Developing Canada's Arctic Oil Reserves: An Assessment of the Interregional Economic Implications

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Assessing the Interregional Economic Implications of Developing Canada's Arctic Oil Reserves: A Dynamic Multiregional Input-Output Approach

By

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A Thesis

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Dedicated to the memory of Mrs. Anna Marie DiFrancesco, my Crandmother. R.J.D.

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ABSTRACT

This dissertation combines published Canadian Provincial and Territorial Input-Output (I-O) data with unpublished expert information to mobilize a Dynamic Multiregional Input-Output Model (MRIO) of the Canadian economy. Specifically, the model is used to assess the interregional economic implications of developing the proven oil potential of the Mackenzie Delta and Beaufort Sea regions of Canada's Northwest Territories (NWT).

The model developed in this dissertation represents a hybrid created by merging the desirable features of the long proven MRIO approach pioneered by Chenery (1953), Moses (1955), and Polenske (1980) with those of the reformulated Dynamic I-O approach espoused by Duchin and Szyld (1985). This hybrid model explicitly accounts for the interdependence between regions, as well as the fact that certain investment plans will result in capacity exceedence in various sectors in the NWT.

Three scenarios of Arctic Oil development are evaluated, and detailed capital investment time-lines provided by the authors of these scenarios (Croasdale and McDougall, 1992) are used to provide the investment and expansion information needed to drive the model.

The dynamic MRIO model is applied to each scenario, and the interregional economic impacts associated with the construction phase for each are assessed.

The results suggest that in all scenarios, as expected, the NWT experiences the largest total impacts, followed by Ontario and Quebec (central region), and Alberta and British Columbia (western region). The effects captured by the NWT are largely direct, while the effects captured by the remaining regions include significant indirect and induced effects. The analysis also illuminated a key structural difference between the economies of the western and central regions; the manufacturing sector of the former exhibited a definite resource processing focus, while in the case of the latter, the manufacturing sector appeared more diverse and mature.

The results also highlight a fact that characterizes the NWTs' experience with large scale resource projects in the past; that is, pipeline construction activities in the NWT are found to have the largest effect on the magnitude of the economic benefit captured by the NWT. Construction activities, by definition, are one of the few economic activities required in each of the scenarios which is satisfied entirely by NWT production.

The fact that the total impact in the NWT, across all scenarios, accounted for approximately 40% of the total output in the NWT (in 1984), combined with the fact that this region is characterized as a staple economy, suggests that a resurgence of oil and gas activity in the Beaufort Sea could lead to another boombust cycle of economic growth and decline in the NWT. Ongoing geopolitical change (e.g., negotiations on a Northern Accord and Comprehensive Land Claim

Settlements), could act to shield this region from such a cycle to some extent, and allow the region to derive some long-term economic benefit from its resource endowment.

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Chapter 1

Introduction

1.0 Context

Canada's status as one of the wealthiest nations of the world is due, in large part, to its large and diverse natural resource endowment. In fact, the current configuration of regional economic specialization in Canada is reflective of the natural resource strengths of Canada's various Provinces and Territories. Not surprisingly, this resource base has allowed Canada to maintain a favourable trade balance in terms of primary materials, while at the same time allowing Canada to be relatively self-sufficient with regard to hydrocarbon based energy. Canada derives approximately 60 percent of its total energy requirement from oil and natural gas, and even though trends are slowly shifting toward more sustainable forms of energy, the immediate future for Canada is one of increasing usage of hydrocarbon based energy, in absolute terms (Croasdale and McDougall, 1992; NEB, 1994). Since the mid 1980s, the oil and gas reserves of the West Coast Sedimentary Basin (WCSB) which underlies all of the producing horizons in Alberta and British Columbia have been in a state of decline. In fact, the NEB (1994) suggests that over 70% of the proven and potential reserves in the

WCSB have been produced, and Croasdale and McDougall (1992) indicate that less than 5 percent of the production from this reservoir in the 1980s was replaced by reserve additions. In fact, at the present rate of depletion, the main producing horizon in Alberta has been estimated to have approximately 1 decade of production remaining before it is either abandoned or enhanced recovery schemes are implemented (Dingwall, 1990; Bone, 1992; Croasdale and McDougall, 1992). This bleak outlook for Canada's primary energy source was compounded by the realization that if all of Canada's requisite oil and gas were to be imported, the price tag would exceed \$11B annually (Croasdale and McDougall, 1992). This would not only have a disastrous impact on the balance of payments, but it would also cause Canada to become vitally dependent on foreign energy. The Canadian economy is already very vulnerable to the vagaries of the international business cycle, and this primary reliance on imported oil and gas would act to exacerbate this situation.

Canada has a significant oil and gas reserve base which has yet to be tapped, but the majority of this is locked up in reservoirs that, ever since the mid 1980s, have been too inaccessible to be exploited economically. As a result of the poor prospect for long-term production from conventional reservoirs in western Canada, the Arctic reserves, along with those off the east coast of Canada, have once again attracted the attention of Ottawa as a potential source of domestic oil and gas.¹ This revived interest was made clear when the Federal Panel on Energy

Research and Development (PERD), which was created in 1973 at the time of the first OPEC oil embargo to ensure the security of Canada's energy supply, commissioned the efforts of two noted experts on the engineering-economics of Arctic oil and gas projects to assess the feasibility of developing these Frontier reserves. The bulk of this report focussed on the Arctic reserves discovered in the 1970s and 1980s, and it aimed to highlight those reserves and associated development techniques which could be economic under current economic and technological conditions. This report not only contained a description of the various sorts of projects that could be economic, but it also made recommendations for future research funding by the PERD which could reduce the cost of these developments. The results of this study indicated that options do exist for the development of Frontier reserves with the Arctic alternatives found to be marginally economic. In fact, the current view is that technological innovations over the past 2 decades have acted to significantly reduce supply costs, and generate renewed interest in the potential contribution from Frontier Reserves (NEB, 1994). Given these supply cost reductions, the NEB's supply/demand report for the 1993-2010 report includes one scenario whereby the reserves of the Mackenzie Delta and Beaufort Sea contribute to Canada's supply of light crude oil (NEB, 1994). This dissertation was motivated by the fact that the Arctic oil options stand to have an unprecedented economic impact not only on the Northwest Territories, which contain the bulk of Canada's Arctic lands, but also

on the rest of Canada's Provinces.

1.1 Objectives of the Dissertation

The purpose of this dissertation, simply stated, is to develop and implement an assessment tool which could be used to gauge the interregional economic impacts of various Arctic Oil development projects in Canada. Assessments of the interregional economic impacts of large scale projects have been conducted in Canada in relatively few instances. Douglas and MacMillan (1981) used Statistics Canadas' 1974 inter-provincial I-O model to assess the interregional economic impacts of developing the Alsands project in Alberta, and, more recently, the Conference Board of Canada (1990;1991) used a similar approach to assess the impacts of various economic growth scenarios and of the proposed GNWT Transportation improvement plan of 1991, on the NWT and the remaining regions of Canada.² A vital consideration in assessing the impacts of such projects on an interregional system, especially when such projects are to be undertaken in an under-developed region like the NWT, is the issue of whether or not sectors in the region of interest have sufficient capacity to meet the demands associated with such projects. All three of the studies mentioned above used a static approach in which contributions to the magnitudes of the impacts from issues related to capacity augmentation could not be included. In the case of large scale oil development projects in the NWT, this issue of capacity (primarily of sectors in the NWT) is critical. Even though the bulk of the backward linkages associated with this sort of activity in the NWT will extend to sectors in other Provinces (primarily British Columbia, Alberta, Ontario and Quebec), sectors in the NWT will undoubtedly be stretched to their limits and likely beyond.³

The purpose of this dissertation therefore is to develop and implement a framework which will allow for a comprehensive assessment of the spatial and temporal distribution of the economic impacts associated with the development of various oil projects in the NWT. That is, a novel reformulation of Leontief's Dynamic I-O model will be merged with the Multiregional I-O framework proposed in the early 1950s by Chenery (1953) and Moses (1955), and refined and implemented by Polenske (1980) for the U.S. economy. The objectives of this research project then could be stated clearly as follows;

- 1. to develop a dynamic multiregional I-O model which could be used to assess the economic impacts of various oil development scenarios for the Canadian Arctic, as proposed by Croasdale and McDougall (1992), both over time and over the 12 regions of Canada, and
- 2. to implement this methodology, using published Provincial I-O data and expert information from GNWT officials, for a set of distinct NWT oil development options.

Although this dissertation was stimulated by thinking about how the NWT and the rest of Canada could be affected by these sorts of projects, the primary contribution of the dissertation will undoubtedly be methodological. The available Provincial I-O tables which included the necessary data for an application of a

Multiregional I-O approach were very aggregate both in terms of industrial sectors and commodities, and, as a result, the scenario specifics had to be aggregated to match this level of sectoral aggregation. The approach however, is novel, and a software system has been developed which will enable a more disaggregate data set to be evaluated.⁴ As such, the model implementation, while interesting in its own right, served more as an example of how this sort of dynamic model could be used to assess the spatial and temporal distribution of economic impacts associated with large capital intensive projects.

1.2 Organization of the Dissertation

The thesis is organized in the following manner. Chapter 2 presents a review of the oil and gas history of the NWT with a focus on the major discoveries made there and of the major development proposals made during the 1970s and 1980s. The purpose of this chapter is to provide the reader with some background on the dimensions of the plans once thought feasible for the Arctic reserves, and on the enormity of the task of bringing Arctic oil to the market place. Chapter 3 consists of a review of some current oil development scenarios for the NWT which are considered to be among the most conservative and respected of any opinions regarding the development of Canada's Arctic oil reserves. Chapter 4 provides a review of the I-O economics literature with an aim toward highlighting regional and dynamic extensions upon which the model developed here was

based. Chapter 5 presents a detailed accounting of exactly how the dynamic MRIO model was built. A significant amount of care was taken to clearly show how such a model could be built using the commodity by industry framework used to compile I-O data in Canada. Chapter 6 then presents a detailed discussion of exactly how expert information was used in conjunction with the published I-O data to implement the model and perform the assessment. Chapter 7 discusses the output of the model for each of 3 oil development options, and chapter 8 closes the dissertation with a discussion of the results, the limitations of the approach, and recommendations for future refinements.

ENDNOTES

1. The NEB notes that in excess of 2.4 trillion barrels of oil can be produced profitably at a price of \$25 U.S. (1993 dollars) (NEB, 1994). At this price level however, various other options are available to Canada including tar sands projects in the WCSB, Frontier Oil and Gas, and enhanced recovery schemes. The fact that enhanced recovery schemes and tar sands projects in the WCSB represent developments at the margin of current activity in western Canada, combined with the extremely high cost of transportation in the Arctic would act to make these WCSB options more attractive at such a price, relative to Frontier developments. If however, a regional development imperative is adopted by the Government of Canada, with regard to the Arctic, as exists currently for eastern Canada, then perhaps Arctic developments could precede secondary recovery schemes in the WCSB.

2. GNWT is an acronym for Government of the Northwest Territories.

3. A backward linkage from a sector in the NWT to a sector in Alberta for example represents a flow of intermediate inputs from the sector in Alberta to the sector in the NWT as a result of an output stimulus to the NWT sector. For example, a increase in the level of residential construction output in the NWT would result in increased purchases of lumber from the primary sector in Alberta...in such a case we say that there is a backward linkage extending from the construction sector of the NWT to the primary sector of Alberta.

4. The Small Level Provincial I-O accounts are published for all 12 Canadian regions. The Medium Level tables while significantly less aggregate are available for the 10 Provinces only. The territorial tables at this level are suppressed due to confidentiality concerns. The GNWT Bureau of Statistics works with a NWT table at the Worksheet Level which is the most disaggregate form available, and through ongoing work with this agency I hope to be granted access to this data in the near future.

Chapter 2

A Chronology of Oil and Gas Activity in the Northwest Territories

2.0 Introduction

The history of oil and gas activity in the Canadian Arctic dates back to the discovery of the Norman Wells oil field in the NWT in 1919. Since then, most northern exploration activity has been focussed on the vast sedimentary basins which underlie much of the high Canadian Arctic. The boom of hydrocarbon exploration activity in the Canadian Arctic, which occurred in the 1970s and early 1980s, was prefaced by a series of events which attracted attention to the hydrocarbon potential of the region generally. These events were, the second world war, the discovery of the Prudhoe Bay oil and gas field on Alaska's North Slope, the creation of Panarctic Oils Ltd. in 1967, and the unprecedented international oil price increases of the late 1970s and early to mid 1980s (see figure 2.1). These events represented critical *pivot points* in the temporal trajectory of oil and gas related activities in the Northwest Territories (NWT). The current downturn of activity in the NWT, cast on the backdrop of the colourful history of the oil and gas sector in the region, suggests that Arctic hydrocarbon



International Crude Oil Price: 1950-90 EMR, 1990

Figure 2.1

exploitation is awaiting another *pivot point* to once again launch the region into a period of economic activity and growth.

Croasdale and McDougall (1992) showed that the price of oil - both domestically and internationally - was stable at about \$20 US (in 1992 dollars) per barrel throughout the 50s, 60s and very early 70s, and that the price shot up to \$60 US (1992 dollars) per barrel by 1980-81, and remained above \$40 US (1992 dollars) per barrel, until 1985-86, when it dropped back down to approximately \$20 US (1992 dollars) per barrel (see figure 2.1). The peaks and valleys on this price curve coincided, to a significant extent, with the peaks and valleys in the exploratory activity levels in the Canadian Arctic. The boom period began immediately after the Prudhoe Bay discovery, accelerated in the early to mid 80s, and dropped off after 1985. This decline in exploratory activity in the Arctic continues unchanged to this day. Croasdale and McDougall (1992) noted, with reference to exploration in the Arctic, that the period from 1973 to 1985 was characterized by an attitude within the industry that the Arctic reserves would be developed regardless of the cost. This same period was characterized by a steadily increasing international oil price primarily in response to OPEC policies, and these price increases, along with the expectation that they would continue, allowed the industry to maintain this bullish attitude. However, three concurrent forces acted to bring this boom in the Arctic Frontier to an end. Firstly, the discoveries in the Arctic, while significant relative to what remained in the Western

Table 2.1

Reserve Summary for the NWT

Area	Estimated Recoverable Reserves		Estimated Additional Potential Reserves		Total Estimate Arctic Frontie Reserve Base	
	Oil	Gas	Oil	Gas	Oil	Gas
All Oil Figures in Billions of Bbls. / All Gas Figures in Trillions of Cubic Ft.						
Mainland NWT	0.305	0.300	0.500	4.000	0.800	4.800
Beaufort Sea / Mackenzie Delta	1.000	12.000	2.500	24.000	3.500	36.000
Arctic Islands	0.455	17.000	0.500	15.000	0.955	32.000
Total Reserves	1.760	29.300	3.500	43.000	5.255	72.800

(Source: Dingwall, 1990; pp.40-41)

Canada Sedimentary Basin (WCSB) by the mid 1980s, were smaller than expected. Initial reserve estimates for the Arctic held that at least 40 Billion Bbls. of oil and over 200 tcf. of natural gas awaited development (Croasdale and McDougall, 1992). However, the exploratory barrage of the 70s and 80s revealed that substantially less oil and gas was available in the Arctic (see table 2.1). Secondly, the Mackenzie Valley Pipeline Project Inquiry headed by Chief Justice Thomas Berger changed the course of northern development projects by recommending that the Mackenzie Valley Pipeline proposal be rejected.¹ The proposal was rejected due to concern, on behalf of Native people living in the area, over how a section of the pipeline which was to cross the Yukon Coast would disrupt the calving patterns of a prominent Caribou herd; the Porcupine Caribou herd represented a major food source for many Native communities in the region.² The Berger Commission's report changed the face of future environmental assessments primarily by increasing the scope and weight given to Native social and environmental concerns. Bone (1992) noted that the Berger Commission also left its mark on future environmental assessments for such projects by making the media an integral part of the process thereby ensuring that the general Canadian population was made aware of the fragility of the northern environment and of the strong dependence of Native communities on the environment; by making this reliance clear to a broad audience, the Berger Commission ensured that future industry initiatives would be met with

considerable public scrutiny with regard to environmental protection measures. The rejection of the Mackenzie Valley Pipeline proposal, and the heightened social awareness embodied within that decision, acted to sour the industry appetite for large scale developments in the Canadian Arctic. The significant drop in the international oil price after 1986 represented the final and conclusive blow to oil and gas operations in the Canadian Arctic.

Croasdale and McDougall (1992) noted that the per barrel cost associated with developing Frontier Oil must be compared not simply to international prices, but more importantly to the cost to Canada associated with becoming progressively more reliant on foreign oil and gas supplies. Based on this, Croasdale and McDougall (1992) endorse the development of currently economic (or marginally economic) reserves in the Frontiers as a means of both assuring Canada a source of indigenous oil and gas, and as a tool for regional development. The regional development side of their argument is not without precedent; the Federal Government has subsidized the development of offshore oil and gas reserves discovered in eastern Canada. The development of this megaproject has more to do with a political desire to generate economic growth in a region beleaguered by economic hardship. The fact that a similar political will does not yet exist for the Northern Frontier is apparent.

Given the precarious structure which determines the price of oil in the international market place, combined with the fact that economics alone may not

trigger the development of the Frontier reserves in Canada, one does not have to resort to any extreme degree of abstraction to envision a resurgence of oil and gas related activity in the Arctic especially since so many large, and potentially marketable, deposits were discovered during the 1970s and 1980s (see figures 2.2, 2.3, and 2.4 for discoveries). The following pages provide a chronologically ordered discussion of the period of full scale exploration activity in the NWT.

2.1 The Early Days - Pre-1970

The existence of oil North of 60 has been known since 1789 when Alexander Mackenzie recorded the presence of "*oil seeps*" along the banks of the river that now bears his name, near the present day location of Norman Wells in the NWT (see figure 2.2). The presence of oil in the area of the Mackenzie River was also reported by Aboriginal people in the early 1800s. These natural seeps had been used as a source of pitch for water proofing canoes for sometime by the Hudsons Bay Company which had even come to sell this waterproofing material through their trading posts in the Frontier. It was not until 1911 that explorers became aware of the oil seeps at the site of present day Norman Wells, and in 1919 a subsidiary of Imperial Oil Ltd., the Northwest Co., conducted extensive studies of the area. The Northwest Co. found many other oil seeps nearby along with many gas seeps under the Mackenzie River. Encouraged by the results of their reconnaissance, the Northwest Co. began drilling and they









- Oil discovery Gas discovery
- 0

17

Figure 2.3



Existing and Proposed NWT Pipelines (Pre-1985)

discovered what is now referred to as the "Norman Wells field" in 1919, and development drilling commenced in 1920. Oil was subsequently discovered in fractured shales at a depth of 783 feet and development drilling led to the discovery of oil in an underlying reef formation, much of which was beneath the Mackenzie River. This structure is still the main producing horizon of the Norman Wells oil field today (DIAND, 1966; FEARO, 1980; DIAND, 1983; Maxwell, 1973; Bone, 1992).

Early production from the Norman Wells field was approximately 600 barrels (Bbls.) per day (bpd), and any oil produced from the field was used for local consumption. The period from 1920 to the beginning of the second world war (WWII) saw activity at Norman Wells remain unchanged. During WWII, the inland oilfield at Norman Wells was expanded, and a pipeline was built from the production site to Whitehorse in the Yukon Territory (YT), where a refinery was built. This *mega-project* was financed by the U.S. Army because Washington wanted an alternative supply of oil which could not be impeded by an enemy submarine or aircraft attack. This war-time project was named the CANOL Project (CANOL being an acronym for Canadian Oil). Work on this project began in 1942 and was completed in 1944 by which time the threat of an attack on Alaska by the Japanese had all but disappeared. Without the military demand, CANOL oil could not compete with the cheaper California crude and the Whitehorse refinery was closed, the new wells at Norman Wells were capped, and the pipeline was
abandoned. The Canadian Government entered into an agreement with Imperial Oil Ltd. on July 21, 1944 which called for Imperial to develop the oil field at Norman Wells with the Canadian government receiving one third of all oil produced and a 5% royalty on all oil sold. The initial term of this agreement was set to expire after 21 years on May 2, 1966. In 1947, the CANOL pipeline, the related pumping equipment, and all support vehicles were sold as surplus war assets. Imperial Oil Ltd. purchased the Whitehorse refinery and moved it to Edmonton where it was used to process oil from the then active LeDuc field (Bone, 1992). Production at Norman Wells rose from 267,000 barrels per year in 1943 to 1,220,000 barrels in 1944. The period from 1945 to 1970 saw oil production at Norman Wells remain at approximately 600,000 barrels per year. Early Canadian Petroleum Association (CPA) estimates held that the Norman Wells field produced 12 million barrels of oil by 1970, and that an additional 48 million barrels remained recoverable.

