. The second is the geographic size of the market which is determined by transaction costs which are predominated by transportation costs. The analysis suggests that substitution on both the supply and demand side is very limited in the short-run, implying relatively well-defined product markets. With respect to the element of geography, the analysis would suggest that a national delineation of the petroleum market is sufficient in that its scope is at least broad enough to encompass all principle supply and demand considerations. All but one element of the Elzinga-Hogarty test suggest that the two markets are strongly delineated. The exception is the LOFI test applied to Canada, where there was a marked increase in exports as a proportion of total production after the recession of 1981-82. The data reveals that this increase in export activity was concurrent with a marked decline in domestic demand, and the increased export activity could be explained by the need to find new markets for the now "surplus" product.

At the other extreme, there remains the possibility that the actual markets are in fact less than national in scope. What then are the implications for an analysis based on a broader-than-regional scope? The answer to this question rests on the actual market structures "nested" in the national market. For example a national market may exhibit a largely competitive structure, but also contains a small degree of sub-markets,which are less competitive in nature. The analysis would be blind to the existence of these sub-markets, and the price-cost margin would be elevated to a degree, depending on both the volume of sales in the less than competitive region and by the degree to which the market is less than competitive - reflecting the ability of producers there to raise prices above the level prevailing outside the region. Alternatively, a national market could be characterized as largely less than competitive, with small pockets exhibiting more competitive pricing behaviour. In this case, the price-cost margin calculated at the national level will be biased downward.

3. MEASURING PERFORMANCE

J.S. Bain's (1951) seminal work in the statistical analysis of structure-performance relationships represented a clear break from the case study approach pioneered by Mason (1939) and which dominated the literature into the late fifties. Bain's work was based on the hypothesis that given pricing behaviour based on the tacit or explicit collusion predicted under tight oligopoly, the average rate of profit realized by firms in highly concentrated industries will tend to be significantly higher than that of firms in less concentrated industries. Profit rates are expected to increase with concentration as collusion becomes more successful, until they reach a maximum attainable - given costs, demand, and entry conditions[23]. This structure-profits relation was the first area of industrial organization to be systematically studied, and has remained the central focus of empiricists over the past few decades.

Beginning in the early sixties researchers took Bain's lead, and a great number of industry cross-section studies examining market structure-profitability relationships appeared in the literature. These cross-section studies have typically taken the industry as the principle unit of observation, and employ econometric techniques in an effort to establish a number of generalities regarding the nexus between profitability

[23] In the short run, profits rates will vary with unanticipated shifts in demand or cost.

and market structure. By the early seventies the extent of rich literature which had accumulated prompted one well-known writer to comment that "statistical testing of structure performance hypotheses became the closest thing industrial organization economists had to sausage production" (Scherer: 1970, p.267).

Most studies[24] examining structure-conduct relationships have employed industry cross-section data and have involved multiple regression analysis of a single-equation model of the general type:

$$\pi_i = Ax_i + By_i + \ldots + e_i \qquad (1)$$

where (π_i), the profit rate of the ith industry ,is a function of various market structure variables (x,y) associated with the ith industry, plus an error term (e_i). The most important structural variables influencing seller conduct are seller concentration and barriers of entry into the industry. Profitability is also expected to be elevated by greater advertising to sales ratios, by fewer imports, by greater economies of scale in the production process, and by greater sales growth and by relatively inelastic industry demand, to name the more frequently-cited variables.

Weiss (1974) conducted an extensive survey of this literature and notes that the typical result of concentration-profits studies, especially those based on firm-level data, has been a significant yet fairly weak positive relationship. Notably, the

[24] An extensive review of this literature was conducted by Weiss (1974). See also Paulter (1983) and Salinger (1990).

estimated coefficients associated with structural variables are generally weaker than theory would predict and, unfortunately, confidence in the conclusions of these studies has been eroded by their propensity to generate considerable variations in the magnitude of the estimated coefficients.

The weakness of the estimated structure-performance relationship has several sources; many of these relate ultimately to limitations of the data employed. The data relating to both the left and right hand side of the equation are quite poor. This arises in part because industry cross-section studies involve onerous data demands. The generalized results sought through the use of cross-section studies demand the collection of data which is consistent across a broad range of industries. Unfortunately, the requirement that data be comparable across many industries can often be met only at the expense of data quality.

Data problems are further compounded by a heavy reliance on proxy measures[25]. Unfortunately, the absence of ideal measures brings into play numerous compromises which jointly contribute to a large random element in the estimates. For example, monopoly theory suggests that the price of products will tend to increase as the number of firms in an industry decreases. But in the absence of price data, either reported profit data or price-cost margins are employed as a proxy variable. And while both profit and margins may be defensible proxies, neither is liable to be a

[25] For a discussion of this issue see Bock (1972).

perfect alternate for price data. The same holds true for estimates of a number of key variables. For example, estimates of scale economies, advertising expenditures and import ratios are all employed as proxies for entry barriers, while concentration measures are constructed to serve as proxies for the ability to collude, etc.

Aside from the data weaknesses described above, cross-section models introduce another empirical hurdle in that the models cannot adequately control for all of the intra-industry determinants of profitability, i.e. what is an important determinant of profitability in one industry may be less relevant in another, and vice-versa. As a result, the estimated coefficients of structural variables vary considerably from one study to the next, and appear to be dependent, in part at least, on the industry sample used in any particular study. The widely diverging estimated coefficients arising from the many studies undertaken to date has contributed to a lack of a general consensus on the interpretation of research results.

The dissatisfaction with these research results has led researchers to turn away from industry cross-section studies and return to single industry studies. These industry studies continue to examine structure-performance or structure-conduct as the principle focus. Where data availability has allowed, the dependent variable in the study may be price as opposed to profit - the former being more directly related to monopoly theory.

Measures of Profitability

It has already been noted that in the absence of price data, profit estimates have been used as a proxy measure for market performance. With some exceptions price data is generally unavailable, and profit measures or price-cost margins continue to be the pervasive proxy. This choice of proxy is grounded in the idea that, ceteris paribus, an increase in price above the competitive norm leads to increased revenue and elevated economic profit.

Economic profit can be defined as the surplus of revenue over cost, including the cost of keeping capital from fleeing to alternative uses. As there is no data relating to "profit" as it has been defined above, empiricists are left to rely on available approximations. In practice, the profit variable is typically estimated in one of two ways. One is the price-cost margin method; the other is to employ an accounting measure of profitability.

Accounting Measures of Profitability

Two classes of accounting measures of profit appear in the literature - the rate of return on assets and rate of return on equity. There is no general agreement in support of either measure (Weiss: 1974, p.198). When employed in empirical tests of structure-performance relationships, accounting measures of profit suffer a number of well-documented drawbacks. One such drawback inherent in reported profit data is the determination of plant cost within multi-plant operations, where each plant shares certain non-allocatable costs with other plants in the firm. Because there is no reliable way of allocating shared capital costs among plants within a firm, plant profit cannot be derived directly from the data.

Second, accounting procedures are frequently arbitrary and may differ considerably across jurisdictions, and this introduces a random element to the data. One such arbitrary measure is the use of book valuation of assets, where the adopted rates of depreciation may vary considerably. Not only do book valuations introduce a random element, they do not reflect the economist's concept of capital cost. Various inventory valuation procedures represent another example of arbitrary treatment which contribute to a random element in the data.

Third, larger and more profitable firms have the most to gain in terms of both tax avoidance and public relations in the understatement of profit, such that reported profit rates are likely biased toward equality[26]. Fourth, accounting measures of profit are particularly questionable when employed in the study of vertically integrated firms, as the utilization of transfer pricing is frequently used to minimize reported profit. Other biases are introduced through problems in accounting for intangible

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[26] Scherer (1970) reports that most companies keep at least two sets of books - one for the tax collector and one for financial reporting purposes. He cites the petroleum industry as an extreme example, which in fiscal year 1976 reported an after-tax return on stockholder's equity of 5.6% according to IRS reports and 12.5% according to the FTC data on reporting companies.

capital goods such as advertising and R&D, the revaluation of corporate assets when they change hands or are written down if profit prospects are low. In short, accounting measures of profit may be poor estimates of economic profits.

The Price-Cost Margin

Use of the price-cost margin (PCM) has a number of advantages when compared to accounting measures of profitability. To begin with, the computation of the price-cost margin is subject to less arbitrary adjustments compared to accounting measures. A second advantage is that price-cost margins reflect the experience of all firms in an industry independently of the ownership structure, and therefore minimize the impact of both corporate diversification and vertical integration. Perhaps more importantly, because most of the data is collected at the plant level, industry PCM's can be matched to data on various characteristics of both the firm and the industry. For example, in addition to advertising expenditures and the specification of technology, revenue and cost data are collected at a level of aggregation which matches the level at which industry concentration ratios are published. Finally, price-cost margins have a particularly strong appeal for research conducted at the international level because they are not affected by the different accounting regimes which prevail across national boundaries.

The price-cost margin is perhaps best understood as a proxy to the Lerner index of monopoly power[27]. The Lerner index can be interpreted as a measure of the firm's (or industry's) ability to command a price for its product in excess of its marginal cost of production. It is this divergence between price and marginal costs which characterizes monopoly market structures[28] and which distinguishes them from the perfectly competitive market. Unlike the monopolist, a firm operating in a perfectly competitive environment - and thus facing a horizontal demand curve - will maximize profit by increasing its output level to the point where marginal cost equals market price. The Lerner index is defined as:

$$L = \frac{(P-MC)}{P} \qquad (2)$$

where P is price, and MC represents marginal costs.

The reasoning behind the Lerner Index can be illustrated in the following example. Consider the usual competitive outcome for an industry which is depicted graphically in panel 'a' of Figure 3. Firms in a competitive industry, and therefore facing a horizontal demand curve, will expand output to the point where marginal cost equals price (and marginal revenue). Collectively, this amounts to expanding output until the aggregate supply (which is the horizontal summation of the marginal cost curves of the firms' in the industry) intersects with the industry demand. In panel 'a' this

[27] Lerner, A.P. (1934).

[28] Monopoly theory not only distinguishes between monopoly and competition but also varying degrees of non-competitive market behaviour. While there is no agreement as to its functional form, there is agreement that the ability to collude increases with seller concentration.

equilibrium position is given by the level of output q^c, and price p^c. The competitive firm continues to expand production up to this point because until this point is reached, its marginal cost of production is less than market price. The competitive firm does not expand output beyond q^c because the costs associated with subsequent units exceed marginal revenue, which in a competitive environment is driven down in the long-run to average total cost. At the point of long-run equilibrium, the firm's marginal revenue includes a normal profit.

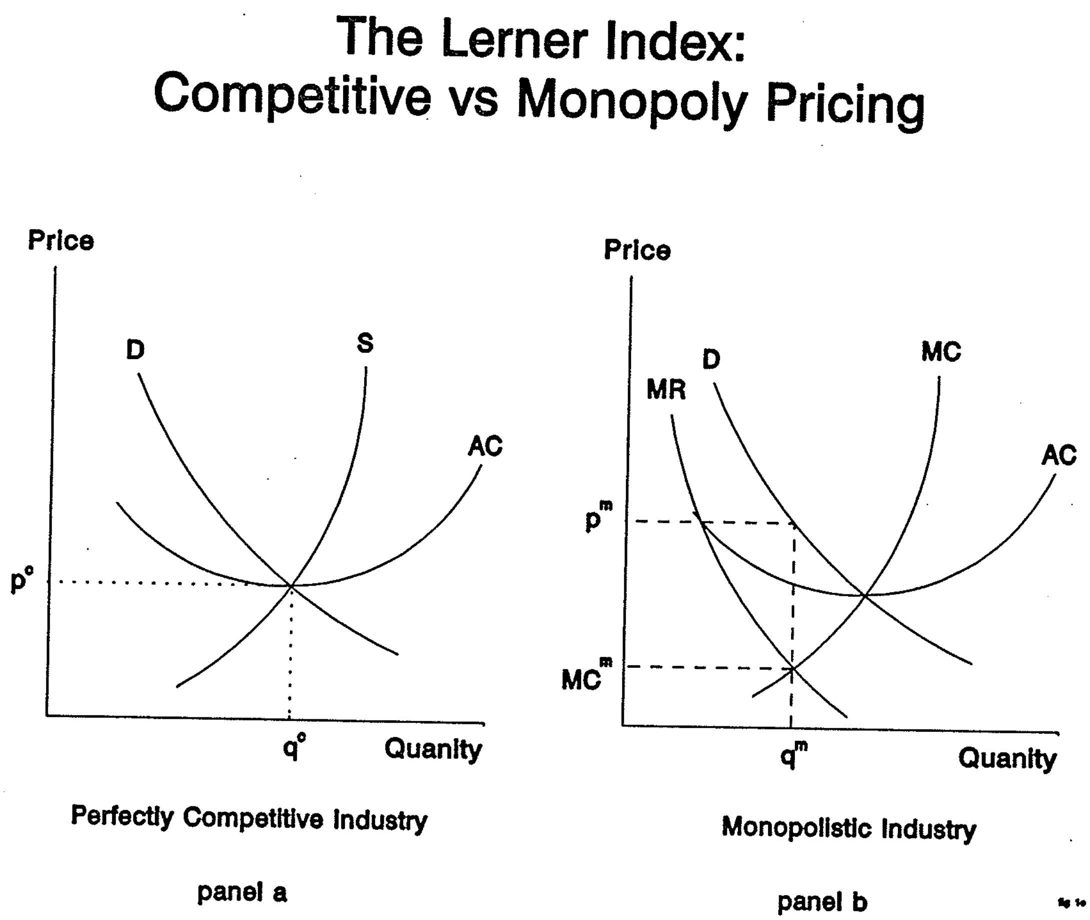

Figure 3

Referring to equation 2, it is clear that in the competitive case, where price and marginal cost are identical, the Lerner index equals zero, corresponding to the case where there is no monopoly power in effect.

The price-quantity outcome in a monopoly market will differ from the competitive outcome even if the market demand curve and the cost curve of the firm in a monopolistic industry is the same as those in a competitive industry. Panel 'b' of Figure 1 depicts the monopolistic industry outcome with respect to price and output. In contrast to the perfectly competitive industry, one cannot speak of an industry supply curve. Rather, the monopolist will chose the level of output (or price) which equates marginal revenue with marginal cost. In panel b, this equilibrium position is given by the price output combination (q^m,p^m). Comparing the two outcomes we can see that in spite of identical cost and demand conditions, the price-quantity equilibrium differs under the two market structures. The ability of the monopolistic firm to raise the price above marginal cost is given by the distance (p^m,MC^m) and the erner index in this case is given by:

$$L = \frac{p^m - MC^m}{p^m} \rangle 0 \qquad (3)$$

In cases such as this, where price exceeds marginal cost, the Lerner index takes a value greater than zero. At the extreme, where marginal costs are very small relative to price, the Lerner index tends toward a value of 1. Thus the Lerner index takes on values between zero and one[29]. Under the assumption that oligopolists can successfully collude, this same outcome applies to oligopolistic industries as well, with price and output taking on values between the perfect monopoly case and that of perfect competition; the actual levels of q and p being dependent on the degree to which the industry successfully colludes.

The Lerner index then, is a measure of the ability of a firm or industry to raise the selling price above the marginal production cost. But without additional assumptions, the Lerner index is not a direct measure of profitability. For example in the case depicted above, the degree of monopoly power is given by (MC^m,p^m) while per unit profit is given by the vertical distance between q^m, and the demand curve.

The distinction between the two measures is an important one for the empiricist to bear in mind because there is no fixed relationship between the two measures. While both measures are determined by the relative positions of cost and demand curves at a given level of output, it is the marginal cost curve which is relevant to the measure of the Lerner index, while profitability is determined by the relationship between the demand curve and the average total cost curve. To clarify, the two measures are

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[29] given that

$$\frac{P - MC}{P} = 1 - \frac{MC}{P}$$

we could alternatively consider the ratio MC/P or the inverse P/MC. These measures are conceptually identical in that they all focus on the ratio of price to marginal cost.

The Price-Cost Margin & Lerner Index

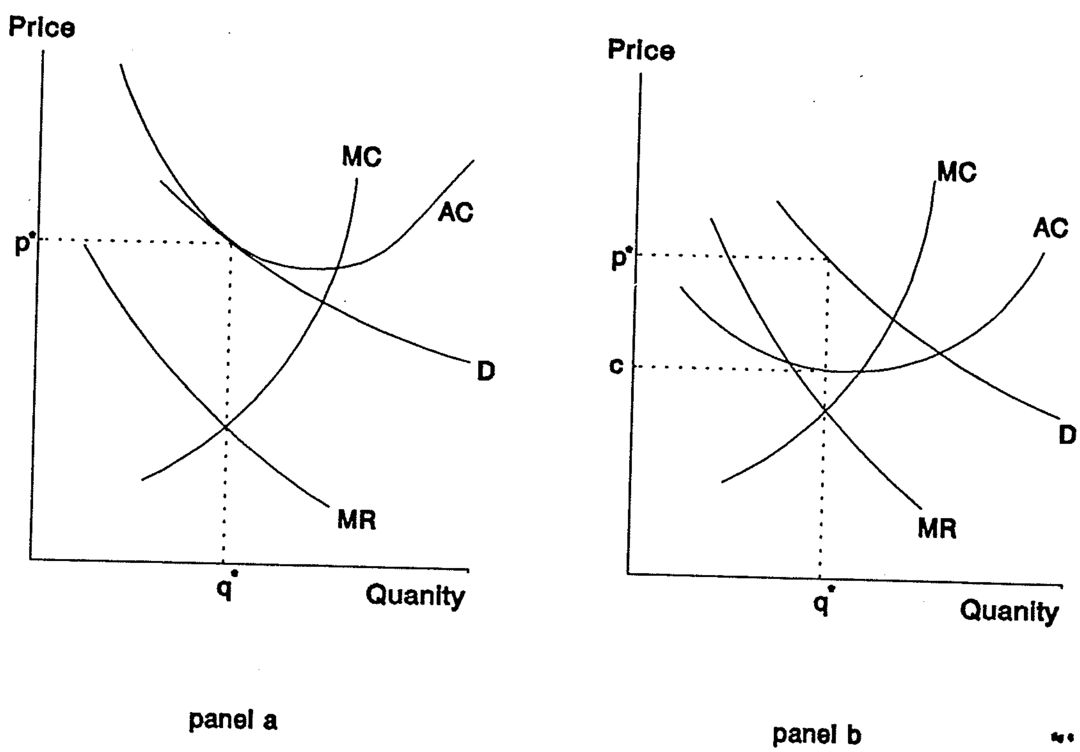

Figure 4

compared in Figure 4. The monopolies depicted in panels **a** and **b** respectively would generate a Lerner index of approximately similar magnitude. However, because of the position of the cost and demand curves the firm in panel **a** earns no extra-normal profit while the firm in panel **b** earns significant economic profits.

In practice, because marginal cost data is not readily available, an approximation to the Lerner index is made through the assumption that marginal costs are constant and therefore equal to average variable costs, i.e.:

$$L' = \frac{P-AVC}{P} \tag{4}$$

If we then multiply through by Q/Q, we arrive at the formulation:

$$L' = \frac{P - AVC}{P} = \frac{P - AVC}{P}.\frac{Q}{Q} = \frac{TR - TVC}{TR} \tag{5}$$

This equation represents the price-cost margin and its relationship to the Lerner index is well defined wherever marginal costs are constant. Equation 5 also amounts to the sum of economic profit and fixed costs as a percentage of sales:

$$L' = \frac{P - AVC}{P} = \frac{P - AVC}{P}.\frac{Q}{Q} = \frac{TR - TVC}{TR} = \frac{\pi + TFC}{TR} \tag{6}$$

The price-cost margin can be interpreted as the ability of an industry to raise price above variable costs, and when fixed costs as a proportion of total revenue are accounted for, is a measure of the firm's profitability.

We have noted above that the industry cost and demand curves impact on the magnitude of the price-cost margin. Since our ultimate objective is to compare the PCM of an industry operating in different markets, elements of both cost and demand must be considered in the analysis. Accordingly, the remainder of this chapter is devoted to a discussion of these issues. In particular, we examine the assumption of constant variable costs, and the impact of differences relating to capacity utilization, capital intensity, economies of scale and demand elasticity. The chapter closes with a discussion of the construction of the price-cost margin.

Industry Demand and Capacity Utilization

As we have noted, a key assumption in studies employing the price-cost margin is that marginal costs are constant and therefore average variable costs are constant. In cases where marginal costs are not constant, sub-optimal utilization of plant capacity of a firm or industry will introduce a bias in the measured price-cost margin.

The Divergence of Marginal Cost and Average Variable Costs

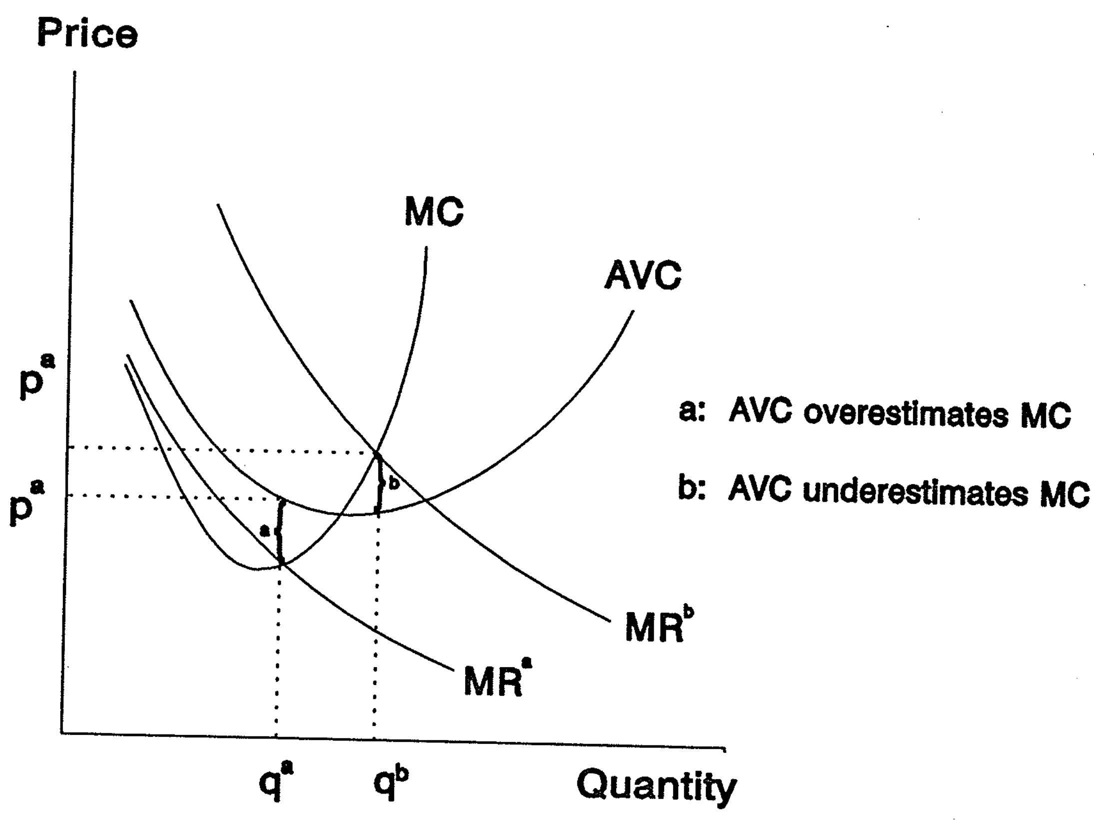

Figure 5

To see this, let us first define the optimal utilization of capacity as that level of output where average costs are minimized[30]. If marginal costs are not constant, the PCM will produce a biased estimate of market power whenever marginal costs diverge from average variable cost. For example, Figure 5 depicts two marginal revenue curves for a monopolistic industry. (The corresponding demand curves are omitted for clarity.) At the level of output q^a which corresponds to MR^a, AVC overestimates MC by the indicated distance 'a' and therefore underestimates the degree of monopoly power in effect. By contrast, at the level of output q^b, AVC underestimates MC and therefore overestimates the degree of monopoly power.

When applied to industry cross-section studies, the application of the PCM requires the strong assumption that firms in all industries of the cross-section experience constant variable costs. The assumption of constant costs may be less bold when the study focuses on a comparison of the performance of a single industry operating in different markets. Furthermore, the limited scope of such a study allows for a more detailed analysis of cost, scale, technology and demand, so that deviations from the constant cost hypothesis can be explored. Because the assumption of constant costs may be evaluated more directly, and data relating to both industry capacity and demand can be examined more thoroughly, greater credibility can be lent to an industry analysis.

[30] Capacity utilization and its measurement is discussed in greater detail in Chapter 6.

Capital Intensity

Because we are measuring average variable cost, the price-cost margin does not account for variations in capital intensity across industries. As we saw in equation 6 above, price-cost margins will typically vary according to capital intensity because a more capital intensive industry must earn more profits per dollar of sales if profit is to be equalized across all industries. An unbiased comparison of industry margins therefore requires an explicit treatment of fixed costs. In many cross-section analyses, the absence of fixed costs from the profit measure has been addressed by including the industry capital-to-sales ratio on the right hand side of the regression.

The potential bias introduced when capital costs are not accounted for is illustrated in figure 6, where we continue to assume constant variable cost. Industries A and B are identical with respect to both the industry demand curve and average variable costs, such that price and output levels are also identical. Although the two industries share identical price-cost margins, industry B employs about twice the capital of industry A, and the profitability of the two industries consequently differs. At the price-output combination (q,p), industry A earns per unit profits of P-C. However in industry B the capital employed per unit of output raises the average total costs to the point where per unit profit is zero. Obviously then, when the price-cost margin is employed as a measure of profitability, an

The Influence of Capital Intensity on the PCM

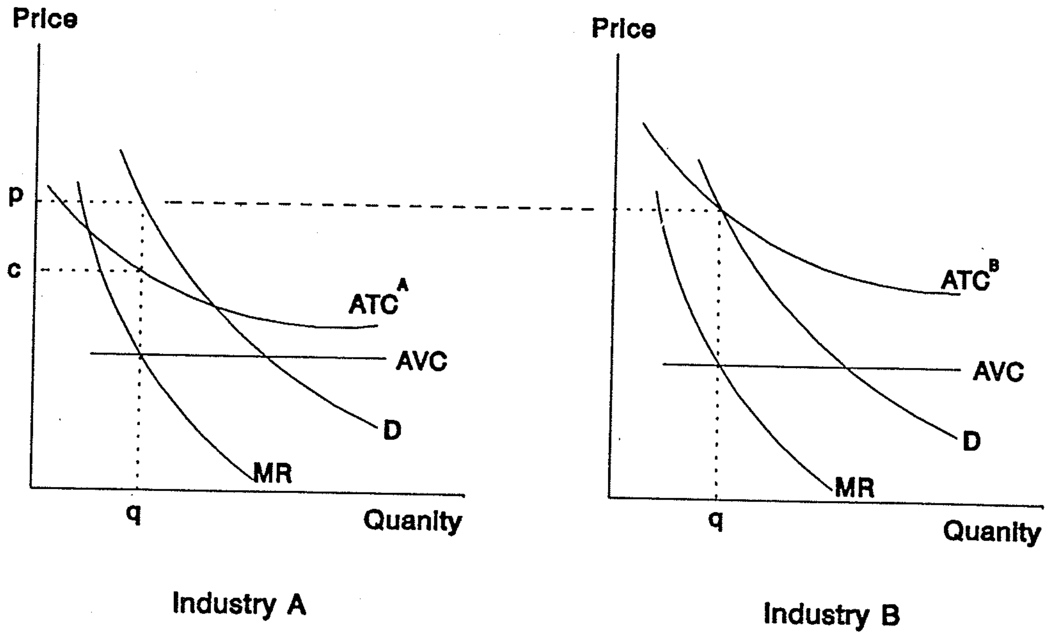

Figure 6

unbiased industry comparison requires that differences in capital intensity across industries be accounted for.

Economies of Scale and X-Inefficiency

An observed difference in industry price-cost margins could also reflect cost differences arising from either scale economies or the presence of x-inefficiencies which are not shared equally across industries or markets. Each of these is addressed in turn below.

The existence of scale economies in relation to market size is a key determinant of market structure. If a market is sufficiently small, the existence of scale economies may imply that the market can only support a limited number of firms of minimum efficient scale, thereby giving rise to an industry which is more concentrated that it otherwise would be. Because concentration is associated with an enhanced ability of member firms to collude in price setting, economies of scale are of particular interest in relatively small markets.

Economies of scale (technical or pecuniary) lead to a reduction in average costs which could partly explain observed differences in price-cost margins. Consider Figure 7, which depicts two scales of operation prevailing in different geographic markets. Assume that the demand conditions in both markets are identical. The smaller scale plants operating in a given market are denoted with the superscript 'a'. In short-run equilibrium, Plants 'a'maximizes profit at output, q^a and price, p^a. The industry composed of larger scale plants, serving a geographically different market, is denoted with the superscript 'b'. Clearly the industry enjoying greater economies of scale will tend to produce at a lower average total cost than its counterparts operating in another market under a smaller scale of operations.

The significance of this latter relationship depends on which interpretation of the margin is being considered. Since the Lerner index is concerned with marginal costs, economies of scale are relevant only if they affect marginal costs, i.e. economies of

Price-Cost Margins and Economies of Scale

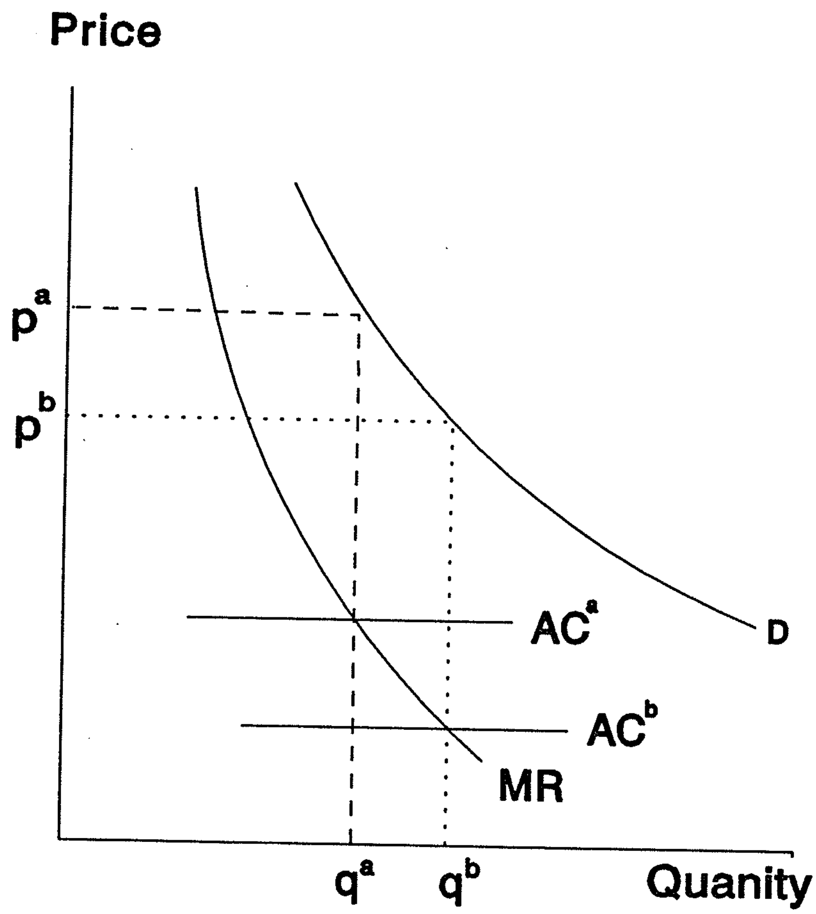

Figure 7

scale which lower per-unit capital costs only, do not affect the interpretation of the Lerner index. On the other hand, economies of scale which lower marginal costs will clearly affect the lerner index. All other things being equal, we would expect an inverse relationship between economies which reduce marginal cost and the Lerner index. In petroleum refining - a highly capital-intensive industry in which the principle variable input (crude oil) is sold in world markets - we would expect scale economies to operate through a reduction in per unit fixed costs, so that it is the alternative interpretation of the price-cost margin as a measure of profitability in which scale economies are really of empirical concern.

X-inefficiency relates to the manner in which a firm utilizes purchased resources, and can be defined as the excess of actual production costs over the technically minimum possible cost. In effect x-inefficiencies, which are always present to some degree[31], raise average costs above a technical minimum. Because it effects the position of the average cost curve, the presence of x-inefficiencies will tend to reduce an industry's price-cost margin. Since competitive pressures are expected to drive them out of the system, x-efficiencies are generally expected to be more prevalent in relatively concentrated markets[32]. Obviously then, the presence of x-inefficiencies may absorb some of the divergence between price and costs which would normally be expected to prevail in more highly concentrated markets. Disentangling the opposing effects of market structure and x-inefficiency on the price-cost margin is empirically difficult because of the absence of very detailed cost data. Such detailed firm level cost data

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[31] Shepherd (1979, p.134) reports that a consensus view of "average" x-inefficiency is about 5 percent of costs for monopolists and roughly 3 percent for an "average" oligopoly with market concentration of 60 percent.

[32] Scherer (1970: 164-6, 216-19) notes further that the PCM is expected to be lower among more mature, homogeneous goods industries because leading firms may be less x-efficient than other firms, owing to the effects of institutional rigidity over time and a reduced scope for product and process innovation. This in turn will accentuate the possibility of umbrella pricing by the leading firms.

is generally unavailable to the researcher, and the few exceptions are generally found outside of the public domain[33].

Demand Elasticity

While demand growth has long been recognized as an important determinant of profitability, the role of demand elasticity has been neglected in almost all but the more recent empirical studies. This omission is attributable to the research emphasis given to large industry cross-sections for which no detailed information is available on demand elasticities. For reasons which will become clear shortly, the omission of the industry elasticity of demand from these studies implies the strong assumption that demand elasticity is constant across industries within the cross-section. Similarly, industry studies which focus on different markets often make the implicit assumption that demand elasticity is similar in different markets.

Demand elasticity is directly related to the equilibrium output decision of the monopolist and therefore a determinant of the price-costs margin. To see this, consider the profit maximizing problem faced by the monopolist:

[33] In the context of the refining industry for example, the Nelson Company collects and analyses detailed cost data from North American refiners on a confidential basis.

$$\max_{p,y} py - c(y) \quad \text{such that } D(p) \leq y \tag{7}$$

where p is price and y, output, c(y) is the cost function, and D(p) is the demand function. In most cases the monopolist will want to produce the quantity demanded, so that the constraint can be written y = D(p). Substituting for y in equation 7 we have

$$\max pD(p) - c(D(p)). \tag{8}$$

Now let p(y) be the inverse demand function - the price that must be set to sell the desired units of output, y. The monopolist's revenue from y units of output is r(y) = p(y)y. Profit maximization is then given by

$$\max_{y} p(y)y - c(y) \tag{9}$$

The first-order condition is

$$p(y) + p'(y)y = c'(y) \tag{10}$$

which can be arranged as

$$r'(y) = p(y)\left[1 + \frac{\partial p}{\partial y}\frac{y}{p}\right] = c'(y) \tag{11}$$

or

$$p(y)\left[1 + \frac{1}{\epsilon(y)}\right] = C'(Y) \tag{12}$$

where

$$\epsilon(y) = \frac{p}{y}\frac{\partial y}{\partial p} \tag{13}$$

is the price elasticity of demand facing the monopolist. Thus the lower the price elasticity of demand, the greater price will diverge from cost at equilibrium. An interesting case arises with a constant elasticity of demand function[34] $y=Ap^{-b}$. If the elasticity of demand is constant and given by $\epsilon(y) = -b$ then we can substitute this into (12) and write

$$p(y) = \frac{c}{1 - 1/b} \tag{14}$$

So if industry demand is assumed to be characterized by a constant elasticity demand function, the equilibrium price is a constant mark-up over marginal cost, with the mark-up increasing inversely with the elasticity of demand.

Applications of the Price-Cost Margin

A number of variations of the price-cost margin are represented in the literature, differing in the degree to which they approximate total variable cost. In general the price-cost margin is computed as the ratio of total sales to direct cost. Direct costs include cost of materials, fuel, purchased electricity and wages. Part of these costs

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[34] Constant elasticity of demand functions are frequently employed in empirical work because they imply that individuals respond to proportionate changes in prices, rather than absolute changes as implied by straight line functions.

are fixed or quasi-fixed[35]. In some cases other variable costs are omitted because out-of-plant costs such as central office expenses, R&D expenditures and in-plant depreciation may not be available. The numerator therefore includes these items in addition to profits. A typical empirical formulation of the price-cost margin is:

$$PCM^i = \frac{P^i - AVC^i}{P^i} = \frac{TR^i - W^i - M^i}{TR^i} \qquad (15)$$

where TR^i is the total revenue associated with the ith industry, W^i is wages and related benefits and M^i is purchased materials which may include supplies and containers, fuel, electrical energy, and contracted work. Accounting for all significant industry costs may be especially difficult if the study involves a large sample of industries. As Liebowitz (1982) has shown, the correlation of the empirical formulation and the actual price-cost margin may be jeopardized when a significant proportion of variable costs are not accounted for[36]. This is demonstrated in equation 8 below where, following Leibowitz, all variable costs not included in the empirical measure are aggregated into a single category called X. If, for example, only material costs are included in the estimated price-cost margin and other variables (X) are omitted, the relationship between the empirical estimate and the measure and the actual price-cost margin is given by:

where PCM_a and PCM_m are the actual and estimated price-cost margins respectively.

[35] An example of a quasi-fixed factor is labour. For a treatment of this see Drouet (1984).

[36] At least where the missing costs are not proportional across the industries included in the study.

$$PCM_a = \frac{P - AVC}{P} = \frac{TR - CM - X}{TR} = PCM_e - \frac{X}{TR} \quad (16)$$

Equation 8 shows that the extent to which the estimated price-cost margin approximates actual the price-cost margin depends on the impact of X/TR - the relative magnitude of the omitted variables in relation to total revenue of the industry. This is an empirical question ultimately determined by the cost structure of the industry in question.

Price-cost margins have been employed to address a number of interesting questions although the literature is dominated by studies investigating the structure-conduct relationship. Studies including other aspects of market performance such as cost minimization and innovative behaviour are also represented in the literature. In general these studies have found a correlation between price-cost margins and market structure, although there is little consensus on the impact of other elements of market structure such as the size of firm, entry barriers, etc. The studies differ in terms of both industry coverage and time period, and the method for computing the price-cost margin is not uniform across the studies. These studies differ in specification of regression models as well, and all of these differences make it difficult to compare the results of one study with another.

Summary

This chapter opened with a discussion of the weaknesses associated with industry cross-section studies of structure-performance which once again pointed researchers in the direction of the industry study. Performance measures have generally focused on profitability, because of the paucity of useful price data and because price-cost margin and prices are expected to be strongly linked. With respect to profit measures we noted that accounting measures suffer numerous weaknesses and that the price-cost margin has been the measure largely preferred by researchers. Under the assumption of constant marginal costs, the price-cost margin approximates the Lerner index, which is a measure of the ability of firms to raise price above marginal cost. Furthermore, when fixed costs as a proportion of sales are accounted for, the price-cost margin can be interpreted as measuring profitability as a percentage of sales.

The discussion then turned to an examination of the various factors which influence the magnitude of, and in some cases bias in, the measured price-cost margin. To begin with, violation of the assumption of constant variable costs will lead to a bias in the estimated market power whenever output is inconsistent with minimum cost production. We also noted that capital intensity (capital as a proportion of sales) influenced profitability through its impact on average total cost. Hence if capital intensity varies within the sample in the study, these variations must be controlled for in the analysis. The same can be said of economies of scale. The difficulty of distinguishing between the margin elevating effects of industry concentration and the opposite effect of x-inefficiencies was touched upon. All other things being equal, concentration is expected to raise prices, but at the same time it provides greater leeway for x-inefficiencies to prevail (which raise costs and therefore reduce the observed margins).

Both the level of industry demand and its elasticity are important determinants of the price-cost margin. In the present context, the level of industry demand is important because of its impact on plant utilization rates and the bias this may introduce if variable costs are not constant. Demand elasticity must also be addressed because an observed difference in margins could arise from a difference in demand elasticity faced by the industries in the study.

Finally, the empirical calculation of the price cost margin was discussed. It was noted that the more closely variable costs were captured in direct production costs, the more closely the empirical measure reflected the theoretic price-cost margin.

4. THE OBSERVED PRICE-COST MARGIN

Introduction

The purpose of this chapter is straight-forward - to calculate the price-cost margin for refiners in Canada and the United States and to comment on the findings. In some industries it is possible (in principle at least) to estimate from census data a price-cost margin on an individual product basis. This approach cannot be applied to the refining industry because of the joint-production nature of the industry - the continuous process of various distillation and reforming processes yields a variety of products along the way, and there is no way of assigning overall cost to the production of the various outputs which make up a refineries product slate[37]. Hence, and with no loss to the current analysis, the margin being calculated is the price-cost margin of all refined products taken together.

The a priori expectation is that the margin is higher in the U.S. given that: the refineries there enjoy greater economies of scale; they are in general more technologically sophisticated than their counterparts in Canada (EMR: 1992); the proportion of gasoline devoted to the product slate is significantly higher; and,

[37] As Adelman aptly put it: "Individual products are joint products and it is altogether useless to seek or to pretend to have found the costs of the individual products - costs that do not exist." (Adelman (1971) *The World Petroleum Market,* p. 175).

transportation costs, because of the much more densely-populated market and the proliferation of product pipeline, are believed to be significantly lower.

Calculation of the Margin: 1973-1991

As we noted in the previous chapter, the literature reflects a considerable degree of variation with respect to the specific direct costs included in the calculation of the price-cost margin. Material costs and labour are generally viewed as the key ingredients, although in other cases considerable effort has been made to include such things as head office expenses, utilities, and advertising costs in the margin. We have chosen here to include only the cost of crude and other direct material costs including semi-refined petroleum products and catalysts. At first glance this would appear to risk considerable loss of valuable information in the estimated margin, but because of the cost structure of the refining industry this is not so.