In early 1966, Imperial Oil Ltd. renewed its agreement with Ottawa for another 21 year term. In late 1967 Imperial estimated that the demand for their oil would increase, and that the output of their field would begin to decline in the near future as the reservoir was depleted. In response to this, Imperial implemented a "*down dip water injection scheme*" in 1968. Imperial also drilled two additional producing wells in 1968 in an attempt to maintain capacity, and to prepare for anticipated additional demand. As of 1970, the Norman Wells refinery

was quite active in manufacturing petroleum products for local consumption. Additives and alkylates for blending were brought to the refinery from Edmonton to provide for the manufacture of premium motor oils and aviation gasoline for markets along the Mackenzie River and the Arctic Coast (DIAND, 1970).

Interest in the Arctic waned in the 1964-1967 period as the high costs and risks associated with the harsh region were weighed against the relative ease and attractiveness of oil and gas from the North Sea and the Provinces of Western Canada. Maxwell (1973) noted that even though many thought that Canada's early incentives for Arctic exploration were too generous, many small companies which were engaged in exploring the massive sedimentary regions of the high Arctic Islands were finding it very difficult to manage. This was evidenced by the very spartan exploratory presence in one of the most promising hydrocarbon regions on the globe, the Arctic Islands (AIs)³. DOME Petroleum was the first to drill in the High Als, with a well at Winter Harbour on Melville Island in 1962. The well cost DOME an estimated \$1.8M which was about three times the cost of a Texas wildcat. In 1963, many smaller oil companies were ready to give up the leases they held in the Als due to the extreme cost of operations and the extreme environment which made even a moderate success rate disheartening. In 1964, a Calgary geologist, J.C. Sproule who believed in the potential of the Als tried to get all companies holding leases in the region to form a joint venture by coordinating land and money, and coordinating exploratory activities. This led to

the formation of Panarctic Oils Ltd., and in 1967 Ottawa agreed to contribute 45% of the venture capital if the new company would settle for a \$20M exploration program in the Als. Panarctic represented the most unusual of partnerships - private companies and government pooling resources- and in 1967 it had combined assets of 35M acres of leased land contributed by 19 companies, and by 1970, Panarctic Oils Ltd. had permits for 60M acres, a capitalization of approximately \$101M, and had made five major gas finds in the Als.

In 1968, Atlantic Richfield Co. Ltd. discovered the huge oil field at Prudhoe Bay on Alaska's North Slope, just a few hundred miles west of the Canadian exploration teams. This discovery triggered a major rush to the Als and the mainland, and by 1969, the amount of Canadian land under permit jumped from 180M acres to 320M acres (DIAND, 1970). The Prudhoe Bay discovery represented a major *pivot point* in the history of oil and gas exploration in the Canadian north generally, and in the Northwest Territories specifically. The sheer enormity of this field - a true "*elephant sized field*" - showed industry that, even with the astronomical costs of operating in the region, large profits could be realized by any company which discovered such a field (Maxwell, 1973).⁴ The Als had already been shown, by geological surveys conducted by the Geological Survey of Canada (GSC) in the 1950s, to be underlain by some of the largest and deepest sedimentary basins on the planet. This realization, along with the impetus of the Prudhoe Bay discovery, catapulted this region to priority status in

the eyes of the oil exploration companies.

2.2 The 1970s

Over the 1965-1969 period, optimism regarding the profitability of reserves in the Canadian Arctic, especially in the Als, was on the increase. This period saw exploratory drilling and leased acreage increase steadily (DIAND, 1966, 1967, 1968, 1969 and 1970). The discovery of the Prudhoe Bay oil and gas field on Alaska's North Slope in conjunction with Panarctic Oil's discovery of significant gas fields in the Als acted to spark even more activity in the Arctic, and to push the exploration frontier westward into the Arctic Ocean along the western shelf of the Als. In fact the discovery of the Prudhoe Bay field in 1968 resulted in a doubling of the acreage under permit relative to 1967.

By the early 1970s, the Als were being referred to as the "*Glamour Boont*" of the decade, and the expectation was that the Al reserves in combination with the Prudhoe Bay reserves could be economically delivered to southern markets via a 48 inche oil pipeline and a 48 inch gas pipeline running from Alaska's North Slope, down the Mackenzie Valley to southern Alberta where it would connect with existing pipelines. A consortium of 4 exploration companies and 2 pipeline companies formed a consortium in 1969 to investigate such a scheme.

The early 1970s also saw a gradual lessening of the rush for acreage in the Als and in the Mackenzie Delta region that was sparked by the Prudhoe Bay discoverv in 1968. Industry and government reports of the time were still overwhelmingly optimistic with regard to the fact that the Als would surrender a field comparable in size to the Prudhoe Bay field, and the construction of large diameter gas and oil pipelines up the Mackenzie Valley was viewed as imminent as evidenced by the establishment of pipeline experimentation facilities in Inuvik NWT which were designed to develop specifications for building pipelines through permafrost. In fact, the situation in the early 1970s had become one of trying to find oil to *justify* such a pipeline. The fact that the Als were still held in high regard in early 1970s as a potential oil producing region was evidenced by Ottawa's overt willingness to provide additional cash to finance Panarctic's Al exploration program (maintaining its 45 percent share in the consortium), along with the establishment of a large supply depot at Resolute NWT in the Als (in 1970) which was stocked with 5000 tonnes of fuel, cement, gravel, etc., by a group of 4 exploration companies sub-contracted by Panarctic to drill in the Als. Another supply depot was established on Banks Island in 1970 which was stocked by barge shipments up the Mackenzie River during ice-free periods. The Federal commitment to Arctic oil development was further underlined by the fact that a Calgary based company, Western Electronics Ltd., received Government approval (in 1970) to construct and maintain a 750 mile long toll road in the Mackenzie Valley to provide access to exploration areas in the Norman Wells and Tuktovaktuk regions. Concurrent activities in the southern NWT in the Pointed

Mountain region were yielding significant natural gas finds, and significant efforts were being mobilized in the early 1970s to design a pipeline which would tie these gas fields into existing gas lines in the Yukon Territory, Northern British Columbia and Alberta (see figure 2.3). In 1971, both Panarctic Oils Ltd. and Imperial Oil Ltd. reached agreements with large U.S. utilities companies for guaranteed access to their oil and gas in return for significant resource development related cash inflows.

By 1972, Imperial Oil Ltd. had received approval to begin dredging sediment from the bottom of the Beaufort Sea to begin building artificial islands. The first such island was completed in 1972 by Imperial ("Immerk") at a total cost of \$3M. Dome Petroleum entered into exploration in the Als in 1972 with 3 U.S. firms agreeing to contribute \$30M. 1972 also saw 4 companies - TransCanada Pipelines Ltd., Panarctic Oils Ltd., Canadian Pacific Investments Ltd., and Tenneco Oils and Minerals Ltd. - form a group which announced an agreement to conduct research and planning for the building of a gas pipelinefrom the Als to southern pipelines. The project was called the "*Polar Gas Project*". Two routes were considered - one passing to the west of Hudsons Bay and the other to the east. Both proposed routes involved detailed engineering requirements for a system of sub-sea gathering lines to connect all Al gas fields to a trunk-line running to the Boothia Peninsula which is the northern most point of the Canadian mainland in the eastern Arctic (see figure 2.3). Panarctic Oils Ltd. announced that as of the

end of 1971, they had approximately 33 percent of the threshold reserve size required to justify the project.

The early 1970s period of Arctic exploration was characterized by the relative lack of Federal regulations regarding environmental preservation and Aboriginal land claims. Ottawa had been scurrying to put in place a set of rules and regulations since the late 1960s and by 1971, the issue of permits for new exploration had been halted while the Federal Government decided exactly how to best manage this activity. The boom was sparked in the absence of any firm rules and regulations, and the pace of exploration had come as somewhat of a surprise to Ottawa. It wasn't until late in 1973 that sections of the Canadian Oil and Gas Lands Regulations pertaining to onshore and offshore drilling were completed in draft form. By the end of 1973 the Federal Government was preparing to present these amended regulations to industry for discussion and feedback.

In 1974 a submission was received by the Federal Government for approval to develop the gas reserves of the Mackenzie Delta region. The proposal included plans for 5 clusters of wells, 18 miles of gathering lines, and 2 gas processing plants (see figure 2.3 for pipeline routes and figure 2.4 for a map of discoveries in the Delta). The proposal noted that the construction of this project would coincide with that of the Mackenzie Valley (Gas) Pipeline (see figure 2.3). 1974 also saw a consortium of 27 companies apply to the American and

Canadian Governments for the first phase of approvals for the Mackenzie Valley Gas Pipeline Project which was the most costly construction project ever planned by private industry. Panarctic unveiled a proposal for drilling in Als using a rig built on a floating reinforced ice island in 1973, and in 1974 Panarctic successfully tested a previously discovered gas field (Hecla) from such a platform. In 1975 Panarctic expanded its ice platform based drilling activities and continued to prove the effectiveness of the scheme. Imperial Oil Ltd. continued building artificial islands in 1974 and 1975 and reported significant oil and gas discoveries in the Delta (see figure 2.4). Sun Oil Ltd. successfully drilled from an artificial island reinforced by a sunken recoverable barge in 1974 and received approval to build another such facility in the Beaufort Sea in 1975. Over the same period of time, Dome petroleum was seeking approval for the use of floating drill ships with a support fleet for a drilling program in the Beaufort Sea.

In 1975, new wharf loading facilities and additional storage tanks for bunker-C fuel were completed at the Norman Wells facility.⁵ 1975 saw increased drilling from ice platforms and artificial islands by Panarctic Oils Ltd., and Imperial Oil respectively, while Dome Petroleum began constructing two floating drill ships and a support fleet for use in the Beaufort Sea. Dome began using barges in the summer of 1975 to conduct experiments with the construction of sea-bed caissons designed to protect sub-sea blow-out preventers from ice scouring. Dome submitted plans in 1975 to drill two wells from floating rigs in the Beaufort Sea at

an estimated cost of \$30M each making these the most expensive exploration wells ever to be drilled. The Federal Government announced plans in 1975 for a satellite which would be used to monitor iceberg migrations. 1975 also saw the completion of an expansion of the air field at Copper Mine, NWT by Gulf Oil Canada Ltd. to handle most of the cargo and passenger planes serving exploration in the North. Also in 1975, Foothills Pipelines Ltd. proposed to build what they called the Maple Leaf Mackenzie Gas Pipeline which consisted of a 42 inche wholly Canadian owned and operated gas transmission line to be built from the Mackenzie Delta - Beaufort Sea region to Fort Simpson, NWT where it would be connected to the West Coast Pipeline Co. Ltd. line in the NWT, and in Northem BC (see figure 2.3). Applications were filed with the Department of Indian Affairs and Northern Development (DIAND) and the Department of Energy, Mines and Resources (DEMR) in early 1975. The Polar Gas Project also received assured funding from the Ontario Energy Corporation and PetroCanada in 1975.

1976 was a big year for the legislative aspect of oil and gas exploration in the Canadian Arctic. Specifically, the Minister of EMR announced that the elements of a new Petroleum and Natural Gas Act were ready to be placed before Parliament in 1977. The new act, in accordance with the National Energy Plan (NEP) announced in April 1976, was designed to stimulate increased exploration in order to furnish the necessary information on which to base an early estimate of Canada's hydrocarbon reserves. Included were fiscal and land holding

incentives, combined with increased government control over the timing, direction, sale, and level of exploration, development and production activities. The legislation was also designed to provide for increased benefits for, and participation by, Canadian firms engaged in developing Canada's resources. The new act also provided for the introduction of a "Progressive Incremental Royalty System" supplementary to the basic production royalties, to ensure a fair economic return to the Canadian people from resource development. The act also gave PetroCanada preferential treatment in the acquisition of Crown reserves and certain existing contracts. Other regulatory reforms announced in 1976 included amendments to the "Existing Oil and Gas Lands Regulations", the "Canadian Oil and Gas Geophysical Regulations", the "Canadian Oil and Gas Drilling Regulations", the "Canadian Oil and Gas Industry.

The summer of 1976 marked the beginning of a new era in hydrocarbon exploration in the Canadian Arctic. Dome Petroleum began drilling in the deeper portions of the Beaufort Sea from its two drill ships. The project cost Dome \$150M, and in the summer of 1976 Dome brought its two drill ships into the Beaufort Sea - the Canmar Explorers I and III. The Explorer II was held up in a Texas shipyard strike. The Explorer I discovered gas on August 9, 1976 at 10,000 feet. The three wells drilled by the Explorers were estimated to have cost Dome between \$40M and \$50M each. By 1978 the "Oil and Gas Activities" reports by DIAND were beginning to acknowledge that the international climate with respect to oil and gas was beginning to change, as the following quote suggests.

"The international situation regarding oil and gas supplies continued to be so uncertain that hydrocarbon deposits previously considered to be uneconomical, now demanded a more favourable consideration" (DIAND, 1978: pp.1)

In a 1992 report to the Federal Panel on Energy Research and Development (PERD), Croasdale and McDougall noted that the international price of crude oil was beginning to "*sky-rocket*" from approximately \$30 U.S. per barrel in 1978 to approximately \$60 U.S. per barrel in 1979 and 1980, and this prompted the re-evaluation of many ignored discoveries in the Arctic. In 1978, international geopolitical indicators must have been suggesting this eventuality to the officials at DIAND. In fact, Croasdale and McDougall went on to say that in the late 1970s, the Alberta tar sands were beginning to look like a possibility.

Even in the light of the increases in the international oil price, attention in the Canadian Arctic was becoming more focussed on established areas such as the Als, the Mackenzie Delta, and offshore in the eastern Arctic with the level of geological and geophysical surveys remaining at very low levels (see figure 2.1). Seismic surveys were down 35 percent in 1978 relative to previous years, and this did not bode well for future drilling rates in the Arctic. Even the seemingly robust schedules of Panarctic in the Als and Imperial in the Mackenzie Delta showed signs of decline in 1978. The late 1970s saw a major shift in the official Canadian attitude regarding the exploitation of it's Frontier resources. Specifically, Bone (1992) noted that the Berger Commission's recommendation that the Mackenzie Valley Pipeline not be approved represented a crucial change in the way Ottawa dealt with the oil industry. Not only were subsequent environmental assessments measured by the standards set by the Berger Commission, but the emphasis of such assessments shifted toward the interests of Native people and the preservation of the environment upon which they depended.

On December 21, 1977, the Polar Gas Project (PGP) group filed an application with the National Energy Board and DIAND for approval to construct the 3765 km (2349 mi.) pipeline including 89 miles of marine crossings, at an estimated cost of \$6.9B (1976 dollars) (see figure 2.3). The proposed route ran from the Drake Point and Hecla gas fields on Melville Island, across Byam Channel to Bathurst Island, across Bathurst Island, Little Cornwallis Island, and Cornwallis Island, under Barrow Strait to Somerset Island and then south to meet the northern most point of the Canadian Mainland - the Boothia Peninsula (see figure 2.3). The pipeline was to be 42 inches in diameter except for certain marine crossings where parallel 36 inch lines were to be used. In addition, the proposal called for a gas processing plant to be built on Melville Island with 10 compressor stations along the route (with an additional 20 stations to be added later to bring the pipeline to capacity). The PGP group also filed for approval on a combined

pipeline - liquid natural gas (LNG) tanker project to move gas from Melville Island to an east coast port (see figure 2.3). This proposal called for the construction of a 22 inch pipeline from the Drake Point gas field on Melville Island to a terminal for LNG tankers at Bridport Inlet on the southeast coast of Melville Island. The PGP Group referred to this as the Polar Gas Pilot Project (PGPP) because they considered this to be a first step in getting gas from the Als into southern distribution systems (see figure 2.3).

2.3 The 1980s

By the early 1980s the Reserves Committee of the Canadian Petroleum Association announced publicly that the conventional reserves of the western provinces were in decline. They noted that only 5 percent of the 1981 production from the WCSB was replaced through discoveries. This was made more alarming by the fact that the international oil price was continuing to climb (see figure 2.1). The new regulatory regime put in place in the late 70s acted to restrict access to 7 of 9 newly awarded PetroCanada exploration sites to facilitate land claims negotiations. These restrictions were to be honoured until 1983, and set a precedent which would significantly slow the process of acquiring and exploring Arctic leases. In addition to the disincentive provided by these types of restrictions to Canadian acreage, the new Oil and Gas Lands Act required an additional royalty of 40 percent of the net profits associated with the oil and/or gas produced (on top of the existing 10 percent royalty). It was also announced in 1981 that holders of existing rights were required to convert their holdings to negotiated exploration agreements with Ottawa or to provisional leases within a Under these provisional leases the work one year transitional period. requirements were considered to be stringent for a short 12 month period. While Ottawa noted that the purpose of these new requirements was to accelerate the pace of exploration and development in the Frontier and to secure a good supply of oil and gas for use and sale in a period of sharply rising oil prices, they appeared to have the opposite effect. In fact, the early 1980s period was characterized by a continual series of regulatory reforms with regard to oil and gas exploration in the Canadian Arctic the objective of which was to increase Canadian content in all ventures and to ensure that Ottawa got a share of all resource rents. The formation of the Canadian Oil and Gas Lands Administration (COGLA) was a direct result of this legislative barrage in the early 1980s. In 1980, the Minister of DIAND began referring all development proposals for the Beaufort Sea and Mackenzie Delta regions to the Minister of the Environment for a formal general review under the Federal Environmental Assessment and Review Program (FEARO). Contrary to the expressed purpose of these regulatory reforms, the early 1980s were characterized by a general slow-down in new exploratory activity with the companies already heavily involved focussing attention in previously discovered structures in the Als, the Mackenzie Delta, and Beaufort Sea regions.

Projected higher demands on the Norman Wells oil field stimulated the desire on ESSOs part to initiate an expansion plan for the facility aimed at increasing productive capacity from 3,000 barrels per day (bpd) in 1981, to 25,000 bpd. ESSO submitted an application to the NEB in 1980 to initiate a secondary recovery scheme (a water-flood operation). The plan called for the drilling of injection and production wells on the mainland and on two natural islands in the Mackenzie River. The plan also called for wells to be drilled from 6 artificial islands in the Mackenzie River which were to be built over the 1980-81 period. In 1981, Interprovincial Pipelines Ltd. (IPL) received permission from the NEB to construct a 12 inch diameter pipeline from Norman Wells to northern Alberta where connecting pipelines would transport NWT crude to Edmonton. Construction was set to begin during the winter of 1983-84 and it was to be completed by July, 1985. Approval for the line was granted despite the Berger Commissions' recommendation of a 10 year moratorium on pipeline construction in the Valley. Bone (1992) noted that the proposal was subjected to the same assessment standards as the Mackenzie Valley Pipeline proposal. The Norman Wells project however, was far smaller in terms of geographic scope, and the proposed pipeline route included zones of discontinuous permafrost which significantly lessened environmental concerns over subsidence and a subsequent pipeline breach. These facts, along with considerable efforts on behalf of IPL to address the issue of subsidence by chilling the oil prior to sending it through the

pipeline led to the approval of the project. By the end of 1981, the list of corporate backers for the Polar Gas Project (PGP) had changed somewhat, but support for the project was still strong. The NEB announced it's intention to hold public hearings on the plans for the PGP in 1982.

In 1984, Gulf Oil made the most important discovery in the history of exploration in the Canadian North when they discovered the *Amauligak* oil and gas field in the Beaufort Sea from its mobile Arctic Caisson based rig - *Moliqupaq* (see figure 2.4). Gulf announced that initial testing results indicated that Amauligak may have the largest oil productive capacity of any field in Canada. Also of great significance was the completion of the Norman Wells expansion project in 1985. Oil began flowing through the IPL line to Zama Alberta at a rate of 25,000 bpd, and by the end of 1985 the central processing facility and 2 final artificial islands were completed bringing the total number of artificial islands in operation at Norman Wells to 6. By the end of 1985 some 38 wells were active at Norman Wells with the *water-flood operation* in full swing.