Direct production costs can be categorized as relating to capital, labour or material costs. The refining industry is renown for its prohibitive capital costs; a large scale refinery today can costs in excess of $1 billion U.S. to construct and put into operation. Furthermore, today's complex conversion units (cracking, reforming, etc.) represent the bulk of fixed costs at refineries. They require very little labour for their operation and there is virtually no substitution between labour and installed process units (Copp: 1986). In addition, the actual output per worker in this kind of continuous-process environment will vary with the technology employed (Scherer et al 1975, p. 68). In these kinds of production environment labour is said to be a fixed, or quasi-fixed factor, because labour costs are more closely linked to the technology employed than the level of output. For these reasons, together with the fact that labour costs constitute such a minor proportion of cost, labour costs are not included in deriving the margin.

The single overriding variable cost in the refining industry is the cost of acquiring crude oil. In fact, the cost of raw crude represents about 85 percent of refinery operating cost (Copp 1976 p. 46). Other material costs, including purchased semi-refined petroleum products, tend to represent about 10% of crude costs. This suggests that the combination of crude costs with purchased semi-refined goods represents in excess of 90% of all variable costs of production. While it would be desirable to include all direct costs in the margin calculation, the other cost categories reported by the two statistical agencies are not compatible. Their omission may be of little significance if it can be reasonably assumed that in both markets the costs omitted from the calculated margin are proportionally similar to the material costs.

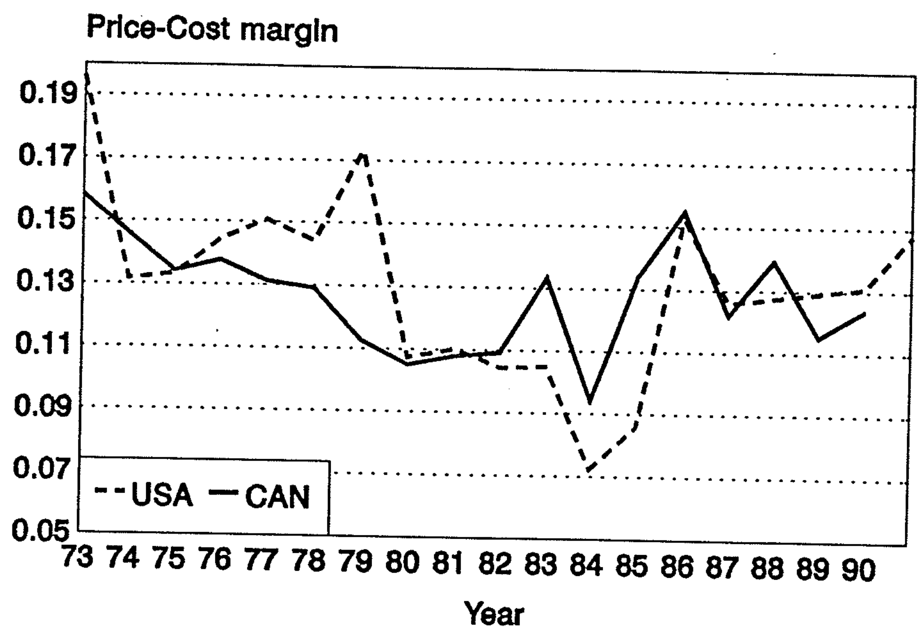
The data employed in the construction of the price-cost margins for Canada and the U.S. are from statistics Canada (45-250) and the U.S. Department of Commerce Annual Survey of Manufacturers (ASM) respectively. In both cases the data are collected at the four-digit level (2911: Refined Petroleum Products). Lubricants and greases (which are subject to further specialized refining processes) are not included within this classification. Both the cost and revenue data are very compatible. Both Canadian and U.S. data relating to the cost of materials category include both crude and semi-refined products. Refining revenue for both countries is estimated as the value of shipments for all petroleum refining establishments, i.e.:

$$TR=\sum (\overline{P_i} \bullet Q_i)$$

where total revenue, TR, is equal to the summation of the average price of each product P_i, times the quantity Q_i, of that product shipped. In both countries the shipments data relate to shipments of goods of own manufacture only, so that there is no contamination introduced from the re-shipment of goods manufactured elsewhere.

Using annual data, the price-cost margin for both Canada and the U.S. was calculated for the period 1973-1991. The results appear graphically in Figure 8 below. The value of the margins in the two markets appear to track each other rather closely. The average U.S. margin over the time period in question was 0.130, while the corresponding figure for Canadian refiners was lower at 0.127. While this does tend to support our a priori assumptions, the difference in the magnitude is considerably less than other factors would suggest it would be. In fact the Canadian refining margin was actually higher in nine of the nineteen observation periods in the sample. The Canadian refining margin tended to be below the U.S. margin during the seventies, but has been higher than the U.S. margin in seven of the ten years since 1982.

REFINERY PRICE COST MARGINS: CANADA & USA 1973-1991



Source: Statistics Canada: 45-250, and U.S. Department of Commerce, Annual Survey of Manufacturers.

Figure 8

Summary

Because of the joint product nature of refinery outputs, only an aggregate price-cost margin relating to the entire product-slate can be calculated. Because of the relative insignificance of labour in the variable costs of production, together with the fact that labour in the refining industry is a quasi-fixed input, labour costs are not included in the calculated margin. The direct production costs to the industry are represented overwhelmingly by the cost of crude oil and other petroleum-based inputs. It is assumed that in both markets the omitted cost categories are of a similar proportion to material costs.

Contrary to prior expectations, the U.S. refiners do not appear to enjoy a consistently larger price-cost margin. In fact in seven of the ten years between 1982 and 1991, the Canadian refiners' margin has been larger than that of their U.S. counterparts.

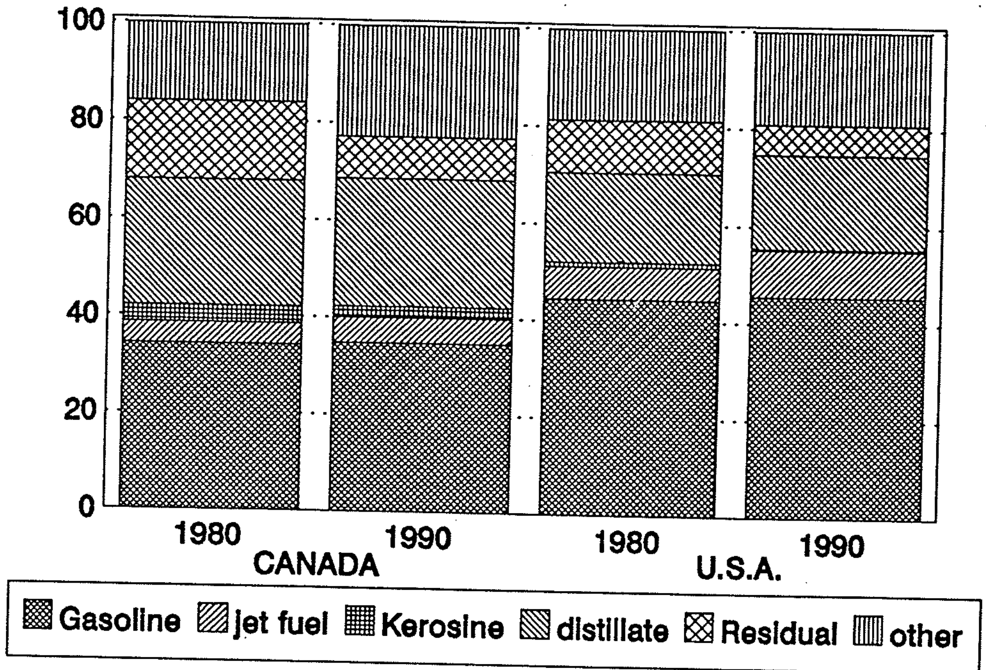
5. THE DEMAND FOR OIL PRODUCTS

Introduction

This chapter is concerned with comparing elements of demand between the refining industry of Canada and the United States. The reasons for doing so were outlined in the discussion of margin determinants in Chapter 3, where it was shown that both industry demand and the price-elasticity of demand are prime determinants of the price-cost margin. In this chapter we examine these two dimensions of demand in detail, with the objective of establishing the extent to which demand characteristics differ between the two markets - differences which would ultimately influence the magnitude of the price-cost margin estimated in the two markets.

The analysis of "industry demand" is complicated by the joint-product nature of the refining industry - the refiner company produces a "slate" of products from virtually a single input, and each product in the slate has its own associated demand characteristics. As we noted elsewhere, the "average" refinery produces a fairly typical product slate comprised in general terms of gasolines, other transportation fuels such as jet fuel and diesel, to the "heavier" products of heating fuels and residual products such as asphalt and coke. Almost all petroleum products can be characterized as basically homogeneous products which conform to standard product

Refinery Product Slates: Canada & USA



Source: IEA International Energy Annual

Figure 9

quality specifications. What can, and indeed does, differ amongst the product slate of refineries around the world is the relative proportion of so-called "light" products to the "heavier" products produced from a barrel of crude. These differences in product slate reflect demand differences across some markets which may in some cases be substantial. Figure 9 compares the product slates of Canadian and U.S. refineries in two periods, 1980 and 1990. In comparing the Canadian slate from 1980 to 1990, the most notable shift is reflected in a sharp decline in the proportion of residual fuel oil in the product slate and a relative increase in "other" products. Residual fuel oil represented about 8.5% of the product slate in 1990, down from 16% in 1980. While the proportion of jet fuel produced increased by about 1%, the proportion of kerosine declined from 3.5% to 2.3% of the product slate over the same period. The U.S. refinery slate experienced shifts in similar proportions. In both countries the relative proportion of gasoline in the product slate has remained constant, although it represents about 45% of the U.S. slate compared to only 35% in Canada. The U.S. also produces proportionately more jet fuel than Canada (10.0% vs. 5.5%); however Canada produces considerably more distillate - 25% compared to 19% in the U.S. These relative differences in the product slates are significant because in general, the higher the proportion of "light" products (which are higher in value) refined from a barrel of crude, the higher the price-cost margin. All things being equal, the substantially larger proportion of gasoline and jet fuels produced in the U.S. suggests that refineries in that market will earn a higher margin.

The question remains, to what extent were other things the same? To anticipate the analysis which follows, it appears that both demand, and the refineries' response to shifts in demand, has been remarkably similar in Canada and the U.S. For example, Dhal (1980) reports that refineries in Canada and the U.S. produce a product slate of relatively similar proportions. The similarity in refinery output is reflected in the use of similar technologies. Canada and the U.S. had a cracking capacity as a percent of distillation capacity of 30 and 23 percent respectively in 1980, while European refineries had a cracking capacity of only 5 percent. This difference in cracking capacity is directly related to the overall demand for gasoline which differs significantly between North America and Europe. In 1980, European refineries utilized 12 percent of a barrel for the production of gasoline; in Canada the figure was 23 percent, and in the U.S. that year, 30 percent.

That there are differences between North America and Europe while there are similarities between Canada and the U.S. can be explained by the relative cost of energy, and both geography and the composition of industry. Canada and the U.S. have historically enjoyed inexpensive energy which in turn has led to the development of energy-intensive industrial activity. Furthermore, Canada and the U.S. share the common characteristics of expansive geography with long distances between major urban centres; North American cities are themselves more sprawling than their European counterparts and are characterized by wider streets, proportionally more (and bigger) single family dwellings, and an abundance of freeways which facilitate automobile usage even in large urban centres. In addition, North American automobiles have been generally less energy-efficient while European countries have relied more heavily on public transportation systems (Heliwell, et al: 1989). In general, the tastes of Canadian and American consumers do not differ much, and probably less than the differences between any other pair of countries (Caves, et al: 1977). For these reasons Canada and the U.S. are similarly "energy intensive[38]" nations whose refineries produce similar product slates.

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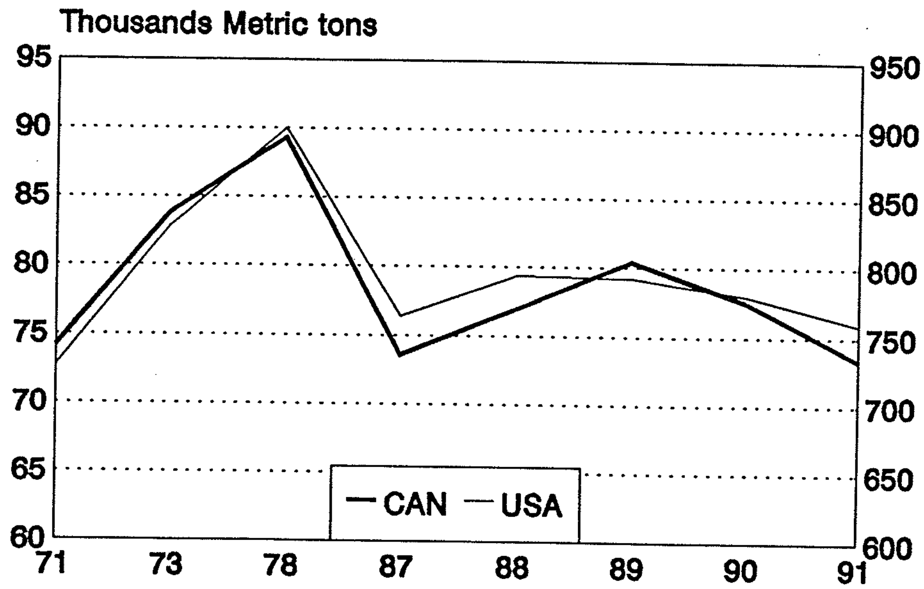
[38] Energy intensity is the ratio of energy consumption to output. The ECC (1985) calculations show that Canada has the highest energy intensity among the 8 industrialized countries examined, with the U.S. following closely behind. European countries and Japan are substantially lower than both Canada and the US in this regard.

With these general comments regarding variations in petroleum product demand we now turn to a comparative overview of trends in petroleum demand, including the demand for individual fuels at the national level and the end-user sector.

Demand by Sector

At first glance it would appear that petroleum products and energy fuels in general are typical non-durable consumer goods, the demand for which would therefore to be predicated on a combination of factors dictated by consumer demand theory - its own price, the prices of substitutable and complementary goods, income, and other relevant socio-economic factors. Petroleum products are indeed normal goods, and their demand is inversely related to price, but the demand for petroleum products is unique in that it is a derived demand - petroleum products are generally combined with other inputs to produce a final product or service (Berndt & Greenberg: 1989). In particular, some form of capital equipment is often used in combination with the consumption of petroleum products, such as vehicles, furnaces, boilers, and generators, to cite the more common examples. The fact that this equipment is relatively high-cost and will generally have a life of several years imposes constraints on demand responses to price changes in the short-run. It is this dimension of petroleum products which makes it a less-than-typical non-durable good.

OIL CONSUMPTION
Canada & U.S.A.



IEA: Oil and Gas Information, 1989-1991. Table 1

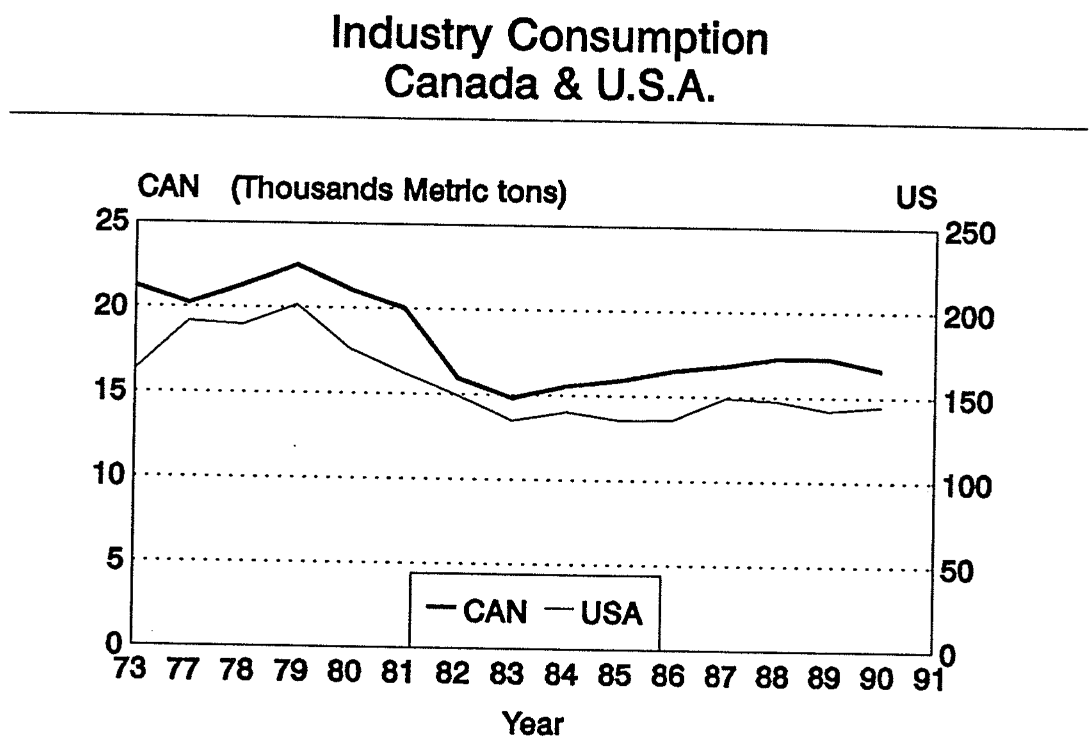
Figure 10

Because the demand for petroleum products is a derived demand, the growth in demand is strongly linked to the prevailing level of economic activity as increases in output (or consumption) require greater inputs of energy. We have already noted the similarity in the energy intensity of Canada and the U.S. This similarity can be inferred from Figure 10 which show the overall level of oil consumption in Canada and the U.S. between 1973 and 1991. Note that Canada's oil consumption is measured on the left hand vertical axis of Figure 10, while U.S. consumption is measured on the right hand axis. Although the absolute level of consumption in the U.S. is larger by a factor of 10, the movements in consumption levels are very similar in the two countries. Between 1971 and 1973 oil consumption in Canada and the U.S. grew 20 and 23 percent respectively. After the oil embargo of 1973, consumption in both countries dropped off in tandem and continued to decline until the economic recovery of the mid-eighties. Growth in consumption resumed once again until the onset of the recent recession. Notably, U.S. consumption began to decline in 1988 in timing with the onset of recession there, whereas Canadian consumption did not turn down until the following year. In general then, the aggregate level of petroleum consumption patterns is very close between the two countries, and in both cases the demand for oil has declined considerably since 1973.

So much for the demand for a barrel of crude oil. It is both useful and desirable to examine the demand for oil products in greater detail. Data relating to the consumption of oil products can be evaluated on the basis of end-user groups, as well as individual product lines. Although gaps exist in each of the two data groups, information relating to end-user demand patterns can be combined with the available product-line data to provide for a fairly complete picture of demand.

We can distinguish among four petroleum product demand groups within the economy: industrial, transportation, residential, and commercial. There is a loose correspondence between these sectors and the type of petroleum product which is predominantly consumed. Industry, for example, is a large consumer of heavy residual fuels, while demand in the transportation sector is dominated by gasolines, kerosines and diesel fuels, while the commercial and residential sectors are large consumers of heating oils. What the following analysis reveals, among other things, is that the decline in the aggregate measure of "oil consumption" which we examined in the previous section conceals much information with regard to movement in different product groups. As we shall see, the reduction in the demand for oil was in fact the combined result of a relatively stable demand for gasolines and middle distillates, and of a very significant decline in the demand for residual fuel oils.

Trends in industry's consumption of oil products appear in Figure 11.



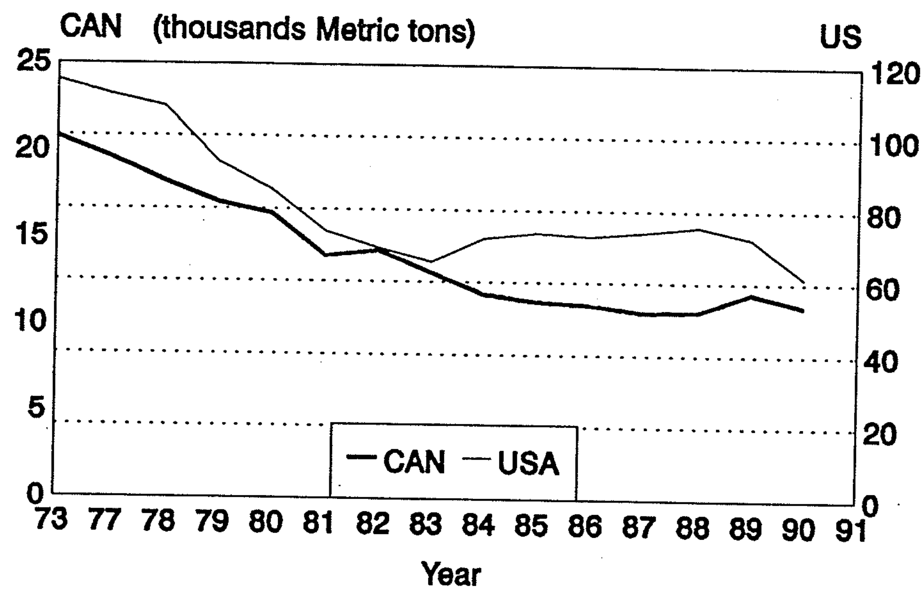
IEA: Annual Oil & Gas Statistics, 1988. Tables 1&3
IEA: Oil & Gas Information 1989-1991. Table 1

Figure 11

The predominant feature of the two trend lines is their similarity. Again U.S. demand exceeds demand in Canada by a factor of about 10, and the overall demand trend in both countries corresponds closely with the level of economic activity. For example, consumption peaked in both countries in 1979 and then experienced an almost identical decline into 1983. After resuming growth during the economic expansion, industry's consumption predictably declined with the onset of recession. Again the decline was experienced earlier in the U.S. than in Canada. Between 1979 and 1991, oil consumption in the industry sector of the two countries declined at very similar rates: 25 percent in Canada vs. 26 percent in the U.S.