Panarctic made history once again in 1985 by delivering the first shipment of Canadian Arctic oil from the Als to the south. Panarctic received the first production licence for high Arctic oil and proceeded to produce oil from their Bent Horn facility on Cameron Island and ship nearly 200,000 barrels of oil through the Northwest Passage to a PetroCanada refinery in Montreal (see figure 2.3). Work at the Bent Horn facility began in March of 1985 with the construction of a 4 km elevated pipeline from the wellhead to a 108,000 Bbl. storage tank. Panarctic also built a separating facility, a heater glycol unit, and a gravity fed loading line (12 inch diameter) from the storage tank to a shoreline loading facility. The Bent Horn well was producing at a rate of 3,500 bpd, and by August of 1985 some 107,000 Bbls. of oil was loaded onto the MV Arctic - an ice class 2 oil tanker - for transmission to Little Cornwallis Island where it was transshipped to the MV Imperial Bedford and shipped through the eastern portion of the Northwest Passage, and then 5,000 kms south to the PetroCanada refinery at Montreal. ESSO Resources, Dome Petroleum and Panarctic Oils Ltd. each made significant discoveries in 1985. ESSO discovered gas from one of their retained islands in the Delta, while DOME made a significant oil find in the western Beaufort from a drillship. Panarctic made two significant oil and gas finds in the Als from ice 1985 also saw the DIAND Minister of the time - David Crombie islands announce to the NWT Legislative Assembly his intentions to discuss with Cabinet the principle of joint resource management and revenue sharing between Ottawa and the GNWT.

The Canadian Petroleum Reserves Act was approved by Parliament and given Royal Assent in November 1986, and upon proclamation in 1987 this legislation was intended to repeal and replace the 1982 Canada Oil and Gas Act, and to greatly simplify the regulatory framework for the disposition of Frontier Lands, royalties and the Canadianization of the oil and gas industry presence in the Frontier. The COGLA reports by 1986 had begun to focus more attention on the east coast reserves, as activity began to subside in the Arctic as prices dropped and the scope of Government regulations increased. While exploration was continuing in the Als, and in the delta in 1986, exploration activity was slumping with the big news of the year being Gulf's continued success with the Amauligak field. Two delineation wells were drilled in 1986 and 3 extended flow tests were conducted from the second delineation well. These extended flow tests produced some 320,000 Bbls. of oil which was loaded onto a tanker and marketed in Japan. This marked the first ever shipment of Beaufort Sea oil. The results of these extended flow tests confirmed significant proven reserves in the field, and led COGLA to report that Amauligak may qualify as the lead project for Beaufort Sea development. Panarctic continued producing at the Bent Horn facility and 1986 saw another shipment of 103,000 Bbls. of oil to the PetroCan refinery at Montreal. Panarctic drilled the last two exploratory wells of its drilling campaign in the Als in 1986 and both were unsuccessful. For the first time since 1967, Panarctic closed it's base camp at Rae Point marking the end of a 19 year drilling campaign in the high Arctic. The cessation of Panarctic's exploration activities in the NWT was precipitated by a significant drop in the international oil price which all but destroyed the chances of the PGP becoming a reality (see figure 2.1). 1986 also saw the beginning of an infill drilling program at Norman Wells with plans to drill 22 new wells by 1987. A total of 14 new development

wells were completed at Norman Wells in 1986, and work started on increasing the capacity of the gas plant at Norman Wells. This was slated for completion by late 1987.

In the 1987 COGLA report, the Administrator noted that "...a continuing but reduced level of exploration took place on Canada's Frontier Lands in 1987..." and he attributed this decline to "...uncertain oil prices..." and "...the difficulty of predicting the future..."(see figure 2.1). COGLA was under the impression in 1987 that the international oil price would continue to drop as would exploration and development activities on Frontier Lands - especially in the Arctic. Industry activity in 1987 mirrored the COGLA assessment by showing a record low in terms of drilling activity and seismic and geophysical crew time. Specifically, the proportion of delineation drilling to exploratory drilling had increased in 1987 suggesting that the industry was focussing their reduced levels of activity on proven fields and not drilling wildcats as they had in the past. As the highlights of 1987, the COGLA report focussed on the continued success of Gulf's Amauligalk field and further evaluation of Panarctic's Bent Horn facility. Specifically, Panarctic expanded storage facilities at the Bent Horn site by 50 percent, and attempted to augment the reserves there by drilling the well to a deeper section of the reservoir. 1987 marked the third consecutive year for the successful shipment of Bent Horn oil to southern markets. Two tanker loads were delivered directly to the Northern Power Commission facility at Resolute (12,000

Bbls.) and to the Polaris Mine on Little Cornwallis Island (34,000 Bbls.). Bent Horn production in 1987 represented a doubling of previous output levels. Gulf announced in 1987 that it was planning to use the Moliqupaq mobile caisson in conjunction with a man-made berm to continue the delineation and testing of the Amauligak field into 1988 and 1989. ESSO proved that it was one of the more daring explorers in 1987 when they drilled an exploratory well from another artificial island in the shallow Beaufort. COGLA reported that the expansion at the Norman Wells field significantly increased the capacity and efficiency of the operation and it also increased the recoverable reserves figure significantly. By the end of 1987 the Norman Wells facility consisted of 168 producing wells and 148 injector wells.

September of 1988 saw the Territorial and Federal Governments reach an agreement-in-principle on a Northern Energy Accord which dictated how the decision making power and the revenues associated with Arctic oil and gas would be shared between the two levels of Government. Exploratory activity however continued to decline on all Frontier Lands in 1988 and 1989 as a direct result of plummeting international oil prices. ESSO continued to explore in the Beaufort in 1989 by drilling an exploratory well north of Richards Island from a "spray-ice" platform which was constructed in 6.5m of water. The island had a working surface diameter of 75m, it took 2 months to build and was abandoned in 1989. No exploratory work was carried out in the Als in 1988 or 1989. The Bent Horn

facility again yielded 2 tankers of oil in 1989 which was transferred to Norwegian tankers and shipped to Denmark.

2.4 The 1990s

Exploration and development activities in the Arctic Frontier Lands continued to decline markedly into the 1990s with ESSO and Gulf continuing significantly scaled down programs. Panarctic's Bent Horn facility produced 1 tanker load of oil in 1990. A Government call for nominations for exploratory rights in the western Beaufort resulted in no feedback from industry. By 1990 the international oil price had fallen to below \$25 per Bbl (1992 dollars) and industry was no longer willing to invest in continued exploration in the Arctic. The Bent Horn and Norman Wells facilities continued to operate and Gulf continued to tweak the Amauligak field, but little of significance has taken place since in the Canadian Arctic. Activity in the Arctic in the 1990s, with the exception of Panarctic producing 2 tankers of oil per year from the Bent Horn field and Norman Wells producing at capacity, had all but come to an end. This state of affairs remains unchanged to the present day.

2.5 Discussion

Clearly, the combined effects of oil price declines, a constantly changing regulatory regime, increased awareness of potential environmental and social impacts associated with the development of Arctic resources, and smaller than expected Arctic reserves brought this vibrant exploration boom in the Canadian Arctic to an end. This 20 plus year exploration boom did however reveal sizeable discoveries totalling 1 to 1.5 billion Bbls. of oil, and 12 trillion cubic feet of natural gas in the Arctic Frontier (see table 2.1). To date, the bulk of these discoveries lay capped awaiting an economic and political climate which will make their exploitation profitable. Croasdale and McDougall (1992) suggested that while the workings of a free market economy may make these reserves untouchable for some time, the fact remains that the WCSB is in decline. Once this reservoir is depleted to the point where enhanced recovery techniques would have to be used, Canada will have to choose between imported oil, using secondary recovery schemes in the WCSB, the development of tar sands projects in Alberta, and the exploitation of Frontier reserves. Croasdale and McDougall (1992) also noted that while the solution to this dilemma will likely consist of a combination of these alternatives, a strong incentive for the development of indigenous oil and gas reserves will exist and that this will force a serious reconsideration of the proven Arctic potential. It was this realization that led the Federal Panel on Energy Research and Development (PERD) to commission Croasdale and McDougall to assess Canada's Frontier energy options by outlining economically feasible Frontier oil development scenarios. Their report suggests that while the reserves of the Mackenzie Delta and the Beaufort Sea are smaller than originally

anticipated, many of these could be economically developed given current technology (or with minor technology uplift) and guarantee Canada's energy self sufficiency well into the next millennium. The following chapter will discuss these options.

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ENDNOTES

1. The Mackenzie Valley Pipeline proposal was put forward by a consortium formed by Canadian Arctic Gas Ltd. and Foothills Pipelines Ltd.. The proposal called for a gas pipeline running the length of the Mackenzie Valley which would carry natural gas from the Prudhoe Bay field to markets in southern Canada and the U.S.. This project was considered by industry at the time to represent the beginning of large scale developments in the Arctic.

2. Mackenzie Valley Pipeline Bone (1992: pp.165) provides an excellent discussion of the details of the Native concerns regarding the proposed .

3. Preliminary geologic investigations of the Als were commenced in the early 1950s by the GSC. These investigations revealed the existence of several thousands of feet of sediments - some of which were potential oil and gas reservoirs.

4. She showed that a 1.8 trillion cubic foot gas field which would requite \$400M to develop would translate into a unit cost of 2.2 cents per Mcf (Mcf=1000 cu.ft.). In 1970, the wellhead price of natural gas was 32 cents per Mcf. She also showed that the exploration and development costs plus the cost of a 48 inch pipeline to US markets would raise this to 8 to 12 cents per Mcf. She concluded that at the tine if her writing - which was 1973 - companies could earn a discounted cash flow rate of return of 20% if the wellhead price of gas was between 30 and 36 cents per Mcf.

5. Prior to this, the "heavy-ends" were simply burned off or "flared".

Chapter 3

Scenarios of Future Oil Development in the Northwest Territories

3.0 Introduction

Chapter 2 provided a description of the history of oil and gas related activity in the NWT and indicated that, while smaller than anticipated reserves and steadily declining world oil prices led to a virtual stoppage of exploration activities in the NWT, Canada still has a vested interest in assessing how it can viably exploit its Frontier reserves. The reserves discovered in the Arctic portion of Canada's Frontier Lands are extensive even though they have, so far, been less than astounding. The fact that the Federal Government is still concerned about what sorts of development activities can actually be undertaken in the Arctic without protection from the international market place was highlighted by the recent commissioning of 2 experts - Kenneth R. Croasdale and James C. McDougall - to assess Canada's options with regard to all Frontier reserves.¹ Specifically, the Federal Panel on Energy Research and Development (PERD) commissioned Croasdale and McDougall to assess the viability of all Arctic reservoirs under current technology and prices and to suggest options for the maintenance of Canada's energy self-sufficiency. In performing this assessment, several scenarios were created based on the major fields discovered in the Mackenzie Delta and the Beaufort Sea in the 1970s and 1980s. These scenarios were used to generate base-case economics and sensitivity analyses for all potential types of projects. The scenarios which generated favourable economics - that is those scenarios which proved to be economic or marginally so - were included in a final report to PERD. The report, as well as the scenarios evaluated within it, have undergone a revision and update since the initial submission in 1992, and the revised report is now ready in draft form. The authors of this report generously agreed to allow me to use their most recent scenarios and the investment data used to generate them, in this analysis. As mentioned in chapter 6, the scenarios included in the revised report represent the most current and most rigourously established of all opinions with regard to the future of oil development in the Canadian Arctic. In each case, the scenarios to be discussed herein have been found to be economic, or marginally so, given current technology and prices and as such each represents a scenario that could be realized.²

While the revised report contained a total of 8 scenarios, a representative set was chosen for this analysis, and these will be the only ones discussed in this chapter. The revised report to PERD contained several *redundant* scenarios so those chosen for this analysis represented the three *distinct* types of options

available - an onshore development focussing on reserves in the Mackenzie Delta, an offshore Beaufort development focussing on the Amauligak field with a large pipeline option, and an offshore scenario focussing on the Amauligak field with a tanker transportation option.³ In all cases, the scenarios included in the revised report to PERD were based on the reserve profile as documented after the exploration boom of the 1970s and 1980s as reviewed by Dingwall (1990).

The purpose of this chapter will be to convey to the reader a picture of the sorts of development options that are available for the development of the oil reserves of the Canadian Arctic. No attempt will be made here to discuss how these scenarios will be fed into the economic assessment tool derived in chapter 5. This material is covered in detail in chapter 6.

3.1 Scenarios of Future Oil Development in the NWT

In the words of the authors of the study;

"The study...is in essence an examination of various Frontier development scenarios in terms of current reserves, economics, and sensitivity of the economics to changes, especially lower costs achieved through technology (Croasdale and McDougall, 1992: pp. 27)

They noted further that the first step in their analysis involved the identification of realistic development scenarios for the Frontier regions. These scenarios were based on the current and potential reserve base of the Frontier Lands, the experience of the authors, and input from industry.⁴ The general scope of each scenario was established in order to identify the associated capital and operating

costs. Generally, the scope was based on inputs from a variety of sources including the experience of the authors, consultation with industry, and from a variety of other sources in the public domain. In certain cases where data was unavailable for a particular scenario, the scope was established using NORCOST[®], a Northern Regions Venture Cost Model developed by **North of 60 Engineering**. The NORCOST[®] model establishes the scope and cost of facilities necessary to produce and transport oil and gas from the Frontier regions to southern markets.⁵ The authors also noted that in preparing the scenarios, if a range of costs were available, the upper end of the range was used to assess the base-case economics of the project (Croasdale and McDougall, 1992).

The transportation systems were sized for each particular development scenario. Pipelines, for example, were sized based on hydraulic considerations which are a function of throughput, operating pressure and pump or compressor station spacing, and associated development and operating costs were established based on input from industry, technical experts, and the NORCOST[®] model referred to above. Tanker costs were based on past studies and input from technical experts (Croasdale and McDougall, 1992).

The economic viability of each development was then calculated using a model developed by **North of 60 Engineering** which computes a venture's rate of return on an after tax, after royalties basis. Required inputs to this model included development costs, production profiles, operating costs, production price

forecasts, and inflation and tax rate assumptions. All costs were expressed in 1992 dollars. Production forecasts were developed for each scenario using a decline model developed by **North of 60 Engineering** which computes the production profile for a project based on a constant percentage decline in the reserve base. The production decline was set to commence after a certain percentage of the reserves had been produced, and this value which was an input variable varied between 40 and 50 percent of the recoverable reserves (Croasdale and McDougall, 1992).

A conservative generic price forecast was used for all scenarios, and since the bulk of Canadian crude oil is exported to the United States, the price of oil was tied to a \$20 US/barrel flat price index for West Texas Intermediate Oil in the Chicago market place. The authors noted that this was in line with the views of most of the industry at the time of writing. The model also treated the transportation costs as tariffs. That is, the tankers and pipelines were assumed to be independently owned and operated by a third party (Croasdale and McDougall, 1992).

3.1.1 Onshore Development - Small Pipeline Option

The discovery of the Amauligak field in the Beaufort Sea by Gulf in 1984 led industry to envision two distinct possibilities for the development of Beaufort Oil. The first possibility, or scenario, consisted of an onshore development based on

the potential reserves on Richards Island and in the shallow Beaufort Sea. Current onshore reserves total approximately 120M Bbls. but in relatively small reservoirs. Specifically, the scenario involves an extension of the existing Norman Wells Pipeline (owned and operated by Interprovincial Pipelines Ltd.) to the Delta to produce oil at a rate of approximately 25,000 bpd from a yet to be discovered onshore field of between 100 and 150 million barrels in size. The 100M Bbl. field on which this scenario is based has not been discovered to date, but Croasdale and McDougall (1992) noted that geophysical and geological interpretations of the area indicate that such fields, and perhaps larger ones, are a possibility and that future drilling would be aimed at such targets. Croasdale and McDougall suggested that this *generic* scenario would also help put in perspective the economics associated with the smaller onshore fields discovered to date.⁶

Costs for surface facilities and development drilling in the base-case were derived from the highest values obtained in discussions with industry. Croasdale and McDougall noted that, based on their experience, these costs were very conservative and that they could be reduced even without technology uplift. The pipeline tariff used was also at the high end of the range of costs to build the extension from Norman Wells to the Mackenzie Delta. They noted that these conservative cost assumptions combined with a flat price outlook resulted in the unattractive base case economics associated with this project (see table 3.1). Sensitivity analyses indicated that this scenario would require an oil price of

\$26.75 U.S. to yield a 10 percent return. These same computations suggested that a 35 percent reduction in capital and transportation costs could make this project economic at a 20 U.S. per Bbl. oil price. They also suggested that given the very conservative cost estimates used, "smart" engineering could bring about such reductions along with some technology uplift through focussed R&D. The big "draw-back" of this scenario, as noted by Croasdale and McDougall (1992), is the need to maintain a flow rate in the pipeline of 25,000 bpd over a 20 to 25 year period. To sustain this level of throughput, a total of 300M Bbls. of oil would be required making additional discoveries in the area an absolute requirement for the economic operation of such a project.

The capital investment time-line discussed in chapter 6 for scenario 1 represents the translation of this generic scenario into an investment plan which stretches over a period of 8 years. The staging of these investments and the magnitudes of these investments were compiled based on the experience of the authors and through feedback from industry.

3.1.2 Offshore Development - Large Pipeline Option

The second type of project envisioned as being possible in the Beaufort consists of a large scale offshore project aimed at tapping the 350M Bbl. Amauligak field with a 16 inch (or greater) pipeline producing at a rate of 80,000

Table 3.1

Base Case Economics for Three Scenarios of Future Oil Developments in the Northwest Territories

Scenario	Oil Price Required for a 10% Return (DCFR)	Oil Price Required with Technology Uplift	U.S. Oil Price	
All Figures are in 1992 Dollars				
100M Bbl. Onshore - Small Pipeline	26.75	21.20	20	
350M Bbl. Offshore - Large Pipeline	22	18.80	20	
350M Bbl. Offshore - Small Tanker	21	17.80	20	

(Source: Croasdale and McDougall, 1992)

bpd running from Richards Island in the Delta to Alberta. Scenario 2 therefore represents a generic case of an offshore oilfield with recoverable reserves of 350M Bbls.. The cost data generated by industry for the development of the Amauligak field was used by Croasdale and McDougall to evaluate the feasibility of this scenario. Based on the series of other smaller but significant discoveries made in the Beaufort, this generic scenario was taken to represent the best case for offshore discoveries to date. As was the case with the onshore scenario, the pipeline tariff model used by Croasdale and McDougall assumed that the pipeline could be run full at 80,000 bpd for 20 years. This would require the discovery of an additional 600M Bbls. of oil during the operational life of this project. Croasdale and McDougall noted that as the tariff decreases through time and as infrastructure improves, it may be possible that some of the smaller offshore fields listed in table 3.2 could be produced economically and would make up this 600M Bbl. shortfall. They also noted that some of the small onshore fields could contribute.⁷ Specifically, they noted that industry would look seriously at a scenario which combined the features of scenarios 1 and 2 with the Amauligak oil field acting as the lead field for the development of the fields on Richards Island. For current purposes however, these scenarios were not combined but evaluated separately as originally designed by Croasdale and McDougall (1992).

This generic scenario assumed a sustained production rate of 80,000 bpd and required a capital investment of at least \$2.2B with 12 percent allocated to the

offshore pipeline, 45 percent allocated to platforms and topsides, 27 percent to development wells, 3 percent to a northern base camp, and 13 percent to engineering costs. Platforms and topsides (processing, equipment, utilities, accommodation etc.) made up the greatest proportion of the total investment for this scenario. Croasdale and McDougall noted that various platform types have been considered for this type of project. The design chosen, based on industry consensus, consisted of a caisson retained island with the topsides built on barges and incorporated into the island. A massive structure is required to resist the ice loads both global and local, which, because of uncertainties had to be specified in a very conservative manner. Ice would also affect the offshore pipeline (which would be needed to tie all offshore fields to a trunk line on Richards Island) which would have to be buried in a sub-sea trench to protect it from ice scour. This would add significantly to the cost of the operation, and the cost would be inflated further by the fact that construction would only take place during a 2 month summer season.