Similar trends are evident in the commercial and residential sectors which appear in Figure 12. Again consumption trends in both countries are similar, although in the wake of the 1983 recession, demand in Canada did not seem to rebound as it clearly did in the U.S. In both markets there are notable differences between the consumption pattern in these sectors compared to the industry. First, whereas industry's consumption of oil products expanded with the economy through the late seventies, this trend was not shared in the commercial and residential sectors. Consumption has declined more or less steadily in these sectors since 1973. Furthermore, the decline in consumption has been dramatic in this sector. For the period 1979-91 consumption declined about 34 percent in the residential and commercial sectors of both countries compared to 25 or 26 percent in the industry.

CONSUMPTION IN COMMERCIAL & RESIDENTIAL SECTORS
Canada & U.S.A.

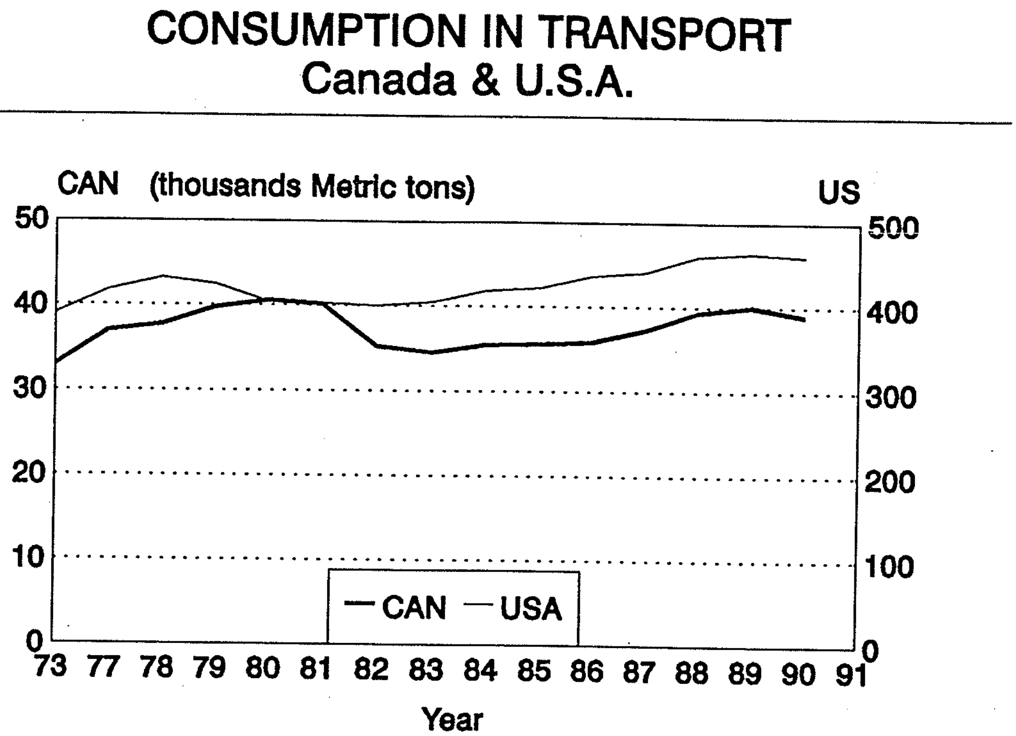


IEA: Annual Oil & Gas Statistics, 1988. Tables 1&3
IEA: Oil & Gas Information 1989-1991. Table 1

Figure 12

The declines have been even more dramatic over the entire 1973-91 period - about 46 percent. The relatively large decline in oil consumption in the residential and commercial sectors include households and firms attempting to reduce their dependence on oil in response to the higher relative prices[39]. This may have been achieved in the short term through belt-tightening measures such as turning down thermostats, and in the longer term through improved insulation and a switch to other forms of energy.

[39] Berndt & Greenberg (1989, p.80) suggest further that reduced oil demand in the residential sector is partly attributable to the fact that costs cannot be passed on as they might in other sectors.



IEA: Annual Oil & Gas Statistics, 1988. Table 1&3
IEA: Oil & Gas Information 1989-1991. Table 1

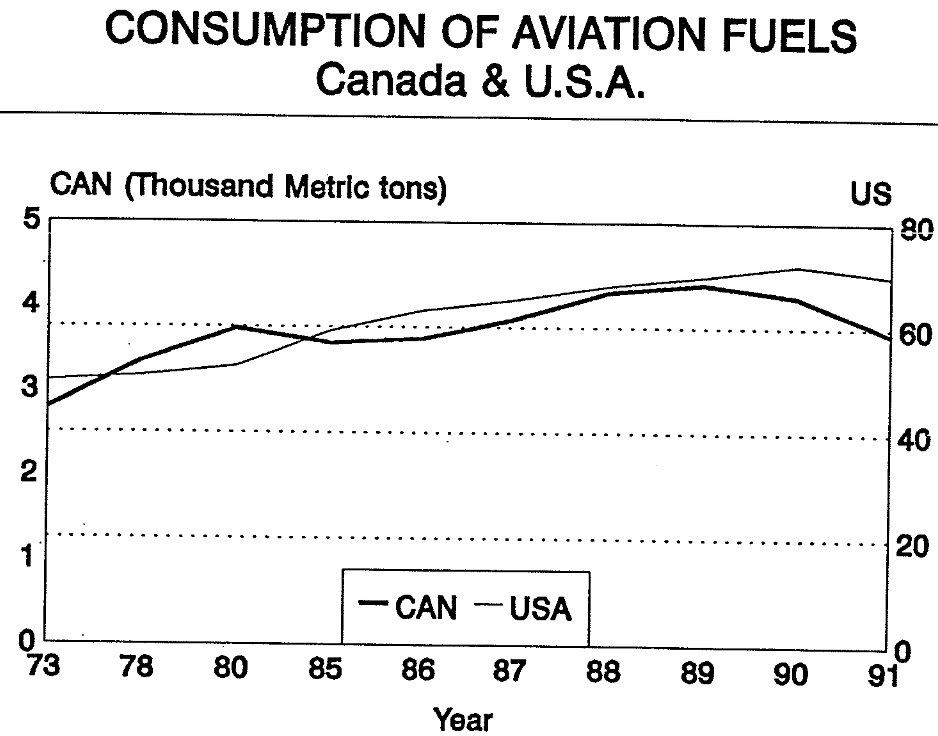
Figure 13

The transportation sector is an anomaly in terms of oil product demand trends. In both Canada and the U.S., it is the only sector to have experienced more or less steady consumption growth which is shown in Figure 13. As with the industrial, commercial and residential sectors, the demand trends in transportation are very similar in Canada and the U.S. with the exception of a brief period between 1978-80, when demand growth appears to have moved in opposite directions. Over the entire 1979-91 period, the transportation industry in both countries experienced an overall increase in demand of 18 percent. The different response to higher prices experienced in the transportation sector can be attributed to the limited scope for substitution in this sector, in which about one-fifth of the energy demand is associated with road vehicles (Berndt & Greenberg:1989).

The preceding analysis suggests that on a sectoral basis, the demand for oil products has been strikingly similar in Canada and the U.S. In both countries the overall demand for oil has declined considerably, although this masks a rather dramatic 35 percent decline in the residential and commercial sectors, about a 25 percent decline in industry and an 18 percent increase in demand in the transportation sector. The different demand responses to higher energy prices which prevailed over this period is in part a reflection of the respective sectors to substitute away from oil consumption to alternative energy forms.

Demand for Specific Products

Because the sectors described in the previous section utilize a number of petroleum products (although one may dominate) the preceding demand analysis does not provide a clear picture of demand developments relating to specific products. The knowledge culled from the preceding analysis is supplemented here with a discussion of the demand patterns for some key specific products. The consumption of aviation fuels, shown in Figure 14, again shows the usual correlation of demand between the two countries. Since the mid-eighties, aviation fuel demand in Canada and the US has moved more or less in tandem.



IEA: Oil & Gas Information 1989-91.Table 4
Includes aviation gasoline and jet fuels

Figure 14

Figure 15 shows the level of gasoline demand for Canada and the U.S. In general the two countries display very similar trends in gasoline consumption. The fact that consumption in the U.S. dropped considerably in 1980 and did not begin to drop in Canada until after 1980 may be explained by the fact that the Canadian market was protected from world prices until the mid-eighties through the Western Accord. In any event the decline in Canada was more dramatic at 14.5 percent between 1980 and 1987, whereas demand in the US declined about 7 percent. During the expansion period of the latter eighties consumption in both countries resumed until tapering off in the early nineties.

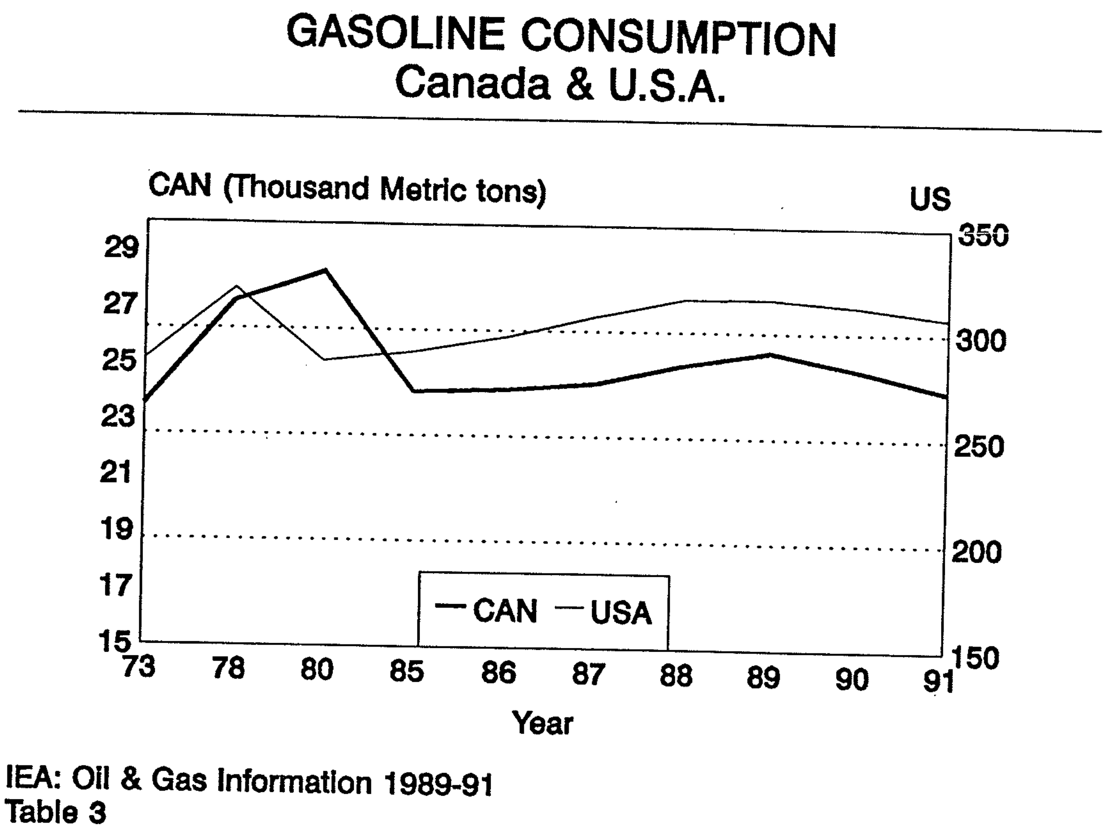
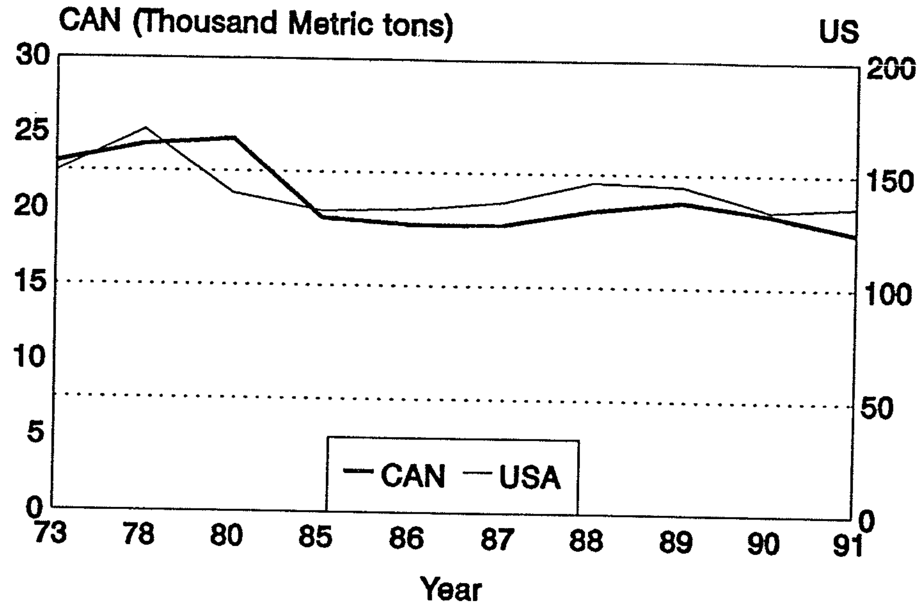


Figure 15

The demand for gas/diesel oil (Figure 16) is similar to that of the demand for gasoline. Like the demand for gasoline, the demand for diesel fuels grew until the latter seventies and then declined for several years until resuming growth again in the mid-1980's. Notably, the decline was not near as pronounced as that which was experienced in gasoline markets, reflecting in large part the fact that gasoline is predominantly the transportation fuel of household automobiles, and as we noted earlier, belt-tightening is the only alternative for households who cannot pass on the impact of higher prices.

CONSUMPTION OF GAS/DIESEL OIL
Canada & U.S.A.

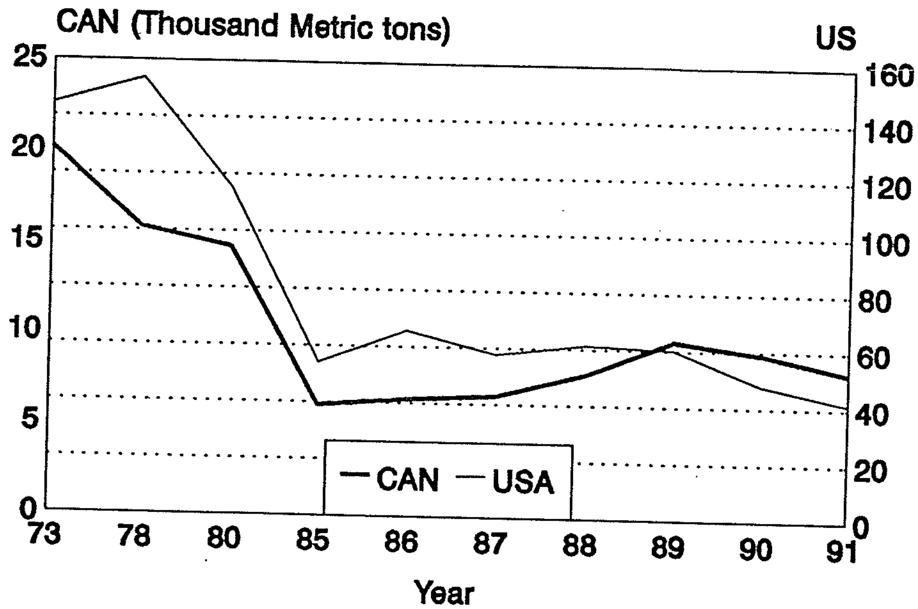


IEA:Oil & Gas Information, 1989-92 Table 5A

Figure 16

The most dramatic declines in the use of petroleum products hve been related to the use of heating fuels - in all sectors and particularly in the residential sector where again, belt tightening and alternative fuels were available. The decline in heating fuel demand is shown in Figure 16. Between 1973 and 1985, heating fuel demand in both Canada and the U.S. experienced declines of about 60 percent. The demand for heating fuel regained strength in Canada over the latter half of the eighties while it remained more or less stable in the U.S., probably reflecting the greater energy intensity of Canada's industrial sector and perhaps differences in seasonal weather patterns over this time period.

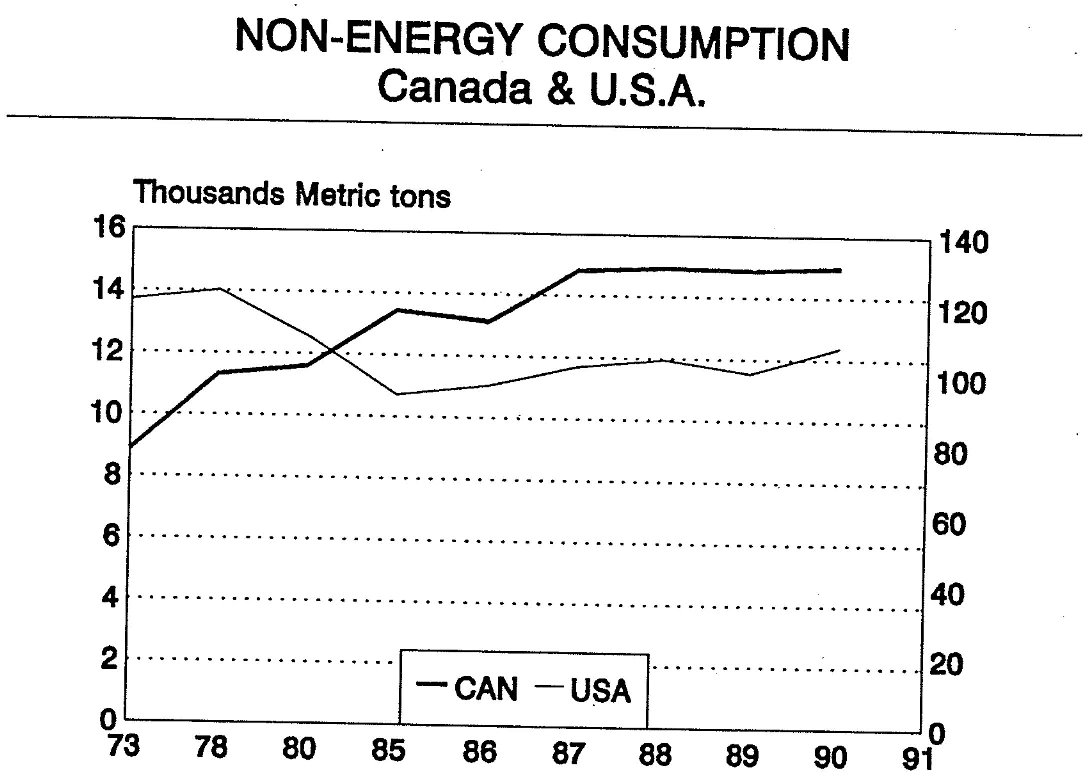
CONSUMPTION OF HEAVY FUEL OIL
Canada & U.S.A.



IEA: Oil & Gas Information, 1989-91. Table 5B

Figure 17

Up until now, the discussion of petroleum products has been focused on energy-use products, i.e. fuels. These products account for the vast majority of products produced from a crude barrel, but there are a good deal of other non-fuel or non-energy petroleum products. Non-energy petroleum products refer to a range of petroleum products which are either used as intermediate or final goods. Non-energy petroleum products include petrochemical feedstock, asphalt, petroleum coke, lubricating oils/greases and naphtha specialties. Petrochemical feedstock and asphalt represent more than 50% of all non-energy petroleum products (Belanger, Bernard & Dubois: 1990). These products have been studied much less, perhaps because although there are a great number of individual products, collectively they only represent about 10 percent of a crude barrel. They can be high value products, however, and for that reason some discussion is warranted.



IEA: Oil & Gas Information, 1989-91. Table 1

Figure 18

Figure 18 shows non-energy consumption of oil products for Canada and the US. Interestingly, with the exception of some minor dips in the mid to latter eighties, Canadian demand for non-energy products has shown increases. In the U.S., demand followed a more "typical" pattern, dropping considerably between the later seventies to 1985 and then experiencing slow increases thereafter. The reasons for this unusual difference in demand patterns between the two countries is not known but Canadian refiners apparently enjoyed an advantage in demand for these products.

Price Elasticity of Demand

The extent to which the demand for any given product is responsive to changes in its own price is referred to as the own price elasticity of demand, defined here as $E_{Q,P}$, given by:

$$E_{Q,P} = \frac{\%change, quantity\ demanded}{\%change,\ price} = \frac{\partial Q}{\partial P} \cdot \frac{P}{Q}$$

where income and all other prices are held constant. Like a typical "normal" good the demand curves for petroleum products are downward sloping and we therefore expect their price elasticities to be negative. But most petroleum products are not typical non-durable goods (Helliwell et al: 1990). Unlike most "normal goods", the demand for petroleum products is a derived demand. The derived nature of the demand for petroleum products was discussed in the previous section where it was noted that petroleum products are generally used in combination with other inputs - usually some form of capital good such as furnaces or automobiles - which are characteristically "fixed stock". Because the technologies embedded in this capital stock change over time, a distinction must be made between short-run and long-run price-elasticities of demand. This is so because the scope for substitution among alternate fuels or technologies is greater in the long run and by consequence, the price elasticity of both crude oil and refined petroleum products is larger in the long run than in the short run. For example in the industrial sector, firms may have little choice in the technologies they employ in the short run and their potential for "belt tightening"[40] may be very limited. As a result, demand will tend to be relatively inelastic in the short-run. Over time, however, firms have the ability to adopt more efficient technologies so that demand in the long-run may be considerably more price elastic. The same relationship between short- and long-run elasticities holds true in other sectors too. Households, for example, may upgrade furnaces or switch heating fuels altogether, and automobiles can be replaced with more energy-efficient models.

The purpose of this section is to determine the degree to which demand elasticities for petroleum products are comparable across Canada and the United States. A priori, there are sound reasons for expecting to find comparable price elasticities of demand in the two markets. First, based on the assumption that incomes and other prices in the two markets have moved in the same direction, the similarity in the patterns of demand growth for petroleum products which we examined in the previous section would suggest that demand elasticities are also similar. In addition, the similar geography with long distances between urban centres has already been mentioned, as was the relatively large proportion of single family dwellings. The similar energy intensity which characterizes the industrial base of the two countries was also noted. To that list we could add the socio-economic similarities between the two countries, including a vaguely defined but generally recognized "automobile culture" which is a rather uniquely North American phenomenon.

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[40] That is, voluntarily restricting their consumption of petroleum products.

Ideally, what we would prefer is to compare the elasticities of demand for the full range of petroleum products marketed in both countries. But a survey of the literature suggests that a search for "the" price-elasticity for any petroleum product is fruitless - the available research offers instead a menu of estimated elasticities, and in some cases the variance among the estimated elasticities for a given product is considerable.

According to Bohi (1981) the differences among statistically-estimated price elasticities arise from two basic sources: differences in economic and institutional conditions which are reflected in the statistical samples, and differences in the statistical estimation procedure. Of course it is the accurate estimation (and comparison) of the former which is potentially compromised by the latter. The differences which arise from the use of different statistical methods are more difficult to assess, in part because of the varying quality of data employed in the studies being compared (Kouris: 1981). Data issues aside, price-elasticity estimates appear to be rather sensitive to the model specification. There is a wide range of models employed for the estimation of energy demand in general, and for petroleum products in particular. These models range from simple single-equation static models to the most complex dynamic simultaneous-equation systems. Because of the differences in the treatment of data and the degree to which any given model adequately captures all the determinants of price elasticity, different model types gives rise to different estimates. Even apparently minor differences in specification within a general model type can generate significantly different estimates. For example, Sandbach (1988) notes that simple changes to the lag structure of various energy demand models has a significant impact on elasticity estimates. Similarly, Kouris (1981) has demonstrated how sensitive elasticity estimates are to the element of time. All of this is not to suggest that the substantial body of existing research is meaningless or that no relevance should be attached to the results. In fact Dhal and Sterner (1980) found that when different model types, time periods and techniques are controlled for, the statistical estimation of gasoline demand elasticities does produce a reasonable degree of consistency in results. Thus in comparing the various estimates, consideration must be given to the variety of procedures employed by different researchers.

It follows from the above discussion that a comparison of demand elasticities cannot be made with great precision. The task is further complicated by the availability of estimates. Ideally, of course, we would prefer to have a full complement of price elasticity estimates covering the entire petroleum product slate. In reality, there is a dearth of information about all but the major products.

Demand elasticities have been estimated either by end-use sector or, in some cases, for specific products. Because of the information gaps encountered within these approaches individually, there is merit to combining the results of both approaches in the current analysis. A number of price elasticities covering the major petroleum products and sectors have been estimated at different times and cover various geographies, and by pooling this information a number of conclusions can be reached concerning the similarity of demand elasticities for petroleum products across Canada and the United States.

Price Elasticity of Demand for Oil

As a first approximation to detecting differences in price-elasticities for petroleum products it is instructive to examine some evidence relating to the price elasticity for a barrel of crude - the primary input for all refined products. Unfortunately there are no comparable short-run elasticity estimates for crude, and only a small handful of long-run estimates are available. Berndt and Greenberg (1989) conducted a review of the empirical work relating to Canada and found that the long-run price elasticity of demand for oil products in Canada ranged from -0.7 to -0.8. These estimates are supported by results reported by the ECC (1985), which reports a long-run price elasticity for oil as a source of energy in Canada at -0.68. Similar magnitudes have been found to hold for the U.S. Houthaker and Kennedy[41] (1975) for example, estimated the long-run elasticity of distillate demand in the U.S. at -0.76, while Verleger & Sheenan reported a value of -0.61. Based on these estimates, which average -0.75 for Canada and -0.68 for the U.S., demand for oil is inelastic in the two countries, and the magnitude of the estimates are very similar.

[41] Reported in Taylor (1977).

Elasticity for Energy by Sector/Product

There are a number of studies which have examined the elasticity for both total energy, and petroleum products, by end-use sector. An examination along sectoral lines is the most theoretically desirable means of evaluating energy demand characteristics because it best approximates end-use demand (Helliwell et al: 1989). Examining price elasticities by sector implies that particular products are associated with particular sectors, and broadly speaking this is true. There is potential bias introduced into the analysis when product end-users and sectors do not perfectly correlate. This is of little concern in the present case because given our assumptions regarding the socio-economic similarities of the two countries, the bias should be fairly consistent across the two markets.

The following discussion of price elasticities of demand is organized by sector, e.g. the industrial, commercial, residential and transportation sectors. In addition, where price elasticity estimates are available for specific petroleum products, these are reported together with the sector to which they are most strongly associated (e.g., gasoline with transportation).

Industrial Sector

A sample of estimated demand elasticities relating to the industrial sector is reported in Table 1. In spite of the different models employed and the different time periods considered in the various analyses, it appears that the short-run[42] demand elasticity estimates cluster fairly closely in the range of -0.2 to -0.5. With respect to total energy demand in Canada, the various periods studied by DataMetrics comes to precisely this conclusion; Watkins and Waverman's results are almost identical, while the range of the estimates summarized by the NEB is slightly larger. Berndt and Wood (1975) estimate the price elasticity for total energy demand in the U.S. industrial sector at -0.49 in the short-run, which falls within the same range found for Canada.

Table 1 (bottom) also includes some estimates relating specifically to the demand for oil (or residuals/distillates). The reported short-run demand elasticity estimates for Canada of NEB (1981) and EMR (1990) are almost identical at -0.17 and -0.18 respectively. The U.S. demand elasticities reported by FEA (1976) and DOE (1978) are generally similar. The elasticity for distillates estimated by FEA (1976) is somewhat greater, but the reliability of the estimate is questionable, given the even greater inelasticity of demand estimated for the long-run. The two Canadian estimates

[42] The long-run elasticities are also reported here, although for present purposes we are primarily interested in short-run responses to price changes. The greater variance in long-run estimates probably reflects the use of different lag structures employed in the various studies.

(which relate to oil as opposed to distillates or residuals) are almost identical and are

Table 1
Demand Elasticity for Energy: Industrial Sector

Author	Country	Period	Short Run Elasticity	Long-run Elasticity
DataMetrics Ltd[1] (80/82)	Canada	Various	-0.2 to -0.5	-0.6 to -0.9
Watkins & Waverman[1]	Canada	Various	-0.29 to -0.45	
ECC (1985)[2]	Canada	Various	-0.21 to -1.00	
Fuss et al (1976)[3]	Canada	1961-71	-0.36	
Berndt & Wood (1975)[3]	U.S.	1947-71	-0.49	
Demand Elasticity for Oil				
FEA (1976)[4]	U.S.	1966-75	D: -0.43 R: -0.26	-0.01 -0.75
DOE (1978)[5]	U.S.	1960-75	D: -0.22 R: -0.13	R: -0.54 R: -0.73
NEB (1981)[6]	Canada		Oil: -0.17	-1.19
EM&R (1990)[6]	Canada		Oil: -0.18	-1.32
Baughman, Zerhoot (1975)	U.S.	1968-72	-0.11	-1.32

1. Reported in Berndt & Greenberg (1989).
2. ECC 1985: compiled from various sources.
3. Reported in Taylor (1977)
4. Reported in Taylor (1977), estimates are for Distillates (D) and Residual fuel (R).
5. Reported in Bohi (1981), estimates are for Distillates (D) and Residual fuel (R).
6. Reported in Waverman 1992. Both studies focus exclusively on the demand for oil.

in the lower range of the U.S. estimates. In general, the estimated elasticities are closely grouped, and based on this evidence it would appear that the demand characteristics of the industrial sector in the two countries are quite similar.

Commercial Sector

The demand for energy in the commercial sector is comprised primarily of heating oils. Eight studies are reported in Table 2. Only the first two relate to the total demand for energy, the remaining three studies provide elasticity estimates for either oil or oil products.

Table 2

Demand Elasticity for Fuel Oil: Commercial Sector

Author	Country	Period	Short-Run Elasticity	Long-Run Elasticity
DataMetrics Ltd[1] (80/82)	Canada	Various	-0.4 to -0.5	approx. -0.8
NEB 1986[1]	Canada	1963-85	-0.12	-0.33
Demand Elasticity for Oil				
Cohn, Hirst, Jackson (1977)[2]	U.S.	1969-74	-0.19	-0.51
Alt, Bopp, Lady (1976)[2]	U.S.	1968-74	-0.13	-0.27
DOE (1978)[3]	U.S.	1968-75	-0.7	-1.5
NEB (1989)[4]	Canada		-0.19	-1.6
EM&R (1990)[4]	Canada		-0.16	-1.19

1. Reported in Berndt & Greenberg (1989).
2. Reported in Bohi 1981. These figures combine the demand for fuel oil in the residential and commercial sectors.
3. Reported in Bohi (1981).
4. Reported in Waverman (1992)

Note that the studies by Cohn et. al. and Alt et. al. combine the commercial and residential sectors in the estimation procedure. With one exception, the estimated elasticities for oil are very closely clustered and are less than -0.2. This value was essentially the lower bound of the estimates reported for the industrial sector, suggesting that in the short-run at least, demand for oil products on both countries is more inelastic in the commercial sector. In any event, the estimated elasticities in the two countries are remarkably similar, given that they are derived from a number of different models, and the data employed cover different time periods.

Residential Sector

Table three reports price elasticity estimates for energy and for oil products in the residential sector. The two price elasticity estimates for total energy both relate to Canada and are very similar in magnitude. The short-run elasticity estimates for oil are not significantly different, and overall the estimates range from -0.2 to -0.44. It is interesting to note that the elasticities in the residential sector of both markets tend to be somewhat higher in the short-run as compared to the commercial sector, and considerably larger in the long-run. This finding is consistent with previous assumptions regarding the socio-economic similarities in the two markets.

Table 3
Demand Elasticity for Heating Oil: Residential Sector

Author	Country	Period	Short-Run Elasticity	Long-run Elasticity
NEB[1] (1986)	Canada	1963-85	-0.2	-0.5
ECC (1985)	Canada	Various	-0.32	-0.60
Demand Elasticity for Oil: Residential Sector				
Verleger & Sheenan (1974)[2]	U.S.		-0.22	-0.93
FEA (1976)[3]	U.S.		D: -0.44 R: -0.17	D: -0.87 R: -1.08
NEB (1989)[4]	Canada		-0.38	-3.39
EM&R (1990)[4]	Canada		-0.23	-2.69

1. Reported in Berndt & Greenberg (1989).
2. Reported in Taylor (1977), includes all home heating oils.
3. Reported in Taylor (1977), includes distillate.
4. Reported in Waverman (1992), includes demand for all oil products.

Transportation Sector

In the industrial, commercial and residential sectors which we have discussed so far, the demand for petroleum products is predominantly a demand for heating fuel in one form or another - from blast furnaces to residential furnaces. The potential for substitution for heating fuels is reflected in the relatively high long-run elasticities in these sectors - especially in the residential sector. By contrast, there is a relative absence of alternate fuels suitable for use in the transportation sector, and this is reflected in the lower estimates of price elasticity.

The transportation sector can be subdivided into sub-sectors: Air, rail, road, and marine. In some cases even these sectors have been subdivided into user groups. The demand for energy in the "road" sector, for example, can be examined in terms of private automobiles, buses and trucks. Unfortunately, there are few empirical studies oriented on a sectoral basis in the two markets which are comparable, and none of these provide short-run price elasticities. Table 4 provides some long-run estimates of demand elasticities for transportation sub-sectors of the Canadian and U.S. markets.

Table 4
Demand Elasticities in the Transportation Sector

(Sub)-sector	Canada[1]	U.S[2].
Road	-.07	
Truck		-0.545
Bus		-0.474
Rail	-0.1	-0.368
Air	-0.2	-0.245
Marine	-0.2	

1. ECC (1985): Demand for energy by sector.
2. DOE (1978): Demand for fuels other than gasoline.

The estimates by ECC reflect the demand for energy by sector, while DOE estimates for the U.S. are the demand for fuels other than gasoline. This reflects, in part, the considerable differences in both the models and the data used in the respective estimation procedures. The available estimates do not provide for direct comparisons across sub-sectors, with the exception of rail and air. On the basis of the estimates presented in Table 4, the long-run elasticity for air travel is very similar in the two countries and tends to be considerably less elastic than the demand for fuels for road transportation. The higher price elasticity of demand in the road sector could reflect the adoption of more energy efficient automobiles over time. The few comparable estimates do suggest similarity rather than differences with respect to price elasticities in the two markets.

Elasticity for Gasoline

Because of the limited scope for substitution in the transportation sector, the demand for petroleum products in the sub-sectors corresponds closely to the demand for particular products: air with jet fuels, rail with diesel fuel and automobiles with gasoline. But with the exception of gasoline, there are few studies which examine a particular fuel type. The overwhelming interest in gasoline demand is not surprising given the relatively low short-run price elasticity associated with gasoline, and the fact that 30-40 percent of the value-added from a crude barrel is in the form of gasoline (CPA: 1989). As such, gasoline consumption is the most important component of oil demand and has been studied in many industrial countries, although the literature is predominantly focused on the U.S market. Relatively little research has been done in Canada. The paucity of empirical work directed at the study of gasoline demand in Canada may reflect an assumption that demand patterns in Canada and the U.S are similar.

Numerous econometric models have been used to study gasoline demand. The simplest models are based on dynamic relationships between gasoline consumption, the price of gasoline in real terms, and real income over time; the more complex models examine the variation of gasoline consumption per capita as a function of the price of gasoline, the stock of vehicles per capita, traffic density and real income per capita. According to Drollas

(1984), the differences in the models can be ascribed essentially to the extent to which the model accounts explicitly for the stock of vehicles and for factors which affect both the stock itself and its utilization rate.

Table 5
Selected Price Elasticities of Demand for Gasoline

Author	Period	Area	Short-Run Elasticity	Long-Run Elasticity
Deewes et al[1] (1975)	1956-72	Can	-0.05	-0.26
Mount & Williams[1] (1981)	1960-75	Can		-0.88
Baltagi, Griffin (1983)	1960-78	Can[2]		-0.36
Gallini (1983)	1969-79	Can	-0.3 to -0.4	-0.6 to 0.8
Berkowitz et al (1990)	1982	Can	-0.24	
Kwast[1] (1980)	1963-77	USA	-0.07	-1.59
PeLaez[1] (1981)	1962-79	USA	-0.122	-0.552
Kouris[1] (1983)	1964-81	USA	-0.40	-1.02
Drollas[1] (1980)	1950-80	USA	-.35	-0.73
Lin et al[1] (1985)	1966-73	USA	-.251	
Greene[2] (1978)	1966-75	USA	-0.19	
Verleger, Sheenan[2] (1976)	1963-72	USA	-0.14	-0.32
Alt, Bopp, Lady[2] (1976)	1968-74	USA	-0.19	-0.50
McGillivray[2] (1976)	1951-69	USA	-0.23	-0.77
Anderson[3] (1972)	1952-72	USA	-0.11	-0.60
Difiglio, Kulash[2] (1972)	1960-73	USA	-0.11	-0.18
Cato et al[3] (1974)	1959-73	USA	-0.24	-0.73
Sweeny[3] (1975)	1957-74	USA	-0.22	-0.73

1. Reported in Al-Sahlawi (1988).
2. Reported in Bohi (1981).
3. Reported in Kouris (1983).

Given the many models employed in the estimation of gasoline demand it is not surprising that there is a considerable range in the estimates generated. Table 5 provides a sample of estimates gleaned for a number of surveys.

In general, the estimates for the price elasticity of gasoline display a considerable degree of stability over time and are fairly tightly clustered. With only a few exceptions, the short-run elasticity estimates range from -0.10 to -0.30 and the overall range of the estimates for Canada and the U.S. are almost identical. Given the many different estimation models, this close clustering imparts considerable confidence in the estimates. In fact, in surveying over one hundred studies of the demand for gasoline, Dahl and Laumos (1990) found that after differences in model type, data sources, etc. are accounted for, there is a considerable degree of consistency in the estimated price elasticity estimates. Even over time, short-run demand elasticities appear to display remarkable stability. Kouris (1983), for example, finds that price elasticity of demand of gasoline for passenger cars has remained remarkably stable over the 1956-1981 period. By using the same model and testing nine different overlapping periods, he finds that the price elasticity of demand varied narrowly between -0.207 to -.269.

Some final supporting evidence is provided in the results of Baltagi and Griffin who used a pooled cross-section time series (of eighteen countries) and found greater similarity between Canada and the U.S. - a result which they conclude arises from similarities in driving conditions in the two North American countries.

Elasticity for Other Products

Non-energy petroleum products (NEPP) refer to refined petroleum products which are used as final goods or as intermediate inputs for other non-energy producing processes, and include petrochemical feedstock, asphalt, petroleum coke, lubricating oils/greases and naphtha specialties. Total NEPP make up a small proportion of all petroleum products.

There is virtually no information relating to the price elasticity for non-energy petroleum products with the exception of one study by Belanger, Bernard and Dubois which focuses on Quebec. The authors of that study suggest that the limited attention paid to NEPP may be attributable to the small proportion of petroleum products which they represent and the heterogeneous nature of the products. Their findings indicate that in Quebec at least, the price elasticity of demand for all NEPP except petroleum coke is less than -1.0. Given the similarities which we have found to generally prevail with respect to petroleum product demand in other areas, it is reasonable to assume that the same holds true in NEPP as well, particularly since the capital goods employed in the two countries - engines, motors, furnaces, etc - are virtually identical.

Summary

This chapter has focused on the demand patterns for petroleum products and was particularly concerned with detecting differences in patterns of industry demand and the price elasticity of demand across the two markets. Because the demand for petroleum products is a derived demand, the distinction between short-run and long-run responses was noted. The detection of differences in either demand growth or elasticity of demand is important because of the potential bias which these differences could introduce in a comparison of the price-cost margins of refineries serving their respective markets. If these differences are detectable, inferences can be made regarding the probable direction and magnitude of the bias in the estimated price-cost margin, and in this way the integrity of the analysis can be maintained.

A refining product "slate" refers to the type and proportions of various refined products produced. The refinery product slates of the two markets were compared and the data revealed that U.S. refiners produce a higher proportion of high-valued "light" gasoline and jet fuels than Canadian refiners. In addition, Canadian refiners produce a higher proportion of distillate (26%) compared to the U.S. (19%). All other things being equal, the fact that the U.S. produces a higher proportion of higher-valued products suggests that U.S. refinery margins should be relatively higher.

The examination of growth patterns in the demand for petroleum products revealed that, by and large, the two countries are strikingly similar. This conclusion held true both in terms of the demand for petroleum products across sectors, and the demand for specific products. In both countries, the overall reduction in the demand for oil reflected a stable demand for lighter products used primarily in the transportation sector - gasolines and middle distillates, and of a sharp decline in the demand for residual fuel oils - used primarily for heating (as either a final or intermediate product). The dramatic decline in the residential and commercial sectors was explained by the relative availability of substitutes, as well as the capacity for "belt-tightening" measures. In both countries, the demand behaviour in the transportation sector was found to contrast sharply with the other sectors. While demand in other sectors contracted, demand in the transportation sector actually increased 18 percent overall between 1971 and 1991. The relatively stable demand in the transportation sector was attributed to the relative absence of substitutes in that sector.