The cost models developed by **North of 60 Engineering** indicated that an oil price of \$22 U.S. would be required for this project to be economic (to yield a 10% return - DCFR).⁸

Table	3.2
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Various Beaufort Offshore Discoveries in Addition to Amauligak

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Field	Estimated Potential (Millions of Bbls.)	Water Depth (m)
	•	
lssunguak	120	19
Tarsuit	100	22
Pitsiulak	50	30
Havik	40	25
Isserk	30	15
Nipterk /	30	7
Adlartok	100	150
Total	470	

(Source: Croasdale and McDougall, 1992)

3.1.3 Offshore Development - Small Tanker Option

Industry experts, in recognizing that the use of pipelines for any Beaufort scenario would require that additional discoveries be made in order to minimize pipeline tariffs, considered alternative transportation schemes to get oil from the Beaufort to southern markets. The only alternative to a pipeline for Beaufort Sea Oil is the use of ice breaking tankers. Croasdale and McDougall (1992) noted that while the use of tankers in ice infested waters is a definite environmental concern. most of the world's oil is moved by tanker. In the early 1980s, debate raged over the use of tankers versus pipelines for the shipment of Beaufort Oil. Dome Petroleum was a strong advocate of tankers, and in 1982 Dome estimated that a tanker tariff of \$8 per Bbl. would be reasonable for a tanker based development of the Amauligak field (at the rate of 80,000 bpd). Croasdale and McDougall noted that up to date estimates for Arctic year-round tanker support are not available, but that one current analogue did exist; Bent Horn Oil shipped via the MV Arctic in summer to Montreal embodies a tariff of approximately \$6 per Bbl.. They also noted that the generic 350 Bbl. field could be economic with a 10 percent return if an average tanker tariff of \$5 or \$6 per Bbl. was assumed.

They found however, that even if tankers were used, a project of the scale of scenario 2 would require storage and mooring facilities that would cost nearly as much as the large pipeline option discussed above. Given this, the notion of tapping this 350M Bbl. pool with a smaller project - both by pipeline and by tanker
- had many advantages from the point of view of industry. To begin with, a small pipeline option - most likely an extension of the Norman Wells Pipeline (NWP) had the benefit of ensuring the added reserves required to make the development of the onshore reserves very economic by assuring a flow rate of at least 35,000 bpd for more than 20 years. It also had the benefit of ensuring that the existing portion of the NWP would operate at full capacity for many more years. By substituting a tanker option for the pipeline in this scaled down Amauligak scenario, further cost reductions could be realized due to the fact that the tanker and well head facilities required in the Beaufort would be considerably less grand. This small scale tanker option for the Amauligak field represents the third and final scenario analyzed in chapter 7. In such a scenario, the offshore platform could be an existing caisson (Gulf's Moligupag for example) with a second small platform added later. Storage would be required and it was assumed that it could be provided for approximately \$150M - approximately the cost of the sub-sea pipeline that would be required for the small pipeline option. Croasdale and McDougall (1992) noted that the tanker and storage size would be chosen in conjunction with transit time so that production could be maintained at a constant level. The scenario run by Croasdale and McDougall assumed a conservative tanker tariff of \$9 per Bbl.. As table 3.1 suggests, this scenario offered the most attractive base-case economics with a 10 percent return at a price of \$21 U.S. per Bbl.

A variation on this theme of scaled down production and transportation facilities involved the use of an existing ice breaking tanker on a seasonal basis in a manner similar to the way the Bent Horn facility is produced. Such a scenario involves a significant decrease in development costs along with a \$2 per Bbl. drop in the tanker tariff. Such an operation would operate for approximately 90 days per year and produce 30,000 Bbls. per day. Experts envision this type of development, along with the previously discussed small scale tanker operation as being an initial form of the full-blown operation depicted in scenario 2 (with tankers).

The analysis conducted in chapter 7 focusses on the generic 100M Bbl. onshore - small pipeline scenario, the generic 350M Bbl. offshore - large pipeline scenario, and on the generic 350M Bbl. offshore - small tanker scenario. These three scenarios comprise a representative sample of the types of Arctic oil developments which industry experts can envision in the not too distant future. Croasdale and McDougall (1992) have shown that each of these scenarios, under certain conditions, could be developed economically (or marginally so) especially if new large fields can be found and if modest technological improvements can help decrease the capital costs for these types of developments.

3.2 Discussion

While current oil prices have all but ended the period of oil and gas activity

in the Canadian Arctic, the fact remains that significant discoveries were made in the region and that these could be developed in a marginally economic manner given careful engineering, good judgment in terms of the size of the development chosen, and especially given the discovery of ancillary reserves which will act to lower pipeline tariffs. The scenarios evaluated by Croasdale and McDougall (1992) represent the current thinking of industry with regard to the potential of this region. Their experience combined with their adherence to the most conservative of cost estimates has resulted in these scenarios being the most highly regarded opinions regarding the possible future of the Arctic oil reserves in Canada. The analysis conducted in the following chapters draws on the capital investment timelines developed by Croasdale and McDougall in fabricating these scenarios through consultation with industry representatives. These scenarios, and the associated investment information was deemed to be the strongest platform on which to base an assessment of the economic impacts of potential Arctic Oil developments.

ENDNOTES

1. Ken Croasdale and Jim McDougall are private engineering consultants who have extensive experience in the engineering-economics of oil and gas developments in the Arctic environment. Mr. Croasdale owns and operates K.R. Croasdale and Associates Ltd. and Jim McDougall owns and operates North of 60 Engineering. The Federal Panel on Energy R&D contracted these two specialists to assess Canada's Frontier energy options.

2. It is important to realize that even if the international oil price were to rise to \$25 U.S. per Bbl., the Arctic development options would not simply "toggle-on" for several reasons; firstly, a high international oil price would have to be accompanied by a set of circumstances which would lead industry to perceive such a price level to be stable. Also, given the short-term focus of the oil industry, this price level would have to be considerably higher than the threshold prices for each Arctic project before such projects would be considered (a risk premium). Also, there are a number of competing projects south of 60 that would be more attractive at higher prices, relative to the Arctic reserves. The fact that any developments in the Arctic would be subject to severe environmental and social review standards also acts to increase the size of the "risk premium" that would be required to attract serious industry attention back to the Canadian Arctic. All this is in lieu of a political desire to transplant industrial activity in the Canadian North.

3. By redundant I mean that from the point of view of the method of analysis described in chapters 5 and 6, certain scenarios would have appeared different only in a quantitative sense. From their perspective, the scenarios were each quite unique since their model depends to a great degree on input parameters representing discount rates, interest rates, materials costs etc..

4. Note that the report deals with all Frontier reserves including those offshore in eastern Canada as well as those offshore in western Canada. The bulk of the report however focussed on the Arctic reserves.

5. It should be noted that the NORCOST[®] Model is the property of **North of 60 Engineering** and it was not used in this dissertation. The scenarios and capital investment time-lines used later in the dissertation are the direct result of the application of this model by **North of 60 Engineering**.

6. These smaller fields may, in total, provide an additional 100M Bbls. of Beaufort Oil, but they are dispersed over several hundreds of kms. and would be less economic to develop than this generic case. The possibility exists that if the lead 100M Bbl. field is found, these many smaller fields could be tapped in time to maintain the throughput in the pipeline thereby reducing the tariff paid to get the oil to southern markets.

7. This is what is meant when Amauligak is referred to as the lead or anchor field in the Beaufort. It will draw the necessary infrastructure which could enable smaller fields to be tapped economically.

8. Note that DCFR is an acronym for discounted cash flow rate of return.

Chapter 4

The Input-Output Model: Extensions for Regional and Dynamic Analysis

4.0 Introduction

In light of the fact that Canada is an amalgam of interacting and diverse economic regions, the fact that the Multiregional Input-Output (MRIO) approach has not been applied extensively is surprising. Canada's central statistical agency, Statistics Canada, maintains and publishes data for an MRIO model of the Canadian economy but to date, use of this resource appears to have been modest. Applications have been associated with the assessment of the interregional impacts of large scale capital projects in the Northwest Territories (NWT) and Alberta. Specifically, Douglas and MacMillan (1981) used Statistics Canada's 1974 MRIO model of the Canadian economy to assess the interregional economic impacts of developing the Alsands Project in Alberta, and more recently, the Conference Board of Canada has used Statistics Canadas' 1984 MRIO model to assess the interregional economic impacts of various resource development scenarios for the NWT and of the implementation of the proposed GNWT Transportation Strategy of 1991 (see Conference Board of Canada, 1990;1991).

The development of the "many-region" approach stems directly from the need clearly expressed in the pioneering regional I-O studies of the late 1950s and early 1960s to take explicit account of the fact that regions in a national system are characterized by a high degree of interdependence. Early studies by Miller (1966; 1969) showed that while a single region model may accurately reflect the production technology of a region as compared to the nation as a whole, the effect of ignoring interregional connections could be significant. These results were substantiated by later studies, and this, combined with the slow emergence of necessary data, allowed this interconnectedness to be taken into account.

The dynamic input-output (I-O) technique represents another variation on this theme of building more and more information into the fabric of the model. Any static I-O analysis makes the implicit assumption that all sectors in the model have sufficient capacity to deliver the goods demanded of them. In an attempt to reflect the fact that sectors also draw inputs to augment capital stocks to maintain and/or enhance productive capacity, the Dynamic I-O approach was developed. While initially fraught with many practical and theoretical difficulties, the approach appeared to represent a major advance, especially for regional analyses where the issue of capacity constraints was even more critical. A logical extension then of this *development pathway* would be a many-region version of the dynamic I-O model, but the literature has yielded few examples of such a framework, with the models offered by Miernyk (1968) and Bargur (1969) being

the noteworthy exceptions. Chapter 5 offers one version of such a model using a reformulation of Leontief's Dynamic Inverse approach. The main objective of this chapter then, is to provide a linkage to the literature which should allow the derivations presented in chapter 5 to be fully appreciated.

This chapter therefore, will chronicle the development of the I-O model as a tool for use in regional impact assessment. Specifically, the evolution of the concept from the simple national model to the single region model, the manyregion model, and finally to the dynamic model will be discussed. The dynamic I-O section will end with a discussion of a reformulation of Leontief's Dynamic Inverse approach which allows the effects of capacity exceedance to be accommodated by the model.

4.1 Leontief's Input-Output Model

The Input-Output model represents the culmination of an analytical framework developed by Professor Wassily Leontief in 1936 for which he received the Nobel Prize in Economic Science in 1973.¹ Leontief's framework was developed for the purpose of analyzing the interdependence of industries in an economy. As later sections illustrate, the Input-Output (I-O) model, in it's most basic form, consists of a set of linear equations, one for each sector present in the economy, which describes the distribution of each industry's product throughout the economy. Richardson (1972), Hewings (1985), and Miller and Blair (1985),

among others, have noted that Leontief's I-O model could be considered to be a formalization of principles developed by the seventeenth century French economist Francois Quesnay, as well as a simplification of the generalised model of Walras (1870). Quesnay, in 1758, published a "Tableau Economique" which consisted of a diagrammatic representation of how expenditures could be traced through an economy in a systematic manner. In later work, Quesnay quantified these expenditure flows between various segments of the economy and represented them in what amounted to an early version of Leontief's transactions table. Leontief (1936), in introducing some very early empirical work, made note of the fact that he was attempting to construct a Tableau Economique of the American economy. Although the concept of tracing the path of each dollar spent in an economy may not have been entirely novel when Leontief was developing his framework, the foundations and extensions both made and facilitated by his work have made a lasting impression on the modern era of economic analysis.

The I-O model has been developed over the five decades since it's formal introduction to the point where it has become one of the most widely used methods of economic analysis and one of the most powerful tools for assessing how an economy could be affected by exogenous changes. This development is the main issue to be addressed in the following pages of this chapter.

The simplest of input-output (I-O) models - the national model - is constructed from observed data for a particular country. Leontief's work rested

on the notion that economic activity could be allocated to a number of transactions taking place between "segments" or sectors of the economy being examined. These sectors may be defined as finely as those that produce steel nails, leather products and advertising services, or in a more aggregate fashion such as manufacturing, travel, advertising and promotion and mines quarries and oil wells.² In either case, arranging the transactions between various sectors in a transactions table as suggested by Leontief (1936) made a detailed analysis of the essence of the intersectoral relations of an economy possible. These interindustry or intersectoral (the terms industry and sector are used interchangeably) transactions are typically measured for a particular time period (usually for a particular year) in monetary terms.

Leontief's primary conceptual leap over and above the earlier descriptive framework of Quesnay (1758), was the idea that the exchanges of goods between sectors, say between sector i and sector j, during a year were related to the amount of goods produced by sector j during that year. That is, the amount of sector i output (e.g., glass) used by sector j (e.g., automobile manufacturing) in a year is directly related to the level of output experienced by sector j (i.e., demand for automobiles) in that year. In addition, Leontief postulated that in any economic area, any sector i also sold output to purchasers who were external to the economic system or "exogenous" such as households (personal consumption expenditures), government (government consumption, construction, investment

etc.) and foreign trade. As Miller and Blair (1985) noted, the demands of these groups or categories, or the magnitudes of their purchases from each of the internal sectors, are generally determined by factors that are unrelated to the level of output being experienced by the external unit (e.g., government demand for aircraft is related to broad changes in national defence policy and not to the level of output of the government sector, etc.). The demand levels exhibited by these exogenous categories then, tend to be much more for goods to be consumed [by final users] and not as inputs to an industrial production process as such. These external or exogenous categories then were distinguished from the industrial sectors and were referred to by Leontief as the "final demand" categories. Once these distinctions were made, the application of Leontief's conceptual framework began with the creation of databases detailing the flow of each sector's output to each of the intermediate and final demand categories - the transactions table. The transactions table, to repeat, made clear how each sector in the economy was disposing of its output. Reading across a row of a transactions table shows how each sector i sells its product(s) to other sectors and to final demand categories, and reading down a column shows how any sector j purchases necessary inputs from all other sectors. To complete this picture of the input recipe for each sector, a payments or "value-added" row (or series of rows) was added to the transaction table to track each sector's purchases of items such as labour services, taxes, imported goods, interest (cost of capital) and profits (the cost of entrepreneurship)

etc.. Thus, reading down a column of the transactions table gives a complete accounting of the purchases made by each sector in producing its output. Leontief's distinctions allowed the total output of each sector - defined as it's deliveries to other sectors and to final demand categories - to be computed by summing across each row of the transaction table as follows;

$$X_i = Z_{i,1} + Z_{i,2} + \dots + Z_{i,n} + Y_i$$
 4.1

where the z terms on the right hand side (RHS) represent the intersectoral sales of sector i's output, and the Y term represents the sales of sector i's output to final demand categories. Given one such equation for each productive sector in the economy, Leontief was able to portray the vital operations of an economy via a system of linear equations.

As mentioned earlier, Leontief distinguished between transactions which occurred between industrial firms and those that took place between industries and the various final demand categories. Using these conventions, Leontief was able to quantify the relationship between the level of output in sector j and the purchases by sector j of sector i output as follows;

$$a_{ij} = \frac{Z_{ij}}{X_j}$$

$$\therefore$$

$$Z_{ij} = a_{ij}X_j$$
4.2

where the a_{ij} term was referred to as a *technical coefficient*. The technical coefficient represents the dollars worth of sector i output required per dollar of sector j output.³ It is this step in the construction of Leontief's framework which both gave rise to a very useful tool for economic analysis, and initiated a process of gradual dislocation of I-O theorists and practitioners from mainstream economics which persists to this day. The fact that these coefficients, which Leontief used to quantify the nature of the relationship between a producer of goods and its input suppliers, were necessarily static implied that input substitution and scale effects could not be represented in the framework (i.e., the assumption of static a_{ij}'s embodies the assumption of constant returns to scale, and the assumption that the elasticity of substitution is zero which implies an assumption of no technological change). This reliance on simple proportions also involved the assumption that marginal changes and average changes were identical.

However, once the notion of a set of fixed technical coefficients was accepted in light of the model's many attractive features, Leontief was able to represent the interdependent nature of the sectors which defined the economy in question with a set of linear equations as follows;

$$X_{1} = a_{11}X_{1} + a_{12}X_{2} + \dots + a_{1n}X_{n} + Y_{1}$$

$$X_{2} = a_{21}X_{1} + a_{22}X_{2} + \dots + a_{2n}X_{n} + Y_{2}$$

$$X_{3} = a_{31}X_{1} + a_{32}X_{2} + \dots + a_{3n}X_{n} + Y_{3}$$

$$\vdots$$

$$X_{n} = a_{n1}X_{1} + a_{n2}X_{2} + \dots + a_{nn}X_{n} + Y_{n}$$
4.3

where the Z_{ij} terms shown earlier in equation 4.1 have been replaced by the expression for z_{ij} derived in equation 4.2. It should be clear that this representation of each industry's total output makes explicit the dependence of interindustry flows on the total output of each sector. Leontief however, did not set out to merely describe the flows of goods between sectors, but rather to explain them. In so doing, the earlier distinction between the endogenous and exogenous portions became critical. Leontief's objective was to be able to answer the following question;

"...if the demands of the exogenous sectors were forecast to be some specific amounts next year, how much output from each of the sectors would be necessary to supply these final demands?" (Miller and Blair, 1985 pp.14)

Clearly, Leontief wanted to be able to model the behaviour of the productive sectors of an economy in response to exogenous changes in the key demand categories - the variety of final users of the industrial products. Once this objective is clearly understood the need for the technical coefficients becomes apparent. Leontief accomplished this task analytically by solving the set of linear equations shown above [which defined the intersectoral relations of the economy in question] for the endogenous variables in terms of the exogenous variables and

the constant technical coefficients. By rearranging terms in equation 4.3 above, and gathering like terms, the following result was realized;

$$(1-a_{11})X_1 - a_{12}X_2 - a_{13}X_3 - \dots - a_{1n}X_n = Y_1$$

- $a_{21}X_1 + (1-a_{22})X_2 - a_{23}X_3 - \dots - a_{2n}X_n = Y_2$
- $a_{31}X_1 - a_{32}X_2 + (1-a_{33})X_3 - \dots - a_{3n}X_n = Y_3$
 \vdots
- $a_{n1}X_1 - a_{n2}X_2 - a_{n3}X_3 - \dots + (1-a_{nn})X_n = Y_n$
4.4

which, for a given set of Y_i's, is a set n linear equations in n unknowns. Leontief's I-O model then, a model which would generate values for sectoral output levels given any vector of Y_i's, was expressed as follows;

$$(I - A)X = Y$$

$$\therefore$$

$$X = (I - A)^{-1}Y$$
4.5

where A is an (nxn) matrix of technical coefficients, X is an (nx1) vector of sectoral output values, Y is an (nx1) vector of final demand values, and I is an (nxn) identity matrix.

The basic national (or single region) model discussed above represents the end result of Leontief's seminal work of 1936. As Richardson (1972) noted, the first empirical application of Leontief's system was undertaken in 1944 using a 46 sector table of the United States in an attempt to estimate the effects of the end of the Second World War on employment in the U.S..

The national I-O model therefore was based on this set of unchanging

technical coefficients. This reliance both made the concept appealing for applied work and opened the door for significant criticism from economic theorists. This set of fixed technological relationships between goods producing sectors and their input suppliers was initially specified for a group of sectors at the national level, and the model was inherently spaceless, not to mention timeless. The aspatial nature of the national I-O model was acknowledged by Leontief, as well as others, and the efforts which culminated in a set of regional I-O approaches are chronicled in the following section of this chapter.

4.2 Regional Extensions

Work in regional I-O analysis has yielded two basic categories of approaches - the "single region" approach, and the "many-region" approach. The earlier works (pre-1965), which are cited below, were concerned primarily with the creation of a representative technical coefficient matrix for the region under examination via the use of various *weighting schemes* applied to a national technical coefficient matrix. While acknowledging the fact that regions which comprise a national economy were interconnected through trade, the early regional I-O applications did not attempt to reflect this interdependence in the I-O model. Rather, the focus was on differentiating regional input structures from the national input structure.⁴ The second branch in regional I-O analysis was focussed on the issue of incorporating the interdependent nature of regions which

define a national system within the fabric of the I-O methodology, and the Interregional and Multiregional I-O (IRIO and MRIO) models, along with subtle reformulations such as Leontief's balanced regional model and the gravity model based commodity flow model of Leontief and Strout, were the result. This section will discuss each of these branches separately and point out how the evolution from the single region case to the many region case represents an attempt to better understand how regions could be affected by exogenous shocks.

4.2.1 The Single Region Approach

Early regional studies such as those by Isard and Kuenne (1953), Moore and Petersen (1955), Miller (1957), and Hirsch (1959) typify the "first-generation" of regional I-O analysis where the focus was on adapting national technical coefficient matrices to reflect regional peculiarities (see also Miernyk et al. (1967), and Miernyk et al. (1970), and Isard and Langford (1971)). Miller and Blair (1985) noted that most of the early studies cited above made use of estimated regional supply percentages (where these were analogous to the weights referred to by Hewings (1985)), one for each sector in the regional economy where each was defined as follows;

$$p_{j}^{R} = \frac{\left(X_{j}^{R} - E_{j}^{R}\right)}{\left(X_{j}^{R} - E_{j}^{R} + M_{j}^{R}\right)}$$
4.6

where E_j^R denotes the exports of sector j output from region R, and M_j^R denotes the imports of sector j output from other regions (including foreign sectors). Clearly, the numerator represents the locally produced amount of good j that is available to purchasers in region R while the denominator represents the total amount of good j available for use in region R either from local suppliers or from imports. Miller and Blair noted that a diagonal matrix of these regional supply percentages could be post-multiplied by the national technical coefficients matrix thereby yielding a rough estimate of the regional technical coefficient matrix as follows;

$$\mathbf{A}^{\mathbf{R}} = \hat{\mathbf{P}} \mathbf{A}^{\mathbf{N}} \qquad \mathbf{4.7}$$

this type of adjustment was used by Isard and Kuenne (1953) and Miller (1957) to generate technical coefficient matrices for the Delaware Valley and the Pacific Northwest respectively. Miller and Blair (1985) also discussed a number of variations of the basic regional supply percentage which were used to get at the underlying character of the region under examination (see Miller and Blair, 1985; pp.295-302). This procedure of forming a regional technical coefficients matrix by weighting a national matrix amounts to what has been referred to in the literature as a *regionalization* scheme where such schemes assume that the fundamental structures of the region and the nation are not dissimilar and that the regional supply percentages (of various sorts) can be used to reflect how much of each

input to a sector in a region actually comes from production within the region itself. Such a procedure allows for an assessment of how prescribed economic changes in the region may affect the regional economy but it precludes an analysis of the true structure of the regional economy. Miller and Blair (1985) make clear the potential for misleading results from the use of the previously discussed regionalization scheme;

"...consider the aircraft sector. In a national table, this would include the manufacture of a mix of commercial, business, and personal aircraft. One input to this sector would be the huge jet engines used on 747 and DC-10 commercial airliners. On the other hand, the aircraft sector in a regional table for the state of Pennsylvania would reflect the manufacture of Piper airplanes only, for which the jumbo jet engines are not an input at all; in a Washington table however, jet engines are an extremely important input." (Miller and Blair, 1985; pp. 49).

Miller and Blair (1985) and Hewings (1985) noted that the surest way of getting around this *product-mix problem* was to directly survey firms in a region and construct a survey-based regional input-output table. Both Miller and Blair (1985) and Hewings (1985) discussed two basic types of survey instruments which could be used to compile the regional tables. They noted that If questions were posed to firms in the region which aimed at identifying how much of sector i's output the firm purchased last year, for example, then a *regional technical coefficient* which accurately reflects the technology of the purchasing sector in the region could be computed. If these coefficients were used in conjunction with a regionally defined exogenous shock vector, then the gross output impacts generated would reflect not only the impacts on sectors in the region but also the

impact on sectors outside the region. This is so since the regional technical coefficients do not differentiate inputs used by a sector which came from local sectors from those coming from sectors outside the region. The result would be an inaccurate picture of the region specific impact. To remedy this situation, a regional supply percentage could once again be applied to form estimates of the *true regional input coefficients*. Alternatively, Miller and Blair (1985) noted that the survey instrument used to acquire the base data could be refined to the point where firms were surveyed as to their input purchasing patterns by region. Based on this data, a regional input coefficient matrix could be computed which would not reflect the technology of the purchasing sector in the region of interest, but which would provide an accurate picture of how regional firms use local inputs. The regional input coefficients would be computed as follows;

$$\mathbf{a}_{ij}^{LL} = \frac{Z_{ij}^{LL}}{X_i^{L}}$$
 4.8

where Z denotes an intersectoral flow, X denotes the total output of sector j, and the superscripted L denotes region L. Similarly, if a complete set of data on the flows to sectors in region L from sectors in region M were compiled then the following coefficients could be computed;

$$\mathbf{a}_{ij}^{ML} = \frac{\mathbf{Z}_{ij}^{ML}}{\mathbf{X}_{j}^{L}}$$

where these were referred to as interregional input or trade coefficients. The application of the regional supply percentages to the national technical coefficient matrix, as discussed above, represented an attempt to approximate the regional input coefficients derived in equation 4.8 above. If the less specific survey instrument (where the locations of the selling sectors were not tracked) were to be used to compile a transactions table then the industry balance equations would reflect the total amount of sector i output used by sectors in region L irrespective of where that input came from. Such data, as previously mentioned would allow for the computation of regional technical coefficients as follows;

$$a_{ij}^{L} = \frac{Z_{ij}^{L}}{X_{j}^{L}}$$
where
$$Z_{ij}^{L} = Z_{ij}^{LL} + Z_{ij}^{ML}$$

$$\therefore$$

$$a_{ij}^{L} = a_{ij}^{LL} + a_{ij}^{ML}$$
(4.10)

where clearly, the regional technical coefficient represents the sum of the regional input coefficient and the regional trade coefficient. Miller and Blair (1985) noted that once the regional technical coefficients were computed, the effects of any regional final demand shock could be assessed as shown in equation 4.5. In this case however the A matrix in equation 4.5 is replaced by the regional technical

coefficients matrix A^{L} (where $A^{L} = [a_{ij}^{L}]$). As mentioned earlier however, the gross output vector generated by such a model would include the effects on sectors in region L of imports from sectors in other regions. It must be kept in mind however that the approach pioneered by Isard and Keunne (1953), Moore and Petersen (1955), Miller (1957), Hirsch (1959), Miernyk et al. (1967), Miernyk et al. (1970) and Isard and Langford (1971) was in response to the unavailability of this sort of regional data. Even today this sort of data is not found in abundance, and in many cases elaborate weighting schemes which amount to a virtual reconstruction of a regions' I-O table have to be used.

4.2.2 The Many-Region Approach

The single region approach discussed above does a better job of assessing regional impacts than would a weighted national model, but the fact remains that the region of interest in these models is, for all intent and purpose, disconnected from all other regions which define the system. At the subnational level, imports and exports begin to play a very significant role in determining how a region could both be affected by a final demand shock in that region and how other regions in the system may be affected. Incorporating the notion of a region as an interconnected component of a national system involves the formal recognition of two principal effects; *interregional spillover effects* (IRSE), and *interregional feedback effects* (IRFE). The former effect represents the fact that a final demand

shock for goods produced in one region may lead to a direct stimulus to production on sectors in other regions. If sector j in region L, for example, were to experience an increased demand for its output, then this sector in meeting this demand would have to draw inputs, in a manner dictated by the regional technical coefficients matrix, from sectors in region L as well as from sectors in all other regions, M (where M denotes a second region which for our purposes will define the entire system). It is important to remember that the regional technical coefficient is inclusive of the interregional trade coefficient. This interregional *backward linkage* then will result in sectors in region M producing direct inputs to sector j in region L to satisfy the demands placed on it. The magnitude of this effect on sectors in region M cannot be estimated with a single region model. Miller and Blair (1985) provide an instructive example which clearly shows how the omission of an explicit representation of interregional backward linkages can lead an incomplete picture of the impact of a shock to an interregional system;

"Next year's national defense budget might include a large order of a certain type of aircraft built in California, the overhaul of a fleet of ships in Virginia, and the expansion of a missile detection facility in North Dakota. Each of these new demands will probably have ramifications not only within the region [state in this example] where the work is done, but also in other regions. Firms outside California will produce goods that will be imported to California for aircraft production; those firms in turn may import goods from other regions for their production. Materials for ship overhaul will come to Virginia from suppliers outside that region. Electronic parts for the missile detection facility in North Dakota will be imported inputs and so on." (Miller and Blair, 1985; pp. 54).

Clearly then, the total impact of the national defense plan on any one region could

not be accurately estimated with a SRM.

The latter effect, the interregional feedback effect (IRFE), represents that output effect felt by sectors in region L which result from the fact that sectors stimulated in region M as a result of the initial shock in region L may require direct inputs from sectors in region L. Thus, the initial shock to sector j in region L. results, due to a circuitous chain of impacts, in an additional stimulus to sectoral output in region L. Once again, the magnitude of the interregional feedback effect cannot be estimated with a SRM. It is also intuitively clear that impacts generated by a SRM will always underestimate the "true" magnitude of the impact by virtue of the fact that the IRFEs cannot be captured by the SRM. In fact, Miller (1966; 1969) highlighted the Isard and Kuenne (1953) study of the impacts of the steel manufacturing sector on the New York-Philadelphia region as an example of a situation where the omission of the IRFEs seriously curtailed the usefulness of the study. He also made the same criticism of one of his own earlier works which attempted to assess the impact of the Aluminum industry on the Pacific Northwest region of the U.S.. It was the recognition of these deficiencies of the SRM which led researchers to seek to make these interregional dependencies an endogenous feature of the I-O system of balance equations. Richardson (1972) makes this clear in the following quote;

"...since it may be argued that it's [the I-O models'] general equilibrium character is the main virtue of the I-O approach, then this character should not be sacrificed lightly. When we introduce space...into the economy, however, as in regional I-O analysis, it is very difficult to retain

the general equilibrium features of I-O theory. The most widespread regional I-O model in common use is the single region model. This is a partial model in it's preoccupation with economic impacts affecting the study region alone and in it's aggregation of the rest of the world into one other region [through a vector of imports and exports]. The interdependence of the local industrial structure is retained, but the model throws no light on the interdependence of economic regions...In short the single region model allows us to take account of local industry feedbacks but neglects interregional feedbacks...The implication of this point is clear. If regional I-O studies are to qualify as general equilibrium analysis, then interregional rather than single region I-O models must be developed" (Richardson, 1972; pp.53-54).

4.2.2.1 The Interregional Input-Output Model

The previous discussion has made it clear that the SRM approach to subnational I-O work is fraught with difficulties due mainly to the fact that as the geographic focus of the I-O analyst gets sharper and sharper and the region of interest goes from being the nation as a whole to a large sub-region encompassing many states/provinces, to the state/provincial level, to the metropolitan level, the importance of accounting for interregional dependencies of sectors in all regions grows exponentially. At the national level, while international imports and exports allow for international linkages which can transmit economic shocks between nations, the national model captures all effects as a result of a final demand shock with no interregional spillovers or feedbacks of interest to account for.⁵ In fact, in the same manner that the regional technical coefficient, the national technical coefficients can be shown to be inclusive of an *international*

trade coefficient. It can be argued however, that at the national level these impacts are tangential to the primary purpose of the application, whereas at the regional level, these effects are vital to a true understanding of regional impacts.

Recognition of the previously discussed need in regional work to account for the interdependency of regions in a national system led to the development of the Interregional Input-Output (IRIO) Model, or "the Isard Model" since the framework was first proposed by Isard (1951).

"The theoretical structure of the of interregional I-O models was first discussed...by Isard (1951), but apart from impressive pioneering work by Moses (1955) little progress was made in applying interregional models until recent years, primarily because of data limitations and computer capacity constraints." (Richardson, 1972; pp.54).

To provide a basic understanding of the approach, consider a national economy which has been totally defined by 2 regions, L and M, and that detailed data exists which describes the flow of goods between each of 2 sectors in each region. Using the same notation as in the SRM case, the complete data set for this 2 region example can be defined as follows;

$$Z = \begin{bmatrix} Z^{LL} & Z^{LM} \\ Z^{ML} & Z^{MM} \end{bmatrix}$$
4.11

where Z^{LL} is a (2x2) matrix, Z^{LM} is a (2x2) matrix, Z^{ML} is a (2x2) matrix, and Z^{MM} is a (2x2) matrix. In the SRM discussed above only intraregional information was used and the elements in the off-diagonal matrices were not considered. In the

process of making the interconnections between regions an explicit feature of the model, the basic industry balance equation discussed earlier in equation 4.1 was extended to account for the fact that sector i output in region L will be consumed by sectors 1 and 2 in region M, as well as by sectors 1, and 2 in region L as follows;

$$X_{1}^{L} = Z_{11}^{LL} + Z_{12}^{LL} + Z_{11}^{LM} + Z_{12}^{LM} + Y_{1}^{L}$$
 4.12

where the first 2 terms on the RHS represent the sales from sector 1 in region L to the 2 sectors in region L, and the final 2 terms represent the sales of region L's sector 1 output to the 2 sectors in region M. The final term on the RHS of 4.12 above represents the sale of region L sector 1 output to final demand categories in region L. Equation 4.12 therefore equates the total sector 1 production in region L to the total uses of all of region L's sector 1 production, and therefore it is often referred to as an industry balance equation. Given that we are assuming the existence of true survey based interregional transactions tables, the interregional input coefficients may be defined as follows;

$$\mathbf{a}_{ij}^{LM} = \frac{Z_{ij}^{LM}}{X_{i}^{M}}$$
 4.13

and likewise for the intraregional input coefficients. Note how the flow of sector i output from region L to sector j in region M is dependent upon the level of sector j output in region M. Based on these regional coefficients then, the industry balance equation for sector 1 in region L could be re-written in the following form;

$$X_{1}^{L} = a_{11}^{LL}X_{1}^{L} + a_{12}^{LL}X_{2}^{L} + a_{11}^{LM}X_{1}^{M} + a_{12}^{LM}X_{2}^{M} + Y_{1}^{L}$$

$$(1 - a_{11}^{LL})X_{1}^{L} - a_{12}^{LL}X_{2}^{L} - a_{11}^{LM}X_{1}^{M} - a_{12}^{LM}X_{2}^{M} = Y_{1}^{L}$$

$$4.14$$

where the second equation in 4.14 above is simply a re-arrangement of the first. Given one such balance equation for each sector in both regions, and adopting the partitioned matrix notation shown earlier, the IRIO system for this 2 region case could be expressed as follows;

$$(I - A^{LL})X^{L} - A^{LM}X^{M} = Y^{L}$$

 $-A^{ML}X^{L} + (I - A^{MM})X^{M} = Y^{M}$

4.15

Miller (1966;1969) showed that relative to the equation which would define the industry balance for region L in a SRM, the extra term on the LHS of the first equation in 4.15 above captures the flow of goods from L to M on product account, and that an analogous interpretation can be ascribed to the first term on the LHS of the second equation in 4.15 which is the industry balance matrix equation for region M (Miller, 1966; pp. 107). Miller (1966;1969) noted that the industry balance equation for region L in 4.15 above could be decomposed as follows using *regular simultaneous equation procedures;*

$$X^{L} = [(I - A^{LL}) - A^{LM} (I - A^{MM})^{-1} A^{ML}]^{-1} Y^{L} +$$

$$[(I - A^{LL}) - A^{LM} (I - A^{MM})^{-1} A^{ML}]^{-1} A^{LM} (I - A^{MM})^{-1} Y^{M}$$
4.16

and likewise for region M. Miller (1966) noted that the total output of sectors in region L is divided, in equation 4.16, into the requirements for production needed to satisfy the final demands of region L, and requirements associated with the demands of region M. He showed, through this expansion of the interregional industry balance equation, that the first large expression on the RHS of 4.16 represents the interregional feedback effect; production in region L which stimulates activity in region M (a spillover effect) for direct inputs which results in a further demand for sectoral output in L for direct inputs (a feedback effect). Clearly the inverse of the SRM is devoid of this expression and hence it is unable to account for IRFEs. The second expression on the RHS of 4.16 represents the total gross outputs in region L which are required to meet final demands in region M. Miller (1966; 1969) defined this feedback effect, in an operational sense, as the difference between the output of a SRM and that of an IRIO model given the same final demand shock. He noted that when the sum of the absolute deviations (SRM gross output for all sectors in L minus the IRIO gross output for all sectors in L) is multiplied by 100, an index called the over-all percentage error (OPE) results which provides a measure of the average percent by which each element in the SRM gross output vector for region L can be expected to be in error as a

result of it's inability to account for the IRFEs. Miller's experiments with various 2 region systems and final demand configurations revealed that the IRFEs can cause a SRM to be in error by as much as 7 percent (Miller, 1966; pp. 114). Gillen and Guccione (1980) attempted to derive upper limits on the magnitudes of the IRFE that could be expected in various IRIO systems. They noted that, as expected, the IRFE exhibited by any region was strongly influenced by the level of self-sufficiency in that region where this self-sufficiency was measured by the extent to which region L, for example, was dependent on region M for imports. A higher level of dependence was reflected by larger coefficients in the interregional input coefficient matrices, ALM and AML, which as equation 4.16 suggests, would result in the generation of a larger IRFE in region L. Gillen and Guccione (1980) also confirmed the intuitive hypothesis that this level of selfsufficiency was a function of the geographic size of the region under consideration. Beyers (1976) was able to show that for some industries in the state of Washington, the IRFEs were larger than the intraregional indirect effects. However, the 2 regions used in this study were quite large - region 1 was Washington State, and region 2 was the rest of the U.S.. Given the findings reported by Gillen and Guccione (1980), we would expect the IRFEs to be large when the regions involved were large. That is, any shock to production in Washington State which called for imports from the rest of the U.S. would guite likely result in a call for inputs from sectors in Washington State thereby resulting

in a large IRFE for Washington State. A large IRFE in the second region should come as even less of a surprise. Hewings (1985) noted that while the evidence regarding the importance of the IRFEs is scanty, the early work of Miller (1966;1969) produced some rather confusing and conflicting results and that it was the work conducted within an expanded economic base regional income multiplier model developed by Brown (1967) and Steele (1969) that demonstrated the importance of these influences, especially in smaller very open regional economies (see also Greytak, 1970). Hewings (1985) went on to note that...

"Subsequent research especially by Miller and Blair (1981) and Blair and Miller (1983) ...continues to provide evidence for the need to recast the regional models into at least a two-region context. Thus, even in the development of a model for a single region, it would be preferable to construct a model with two "regions" - the region in question and the rest of the country of which it is a part." (Hewings, 1985; pp. 59)

The IRIO approach therefore represented a clear departure from the SRM approach by making the interdependence which characterizes most sub-national economies an endogenous feature of the framework, and as Richardson (1972) noted above, retaining the general equilibrium character of the basic I-O methodology at the regional level. Miller's experiments of 1966 and 1969 may have down-played the importance of interregional feedbacks in assessing the impacts of change on regional systems (since his experiments suggested that the IRFEs ranged from between 0.25 to 7.0 percent), but the fact that the spillovers and feedbacks could be measured in the IRIO framework indicated the clear

superiority of the approach relative to the SRM approach.

While intuitively and theoretically attractive, the IRIO model with a few exceptions has not been implemented to any considerable degree due to the fact that the requisite data on shipments of goods between sectors and between regions were not, and still are not, readily available.⁶ A survey of firms aimed at acquiring such information would also be fraught with difficulties of reconciliation, confidentiality, and cost. As the following section will show, a compromise between the SRM approach and the IRIO approach yielded a framework which still endogenized interregional interdependence but which significantly reduced the data requirements which have acted to impede the general application of the pure IRIO approach.

4.2.2.2 The Multiregional Input-Output Model

The end result of the compromise mentioned above was the Multiregional Input-Output (MRIO) model. Miller and Blair (1985) noted that;

"While a complete interregional model...is generally far beyond possibility for very many regions and/or sectors because of the problems of data availability...the framework has inspired modifications and simplifications in the direction of operationality." (Miller and Blair, 1985; pp. 69).

These modifications and simplifications were pioneered by the work of Professor Polenske and her associates at MIT in the early 1980s (see Polenske, 1980). Polenske's work was focussed on developing a many region I-O model for the U.S. economy which treated the trade flows between all states as endogenous variables. Miller and Blair (1985) noted that the Polenske model represented an extremely ambitious empirical application of the framework suggested (independently) by Chenery (1953) and Moses (1955), and that as a result the MRIO model is often referred to as the Chenery-Moses model.

The modification which made the MRIO model a more practical model as compared to the IRIO model was the use of regional counterparts to the regional input coefficient matrices, A^{LL}, and the trade coefficient matrices, A^{LM}. That is, in place of the regional input coefficient matrix (A^{LL}) used in the IRIO model, a regional technical coefficient matrix (A^L) is used in the MRIO model. The regional input coefficients were derived from detailed survey data which indicated for each sector in region L the inputs purchased from sectors in that region only, and the trade coefficients indicated the purchases made by each sector in region L which came from every other region M. More generally, to construct all matrices for the IRIO model, a detailed survey which established the sectoral and regional source for all inputs used by sectors in a region had to be conducted. Regional technical coefficients, on the other hand, are computed from data gathered by the implementation of a far less detailed survey instrument. This reliance on regional technical coefficients was a feature of the SRM approach discussed above, and this is why the MRIO model was referred to as a compromise between the SRM and IRIO approaches.