The latter half of the chapter was devoted to an examination of price elasticities of demand. A priori, the similarities of geography, housing characteristics, and energy intensity of industry, together with the similar characteristics of demand growth suggest that price elasticities should be quite similar in the two markets. Price elasticities were first examined on a sectoral and product basis. In terms of specific products, elasticity studies were found to be highly focused on gasoline - and particularly on the U.S. market.

The literature reveals that "the" price elasticity of demand for any given petroleum product is empirically non-existent. The variance found among the available elasticity estimates can be attributed to the many different models, data quality and time periods considered. In spite of this, the estimated price elasticity of demand was found to be relatively consistent when estimates for comparable product categories in the two countries were compared. The available evidence does not allow us to conclude that the price elasticities for the refinery product slate in the two countries are identical, but the range of any comparable elasticity was found to be similar in the two markets. Thus the available evidence suggests that the price-elasticity of demand for petroleum products probably does not differ significantly between Canada and the U.S. This suggests that the estimated industry price-cost margins will be unbiased with respect to demand characteristics.

6. REFINING CAPACITY AND TECHNOLOGY

The purpose of this chapter is to examine some issues relating to productive capacity of the refining industry, and more importantly, on the rates of capacity utilization over the time period of the study. A second purpose of this chapter is to look at the technology employed for the refining of petroleum in the two markets. A comparison of refining technologies is important to the determination of cost because of the joint-product nature of the industry. As we noted in Chapter 1, the appropriate technology is crucial in maximizing the value of output by efficiently deriving a product slate in proportions to that demanded.

In Chapter 3 we discussed the role of both cost and demand as determinant of the size of the margin. Under the assumption that marginal costs are constant, the price-cost margin is an unbiased estimate of the Lerner Index. One reason to examine capacity is to establish in what way the results of the analysis are compromised if the assumption of constant costs are not upheld. A second reason is that capacity utilization continues to play a role in interpreting differences in the price-cost margin when it is employed as a measure of profitability. In the latter case, capacity utilization is expected to play a more critical role in a capital intensive-industry because of the steep slope it imposes on the average cost curve. In this way, differences in the rate of capacity utilization in the two markets under consideration could impact on the profitability of the industry.

This section begins with a brief discussion of the concept of "capacity" and various measurement options. Both the choice of capacity measure and the data are discussed. This section ends with a discussion of the trends in capacity utilization and their implications with respect to the estimated price-cost margins. The discussion then turns to the technologies employed in the respective market with the hope that some conclusions can be drawn with respect to the relative "appropriateness" of technologies employed in the two markets which will ultimately be reflected in the industry cost curve.

Concepts of Capacity Utilization

Capacity utilization is a prominent analytical variable in several areas of economic analysis including business cycle theory, productivity studies, inflation, and strategic behaviour in oligopolistic markets[43]. Similarly, the use of published capacity utilization rates have at times been employed in industry cross-section studies[44] as a determinant of the price-cost margin but rarely, if ever, is the relationship between the theoretical concept and the empirical measure articulated. In spite of frequent references to the subject, there is little discussion regarding the precise theoretical

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[43] For a discussion of excess capacity as an entry barrier see von Unger-Sternberg (1988) and Lieberman (1987).

[44] See for example Sahawney & Sahawney (1973).

meaning of the term and there is no general consensus on either its definition or proper measurement. Four different conceptual measures of capacity appear in the literature: two economic measures of capacity utilization, measures of *capital* utilization including an engineering definition, and a kind of hybrid generated from business surveys.

Two related terms frequently accompany discussions surrounding industry capacity utilization: excess capacity and the rate capacity utilization. In the most general sense, capacity refers to the level of output that a unit of production is capable of producing. In the short-run, capacity is conditioned by the existence of fixed factors of production which impose a ceiling on the level of output. Capacity utilization, then, simply refers to the full utilization of these fixed factors. The proportion between the actual level of output and the capacity level of output is referred to as the rate of capacity utilization. "Excess capacity" simply describes the condition where capacity utilization is less than full capacity; consequently some proportion of the potential productive capacity sits idle. For example, if the potential capacity of a plant is denoted by Q^{pot}, then capacity utilization at any time is calculated as the ratio of actual output to potential output, or Q/Q^{pot}, where Q is the actual level of output[45].

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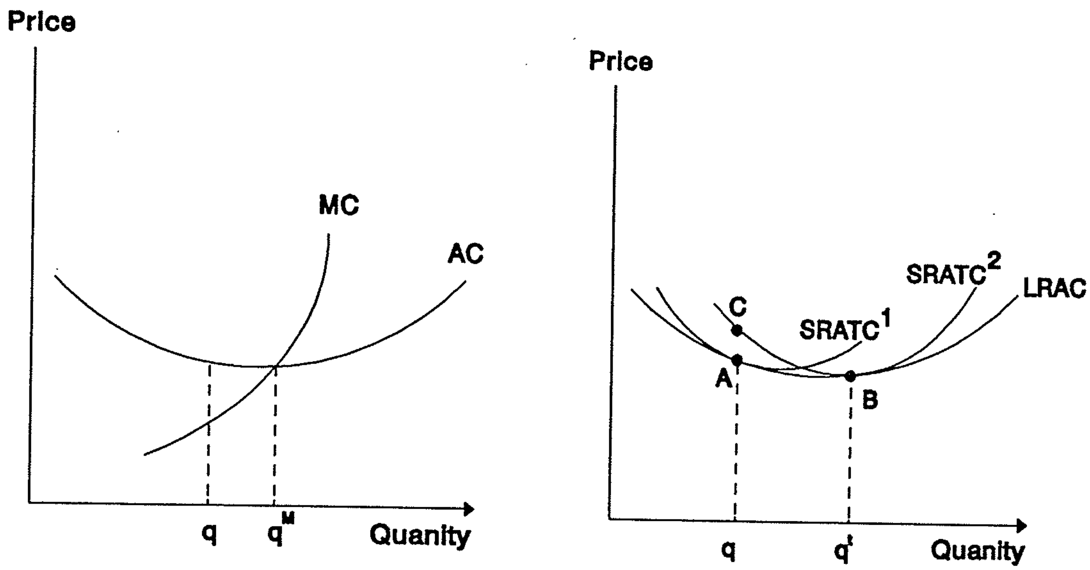
[45] The concept of capacity has a very different meaning in a long-run context. In the long-run there are no fixed factors, and the term "excess capacity" refers to the idle capacity of all factors employed in an industry (Cassels (1937).

Two economic interpretations of capacity appear in the literature. The first was originally put forward by Cassels (1937) who argued that full capacity is best defined as the output level associated with competitive equilibrium in the short-run, given by the minimum of the short-run average total cost curve. This is depicted in panel A of Figure 1, where capacity is denoted Q_m and actual output Q. Capacity utilization is given by Q/Q_m. This interpretation of capacity is attractive because in the long-run it coincides with the welfare theoretic notion of optimal output, where atomistic firms possessing identical cost curves earn zero economic profits. At this equilibrium position, price is equated with marginal cost, which is identical to average total cost. In other words, the equilibrium price is that price which is consistent with the low point of each firms's long-run average total cost curve. In a perfectly competitive environment the profit maximizing rule drives the equilibrium price to the lowest point on the average cost curve because, by definition, firms face an infinitely elastic (horizontal) demand curve. The case is different in non-competitive environments, but discussion of this is deferred for the moment.

An alternative economic interpretation of capacity was suggested by Klein who defined capacity as that point at which the short-run average total cost curve is tangent to the long-run average total cost curve. The significance of this is that at these points of tangency, the firm is in long-run equilibrium with respect to its use of capital. In the short-run, the rate of capacity utilization is calculated in reference to the tangency point of the relevant SRATC to the LRATC. Determining which short-

ECONOMIC MEASURES OF CAPACITY UTILIZATION



1. Minimize SR AC

panel a

2. Tangency of SRATC & LRAC

panel b

Figure 19

run cost curve the industry occupies is crucial to the exercise. For example in panel 'b' of Figure 19, a firm producing at point 'C' along SRATC^2 is not in long-run equilibrium. The relevant measure of capacity for this firm is at the level of output q^t, where the long-run and short-run cost curves are tangent (point B on SRATC^2). The rate of capacity utilization for the firm operating at point **C** is given by q/q^t. By contrast point **A**, which reflects the same level of output as point **C**, is actually a point on a different costs curve - SRATC^1. Point **C** then, is a level of capacity output associated with a different (and higher) equilibrium level of capital associated with SRATC^2.

Notice that because of the U-shape of the LRATC curve as it is generally drawn, the point of tangency for the short-run cost curves to the left of the minimum point of the long run average costs curve will be to the left of the minimum point on the short-run average cost curve. In other words, to the left of the long-run minimum average cost, capacity in the short-run is not identical to minimum average cost (as in position A above) and therefore differs from the measure advanced by Cassels. The converse is true for short-run costs curves to the right of the long-run minimum. The difference in magnitude between the two measures is largely a function of the shapes of the long- and short-run cost curves. If the short-run cost curves are very steep, as is generally considered to be the case in highly capital-intensive industries, the divergence in the two measures will be minimal. The converse is true with respect to the steepness of the long-run average cost curve. At the extreme where returns to scale are constant, the points of tangency are always at the minimum of the SRATC curve, and thus the measure advocated by Klein is identical to that proposed by Cassels.

The economic concepts of capacity output outlined above have rarely been studied empirically, primarily because of the conceptual and computational difficulties (Berndt & Morrison: 1981). A draw-back to employing economic concepts of capacity is that they require the estimation of a cost function which, among other things, requires an economic valuation of the capital stock - a task which can be approached in a number of different ways (Cassels: 1937). Even assuming that the capital measure can be adequately addressed, consideration must also be given to the effect that changes in both input prices and product prices have on capacity output (Q_*) and therefore the capacity utilization rate (Q/Q_*). Assume for example, that there is only one fixed factor - in this case the petroleum refinery. An important question to address is what impact does a change in crude price (the primary variable input) have on Q_* and therefore on Q/Q_*? Would we expect an increase in crude or some other variable input price to increase Q_* by shifting the minimum point of the short-run average cost curve to the right, or increase Q_* by a movement in the opposite direction, or to shift the average cost curve upward without any affect on Q_*? This question has been addressed by Rasche and Tatom (1977)[46] who report that if the fixed capital and the variable input are independent inputs such that long-run substitution elasticities between them are zero, then variations in variable input prices do not affect Q_*. Furthermore, they report that if the variable input and fixed input are substitutes (complements) then an increase in the price of the variable input decreases (increases) Q_*. Since crude oil and refinery capital can be considered complements, we would expect Q_* to move in the same direction as crude prices. While Rasche and Tatom provide some insights into the influence of input prices on capacity, estimation difficulties continue to limit the use of economic measures of capacity.

In contrast to economic estimates of capacity utilization, there exists a group of capacity estimates which focus on the utilization of capital. Capital utilization

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[46] An unpublished paper reported in Berndt and Morrison (1981).

estimates are derived in one of two general approaches: one is based on estimated capital-output ratios, while the other method uses engineering estimates based on surveys. With respect to the former, a number of techniques have been employed including the Wharton Trends-through-peaks method (Berndt & Morrison: 1981), and a method based on the "perpetual inventory method" which examines the historical peak values of the capital-output ratios and cumulative net investment to determine the capital stock in a given year[47].

Two engineering definitions of capacity are published. The first and simplest identifies capacity from the manufacturer's "nameplate" associated with the machinery or plant in question. Because of the learning curve associated with the establishment of new plants, later upgrading or expansion of existing plants and the declining efficiency of equipment with age, the "nameplate" estimates may often be a poor reflection of current output capabilities. For this reason, engineering capacity Q_e, is sometimes determined through a survey of plant engineers and management, who may be better positioned to estimate the plant's current physical capabilities. The estimated utilization rates, Q/Q_e, are based on a capacity defined in terms of physical quantities. In contrast to the economic interpretations discussed above, engineering estimates of capacity are, in effect, a measure of capital utilization. These engineering estimates of capacity will generally exceed those based on economic

[47] This method was employed by Statistics Canada to estimate capacity utilization rates until 1987. The details of the methodology are available in the Statistics Canada Publication 13-568.

criteria because, as Cassels pointed out:

> "...the absolute technical upper limit of the potential output from fixed factors is likely to lie far beyond the realm of practical economic operations...[48]".

The relationship between the estimated magnitude of the two economic measures and the engineering measure can be summarized as follows: In general, since the engineering measure of capacity Q_e is greater than the minimum point of the short-run average cost curve Q_m, and the minimum of the short-run average cost curve is greater (when costs are declining) than the point of tangency Q_t, it follows that $Q/Q_t > Q/Q_e$ and $Q/Q_m > Q/Q_e$ (Nelson: 1989). In words, the engineering estimate is expected to produce the lowest estimate of capacity utilization. When output is to the left of the minimum point of the long-run average cost curve, Q/Q_t will be greater than Q/Q_m.

A final and rather different measure of capacity is based on a unique business survey. The logic of this approach[49] is that the physical capacity of a plant may be a poor reflection of the economic capacity of all factors, and a firm's management may be in the best position to assess their current level of output in relation to the economic optimum. Unlike the survey discussed previously which asked managers to estimate the physical capacity of the plant, here the firm's management is asked to provide

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[48] Cassels (1937): p. 428.

[49] The capacity utilization rates generated from this approach are published by McGraw-Hill and reported in Nelson (1989). A similar method covering UK industries is employed by the Confederation of British Industry (CBI).

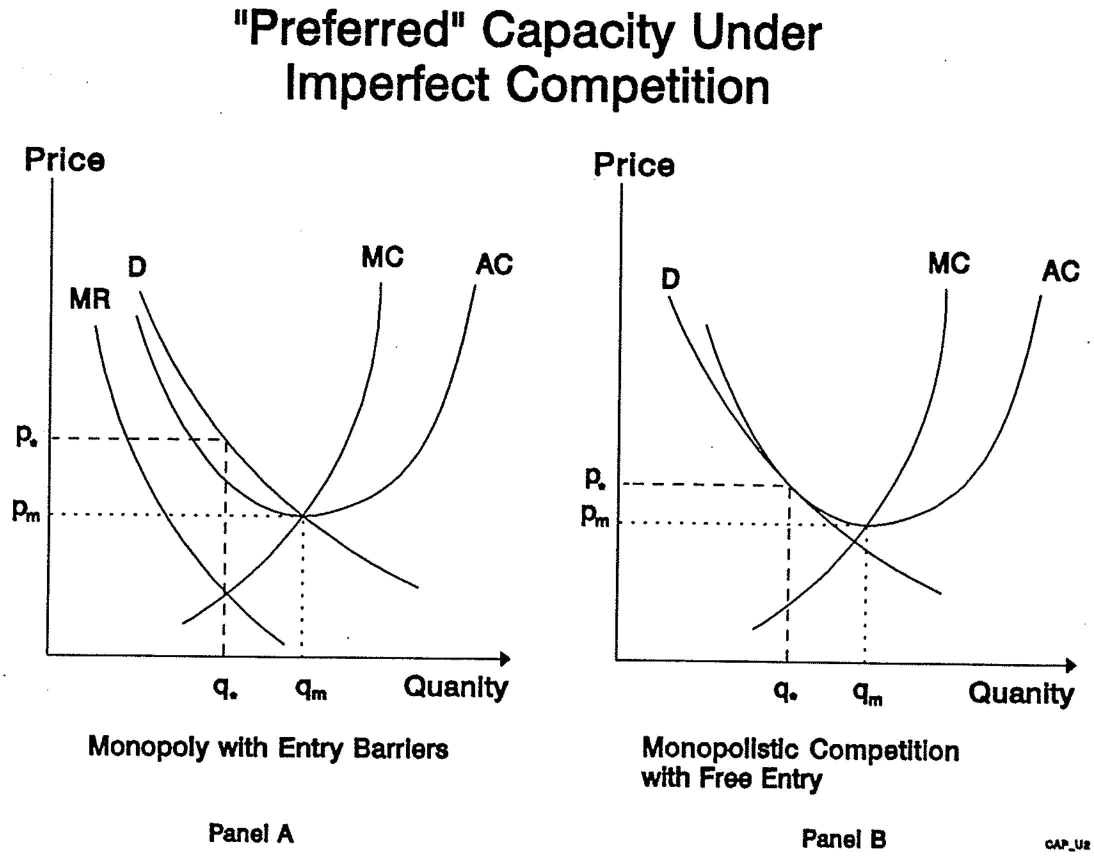

Figure 20

information regarding its current level of output, Q, in relation to the level of output it would <u>prefer</u> to be operating Q_p. The assumption being that Q_p is probably a better reflection of the economic capacity of the plant and would incorporate all factors of production in its estimation. Capacity utilization is given in this case by the ratio Q/Q_p. This index of capacity can only be considered a very rough estimate of the actual economic rate of capacity utilization in the industry. Its major advantage is that the data is readily available, and unlike the economic estimates of capacity does not depend on derived estimates of capacity (Harris & Taylor 1985).

However, the survey method may not be appropriate for all applications. Recall that from a welfare theoretic point of view, capacity is defined as the minimum point on the long-run average cost curve. In a competitive environment, firms face a horizontal demand curve and are therefore compelled to produce at this level of output. In all other market structures, where competition is imperfect, each firm possesses some degree of monopoly power which is reflected in the firm's downward sloping demand curve. A consequence of this is that the equilibrium level of output will fall short of the minimum point on the average total cost curve. This condition of "excess capacity" which is commonly associated with imperfectly competitive market structures, is depicted in panel A of Figure 20, where for the moment we assume the existence of entry barriers. The level of capacity output denoted Q_m is the equilibrium position for a firm in a competitive industry. A firm with some degree of monopoly power will maximize profit by setting price equal to marginal revenue. In the presence of entry barriers, per unit cost will not be minimized at equilibrium. In panel A this is given by Q_*, where output falls short of Q_m and average cost is higher. The excess capacity from a welfare theoretic point of view is given Q_*/Q_m.

Notice that the firm in panel B earns real economic profit which, on a per-unit basis, is given by the vertical distance between the average cost curve and the demand curve above it. In the presence of entry barriers, these economic profits could persist even in the long-run. But even where market entry is uninhibited, equilibrium output will settle at a level of output to the left of the minimum point on the average cost curve.

Suppose, for example, that panel B of Figure 2 represents the same industry in panel A except that at some point the entry barriers were somehow eliminated. Given free entry and the existence of real profits as depicted in panel A, firms will enter the market and add to industry capacity. The additions to capacity are reflected in an inward shift of the demand curve of each firm. This process will continue until real profits are driven to zero, which is given by the point of tangency between the average costs curve and the demand curve. But because of the downward sloping demand curve, this equilibrium output (given by Q_* in panel B) is not the same at the cost minimizing point Q_m. Again excess capacity persists, even in the long-run.

We can now see that the persistence of excess capacity has implications with respect to the survey method of determining rates of capacity utilization. Normally we may want to know the extent to which the level of output at which firms are producing at a given point in time diverges from the economic optimum. However the survey procedure in question would determine the level of output in relation to the level of output the firm would **prefer** to operate at. Hence, for the two cases in panel A, the survey results would determine that the firms were operating at full capacity, given that in both cases the preferred level of utilization is given by Q_*.

Summary of Concepts

In this section three methods of measuring capacity were examined. The common element in these measures is that the concepts of capacity and capacity utilization are short-run in nature, and conditional on the firms' stock of fixed factors. The economic concepts of capacity are based on the theory of the firm, and recognize that potential output is conditioned not only on physical constraints but also on broader economic circumstances. The second group of measures differ from the first in that they are really measures of capital utilization, and of these the simplest measure is an engineering measure based on the manufacturers' nameplate. A third measure mentioned involved surveying preferred operating rates which is intended to be an approximation to an economic measure of capacity utilization. Where the engineering methods tend to overstate economic capacity, this latter method would tend to understate it. In general, the estimated level of capacity (and consequently capacity utilization) will differ, depending on which method is employed. It follows that a source of bias is introduced into a comparative industry analysis if a particular capacity measure is not used consistently. Furthermore, the various measures of capital utilization will provide biased estimates of economic capacity. However the bias will be consistent provided that the shape of the relevant demand and cost curves are similar.

Refining Capacity Utilization: 1970-1992

The foregoing discussion suggests that the preferred approach to comparing capacity and capacity utilization rates is to consistently employ an economic measure of capacity across the two markets. Unfortunately, an economic measure which covers the time period in question does not exist. In Canada, a number of estimates have been employed at various times. For example, the Department of Industry, Trade and Commerce produced an index of capacity utilization of goods-producing industries using the Wharton trend-through-peak procedure, and until 1987, Statistics Canada used an alternate approach based on the capital output ratio of each industry to derive a measure of capacity which was defined as "the maximum output attainable under normal technological and market conditions"[50]. The Bank of Canada uses a similar method but adjusts the capital-output ratio to reflect changes in productivity. Statistics Canada has since revised their estimation procedure so significantly that the comparability of the two measures is questionable[51]. In the U.S., McGraw-Hill publishes estimates of capacity utilization based on the "preferred rate of utilization" method, and the Federal Reserve estimates capacity using a method similar to that employed by Statistics Canada until 1987.

The most readily available and comparable measures of capacity utilization for the refining industry of the two countries are those published by The Energy Division of

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[50] Statistics Canada publication #13-568, *Industrial Utilization Rates in Canadian Manufacturing by Quarters*.

[51] The new methodology has three main elements: the use of the Hodrick-Prescott non-linear filter for estimating trends in capital productivity, surveyed estimates of capacity utilization, and sectoral indicators of "market tightness". The procedure is discussed briefly in Statistics Canada Publication #31-003 Vol. 19, No. 1.

Natural Resources Canada[52] (NRC), and the U.S Energy Information Administration (E.I.A.). In both cases, the measures of capacity are based on survey results in which refiners are asked to report on the maximum output potential of the refinery. In the U.S., the survey estimate of operable capacity is based on the "maximum number of barrels of input that can be processed in a 24 hour period[53]", where operable capacity is the sum of the operating capacity (that capacity which is currently in operation) and idle capacity (capacity capable of being placed in operation within 30 days). The survey estimate of plant capacity is combined with the actual levels of refinery throughput to estimate capacity utilization.

The estimation procedure employed by NRC is virtually identical to that of the E.I.A., at least for the post-1983 period. Previous to 1983, refinery capacity was determined solely on the basis of the manufacturers nameplate, with actual utilization determined through crude runs reported in a survey conducted by the National Energy Board[54]. However in the upstream sector of the oil industry, events after 1973 set off a period of rapid changes in the refining sector including plant upgrades, expansions to existing facilities and closures of some older plants. Many of these events are not captured in nameplate capacities. The (then called) Department of Energy, Mines and Resources (EMR) eventually revised their estimation procedures

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[52] Formerly Energy, Mines and Resources.

[53] E.I.A. Survey EIA-S10, p. 3.

[54] NEB #153 Crude Report.

by estimating plant capacity through an industry survey procedure similar to that of the EIA[55]. The similarity of the two estimates from a conceptual and empirical perspective suggests a minimum of distortion between the estimated rates of capacity utilization in the two markets.

Refining Capacity

Figure 21 plots the capacity utilization rates for Canadian and U.S. refiners beginning in 1970 and extending to 1990 for Canada and 1992 for the U.S. The demand for petroleum products slackened considerably after the 1973 oil crisis and capacity utilization rates began a period of decline which continued until the post-recession period of the early eighties. The declines in CU rates were exacerbated by the fact that in the 1960's investment decisions were based on the growth of that period (and reflected in the "tight" capacity up to 1970), but these decisions did not result in new capacity coming on stream until after the 1973 embargo (Jones: 1988). The combined effect of constrained demand in the face of substantial additions to capacity led to considerable reductions in refinery utilization rates. At first sight, it appears that the U.S. and Canadian rates of capacity utilization are largely similar. For 13 of the 22 observations up to and including 1990, the difference between the reported rates of capacity utilization in the two countries is within a range of only 1% to 3%.

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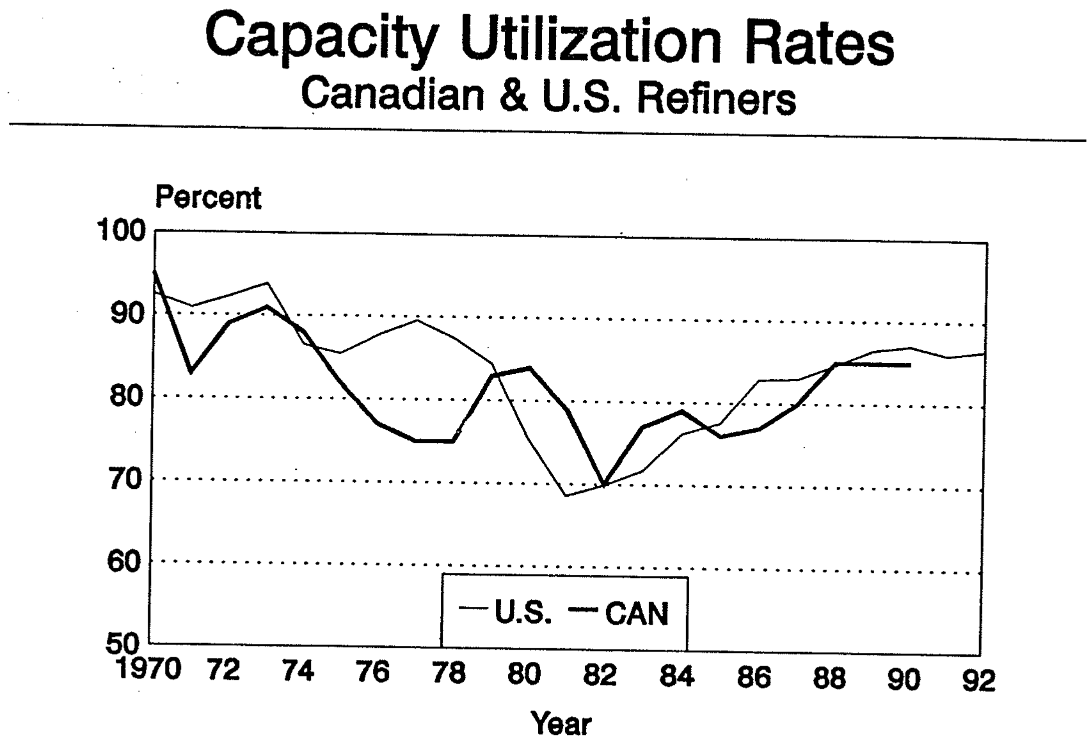
[55] Discussion with Natural Resources officials (July, 1994).



Source: Can: CPA: Statistical Handbook 1989; Petroleum Processing in Canada (1990). U.S.: E.I.A. 1992 Annual Energy Review.

Figure 21

Yet between 1974 and 1978, when the CU rate in the U.S. remained fairy stable within a range of 86%-89%, Canadian CU rates fluctuated from a high of 88% to a low of 75%! The roughly 5 percent drop in Canadian crude throughput between 1974 and 1976 does not adequately explain this. In fact the erratic behaviour of the Canadian trend and the associated wide divergence from U.S. rates - sometimes by as much as 12% - can be explained largely as the combined result of the relatively small size of the Canadian market in relation to the capacity of a typical plant, and the method employed to measure refinery capacity in Canada in the pre-1983 period. Thus, for example, the dramatic decline in Canada's refining CU rate over this period can be largely explained by the introduction of considerable refining capacity in the period 1973-1978 including the fateful Come-by-Chance refinery. Between 1973 and 1975 this refinery gradually introduced a nameplate capacity of 100,000 barrels/day to Canadian crude capacity (EMR: 1987). The plant's hydro-cracking and hydro-fining facilities commenced operation in 1975, and was for the most part shutdown in 1976 although the plant held capacity "on the books" until 1979. In such a short period of operation, the plant probably lacked the time to climb the necessary learning curve to a point where the plant should approach a reasonable rate of utilization. This last point probably applies to the introduction of the Imperial Toronto plant (1975), the Petrosar plant (1977), the expansion of Suncor (1977), and the introduction of Texaco's Toronto plant (1978). The significance of this rapid appearance of nameplate capacity - whose rate of utilization ranged from near zero to probably well under a reasonable rate of capacity[56] - is easily understood given that over the 1973-78 period this small handful of refineries introduced net additions to nameplate capacity representing about 20% of total Canadian capacity in 1978. A similarly rapid expansion of nameplate capacity is associated with the brief dip in the apparent Canadian CU in 1971.

With the exception of these two brief periods, where estimates of capacity in Canada are particularly questionable, Canadian and U.S. refineries have operated at levels of

[56] The apparent consensus suggests that a CU rate of about 85% is sustainable and reasonable.

capacity utilization which do not differ markedly. It seems reasonable to suggest that if the survey of Canadian capacity throughout this period were based not on nameplate capacity but on "operable capacity" as defined by the E.I.A., the reported capacities would have been considerably lower and actual capacity utilization in Canada would therefore be much closer to the U.S. figures.

Refining Technology

The individual products represented in the output slate of a refinery are joint products, which makes it impossible to speak of costs associated with the production of any single product. The profitability of refining a barrel of crude can only be assessed by subtracting total costs from total receipts (Adelman: 1972). Total receipts are in turn determined by the composition of the product slate and the corresponding value-added associated with each product. If the refining technology employed in the industry were completely rigid, then the proportions of the various products produced would be fixed for a given type of crude input. Since relative product prices are subject to change, the margin would be closely linked to the technology employed. Although now-obsolete refineries were not entirely rigid, they didn't have near the flexibility found in today's technology. The flexibility of modern refineries reflects the changing demand patterns which arose in response to the higher crude prices which followed after 1973. The decline in the demand for fuel oil drove refiners to install technologies which could convert fuel oil, which was almost continuously experiencing declining demand, into lighter products. The ability of the industry to meet the rapidly changing market demand of that period will ultimately be reflected in the price-cost margin. This raises the question as to how well refiners adapted to the changes in demand and whether there were significant differences in the two countries. Given the often made assumption that Canada is slow to adopt new technologies, the concern here is that the rate of diffusion of new technologies among Canadian refiners could have been slower than that of their American counterparts[57]. If this was the case, Canada's costs would be relatively higher and the margin correspondingly lower.

The evolution of technology in the refining industry has gone through two phases. The initial phase was concerned with processing technologies: extracting the desired proportion of finished products from a crude barrel at lowest cost. During most of the post WWII period, the industry has been concerned with viable ways of breaking up large hydrocarbons into smaller one and thereby gaining a proportionally larger "light" end of the barrel. While the efficient production of a high yield of light products continues to be a consideration for refiners, this has been overshadowed by the need to meet increasing environmental standards which have been gradually phased in since the early seventies. The elimination of leaded gasoline, and now the reduction of sulphur content, are two examples.

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[57] Slow in either of two senses: slow in that there is a lag in the timing of initial introduction of a technology into the markets, and slow in terms of time lapsed between the introduction of the technology and complete adoption by the industry.

The Diffusion of Innovation

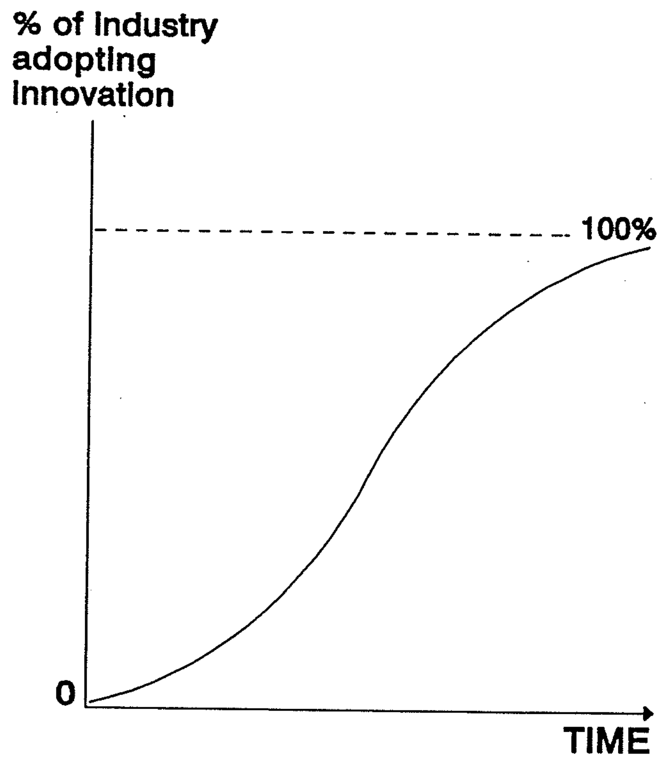

Figure 22

The decision to adopt new technologies is a strategic decision for the individual firm which involves the weighing of financial cost and risk into the equation. The rate of diffusion of a particular innovation within an industry is often viewed as having three stages. In the earliest stage a process is adopted quite slowly, perhaps because knowledge of the process is limited and the risk of adoption is considered high. After a period of gaining initial acceptance - perhaps because information costs decline and the experience of previous adopters becomes better known across the industry - innovation may spread more rapidly until finally levelling off as the market becomes "saturated". This pattern of diffusion can be pictured as a logistic (s-shaped) curve like the one depicted in Figure 21.

According to Bernardt (1970) the refining industry has historically been characterized by the rapid adoption and diffusion of new technologies, particularly in the period after the Second World War. This period of rapid change was associated with the rapid growth in the number of automobiles in North America which pulled the demand for gasoline along with it. The need to extract an increasingly larger proportion of gasoline (with an increasingly higher octane rating) from a barrel of crude was thus the principle driving force behind the rapid adoption of new technologies over this period. Bernhardt (1970) suggests a number of factors which contribute to explaining the high rate of diffusion of new technologies in refining. First, while there is always some degree of cost uncertainty associated with new technologies, the refining industry is characterized by a limited choice of process technology at any given time. Second, if changing demand conditions threaten the viability of a firm's current technology, it must choose to either adopt a new technology or withdraw from the industry. The fact that the choice in available technologies is limited at any given time may reduce the uncertainty for firms considering adopting new technologies since information becomes relative inexpensive under these conditions i.e. once a number of leading firms have adopted a narrow range of new technologies it is relative easy for their competitors to evaluate the relative merits of each.

There have been a number of studies conducted which suggest that, in general, new technologies appear to spread more slowly in Canada than in the U.S (Green: 1989, Ch. 10). But the evidence suggesting that the Canadian refining industry has been slower to adopt new technologies compared to the industry in the U.S. is mixed. For example, in the U.S., catalytic cracking quickly replaced thermal cracking as the preferred technology. Initially introduced in 1936, it represented about 42% of all U.S. cracking capacity by 1950 (Enos: 1962). By comparison, catalytic cracking did not make its debut into the Canadian industry until 1948, although once introduced it was readily adopted, and by 1952 represented 20% of total crude capacity (EMR: 1987). The trend in the adoption of catalytic reforming techniques was similar. First introduced commercially in the U.S. in 1939, catalytic reforming was still relatively unknown to U.S. refiners in 1950 (Gabel: 1979); it was introduced to Canada that same year and by 1960 represented 16% of refinery capacity (EMR: 1987).

Unfortunately, comparable data describing the proportion of total refining capacity represented by different technologies is not readily available except for the years 1970-77. This data is presented in Table 1. It would appear that with the exception of hydrocracking, most of the available downstream processes were mature and fully adopted by industry in both Canada and the U.S. Table 1 provides the capacity of selected technologies (downstream capacities) as a percentage of total refinery capacity from 1980 through 1987, the most recent period for which Canadian data is available. U.S. data on downstream capacities is not readily available for periods prior to 1980. Four major downstream capacities are listed in Table 1: thermal cracking, catalytic cracking, catalytic reforming and hydrocracking. The data reveal that, with the exception of hydrocracking, there has been no significant change in the proportion of refining capacity represented by these processes. This suggests that the major process technologies were largely established in both countries by 1980.

Table 1

NUMBER OF REFINERIES AND SELECTED DOWNSTREAM CAPACITIES: 1980-1987

PROCESS\YEAR		'80	'81	'82	'83	'84	'85	'86	'87
NUMBER OF REFINERIES	CAN	36	36	36	31	30	29	28	29
	U.S.	319	324	301	258	247	223	216	219
Thermal Cracking	CAN	2.8	2.9	2.4	2.7	2.7	2.7	2.8	2.7
	U.S.	8.8	9.5	9.6	10.0	11.8	12.0	2.5	13.0
Catalytic Cracking	CAN	21.8	21.9	21.6	21.5	21.4	21.4	21.1	20.4
	U.S.	34.1	32.4	32.9	34.4	35.5	36.2	36.9	37.3
Catalytic Reforming	CAN	17.6	18.0	18.2	19.0	19.0	19.0	19.4	19.6
	U.S.	22.7	21.3	21.9	23.2	23.2	23.9	24.4	25.0
Hydrocracking	CAN	3.7	3.1	3.1	3.5	3.6	7.2	7.6	7.4
	U.S.	5.0	5.0	5.2	5.6	6.4	7.2	7.7	7.5

Source: for Canada: Energy Mines & Resources, *Petroleum Processing in Canada*, 1987, Table 8. for U.S.: Energy Information Administration, *Petroleum Supply Annual 1992, Volume 1*, Table 40.

Hydrocracking, which is a relatively recent innovation, had become a widely accepted alternative for catalytic cracking in the U.S. by 1964 (Copp 1976) but it was only introduced into Canada that same year (EMR: 1987). It is an attractive technology to North American refiners because of its ability to convert heavier products into gasoline and other light products, and therefore offers greater flexibility in the product slate. Another attractive feature of hydrocracking is that it yields a 25% gain in volume because the resultant products are so much lighter than the feedstock (Leffler: 1985). As indicated in Table 1, refiners in both Canada and the U.S. have continued to increase their capacities using this technology. Hydrocracking is something of an exception in that by 1987, refiners in both countries shared equal downstream capacities in this technology. Other downstream capacities represent a significantly higher proportion of capacity in the U.S. compared to Canada.

More recently, the technological innovations in refining technology have focused on meeting new environmental standards as well as improving refinery operations through the introduction of process control equipment, including gasoline blending instrumentation (EMR: 1990). Environmental measures aimed at pollution control have had a direct or indirect effect on refining techniques. These regulations have led to the adoption of isomerization and alkylation processes to improve the octane number and reduce the lead content of gasoline (Drouet: 1984). Unfortunately, there is no readily available data which would allow for a systematic comparison of costs associated with environmental regulations in the two countries.

The Number of Plants and Concentration

The introduction of new processes has corresponded with the gradual reduction in the number of plants operating in both countries. In 1973 there were 268 operating refineries in the U.S. compared to 41 in Canada (not reported in Table 1). By 1980 the number of operable refineries in the U.S. had increased almost 15% to 319[58], while in Canada, there were 41 operating refineries in 1973, a number which had been stable since at least 1967. But by 1987 there were only 219 refineries operating in the U.S. and 29 operating in Canada, representing a decline of 45% and 24% respectively. With the little systematic evidence readily available, it appears that refinery rationalization continues in both countries. There were only 208 U.S. refineries operating in 1990, and by the latter half of 1992 the closure of 6 Canadian refineries (representing 18% of 1991 of Canadian capacity) left only 23 Canadian refineries operating.

The number of refineries provides only a general indication as to the degree of competitiveness in an industry. Industry concentration is an important structural variable which is intended to serve as a rough proxy measure for the degree of successful collusion within the industry. Other determinants of the margin being equal, higher concentration is associated with an enhanced ability to raise price above

[58] Whether these additions represented new capacity or were previously mothballed facilities is not known.

margin cost.

There are a number of measures of concentration proposed in the literature. These include four- eight- and twenty-firm concentration ratios, the Herfindhal Index, and marginal concentration measures (Kwoka). The measures used here are the four-firm and eight-firm concentration ratios which reflect the proportion of total industry shipments accounted for by the largest four firms (CR4) and eight firms (CR8), respectively. The CR4 is employed here because it is readily available from the statistical agencies of both countries, and for present purposes, is at least as good as the alternative measures. Table 2 shows the four firm concentration ratios for the Canadian and U.S. petroleum refining industry for selected years. Similarly, Table 3 below provides the eight-firm concentration ratio.

Table 2
4-Firm Concentration Ratio: Canada and the U.S.

YEAR MKT	'72	'75	'77	'78	'79	'82	'83	'84	'87	'88
Canada		75.4		72.3	66.5		64.6	67.9		74.5
U.S.	15		17			17			19	

Source: Canadian data is from Statistics Canada Cat. #61-210 *Capital and Labour Unions Relations Act*. U.S. data is from U.S. Dept of Commerce, *Annual Survey of Manufacturers, 6-22: Concentration Ratios in Manufacturing.*

In Table 2 and 3, the series for both Canadian and U.S. refineries are the proportion of industry sales represented by the largest four and eight firms respectively. In the U.S., production by the top four firms represents about 15-17% of industry sales.

The corresponding figures for Canada range from about 65-75%. Thus only four firms in Canada produce well over 50% of industry output.

The data in Table three indicate that almost 90% of Canadian industry output is controlled by the top eight firms, while the top eight U.S. firms control about a quarter of industry output. The differences are very large and suggest that the Canadian market is substantially more amenable to collusive pricing that its American counterpart.

Table 3
8-Firm Concentration Ratio: Canada and the U.S.

YEAR / MKT	'72	'75	'77	'78	'79	'82	'83	'84	'87	'88
Canada		88.0		89.2	88.3		88.3	91.3		90.8
U.S.	23		23			24			27	

Source: Canadian data is from Statistics Canada Cat. #61-210 *Capital and Labour Unions Relations Act*. U.S. data is from U.S. Dept of Commerce, *Annual Survey of Manufacturers, 6-22: Concentration Ratios in Manufacturing.*

Summary

In this chapter the available measures of capacity were discussed, as was the importance of using a consistent measure to compare capacity in the two markets. Fortunately, a comparable engineering measure is available for the refining industry of both Canada and the U.S. The use of an engineering estimate of capacity utilization implies that the measured rate of utilization is biased downward in both countries. Providing that the measurement bias is of the same magnitude in both cases, the measured rates of capacity utilization should be comparable.