The fact that the region of origin for inputs to sectors in each region was

dropped meant that the interregional trade tables, A^{ML} and A^{LM}, could not be formed as they were in the IRIO case. Instead, the MRIO approach captured the interconnections among regions with the use of interregional trade share coefficients. In a manner analogous to the regionalization of the national flow data discussed above in the SRM case, the MRIO model's trade share coefficients were used as weights to allocate the regional technical coefficients to the interregional off-diagonal - portions of the block A matrix. As will be clear in the following exposition, this procedure is completely analogous to the weighting procedure used to create regional coefficients from national coefficients. This modification was motivated by the need to take advantage of the types of information that were likely to be available in a system of regional accounts.

For sector i, for example, data are gathered on the flows of good i from a particular region to all others. If we let Z^{LM} denote the dollar flow of good i from region L to region M irrespective of the sector of destination in the receiving region, then a shipments table detailing the flows of good i (for all goods, i) from each region to each other region could be created. Based on this sort of information, coefficients which represent the proportion of all of good i used in region M that comes from each other region, L, could be computed, c^{LM}. The computation of these trade shares required only that sector specific export data be tracked for each region in the system. These trade shares were defined as follows;

$$\mathbf{c}_{i}^{\mathrm{LM}} = \frac{\mathbf{Z}_{i}^{\mathrm{LM}}}{\mathbf{T}_{i}^{\mathrm{M}}}$$
 4.17

where T^M denotes the total amount of good i used in region M. The quotient clearly depicts the proportion of all of good i used in region M that originated in region L (with no sectoral source specified). Once the shipments tables for all goods have been converted to these proportions, trade share coefficient matrices are formed for each trading pair over all goods. That is, for a 2 region system with 3 sectors in each, two interregional trade share coefficient matrices would have to be created, C^{LM} and C^{ML}, where these are defined as diagonal matrices with the trade shares for sectors 1, 2 and 3 run down the diagonal of each, where these shares pertain to the respective trading pairs. Intraregional versions of these matrices also had to be computed, C^{LL} and C^{MM}. The MRIO model then made use of C^{LM}A^M instead of the interregional input coefficient matrix, A^{LM}, used in the IRIO model. The industry balance equation for a 2 region MRIO model could be written as follows;

$$(I - \hat{C}^{LL}A^{L})X^{L} - \hat{C}^{LM}A^{M}X^{M} = \hat{C}^{LL}Y^{L} + \hat{C}^{LM}Y^{M}$$

$$-\hat{C}^{ML}A^{L}X^{L} + (I - \hat{C}^{MM}A^{M})X^{M} = \hat{C}^{ML}Y^{L} + \hat{C}^{MM}Y^{M}$$
4.18

where;

$$\mathbf{A} = \begin{bmatrix} \mathbf{A}^{\mathsf{L}} & \mathbf{O} \\ \mathbf{O} & \mathbf{A}^{\mathsf{M}} \end{bmatrix}$$
 4.19

$$C = \begin{bmatrix} C^{LL} & C^{LM} \\ C^{ML} & C^{MM} \end{bmatrix}$$
4.20

and where;

$$\mathbf{X} = \begin{bmatrix} \mathbf{X}^{\mathsf{L}} \\ \mathbf{X}^{\mathsf{M}} \end{bmatrix}$$
 4.21

$$\mathbf{Y} = \begin{bmatrix} \mathbf{Y}^{\mathsf{L}} \\ \mathbf{Y}^{\mathsf{M}} \end{bmatrix}$$
 4.22

and the final form of the MRIO model is expressed as follows;

$$(I-CA)X = CY$$

4.23
 $X = (I-CA)^{-1}CY$

the role of the interregional trade shares is clear. They act in a manner analogous to the regional supply percentages in the SRM. Each region's technical coefficient matrix is split to reflect those inputs which come from inside the region and those which come from sectors in other regions. The product of the C matrix and the A matrix acts as a "best-estimate" of the true interregional block input coefficient matrix. This is made clear when one examines the first row of the product matrix, CA;

$$\begin{bmatrix} c_{1}^{LL} a_{11}^{L} & c_{1}^{LL} a_{12}^{L} & c_{1}^{LM} a_{11}^{M} & c_{1}^{LM} a_{12}^{M} \end{bmatrix}$$
 4.24

which is clearly an approximation of the first row of the 2 region 2 sector IRIO input coefficient matrix. The trade proportions act to weight the regional technical coefficients in a manner which reflects the proportion of each commodity used in a region that comes from that region and that which comes from the second region. Applications of this sort of model can be seen in Polenske (1980), Douglas and MacMillan (1981), and Conference Board of Canada (1990;1991), to name a few. It is important to note that the Chenery-Moses MRIO formulation represents a compromise between the SRM and the IRIO approach. While the industry balance equations make interregional trade flows endogenous, the model relies on trade shares to allocate intersectoral flows to various trading pairs in a manner not dissimilar from the way regional supply percentages were used to regionalize national technical coefficients, and the same product-mix problem
exists.

Hewings (1985) noted that a few attempts have been made to get around this problem with the Chenery-Moses MRIO formulation by superseding the trade share method of estimating interregional trade flows with a gravity model based module which was designed to estimate the flow of goods between a pair of regions. He noted that the model developed by Leontief and Strout (1963) was typical of this approach and the most noteworthy. Hewings (1985) noted that in the Leontief-Strout version of the MRIO model, the flow of goods between regions were assumed to move into regional supply pools from which firms located within that region drew their inputs. Hewings (1985) noted that these regional supply pools could be considered as collections of the output of the various sectors which are differentiated by product but not by selling region. In the Leontief-Strout reformulation of the MRIO model then, the firms were assumed to be indifferent to the region of origin of the input requirement purchases. The general form of the trade component of the Leontief-Strout model appeared as follows;

$$Z_{i}^{LM} = \left[\frac{Z_{i}^{L} Z_{i}^{M}}{Z_{i}^{"}}\right] K_{i}^{LM}$$
4.25

where Z_i^{LM} denotes the total shipment of good i from the supply pool in region L to the demand pool in region M., z_i^{L} denotes the supply pool in region L, z_i^{M} denotes the demand pool in region M, and z_i^{M} denotes the total amount of good

i produced in the nation as a whole, and K_i^{LM} is an empirical constant which was defined as follows;

$$K_{i}^{LM} = (C_{i}^{L} + H_{i}^{M})d_{i}^{LM}$$
 4.26

where C and H are empirical constants and d is a measure of the reciprocal of distance between regions L and M for good i. Hewings (1985) noted that the value of d could be adjusted to a value of physical distance, time, or costs and thus may vary depending on the nature of the good shipped. Leontief and Strout (1963) noted that the expression in 4.25 above implied that the flow of a particular good i from region L to any other region M is assumed to be directly proportional to the total output of commodity I in region L, and to its total input in region M, and inversely proportional to the aggregate amount of commodity i available for use in the national economy. The definition of the constant term in 4.26 above suggests that this interregional flow was also proportional to some measure of the distance separating the two regions. Leontief and Strout (1967) noted that the multiplicative form in which the total output of good i in the exporting regions and of it's total input in the importing regions, as shown in 4.25 above permited them to characterize the interregional trade model as a gravity or potential model. They noted that an implication of this functional form for the interregional trade component was that if either of the 2 magnitudes for region L or M were zero,

then there could be no flow of good i between these two regions. However, as long as all elements are non-zero, 4.25 implies that good i will be shipped between regions L and M simultaneously in both directions. Leontief noted that while this sort of cross-haul effect represents less than rational behaviour, the fact that the data pertains to a period of time and not an instant in time makes this simultaneous flow generation a desirable feature. Leontief and Strout (1967) wrote;

"...the multiregional I-O scheme described...is not intended to provide a systematic theoretical description of the many factors and relationships that ultimately determine the pattern of a multiregional economic system; it is designed rather as a rough and ready working tool capable of making effective use of the limited amount of factual information with which ... economists have to work." (Leontief and Strout, 1967; pp.130)

Hewings (1985) discusses a variety of other commodity flow models which attempted to supersede the Chenery-Moses formulations' reliance on trade shares. He noted that while the approach was intriguing, model results were less than impressive.⁷ While these alternative approaches to estimating trade flows between regions are interesting, the literature has yielded few applications of this approach with the Chenery-Moses formulation accounting for the majority of applied MRIO studies. The point to be drawn from this brief discussion of modifications to the MRIO approach is that they all focussed on the development of a framework for estimating industry specific trade flows which could be nested within the industry balance equations thereby retaining the general equilibrium nature of the MRIO approach while getting around the product mix problem

inherent in the use of regional trade shares.

The many region approach then has some clear and significant advantages over the use of a single region model for all regional applications. In no case would it be desirable to evaluate the effects of a certain shock in a region without having properly endogenized interregional trade flows in some fashion. Even if the focus of a study was intraregional, to ignore the role of interregional trade would lead to misleading results especially if the region under examination is relatively open and small in relation to the nation of which it is a part (small in terms geographic size and/or sectoral potency). The previous discussion has indicated that not only do interesting and theoretically pleasing formulations exist. but practical approximations to the extreme case of a pure IRIO model are The data required to create such a model should exist, or be available. obtainable, for nearly any region considered. The more experimental gravity model reformulation of the MRIO model while intriguing has not been successfully proven to be worthy of the extra effort required. The following section will discuss one final type of regional model which characterizes one significant extension of the I-O concept to the sub-national level of analysis.

4.2.3 The Balanced Regional Model

The Balanced Regional Model (BRM) represents yet another variation on the theme of adapting Leontief's original framework to deal well with the fact that

production in a national system takes place in specific geographical locations. As stated above, the IRIO model and MRIO model represent the culmination of efforts to make interregional trade flows endogenous within the I-O system. The BRM however makes a different distinction initially. It divides the types of economic activities taking place in a national system into two groups; those which serve a regional or local market, and those which serve a national market. Miller and Blair (1985) noted that the BRM was first proposed by Leontief (1953) and first implemented by Leontief et al. (1965) in an analysis of the effects of a diversion of production away from military goods to nonmilitary goods on the U.S. economy. The basic mathematical structure of the BRM is identical to that of the IRIO model discussed above, but the interpretation of each of the pieces of the model differs significantly. Miller and Blair (1985) noted that the entire analytical structure is based on the observation that in any national economy there are goods which serve different types of market areas. That is Leontief (1953) envisioned two types of goods being traded in a national system; those for which production and consumption balanced at the national level and those for which production and consumption balanced at the regional or local level. Examples of the former, as suggested by Miller and Blair (1985) would be automobiles, aircraft, furniture or agriculture to name a few, while examples of the latter would be electricity, real estate, warehousing, and personal and repair services. Actually, there is an entire spectrum of possibilities from sectors which serve extremely

small local areas, such as a shoe repair shop, to sectors which serve large national or international markets, such as the Boeing Plant in Seattle Washington. For the purposes of the model however, Leontief assumed that economic entities could be assigned to either the regional or national categories. Once a listing of national sectors has been classified in such a manner, Miller and Blair (1985) indicated that the first step in implementing Leontief's BRM involved a rearrangement of sectors in the national technical coefficients matrix so that those which clear at the regional level are listed first, while those that clear in national markets are listed last. That is, for a total of n sectors in a national I-O table, sectors i=1, 2, ..., r denote regional sectors while sectors i=r+1, r+2, ..., n denote the national ones. The rearranged technical coefficients matrix would appear as follows:

$$\mathbf{A} = \begin{bmatrix} \mathbf{A}^{\mathbf{R}\mathbf{R}} & \mathbf{A}^{\mathbf{R}\mathbf{N}} \\ \mathbf{A}^{\mathbf{N}\mathbf{R}} & \mathbf{A}^{\mathbf{N}\mathbf{N}} \end{bmatrix}$$
 4.27

where R denotes regionally balanced sectors and N denotes nationally balanced sectors. The associated X and Y vectors would appear as follows;

$$\mathbf{X} = \begin{bmatrix} \mathbf{X} & \mathbf{R} \\ \mathbf{X} & \mathbf{N} \end{bmatrix}; \ \mathbf{Y} = \begin{bmatrix} \mathbf{Y} & \mathbf{R} \\ \mathbf{Y} & \mathbf{N} \end{bmatrix}$$
4.28

and the model could be solved in exactly the same manner as was the 2 region

IRIO model discussed above;

$$(I-A^{RR})X^{R}-A^{RN}X^{N} = Y^{R}$$

$$-A^{NR}X^{R}+(I-A^{NN})X^{N} = Y^{N}$$
4.29

where R and N do not refer to regions. These equations provide the total outputs of each sector in each of the two categories due to an exogenous change in final demand for the outputs of one or more of the national sectors and/or one or more of the regional sectors. It is very important to realize that this solution procedure only provides a gross output vector for national level sectors where some serve local markets while others serve national markets, and as such, no specific geographic locations for this production has yet been specified. In the Leontief et al. (1965) study, there was an assumed 20 percent reduction in government demand for the output of military related goods, some of which were national (e.g. aircraft) and some of which were regional (e.g. warehousing), along with an assumed across the board increase in non-military final demands. Thus, components in each of the Y^{R} and Y^{N} block vectors were altered.

To build a spatial dimension into the BRM, the final demands for regional sectors, Y^{R} , had to distributed across regions. Using Miller and Blair's notation, this meant that the Y^{R} vector had to be split into $Y^{R(L)}$ vectors for L = 1,..., r. Miller and Blair (1985) also suggested that for each region L, an estimate of the proportion of the total output of each nationally balanced sector that is produced

in region L (for all regions L) had to be computed, and that this information be used to form the following vector;

$$P^{L} = \begin{bmatrix} p_{r+1}^{L} \\ \vdots \\ p_{n}^{L} \end{bmatrix}$$
4.30

where p_{r+1}^{L} denotes the proportion of the total output of nationally balanced sector r+1 that is produced in region L. Therefore, given these regional proportions sectors r+1 though *n* in region L will have to produce $\hat{P}^{L}X^{N}$ (L = r+1, r+2,..., n) respectively. Thus, the total output in region L, X^L, is an n element column vector of the following form;

$$\mathbf{X}^{\mathsf{L}} = \begin{bmatrix} \mathbf{X}^{\mathsf{R}^{\mathsf{L}}} \\ \mathbf{X}^{\mathsf{N}^{\mathsf{L}}} \end{bmatrix}$$
 4.31

where clearly this vector is made up of the outputs of the r regionally balanced sectors that are produced in region L and the production of the nationally balanced sectors located in region L. Miller and Blair (1985) showed that the subvector which applies to the regionally balanced sectors in region L was actually a composite of 2 effects; production in region L to meet region specific final demands for regional balanced goods, and production in region L of regionally balanced goods as input to that region's share of the total production of nationally

balanced goods. This is made clearer in the following expression derived from a partitioned matrix form of the BRM;

$$X^{R^{L}} = (I - A^{RR})^{-1} Y^{R^{L}} + (I - A^{RR})^{-1} A^{RN} X^{N^{L}}$$
4.32
$$X^{R^{L}} = (I - A^{RR})^{-1} Y^{R^{L}} + (I - A^{RR})^{-1} A^{RN} \hat{P}^{L} X^{N}$$

where the first effect referred to above can be seen in the first expression on the RHS of 4.32 above, and the second effect can be seen in the second term in 4.32. Region L's share of the production of nationally balanced goods is given by the following;

$$\mathbf{X}^{\mathbf{N}^{\mathsf{L}}} = \hat{\mathbf{P}}^{\mathsf{L}} \mathbf{X}^{\mathsf{N}}$$
 4.33

and in this way, the balanced regional model not only distinguished between nationally and regionally balanced goods but it also allocated the production of these types of goods to the various regions in a national system (the results obtained from equations 4.32 and 4.33 form the vector shown in equation 4.31).

The preceding discussion of regional I-O modelling has covered the major advances witnessed in this field over the past 4 decades with the bulk of the emphasis placed on the many-region approach. This emphasis was chosen because of the fact that the MRIO formulation formed the conceptual framework for the model developed in chapter 5. While the regional approach pioneered by Leontief and Strout (1963) which focussed on the development of a tool which could estimate trade flows between regions in the absence of such data is intriguing, it has not received many positive remarks in the literature, and the framework was in no way related to the model chosen for this dissertation. As a result, the coverage of this type of model is rather light, as is the coverage of the balanced regional model. I refer the reader to Leontief and Strout (1963) and to excellent reviews by Miller and Blair (1985), Hewings (1985), and earlier ones by Bourque and Cox (1970) and Giarratani, Maddy and Socher (1976) as well as to the compendiums for the various Input-Output symposia for further reading on this approach.

The highlight of the past 4 decades in regional I-O analysis has been the development of the IRIO and MRIO frameworks which allow for the endogenous treatment of trade flows between regions and the concurrent drive to compile the requisite data in most countries. The model to be developed in chapter 5 will draw heavily from the IRIO and MRIO concepts discussed above. At the outset of this chapter however, it was noted that the primary objective of this chapter was to review the developments in the field of I-O economics which could be of use in the design of an impact assessment tool which could be used to assess the impacts of capital intensive projects in an underdeveloped region. The issue of interregional dependencies for such a situation has been well addressed above, and the MRIO framework provides the best practical approach to this problem.

fact that such projects often require that capital stocks in the underdeveloped region be augmented even though the bulk of the backward linkages will likely extend to more developed regions. The remainder of this chapter therefore will examine the development of the dynamic I-O model and end by discussing in detail a current reformulation which will ultimately set the stage for the model developed in chapter 5.

4.3 The Dynamic Input-Output Model

Richardson (1972) noted that if an I-O is to be used for long run regional (or national) forecasting, then the dynamic I-O model must be used. Specifically, he noted that in such a situation;

"...a truly dynamic model must allow for the structural relations between stocks (capital) and flows (output) and take explicit account of the fact that substantial increases in output will create additional capacity requirements so that projected changes in final demand will not only require more intermediate goods but also investment goods from all appropriate sectors in the economy." (Richardson, 1972; pp. 183)

The Dynamic Input-Output model (DIO) as described by Richardson (1972), Duchin and Szyld (1985), Hewings (1985), and Miller and Blair (1985) to name a few, extends the properties of the static I-O model to include the determination of the sectoral production and accumulation of capital goods through a *multi-sectoral accelerator formulation*.⁸ Miller and Blair (1985) noted that for current production in any sector the capital stock such as buildings and equipment must already be

in place, but if the economy in question is growing then anticipated production (say next year) will be different from current production (this year), and the amount of supporting capital may change. They noted that one simplifying assumption that is often used is that the amount of new production from sector i for capital stocks in sector j in time period t+1 will be given by the following;

$$b_{ij}(X_j^{t+1}-X_j^{t})$$
 4.34

where this is the accelerator formulation referred to by Duchin and Szyld (1985). Note that the b_{ij} term in the previous equation is defined as a capital input coefficient.⁹ Each column in a capital coefficient matrix, B, depicts the composition and amount of each sector's demand for capital goods per unit increase of it's own output. Each column therefore represents the detailed technical requirements for capital goods of each sector in the model. Miller and Blair (1985) suggested, for example, that if sector i was the construction sector and sector j was the automobile sector that a flow of capital from i to j, v_{ij}, could represent the dollars' worth of factory space required by sector j per dollar of it's output. While the <u>MIT Dictionary of Modern Economics</u> suggests that this simple accelerator formulation ignores the role of interest rates (the user cost of capital), Duchin and Szyld (1985) suggest that the characteristic advantage of the dynamic I-O framework is that it imposes inter-temporal consistency simultaneously for all sectors between the specific capital items produced and delivered in one period

and increments of output that in subsequent periods will be available for use. While Hewings (1985) noted that the dynamic model has not been widely applied at the regional level due to issues revolving around the role of capacity adjustments (with Miernyk, 1970 being an exception), the development of this framework will be traced since the model developed in chapter 5 takes a somewhat novel approach to analyzing the inter-temporal impacts of various long term capital intensive projects.