Similar trends are observed in the rate capacity utilization of both Canadian and U.S. refineries. Both countries began the seventies with high rates of utilization, about 95% in each case. Both countries had additional capacity coming on-stream in the early to mid-seventies which collided with the contraction in demand in the wake of the 1973 oil embargo. In both countries capacity utilization rates bottomed in the early eighties and then gradually increased to the 87-88% percent range by the early nineties. The similarity in rates of utilization substantially eliminates the possibility that observed differences in the margin reflect different cost levels arising from differing rates of capacity utilization.

A few conclusions can also be drawn from the analysis of industry technology. While Canada has been slower in some cases in introducing new process technologies, once introduced, they appear to spread amongst firms at a rate comparable to their U.S. counterparts. One explanation for this pattern may be that innovations are likely introduced into larger plants first and then are later adapted to smaller facilities. As we discuss in Chapter 7, Canada's refineries are substantially smaller than those in the U.S. so that a new technology may spread through the large-sized plants in that market before finally filtering down to smaller plants in both countries. The second main conclusion is that with the limited exception of hydrocracking, the major process technologies were well established in both countries. Third, following a trend which has characterized the industry since its modern introduction, the new technologies introduced over the study period are only economical at larger plant scales and this is reflected in a significant decline in number of plants. Finally, the divergent measure of concentration between the two markets is remarkable and suggests that the Canadian market is much more amenable to collusion than the U.S. market.

7. SCALE AND CAPITAL COST

Introduction

In Chapter 3 it was shown that the price-cost margin reflects both profit and capital as a percentage of sales. Thus if we had a good estimate of the rental value of capital employed in the refining industry, we could calculate profit as a proportion of sales. Unfortunately, reliable estimates are not available so that capital cost and profitability cannot be determined directly. However some information about the relative position of the total cost curves for Canadian and U.S. refiners may be surmised from an examination of the extent of scale economies in the two markets. The chapter begins with a brief discussion of capital costs and then turns to the concept of scale economies. After a discussion of measurement issues, the available empirical evidence on the economies of plant scale are examined. The chapter closes with a discussion relating the empirical finding on scale to the observed price-cost margin.

Capital Cost

The capital referred to in a standard production function is a measure of the rental value of capital which is empirically problematic. Most theorists agree that an aggregate measure of the stock of physical assets is impossible except under extremely stringent conditions (Patterson & Schott: 1979). As an alternative, empiricists use measures of physical capital which are not value measures but volume measures. In the latter sense physical capital equipment is valued at its replacement cost and not in terms of its contribution to the value of output. In empirical work this measure is often used as a proxy for physical capital services in the production function.

Capital stock estimates are available either from company balance sheets (book value) or as the sum of investment flows (gross fixed capital stock). Because it comes from company balance sheets, book values can only be defined in terms of historic dollars. The time profile of investments may thus affect the relative book value reported for the same industry in two different countries in spite of the fact that no difference exists (Baldwin & Gorecki: 1986). In addition, since book values are collected at the company level, the book value is assigned to the industry which accounts for the largest percentage of a company's assets, so they are not an accurate reflection of the capital relating to a particular production activity (Baldwin & Gorecki: 1986). For the same reason they are not very useful in a study of integrated industries.

In contrast, capital stock series constructed from investment flows potentially suffer from neither an aggregation nor a pricing problem. Because investment activity is measured at the establishment level, investments in secondary production activities should be minimized (Baldwin & Gorecki: 1986). The accuracy of capital stock estimates depends on the validity of assumptions regarding service life, mortality functions and depreciation rates that are used in its construction. The formula for gross capital stock requires an average service life and some assumption about the rate of asset discard (the mortality function). In addition, an estimate of net stock requires the specification of a depreciation function. An additional problem is that capital stock data are not available at the four-digit level and book value is only available at the three digit level. Finally, the published fixed capital stock estimates for Canada and the U.S. do not use the same assumptions in the estimation procedure and are therefore not comparable (Baldwin & Gorecki: 1986).

Economies of Scale

Very generally, economies of scale are reductions in average cost which can be attributed to increases in the scale of production. In other words, returns to scale implies that increasing all inputs by some constant results in a more than proportionate increase in output. Scale economies which arise because fewer resources are required to produce a given output are referred to as technical economies of scale to differentiate them from pecuniary economies. The latter refers to the situation where, by growing larger, a firm is able to establish market power through which it is able to extract higher prices from its customers or pay lower prices to its suppliers (McFetridge & Weatherly: 1977).

A distinction can be drawn between product-specific, plant-specific, and multiplant economies of scale. Scherer described the reasons why there may be economies of scale relating to plant size. Plant economies of scale have a number of sources and may arise from indivisibilities in management, maintenance, repair, inventories and the construction of the plant itself (Lecraw: 1978). For many types of capital equipment both initial and operating costs increase less rapidly than capacity. For example, economies are associated with the construction of vessels and pipes like those used in refineries and pipelines because the costs associated with increased capacity increases approximately in proportion to the surface area, while the capacity of the vessel or pipe rises in proportion to its cubic capacity (Pratten: 1971). In addition, direct labour costs do not rise proportionately in many process industries because the larger scale equipment does not require proportional increases in manpower to operate it.

Scale economies may also be associated with the operation of multiple plants. A multi-plant firm may be able to lower its costs by balancing transportation costs with product and plant economies of scale (fewer plants usually imply higher transportation costs but lower production costs) (Lecraw: 1978). Firm-related economies refer to the size of the firm as opposed to the plant (or plants). Economies of scale may arise at the firm level due to increased efficiency in management, finance, information and control, R&D, marketing, advertising and distribution, export activities, risk taking, insurance and legal services. The extent of the economies of scale in any one of these activities is very much in dispute in the literature (Lecraw: 1978). One of the problems in answering these questions about firm-level economies of scale is the difficulty of measuring efficiency along any of these dimensions and then relating it to the size of the firm. Distinguishing between real and pecuniary economies of scale arises because large firms may be able to secure lower costs in advertising, capital, or legal advice through the exercise of market power in these factor markets and not because of real lower supply costs (Lecraw: 1987).

Because of conceptual and empirical complexities, there has been relatively little empirical work done in the areas of firm or multi-plant economies of scale. Relating firm size to the existence of economies of scale is problematic because a firm's size is not necessarily determined by a desire for increased efficiency. The size of a firm will be partly determined by the scope of activities a firm chooses to internalize. These activities may have strategic significance which may change along with changing market conditions. Firm size may also be sought as a means of reducing risk, security of supply, and other managerial prerogatives. Attaining larger size may also be desirable in order to garner market power over inputs or outputs. In such a way, a concentrated industry may prefer to operate on a large scale to gain monopoly profits even if technical economies of scale are not significant (Lecraw: 1978).

While there is no known research relating a refinery's firm size to scale economies, Scherer *et al* (1975) have estimated the extent of multi-plant economies of scale. In his study of multi-plant economies of scale Scherer found that in petroleum refining there were no multi-plant economies relating to market access, distribution channels, procurement of materials, or management. Multi-plant refiners do have what Scherer defined as slight-to-moderate economies in the acquisition of capital, integration into crude inputs and advertising, but overall, the adverse consequences of operating only one MES plant was deemed slight.

There is little else which can be added to the discussion of scale in terms or firm and multiplant dimensions. The bulk of empirical work relating to scale has been focused at the plant level and for technical reasons alluded to above, this is likely the source of most scale economies in petroleum refining.

Measuring Plant Scale

It is important to distinguish scale from technology improvements. Although this can be done conceptually, it is rather difficult to do so empirically. Because scale estimates are often derived from time series, the resulting estimates invariably mix the effects of both technology and scale[59]. There are three basic methods of measuring economies of scale at the plant, multi-plant or firm level: 1. econometric estimation,

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[59] The history of refining indicates that economies of scale have been largely determined by the state of technology. For example prior to the advent of cracking technology economies of scale were estimated to exist only to a rate of 88.5 U.S. barrels per day. By 1939 MES was estimated at 30,000 barrels per day (Enos, p.260), and by 1951 Bain estimated MES at about 125,000 barrels per day (Enos, p260).

2. the Survivor Technique, and 3. the Engineering Method. With respect to econometric techniques, Rao (1988) notes that industry returns to scale can be estimated through either a total cost function of a production function in combination with time-series or cross-sectional analysis on either value-added data or gross output. Rao argues that a cross-section analysis using the cost function approach is the best approach: cross-section because time series techniques make it difficult to abstract scale effects from technical progress embodied in capital over the sample period, and cost functions because of the flexible functional forms available for empirical work.

The "survivor" technique observes which scales of operations are most prevalent or alternatively, which direction the scales of new capacity (or firms) tend to take over time, and designates this to be the optimal size (Lecraw: 78). One problem with the survivor technique is that it does not say anything about cost increments associated with operating at less than MES but it is a useful starting point of investigation and serves a descriptive function. The engineering approach to scale estimation involves questionnaires designed to find the cost functions as perceived by managers or engineers of the firms. Compared to the survivor method, the engineering method more closely reflects the concept of declining average cost reflected in the long-run average cost curve (Gorecki: 1984) but it abstracts from transportation costs and the relative size of the market. In reality, increases in the scale of operation are associated in most cases by an increase in the geographic scope of the market, and therefore involve increasing transportation costs. Eventually as shipping distances increase, these transportation costs may negate the economies of scale associated with the size of the plant.

There are two aspects of scale economies which are of interest. The first is the minimum efficient scale (MES), and the second is the unit cost increment incurred by operating a plant at less than efficient size. These two pieces of information, together with a profile of the industry, allow us to make some judgement about the effects of scale on the observed margin differential (Gorecki: 1986). MES is that point on the LRC curve where increases in volume do not lead to significant cost decreases. In general MES is a function of the relative cost of inputs, and in many cases is country-specific. Where there is scope for substitution between capital and labour, MES will decrease as labour costs decrease relative to capital because the former will be substituted for the latter. Because the elasticity of substitution between capital and labour is virtually zero in refining (Copp: 1976), plant MES is determined by technical considerations. This technical determination implies that MES is determined independently of relative factor prices which is convenient empirically because the benchmark MES will be consistent across two markets even if factor costs are different in the two markets (Lecraw: 1978).

Empirical Evidence on Scale

The available evidence strongly suggests that refining is subject to substantial economies of scale at the plant level[60]. A number of estimates of scale have been derived from engineering methods. In the U.S. Scherer[61] found that refinery MES[62] was 1.9% of the U.S. market (i.e. the output of one MES plant would represent 1.9% of total demand). In Canada, Eastman and Stykolt estimated the efficiency of Canadian plants in 1959. They estimated that the output of one MES plant in Canada could meet 16.7% of demand. From this they estimated that the number of plants of MES which were compatible with the Canadian market was 7 although there were actually 40 operating refineries that year (Lecraw: 78).

Gorecki (1976) conducted a similar exercise, comparing the number of MES plants compatible with domestic consumption around 1968 with the actual number of plants in 1967. He estimated the number of MES refineries consistent with domestic consumption at 6.0 when the actual number was 41.

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[60] The bulk of the evidence derives from engineering techniques or the survivor method but Shoesmith (1988) used econometric techniques and estimated optimal capacity at about 300,000 b/day.

[61] Reported in Sheperd (1985).

[62] In some industries including petroleum refining, unit costs may fall even beyond the size of the largest modern plant. MES is then defined as that scale beyond which unit costs are expected to fall by less than a small (arbitrary) amount.

One way to evaluate the extent of sub-optimal scale is to examine the average size of the largest plants in the industry which account for half the industry as a ratio of MES. Using this technique, Scherer (1975) estimated that in the U.S. the ratio was 97 (i.e., these plants were 97% the size of MES) whereas in Canada the ratio was only 38. Another way to evaluate scale is to look at employment figures. Scherer (1975) took the average number of employees in the largest twenty plants as a point of comparison. Setting a scale of US=100, Canadian refiners ranked 17, suggesting a scale size 1/5 the size.

The evidence clearly indicates that Canadian and U.S. refiners operate at different scales. The more important question though, is the extent to which scale affects cost. A few estimates are available. Pratten (1971) defined MES as that point where a subsequent doubling of scale would reduce total average unit cost by less than 5 percent. Using an engineering approach and obtaining estimates of costs for new refineries of varying size. His results are reproduced in Table 12 below. These estimates suggest that economies would tail off at around 200,000 barrel per day. Thus a firm operating at 50% of MES would incur a plant cost disadvantage of 27% and a total per unit cost increase of 5%. The general magnitude of these estimates are supported by other research as well. Gorecki (1976) for example, estimated that refineries operating at one-third MES faced 4.8% higher unit costs. In term of capital costs alone Molle (1984) estimates that the ratio of increase for capital outlays to increases in capacity is for most processes in the order of 0.7.

Table 12
Cost and Scale for New General Purpose Refinery circa 1970[1]

Crude Capacity[2]	Refinery Cost/Barrel	Ex-Refinery Cost/Barrel
20,000	100	100
41,000	75	92
102,000	56	86
204,000	44	82
400,000	40	81

1. Adapted from Pratten (1971)
2. Converted from metric tonnes and rounded to thousands.

Summary

As discussed in Chapter three, knowledge of capital cost is required to facilitate the price-cost margin as a measure of profitability, but the relationship between the theoretical concept of capital and the empirical estimates is suspect at the best of times. The estimation problem is further complicated by the fact that capital estimation procedure followed in Canada differ from that used in the U.S. In the absence of direct estimates of capital cost, the subject of capital costs was approached by examining the extent of scale economies. The evidence, based on various estimation methods, suggests that there are substantial economies of scale in the refining industry, although it must be recalled that these estimates do not account for transportation costs associated with larger plant size. Engineering methods tend to suggest most economies of scale are exhausted at around 200,000 b/day, while

Shoesmith's (1988) econometric estimation estimated optimal capacity at 300,000 b/day. The U.S. industry exploits these economies of plant scale to a considerably greater degree than the Canadian industry[63]. That suggests, all things being equal, that the U.S. industry should be more profitable than its Canadian counterpart, although as we noted in the previous discussion of technology Canadian refineries utilize cracking capacity to a lesser degree.

[63] At least in part because in Canada the benefits of large scale weigh against increasing transport costs. At some point the increasing transport cost overtakes the lower average cost associated with increased scale.

8. SYNTHESIS AND CONCLUSION

The principle objective of this research was to evaluate and draw conclusions on the relative performance of the Canadian and U.S. refining industries. The performance measure utilized was the price-cost margin, which is a proxy to the Lerner index and which "contains" information on industry profitability. The Lerner index measures the ability of the industry to command prices in excess of marginal cost. Chapter one highlighted the evolution of the industry prior to 1973, and described how access to cheap crude, combined with the prevalence of large vertically-integrated firms, meant that the integrated's profitability was determined by the volume of crude lifted and processed. The rules changed when crude reserves were patriated by host countries throughout the Middle East, and the downstream operations - now an important profitability determinant for the integrated firms - underwent a period of adjustment.

Chapter two examined the degree in which the two markets were conceptually "separable". There are two elements which act in tandem to define a market - the product, in particular the degree to which substitution is a factor, and transaction costs. The analysis suggested that given the nature of petroleum products, in the short-run there was virtually no substitution available on the supply-side and only a very limited potential for substitution on the demand-side. With respect to the geographic size of the market, transaction costs are the predominant factor in most cases. The Elzinga-Hogarty test results supported the proposition that the two markets are independent, although no attempt was made to determine the extent of regional markets operating within the two national markets. The existence of regional markets would suggest a degree of market concentration higher than that calculated at the national level. Furthermore, if the degree of competitiveness differed in these sub-markets, the price-cost margin calculated at the national level may conceal the existence of different margins across sub-markets.

The theory behind the price-cost margin was discussed in Chapter three where it was shown that the price-cost margin is a good proxy to the Lerner index, assuming that marginal cost was constant and therefore equal to average variable cost. The various determinants of the margin were then discussed, including demand growth (and the related impact of capacity and capacity utilization), price elasticity, and cost determinants such as capital intensity, economies of scale, technology, and x-inefficiency. These factors were then examined in turn in subsequent chapters.

Chapter four dealt with the empirical calculation of the Canadian and U.S. price-cost margin and concluded that the observed margin in the two countries was of a similar order of magnitude. Chapter five compared the demand characteristics of the two markets. Given the similarities between Canada and the United States in terms of the relative cost of energy, and both the geography and the composition of the industry, it is not surprising that demand characteristics were found to be similar as well. The analysis found that with some variations, the same pattern of demand growth for various petroleum products was experienced in both countries. The price elasticities for selected products were compared in the two markets and were found to be largely similar. But while the demand growth and demand elasticities for various products are largely similar in the two markets, the U.S. product slate is composed of a higher proportion of high-valued light products. Because these light products are price-inelastic, we would expect that the U.S. price-cost margin would be higher than that in Canada, other things being equal.

Chapter six examined capacity utilization and the capacities relating to some selected technologies. The analysis suggests that the industry in both markets experienced similar rates of capacity utilization so that, assuming the shape of the supply curve is similar, the effect of changing demand would impact the price-cost margin in a comparable way. With respect to the technology employed in the two markets, the Canadian industry was found be somewhat slower in introducing new technologies, but once a new technology is introduced, the rate of diffusion appears comparable to that in the U.S. In addition, the Canadian industry was found to have proportionately smaller cracking capabilities which reflects the fact that less gasoline is extracted from a barrel of crude.

Industry concentration was examined through a comparison of the four- and eight-firm concentration ratios. The Canadian market was found to be significantly more concentrated than that of the U.S. The number of refineries has been declining in both markets. But there are far fewer refineries operating in Canada and therefore the market is more concentrated than the U.S. market. All things being equal, the higher industry concentration in Canada is expected to facilitate collusion to a greater degree than in the U.S. market. This in turn should be reflected in a higher price-cost margin.

Chapter eight discussed capital costs and economies of scale. An analysis of capital costs is interesting because it would facilitate the use of the price-cost margin as a measure of profitability. However the relationship between the theoretical concept of capital and the empirical estimates is weak. The estimation problem is further complicated by the fact that capital estimation procedures followed in Canada differ from those used in the U.S. Because direct estimates of capital cost are not available, the subject was analyzed indirectly by examining the extent of scale economies. When we abstract from transportation cost, the evidence suggests that there are substantial economies of scale available to the refining industry. Furthermore, the evidence suggests that the because of the much greater size of the market, the U.S. industry exploits these economies of plant scale to a greater degree than the Canadian industry. However because the U.S. cracking capacity is greater than in Canada, we can only tentatively conclude that that the U.S. industry is more profitable.

The evidence examined can be summarized as follows: The two markets share the same marginal cost curve (MC), given that the price of crude, whose price is determined on global markets, will not differ significantly. Given that demand growth and demand elasticities are similar in the two markets, the lower proportion of high-value light products represented in the Canadian product slate suggests that the margin derived from a barrel of crude would be smaller in Canada. But to the contrary, the Canadian margin was found to be similar to that of the U.S. The evidence suggests that the higher-than-expected Canadian margin is consistent with the observed level of concentration of the industry in that market. The relatively high concentration of the Canadian industry facilitates collusion to a greater degree than the U.S. market. Because the computation of the price-cost margin used here does not address fixed costs, this finding does not necessarily imply that Canadian refiner profitability per se is higher. The evidence suggests that plant economies of scale are exploited to a higher degree in the U.S. market, although given the different cracking capacities in the two markets only tentative conclusions were drawn regarding the magnitude of this impact on per unit capital costs.

The price-cost margin has been a tool of analysis in much empirical work over the past few decades, largely in industry cross-section studies. Because it is poorly suited for cross-section studies, much of this work has been criticised. An industry time-series study such as the present one has a number of advantages over cross-section studies, particularly with respect to the treatment of industry demand. In industry cross-section studies, the implicit assumption is that all industries face the same demand elasticity. This assumption is also made in most industry studies, but with considerably greater confidence. A unique element to the present research was in the integration of an explicit treatment of demand characteristics into the analysis. The analysis suggests that the price-cost margin can yield valuable insights to which we can ascribe greater confidence when the relevant variables are accounted for in the analysis.

The analysis has a number of weaknesses as well. First, the treatment of capital cost is weak, although the problem may be intractable. Second, the geographic element of the markets may have been defined too broadly. Both markets probably have regional sub-markets and the aggregate (national) measure of the price-cost margin may conceal low margins in relatively competitive regions and higher margins in more isolated regions. This suggests a study at the regional level as the next logical step, although such a study must be approached with a somewhat different margin calculation[64]. There are other areas to direct future research as well, some of which would require little additional data collection. One possibility would be to model and estimate the interaction of demand growth and capacity utilization as determinants of the margin, the basic hypotheses being that in industries characterized by high sunk costs, the ability to collude is very sensitive to the presence of excess capacity (Kwoka: 1990). A second tack for future research would be to examine more formally the collusive behaviour inferred from this analysis. One could use a model similar to that employed by Dickson (1982), for example, to examine the nature of

[64] Revenue data from Statistics Canada are only available at the national level.

collusion through econometric estimation. Finally, the impact of concentration on the speed of price adjustment could be examined. Much of the work in this area has been conducted within the traditional industry cross-section study and suffers the usual criticisms as a result.

As a final general comment, the paucity of reliable estimates of demand for most industries, combined with the difficulties in comparing demand in monopolistically competitive markets, suggests that the use of the price-cost margin in this context may not have wide applicability.

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