The dynamic I-O (DIO) model was formulated originally by Leontief in 1949 and the first published study which made use of this model appeared in the journals in 1953 (see Leontief, 1953). Originally Leontief represented the level of investment activity by a sector as the rate of change in required capital stocks with a vector differential equation as follows;

x-Ax-Bx = y
where
$$\dot{x} = \frac{\partial x}{\partial t}$$

4.35

where x was a vector of outputs, A a matrix of input requirements on current account, B a matrix of capital requirements, and y a vector of non-investment final demand. Essentially the industry balance equations were altered to endogenize the level of investment expenditures by each sector, and, as a result, the investment vector was removed from the matrix of exogenous final demand categories. Richardson (1972) noted that this process of endogenizing investment, by virtue of the fact that investment goods have the property that they do not have to be used up in the current period (with the possibilities of unused capacity and building ahead of demand), imparts the time dimension to the DIO model. In the static model, he noted that the temporal aspects are merely implicit and that they have no operational significance.

Leontief (1970) reformulated his early DIO model in terms of difference equations with dated technical matrices reflecting structural change in the economy. Miller and Blair (1985) presented the industry balance equation for sector i in period t for such a system as follows;

$$X_{i}^{t} = \sum_{j=1}^{n} a_{ij}X_{j}^{t} + \sum_{j=1}^{n} b_{ij}(X_{j}^{t+1} - X_{j}^{t}) + Y_{i}^{t}$$
4.36
$$X_{i}^{t} - \sum_{j=1}^{n} a_{ij}X_{j}^{t} + \sum_{j=1}^{n} b_{ij}X_{j}^{t} - \sum_{j=1}^{n} b_{ij}X_{j}^{t+1} = Y_{i}^{t}$$

which could be re-written more compactly in matrix notation as follows;

$$(I-A+B)X^{t}-BX^{t+1} = Y^{t}$$

BX^{t+1} = $(I-A+B)X^{t}-Y^{t}$
4.37

for t = 0, 1,...,T. Miller and Blair (1985) noted that if the time superscripts denote years equations 4.36 and 4.37 represent a set of relationships between gross outputs and final demands starting in the current period (year t=0) and extending

T years into the future. They also noted that equations 4.36 and 4.37 indicate that the values of the X's are related from period to period, and, as a result, these represent linear difference equations and that appropriate solution procedures need to be used to solve for X^{t} in terms of $X^{(t+1)}$ and Y^{t} . Duchin and Szyld (1985) noted that a minimal condition for an economically meaningful solution to equation 4.37 is the existence of a set of nonnegative vectors of output, X^t, which satisfy 4.37 above. That is, Duchin and Szyld (1985) were pointing out the fact that if output were to decline from one period to the next, the model would then necessarily produce negative output values implying a drop in shipments from sector i to sector i for example. This has been referred to as the implicit assumption of the reversibility of capital stock which characterizes the Leontief DIO model. Duchin and Szyld (1985) noted that a sector's stock may be said to be reversible if capital in place but not in use is freely transferable to other uses within the economy, and that this occurs in the Leontief DIO when the elements of (X^{t+1} - X^t) are negative. In other words, the solution of the standard Leontief DIO rests on the assumption that the economy in question is following what is called a *balanced* growth path.

Duchin and Szyld (1985) noted that to solve this dilemma by assuring the irreversibility of capital already in place, a multi-phase process was suggested by Leontief (1953) according to which capital stocks were increased only when output was growing. At the regional level, Richardson (1972) noted that Miernyk

(1968;1970) and Bargur (1969) suggested that combined I-O and linear programming models could be used to allow for the existence of excess capacity and building ahead of demand. Richardson (1972) also noted that in such a model it may be efficient to build capacity ahead of demand, and optimisation procedures have to be used to solve the choices among output and resource allocation alternatives. Duchin and Szyld (1985) discussed a procedure offered by Uzawa (1956) which replaced the B($X^{t+1} - X^{t}$) term in the Leontief DIO model with the following;

$$B \cdot max(X^{t+1} - X^{t}, 0)$$
 4.38

where under certain conditions, solutions to this formulation of the DIO model were proven to exist. Duchin and Szyld (1985) noted that the introduction of this nonlinearity amounted to allowing for unused capacity when output is falling. This was so since the Uzawa model was setup to chose the B 0 option whenever the difference in 4.38 was less than 0. This approach was however not well received by various theorists of the time since it amounted to switching from one regime to another depending on whether output was rising or falling. Duchin and Szyld (1985) noted that this problem was not encountered if one realistically abandoned the requirement of full capacity utilization even when output was rising. That is, if output and capacity are not defined to be identical, then the model must provide for the computation of output as well as a specific sectoral pattern of capacity

utilization. It was this contention that led Duchin and Szyld (1985) to offer their reformulation of the Leontief DIO model.

In the new formulation, Duchin and Szyld (1985) introduced the notion of an investment plan for expansion in each sector. They assumed that the effective expansion of a sector's capacity may require several periods and that the expansion plans must be formulated and acted upon this amount of time in advance. They assumed that the amount of planned expansion was dependent upon future sectoral production as anticipated when the plan was formulated, and that once in place, the plan was carried out even if the sector's circumstances were to change.

The Duchin and Szyld reformulation focussed on a reworking of the investment term used in Leontief's early dynamic I-O models. Specifically, this investment term was replaced by expressions formulated in accordance with the following considerations;

1. Once capacity is in place, it need not be fully utilized and is not reversible.

2. In each time period, expansion decisions are made for each sector based on recent past growth rates, and capital goods are ordered.

3. Some capital goods must be delivered several periods before the new facility of which they are a part can effectively add to the investing sector's capacity.

4. Replacement investment is explicitly represented, separately from expansion.¹⁰

To begin, Duchin and Szyld introduced 2 vector variables;

 $c(t) \equiv$ output capacity during period t, and $o(t) \equiv$ increase in productive capacity between periods t-1 and t,

where;

$$c(t) = c(t-1) + o(t)$$
 4.39

Clearly, if for a sector i, $c_i(t) > x_i(t)$, then capacity is being under-utilized, and if the opposite were true, then capacity is being over-utilized. Next, they assumed that each sector's future capacity requirements could be projected several periods in advance, independent of the capacity in place. They defined $c^*(t)$ as the vector of projected capacity requirements for future period t, and they defined the increase in capacity of sector i as follows;

$$o_i(t) = \max[0, c_i^*(t) - c_i(t-1)]$$
. 4.40

Thus, if $c_i(t-1) \ge c_i^*(t)$, then $o_i(t)=0$, and no new output capacity is needed. Otherwise, the change in capacity of sector i, o_i , is the increase needed to achieve the projected capacity requirement, c_i^* . Duchin and Szyld noted that at this point the investment term for period t could be written as follows;

implying that investment goods required to increase the capacity in period t+1 are produced and delivered one period earlier (note that K has been used to denote the capital coefficient matrix to avoid confusion with the B matrix used in chapter 5). In the new formulation, Duchin and Szyld recognized that different types of

capital inputs require different *gestation periods*; that is, certain types of capital may have to be delivered one or two periods before the capital items can add to the effective capacity of the purchasing sector. To represent this notion, τ_{ii} was used to denote the lag between the period when a capital item is produced by sector i and the period when it effectively adds to the capacity of sector j. Given that the length of time for any capital project to be completed is dependant upon the lag associated with the capital input which requires the most lead time, τ_i was used to denote the maximum lag for any capital good required by sector j. Therefore, planned capacity in sector j will require τ_i periods for its realization, and therefore will need to be formulated at least this many periods in advance. Duchin and Szyld assumed that this lead time, or gestation period, τ_i , would be the same for all capital using sectors.¹¹ Therefore, the only variable associated with the gestation period was the length of time required by each type of capital to be integrated with existing equipment, τ_i . They further defined τ as the max (i) τ_i , which implied that the length of time associated with a capital project for any purchasing sector would be defined solely by that capital item which has the longest gestation period associated with it. Therefore, τ represented the gestation period associated with any capital expansion project.

Based on the aforementioned arguments, Duchin and Szyld defined the investment term for their model as follows;

$$\sum_{\theta=1}^{\tau} \mathsf{K}^{\theta}(\mathsf{t}) \,\mathsf{o}(\mathsf{t} \!+\! \theta) \tag{4.42}$$

where the ijth element of the $K^{\theta}(t)$ matrix represented the amount of capital produced in period t by sector i to increase the capacity of sector j by one unit in period t+ θ . The new investment term allowed for the fact that a specific capital investment project will not result in an expansion of the effective capacity of specific sectors for a number of periods, to be defined by τ .

Expanding the investment term shows more clearly how this idea of a gestation period operates. To begin, each K^{θ} matrix is of the dimension (nxn) where n represents the number of sectors in the economy. The o vectors of capacity adjustments are of the dimension (nx1). Therefore, the first element in the first product vector, which is the first row of K multiplied through the first o vector, yields the total capital produced by sector 1 in period t_0 (where t_0 is the present period) needed to allow for the projected capacity adjustment which must take place between period t_0 and t_0+1 . The corresponding element from the second vector product represents the total amount of capital produced by sector 1 in period to allow the projected capacity increase which must take place between periods t_0+1 and t_0+2 , and so on. Therefore the summation of all of these vector products results in a vector with the dimension (nx1) where the first element represents the total amount of capital produced by sector 1 in period

 t_0 needed to allow for the sequence of yearly capacity increments which culminate in period $t_0 + \tau$ with the realization of the projected sectoral capacity level, $c_j^*(t_0 + \tau)$.

Future capacity, that is capacity at a future period $t+\tau$, c^* ($t+\tau$), was assumed to be planned τ periods in advance. Duchin and Szyld based these projections, for each sector, on output levels in the last completed period and recent past changes in output. The following expression was designed by Duchin and Szyld to produce linear projections of sectoral capacities on a yearly basis.

$$c_{i}^{*}(t+\tau) = \min\left[1+\delta_{j}, \frac{x_{i}(t-1)+x_{i}(t-2)}{x_{i}(t-2)+x_{i}(t-3)}\right]^{r+1} x_{i}(t-1)$$
4.43

The above expression simply provides two linear growth rates - the first represents a sector specific maximum admissible annual rate of capacity expansion, δ_{i} , while the second represents a linear moving average growth rate which is based upon the recent experience of each sector. The minimum of these two rates is used to project the capacity of sector i τ periods into the future, by applying one of the linear growth rates to the output for sector i in the previous period.¹²

Once sectoral capacities are projected, the next task involved the computation of the yearly increments to sectoral capacity. The following expression was designed to compute the capacity increase which must take place between period $t+\tau-1$ and $t+\tau$ so that the capacity level projected for sector i by

period $t+\tau$ can be realized.

$$o_i(t+\tau) = \max \left[0, c_i^*(t+\tau) - c(t+\tau-1) \right]$$
 4.44

This expression suggests that the necessary increment to sector i output that must take place between periods $t+\tau-1$ and $t+\tau$ (the last period before the expansion plan must be realized) is either 0 or that increment called for by the second part of the expression. As before, this expression allows for periods of no change in sectoral capacities while disallowing the dismantling of capital stock in periods of declining output in a manner not dissimilar from that suggested by Uzawa (1956). Once these sectoral capacity adjustments were computed, the next task simply involved updating capacity by sector using the following identity.

$$c_i(t+\tau) = c_i(t+\tau-1) + o_i(t+\tau)$$
 4.45

The final step in computing $x(t_0)$ involved using the yearly capacity upgrade vectors to build the investment term described above. Finally, $X(t_0)$ was computed as follows;

$$\mathbf{x}(t_{0}) = \left[\mathbf{I} - \mathbf{A}(t_{0}) - \mathbf{H}(t_{0})\right]^{-1} \left(\sum_{\theta=1}^{\tau} \mathbf{K}^{\theta}(t_{0}) \mathbf{o}_{i}(t_{0} + \theta) + \mathbf{y}(t_{0})\right)$$
4.46

where the A and H matrices represent current account and replacement investment transactions respectively.¹³ Duchin and Szyld pointed out that in this

formulation the problem of a singular K matrix was avoided since it did not have to be inverted in this formulation.¹⁴

Another point of interest with regard to this formulation is the fact that the capacity projection equation specified above, and the subsequent yearly increase vectors can be directly substituted for by any "...admittedly arbitrary formulation determining future desired capacity..."¹⁵ Admittedly, the use of linear growth rates to project sectoral capacities based on past sectoral output experiences is quite rough. In fact, this treatment can be considered to be no better, in fact probably worse, than using an ex ante approach to develop scenarios of sectoral growth to determine the yearly capacity adjustment vectors. It is important to remember that the ultimate purpose of the above equations (excluding the final I-O equation) was to produce yearly capacity adjustment vectors which culminate in the planned capacity level in a certain future period. The final form of the model could be retained even if the capacity expansion component were to be superseded by one which was driven mainly by the prescription of ex ante scenarios. The downfall of such an approach is that the pattern of sectoral capacity utilization rates would no longer be endogenous. This will be the approach taken in the dissertation.

4.4 Discussion

This review of the literature concerning the input-output model and its various extensions, while not exhaustive in its reach, attempts to provide the

background material necessary for a full appreciation of the strategy taken in chapter 5 where a MRIO model that makes use of the many of the concepts espoused by Duchin and Szyld (1985) is derived. It should be clear that the regional I-O literature is quite rich and that much room is left for refinements and improvements. Chapter 5 will now build on the concepts discussed in the pages above by providing a detailed description of the logic and mechanics involved in developing a Dynamic Multiregional Input-Output model.

ENDNOTES

1. Leontief, W. (1936). "Quantitative Input-Output Relations in the Economic System of the United States", <u>Review of Economics and Statistics</u>, 18, no.3: 105-125.

2. This is the case in the Canadian S level I-O data.

3. Constant dollar I-O tables allow these technical coefficients to be interpretted as physical flows between sectors.

4. It must be noted that in this era of regional economic analysis no regional I-O tables existed, and as such early empirical regional studies had to focus on adapting a national table to the region in question. The concept of a many region model pre-dates these applications (see Isard, 1951; Chenery, 1953; and Moses, 1955).

5. Leontief's work since the mid 1970s has been directed toward making the flow of goods across international borders an endogenous feature in a multi-national framework. Strictly speaking though, at the national level, the use of a single region approach should capture the bulk of the economic effects of interest. Leontief's multi-national models are motivated by the desire to assess the impacts of actions in developed countries on the 3rd World nations.

6. Japan has been compiling survey based IRIO data since 1960 and they have been updating this data every 5 years (see Polenske, 1970); Miller and Blair (1985) also note that Holland has been maintaining a survey based 3 region IRIO model since 1961, and Hoffman and Kent (1976) estimated a rectangular IRIO model for Canada.

7. He noted for example, that a Korean application indicated that anywhere between 25 and 70 percent of the trade flows were explained by the model.

8. The <u>MIT Dictionary of Modern Economics</u> defines the accelerator principle as it pertains to the theory that the level of aggregate net investment is a function of the expected change in output. The theory suggests that firms attempt to maintain a fixed ratio of capital stock to expected output.

9. Where such a coefficient denotes the dollars worth of sector i output purchased by sector j as capital per dollar of expanded output in sector j, which is not entirely consumed in the current period.

10.See Duchin and Szyld (1985), p. 273.

11.For example, if i denotes semiconductors and j denotes the purchasing sector, there is no reason not to assume that the uptake time associated with semiconductors won't be fairly consistent across aggregate industrial sectors. A metal working sector and a textile mill will have similar lead times associated with a move to computer numerically controlled production methods.

12. This first rate in equation 8 works in a fashion which is completely analogous to projecting the balance of a savings account at some future time period. If the yearly interest rate was 10% and the beginning balance was \$20.00, then the balance 5 years from now is simply $[(1+0.10)^{5}*20]$. The second rate is simply a 3 period moving average of previous output levels which results in a decimal fraction which is raised to the same exponent as the previous rate, and then multiplied by the base figure.

13. It should be noted that the B matrix referred to here, and previously when discussing the Duchin and Szyld reformulation should not be confused the B matrix for Use matrix coefficients used in the commodity by industry model. When this model is re-cast for the rectangular system, this matrix will be denoted as K^{θ} .

14. In applied work with the Leontief DIO model, the K matrix was often singular since not all sectors produce capital goods, and, as such, these would be represented by rows of 0s in the K matrix.

15.See Duchin and Szyld (1985), p. 277.

Chapter 5

Model Development

5.0 Introduction

The primary objective of this dissertation is to assess how each of the Arctic oil development scenarios discussed in chapter 3 could affect the economies of the NWT and the remaining regions of Canada with a specific focus on the construction phase associated with each type of project. The capital investment time-lines for each of the scenarios, which were generously provided by the authors of the scenarios, indicated that each of these types of projects would require massive investment expenditures in the NWT over a period of years to become operational. While the NWT is a relatively under-developed regional economy and many of the critical linkages associated with these types of projects in the NWT will extend to sectors in other regions, the fact remains that this sort of capital intensive activity in the NWT would affect the economy of the region in two major ways. Firstly, the investment expenditures associated with each of the projects would undoubtedly cause the output of most NWT sectors to be significantly affected along with the level of personal income earned in the NWT. Secondly though, the investment expenditures called for by each of the scenarios would almost certainly cause the capacity of certain sectors in the NWT to be taxed beyond capacity as a result of the direct, indirect and induced effects associated with the investment plans for certain years. For an assessment tool to be effective in capturing the true magnitude of the effects of these projects both in the NWT and in the remaining regions of Canada, it would have to allow for the inclusion of both of these types of effects.

Based on this perceived need, I decided to devise an Input-Output model that was able to accommodate the combination of these two effects. Given that any such project undertaken in any region of Canada, especially in the NWT, would result in significant interregional spill-over effects both in terms of sectoral output and personal income levels, it was decided that the modelling framework of choice would have to capture the true interregional nature of the Canadian Inter-Provincial system. The availability of Provincial and Territorial Input-Output Tables which include the interregional import and export data necessary for the construction of a Multiregional Input-Output (MRIO) model of the Canadian economy, along with requirements discussed above, dictated that the best tool for conducting this assessment would be an Extended Dynamic MRIO model. To say that such a model is extended implies that the effects of feedbacks from personal income effects to sectoral output levels are built into the model. To say that such a model is dynamic implies that the model is able to assess sectoral impacts in a manner which takes into consideration the effects of capital stock

augmentation through time.

The standard Leontief dynamic I-O model was designed to include the effects of the direct capital input requirements of each sector regardless of whether or not the capacity of any sector was found to be lacking. Periods of declining output demands would also cause such a model to *roll-back* capital stock in some sectors resulting, in some cases, in the generation of negative output impacts. The model to be described in this chapter includes many of the basic tenets of the Leontief Dynamic model, but with extensive modifications along the lines introduced by Duchin and Szyld (1985). Specifically, the Duchin and Szyld model is driven by capacity adjustments in all sectors in the face of specified investment plans, and it has the benefit of never producing negative output figures implying that excess capacity could exist in various sectors.

The task for this chapter then, is to develop a multiregional version of this Duchin and Szyld (1985) model that can be driven by a combination of the effects discussed above. Specifically, this chapter takes a *grass-roots* approach and begins with the static single region commodity by industry I-O model, and step by step proceeds to enhance the simple model by endogenizing personal consumption, and interregional trade flows. An exogenous "*drive systent*' is also designed which enables the effects across all sectors in all regions of current period investment expenditures in the NWT, as well as capacity expansion activities in the NWT, to be assessed. In terms of structure, this chapter begins

by discussing how a closed single region model is constructed from the available data and ends by describing in detail how an Extended Dynamic MRIO model is constructed from available Canadian I-O data. This protracted progression from the simplest case to the model actually designed for use in this assessment was included because many of the manipulations used with the final model are more easily understood when the logic is first detailed with a simple model.

5.1 The Logic Behind Endogenizing Final Demand Categories

The notion of closing an I-O model to any of the exogenous final demand components (e.g., personal consumption, competitive imports, interregional trade in the case of a multiregional model, or capital formation activities in the case of a dynamic I-O model) is based on the perceived need to augment the basic I-O model in order to maintain it's many desirable features while at the same time making it a more comprehensive, and hence realistic, representation of the economy under examination. It is important to realize that the progression from the open static single region model to the multiregional model to the dynamic model represents a series of variations on this theme of bringing previously exogenous variables into the I-O system of equations (i.e., making them endogenous). The purpose of this chapter is to review, in a rigorous way, how the simple open model could be transformed into a model which is closed with respect to personal consumption, and interregional commodity flows. A version

of this model which is driven by a combination of current period investment expenditures along with capacity adjustment effects will also be derived.¹ The model developed below, while referred to as a dynamic I-O model, does not make investment "purely" endogenous unlike the basic Leontief Dynamic I-O model.² The fact that the effects associated with capacity augmentation through time are included justified the designation of the model as dynamic.

5.2 The Basic Commodity by Industry Single-Region Model

The commodity by industry I-O framework was developed to better represent secondary products created by various sectors of an economy.³ Where the industry by industry (square) I-O system required one inter-sectoral transactions matrix to represent the macroeconomy in question, the commodity by industry (rectangular)⁴ framework makes use of three such matrices, each recording a different aspect of the production process. Specifically, the *Use, Make* and *Final Dermand* matrices record the input, output and final demand aspects of the production process respectively. These three matrices are linked by various accounting identities which, by definition, have to hold in the data. These accounting identities allow this system of I-O accounts to be transformed into an I-O model of the macroeconomy to which the data pertains. A set of these commodity by industry tables exists for each of the Provinces and Territories of Canada.

To begin the process of deriving an I-O model from a rectangular I-O database, consider the following commodity balance equation;

$$Q_i = b_{i,1}X_1 + b_{i,2}X_2 + \dots + b_{i,n}X_n + Y_i$$

where
$$b_{i,j} = \frac{U_{i,j}}{X_j}$$

where Q_i denotes the sum across row i of the use matrix, b_{ij} denotes a direct input coefficient for commodity i, U_{ij} denotes the total amount of commodity i used by sector j in producing its output, Y_i denotes a final demand vector with all originally exogenous categories intact, and X_j denotes the gross output of sector j (summing down column j of the Make matrix).⁵ In matrix notation, the commodity and industry balance equations may be expressed as follows;

$$Q = BX+Y$$
 5.2
X = D'Q 5.2

where the commodity balance serves to *connect* the three matrices of the commodity by industry system of I-O accounts.⁶ Specifically, the commodity balance equation accounts for all uses and sources of each commodity in the region to which the data pertains. For example, Q is a column vector formed by summing across all rows of the Use matrix, and as such, it represents the total amount of each commodity available for use in the economy in question. The BX

term in 5.2 above is the product of a matrix B (derived from the Use matrix) and a column vector, X, which is a vector of gross sectoral output values, and it represents the use of all commodities as inputs to production. The Y term represents a commodity based total final demand vector.⁷ This vector records the usage of all commodities by the various final demand categories (e.g., personal and government consumption, exports-imports, etc.). Therefore, the LHS of the commodity balance represents the total available supply of all commodities in the economy, and the RHS represents all uses of these commodities - therefore LHS=RHS. The second equation in 5.2 above is referred to as the industry balance equation, and it serves to translate the logic of the commodity balance equation into sectoral terms.⁸ In light of the derivations which follow, it is important to realize that the final demand vector referred to in equation 5.2 represents the sum across all final demand categories (e.g., personal consumption, exports, business sector investment, government sector investment etc.) in the final demand matrix (where each category is represented by one column in this matrix). These two balance equations, and the logic embodied within them, allow a commodity by industry I-O model to be derived.

The derivation of such a model could begin in one of two ways - the goal being to express Q and X as functions of constants and exogenous variables. The easiest method involves substituting the industry balance expression for the X term in the commodity balance equation as follows;

Q = B(D'Q)+Y
Q-BD'Q = Y
Q(I-D'B) = Y
Q =
$$(I-D'B)^{-1}Y$$

5.3

yielding a commodity based I-O model.⁹ A corresponding industry based model could be created by substituting the final expression for Q in 5.3 above for Q in the industry balance equation in 5.2 above, as follows;

$$X = D'(I - D'B)^{-1}Y$$
 5.4

The industry based model is most commonly used. It is important to note that the transformation from a commodity based model to an industry based model involves the assumption that each sector produces a constant proportion of the total amount of each commodity. In it's current form, the model is entirely open - that is, none of the final demand components have been made endogenous. It is reasonable to expect a shock to foreign exports (foreign exports are tracked as 1 column in the Final Demand matrix), for example, to generate a large output response from all sectors in the economy, and thereby generate additional labour income, additional consumption expenditures and, as a consequence, an additional output response from all sectors. This simple feedback from an initial output impact to an additional consumption induced output effect is referred to in the literature as an *induced output effect*, and it can only be measured if the

household sector (i.e., personal consumption) is "*brought inside*" the model, or *endogenized*. In a square system this is easily accomplished by treating the value added row and the personal consumption column as the $(n+1)^{th}$ sector in the model. In a commodity by industry system however, this feedback has to be built into the balance equations used to derive the rectangular I-O model. The logic behind endogenizing consumption can be extended to many of the exogenous final demand categories, as the following pages will show.

5.3 Endogenizing Consumption

In the event of a significant stimulus to the demand for a sector's (or group of sectors) output, one would expect, in addition to an output response from all affected sectors, an increase in the total amount of personal income earned in the economy. This is so since an establishment has to draw from all input suppliers to produce output, and one major input supplier is the *household sector* which provides labour inputs to all industries in the economy. A portion of this added personal income then would be used for personal consumption and, as a result, the initial industry output response would result in an additional final demand increment which must also be satisfied by sectoral production in the current period. Induced effects can be measured only if an I-O model is designed to incorporate this feedback - that is, if the model is closed with respect to personal consumption.¹⁰ Hence, the open model will, strictly speaking, always under-

estimate the "true" impact of a final demand shock.

To build this feedback into the model, the balance equations of the commodity by industry system need to be altered to include a Keynesian-type multiplier effect. That is, a multiplier that is always greater than one must be imbedded in the commodity balance equation to establish this linkage between initial output responses and the induced effects caused by a consequent stimulus to personal consumption. The procedure used to build this feedback effect into the model begins with the realization that consumption can be disaggregated into exogenous and endogenous components as shown below in equation 5.5;

$$\Delta C_{i}^{ex} = e_{i} \Delta C^{ex}$$

$$\Delta C_{i}^{en} = e_{i} \Delta C^{en}$$
where
$$\Delta C^{en} = \beta \Delta N$$

$$N = LI_{T} + UI_{T}$$

$$e_{i} = \frac{C_{i}}{C_{T}}$$

$$\beta = \frac{C_{T}}{N}$$

where;

Cτ	m	total personal consumption expenditures,
C,	=	total consumption of commodity i,
Lİ	E	total labour income earned (paid out) for production,
UI	=	total unincorporated business income earned (paid out) for
production,

N	≡	total personal income earned in production (LI+UI),
е	≡	commodity share of total consumption expenditures,
β	=	approximate average propensity to consume,
en	≡	endogenous portion,
ex	≡	exogenous portion.

Endogenous consumption is defined as that portion which is a function of sectoral output levels via personal income effects. Exogenous consumption is that portion which is not a function of sectoral activity. For example, a government labour contract which creates 1000 new jobs in the public sector and a wage increase for existing employees would result in extra consumption, and this would be exogenous to the I-O system (insofar as the system itself did not generate these consumption impacts). Endogenous consumption then, is represented in the model by the multiplier formulation shown above in equation 5.5, and the consumption vector is removed from the final demand matrix. Exogenous consumption only comes into play if the closed model is used to assess the impacts of some delta consumption vector (the example given above would generate such a vector). Equation 5.5 makes this clear by expressing endogenous consumption as a function of personal income levels which, in the following pages will be analytically linked to sectoral output levels.

To make this connection, the commodity balance equation presented earlier (equation 5.1) can be expanded further as follows;

$$\sum_{j} b_{ij} X_{j} + C_{i}^{en} + \overline{Y}_{i} = Q_{i}$$
 5.6

it must be stressed that the final demand vector (Y) has been split into two components - an endogenous consumption component (C_i^{en}) and an "everything else" component (denoted as \overline{Y}). By manipulating equations in 5.5 above, the following expression for endogenous consumption of commodity i can be derived;

$$C_i^{en} = e_i \beta N$$
 5.7

where, as mentioned earlier, β denotes the average propensity to consume.¹¹ Therefore, a connection has been established between personal income (N) and personal consumption activity across all commodities.

The next stage of this procedure involves connecting personal income (N) to sectoral output (X). That is, we must be able to express personal income in terms of variables available within the I-O system of balance equations. One way of making this connection would be to define personal income in the following manner;

$$N = \sum_{j} \mu_{j} X_{j} + \mu_{e} \beta N + N^{EXOG}$$
where
$$\mu_{j} = \frac{N_{j}^{SCTR}}{X_{j}}$$
5.8
$$\mu_{e} = \frac{N_{con}^{CON}}{C_{T}}$$

where;

N	≡	total personal income earned,
NSCTR	=	personal income earned as a result of sectoral activity,
N ^{CON}	=	personal income earned as a result of consumption (i.e., wages paid out by the consumption category in the final
N ^{EXOG}	£	personal income tracked in other categories of final demand matrix - except for exports abroad.

By assuming away exogenous changes in labour income (personal income entries in final the remaining demand columns) and re-arranging terms, the following

expression for personal income is obtained;

$$N = \sum_{j} \mu_{j} X_{j} + \mu_{e} \beta N$$

$$N - \mu_{e} \beta N = \sum_{j} \mu_{j} X_{j}$$

$$N = \frac{1}{(1 - \mu_{e} \beta)} \sum_{j} \mu_{j} X_{j}$$
5.9

where personal income is defined to be a function of sectoral output levels. This provides a connection between personal income and sectoral output. By substituting the final expression in 5.9 for the personal income component of

equation 5.7 above, an expression which connects endogenous consumption to sectoral output (by way of personal income) is obtained as follows;

$$C_{i}^{en} = e_{i}\beta N$$

$$\therefore \qquad 5.10$$

$$T C_{i}^{en} = e_{i}\beta \left(\frac{1}{1-\mu_{e}\beta}\right) \sum_{j} \mu_{j}X_{j}.$$

This new expression for endogenous consumption can be substituted for the C^{en} term in the expanded commodity balance equation shown above in equation 5.6, and a new commodity balance equation can be derived as follows;

$$\sum_{j} \mathbf{b}_{ij} \mathbf{X}_{j} + \left[\mathbf{e}_{i} \boldsymbol{\beta} \left(\frac{1}{1 - \mu_{e} \boldsymbol{\beta}} \right) \sum_{j} \mu_{j} \mathbf{X}_{j} \right] + \overline{\mathbf{Y}}_{i} = \mathbf{Q}_{i}$$

$$\vdots$$

$$\sum_{i} \mathbf{b}_{ij} \mathbf{X}_{j} + \mathbf{e}_{i} \boldsymbol{\beta} \mathbf{N} + \overline{\mathbf{Y}}_{i} = \mathbf{Q}_{i}$$

5.11

clearly the effects of personal consumption have been *taken inside the model*. This expanded balance equation makes clear the connection between increased sectoral output (in response to a final demand shock), increased personal income, increased consumption purchases and a further increment to sectoral output *induced output*.

The μ terms in equation 5.11 which represent the response of personal income to sectoral output and consumption impacts can be better understood, in an empirical sense, if we make the following explicit definition of personal

income (N);

and, by rearranging terms, the following expression for total personal income can be derived.

$$N = \sum_{j} (\zeta_{j} + \zeta_{j}) X_{j} + (\zeta_{c} + \zeta_{e}) C_{T} + (LI^{EXOG} + UI^{EXOG})$$

$$\therefore$$

$$N = \sum_{j} \mu_{j} X_{j} + \mu_{e} C_{T} + N^{EXOG}$$

5.13

This explicit definition of personal income makes clear the meaning ascribed to the μ terms in the expanded commodity balance equation shown in equation 5.11 above.

Based on the above derivations, the commodity and industry balance equations for the entire system can be represented very compactly by the following two matrix equations;

$$\begin{bmatrix} \vec{B}\vec{X} + \vec{Y} \end{bmatrix} = \vec{Q}$$
 5.14
$$\vec{X} = \vec{D}'\vec{Q}$$

where the structure of all of these matrices has been altered (relative to equation 5.2) to allow for the expanded commodity balance elements (see structure in equations 5.34, 5.35, 5.36, and 5.38).¹² Based on the equations shown in 5.14, a commodity based I-O model can be derived by substituting the industry balance equation into the commodity balance equation and solving for Q as follows;

$$\begin{bmatrix} \vec{B}\vec{D} & \vec{Q} + \vec{Y} \end{bmatrix} = \vec{Q}$$

$$\vec{Q} - \vec{B}\vec{D} & \vec{Q} = \vec{Y}$$

$$\begin{bmatrix} I - \vec{B}\vec{D} & \vec{Q} \end{bmatrix} = \vec{Y}$$

$$\vec{Q} = \begin{bmatrix} I - \vec{B}\vec{D} & \vec{Q} \end{bmatrix}^{-1}\vec{Y}$$

5.15

and an industry based model can be derived by substituting the final expression for \overline{Q} in equation 5.15 for that term in the industry balance equation shown in equation 5.14 as follows;

$$\overline{\mathbf{X}} = \overline{\mathbf{D}}' [\mathbf{I} - \overline{\mathbf{B}} \overline{\mathbf{D}}']^{-1} \overline{\mathbf{Y}}$$
 5.16

and the result is an I-O model which will compute sectoral gross output vectors in response to exogenous final demand shocks, accounting for induced consumption effects.

5.4 Endogenizing Interregional Commodity Flows

The previous material has focussed on the derivation of an I-O model, which was closed to personal consumption, from standard Canadian commodity by industry based Provincial I-O accounts. The final model (shown above in equation 5.16), represents a significant improvement over the completely open model (shown earlier in equation 5.4), especially for regional applications. At the regional level, especially when the region under examination is one of many interdependent regions which make up a national system, it would be desirable to develop a model which was also closed with respect to interregional commodity flows. That is, a regional analysis could only be enhanced by making these flows endogenous. This section will begin by developing a model which is closed with respect to interregional flows only, and show that this procedure yields the Multiregional I-O (MRIO) model. After the MRIO model has been derived from the commodity by industry accounting relationships, the model will be further closed with respect to personal consumption. The end result will be a multiregional version of the model shown in equation 5.16.

To begin closing the standard commodity by industry based I-O model (that is, the model shown in 5.4 above) to interregional commodity flows, assume that two regions define the entire system. Any expressions derived for the two region case can be easily extended to deal with any number of regions (12 in the Canadian case - 10 provinces and 2 territories), and this acts to greatly simplify the task of conceptualizing the relationship between interdependent regions (the two regions are denoted as L and M). To simplify further, each region is assumed to produce 2 commodities through 2 sectors. Again, any expressions derived for

the 2 region, 2 commodity, 2 sector case can easily be extended to deal with any number of each.

Given the following assumptions;

$$\lambda_{i}^{LL} = \frac{Z_{i}^{LL} - (M_{i}^{L} - R_{i}^{L})}{T_{i}^{L}}$$
where
$$T_{i}^{L} = Z_{i}^{LL} + Z_{i}^{ML}$$

$$m_{i}^{L} = \frac{M_{i}^{L}}{T_{i}^{L}}$$

$$\lambda_{i}^{LL} + m_{i}^{L} + \lambda_{i}^{LM} = 1$$

$$\lambda_{i}^{LL} = 1 - m_{i}^{L} - \lambda_{i}^{ML}$$

where;

λi ^{LL}	E	the interregional trade share coefficient for commodity i in region L; that is, this coefficient denotes the proportion of the total supply of commodity i available in region L which was
		produced in region L, and
Zi⊥⊥	Ħ	the total flow of regional L commodity i to sectors in region
Hi ^r	£	re-exports of commodity I from region L, and
Mi	Ξ	imports of commodity i into region L, and
Ti	≡	the total available supply of commodity i in region L, then

the commodity balance equation for region L could be written as follows;

$$\lambda_{i}^{LL}\left[\sum_{j=1}^{n} b_{ij}^{L}X_{j}^{L} + \tilde{Y}^{L}\right] + \lambda_{i}^{LM}\left[\sum_{j=1}^{n} b_{ij}^{M}X_{j}^{M} + \tilde{Y}^{M}\right] + E_{i}^{L} = Q_{i}^{L}$$
5.18

where;

- $\tilde{Y} \equiv$ denotes a domestic final demand vector which has had interregional imports and exports removed, and
- $E_i^L \equiv$ denotes foreign exports of commodity i from region L. Foreign exports are kept outside of the trade share multiplication due to the fact that the demand for exports is not a function of the total amount of i used in L that comes from production in L,

and likewise for region M;

$$\lambda_{i}^{MM}\left[\sum_{j=1}^{n} b_{ij}^{M} X_{j}^{M} + \tilde{Y}_{i}^{M}\right] + \lambda_{i}^{ML}\left[\sum_{j=1}^{n} b_{ij}^{L} X_{j}^{L} + \tilde{Y}_{i}^{L}\right] + E_{i}^{M} = Q_{i}^{M}$$
5.19

where regions L and M totally define the economy. It is important to note that the domestic final demand vector, \tilde{Y} , is now devoid of all interregional import and export columns. The interregional trade coefficients (λ s) act to make these flows endogenous. Note also that the original accounting identity shown in equation 5.1 still holds; this procedure removes interregional imports and exports from exogenous final demand and places them "*inside the model*" - that is on the LHS of equation 5.1, as opposed to the RHS.¹³ In matrix notation then, the commodity and industry balance equations for the entire system could be written as follows;

$$\Lambda \begin{bmatrix} \tilde{B}\tilde{X} + \tilde{Y} \end{bmatrix} + \tilde{E} = \tilde{Q}$$

$$\tilde{X} = \tilde{D}' \tilde{Q}$$
5.20

where $\tilde{Q}, \tilde{X}, \Lambda, \tilde{B}, \tilde{Y}, \tilde{E}$ are all block matrices of the following form;

$$\tilde{\mathbf{Q}}' = \begin{bmatrix} \mathbf{Q}_1^{\mathsf{L}} & \mathbf{Q}_2^{\mathsf{L}} & \mathbf{Q}_1^{\mathsf{M}} & \mathbf{Q}_2^{\mathsf{M}} \end{bmatrix}$$
 5.21

$$\tilde{\mathbf{X}}' = \begin{bmatrix} \mathbf{X}_{1}^{L} & \mathbf{X}_{2}^{L} & \mathbf{X}_{1}^{M} & \mathbf{X}_{2}^{M} \end{bmatrix}$$
 5.22

$$\Lambda = \begin{bmatrix} \lambda_{1}^{LL} & 0 & \lambda_{1}^{LM} & 0 \\ 0 & \lambda_{2}^{LL} & 0 & \lambda_{2}^{LM} \\ \lambda_{1}^{ML} & 0 & \lambda_{1}^{MM} & 0 \\ 0 & \lambda_{2}^{ML} & 0 & \lambda_{2}^{MM} \end{bmatrix}$$
5.23

$$\tilde{B} = \begin{bmatrix} b_{11}^{L} & b_{12}^{L} & 0 & 0 \\ b_{21}^{L} & b_{22}^{L} & 0 & 0 \\ 0 & 0 & b_{11}^{M} & b_{12}^{M} \\ 0 & 0 & b_{21}^{M} & b_{22}^{M} \end{bmatrix}$$
5.24

$$\tilde{D} = \begin{bmatrix} d_{11}^{L} & d_{12}^{L} & 0 & 0 \\ d_{21}^{L} & d_{22}^{L} & 0 & 0 \\ 0 & 0 & d_{11}^{M} & d_{12}^{M} \\ 0 & 0 & d_{21}^{M} & d_{22}^{M} \end{bmatrix}$$
5.25

$$\tilde{E}' = \left[E_1^L \ E_2^L \ E_1^M \ E_2^M \right]$$
 5.27

By following through, element by element, it is clear to see that the commodity balance matrix equation yields a set of commodity and region specific commodity balance equations which are identical to those derived earlier (see equations 5.18 and 5.19). Therefore, the commodity and industry balance equations shown in equation 5.20 define a commodity by industry system which is closed with respect to interregional commodity flows.

As before, substituting the industry balance equation for \tilde{X} in the commodity balance equation yields an expression for \tilde{Q} ;

$$\begin{split} &\Lambda \begin{bmatrix} \tilde{B}\tilde{D} \ \tilde{Q} + \tilde{Y} \end{bmatrix} + \tilde{E} = \tilde{Q} \\ &\Lambda \tilde{B}\tilde{D} \ \tilde{Q} + \Lambda \tilde{Y} + \tilde{E} = \tilde{Q} \\ &\tilde{Q} - \Lambda \tilde{B}\tilde{D} \ \tilde{Q} = \Lambda \tilde{Y} + \tilde{E} \\ &[I - \Lambda \tilde{B}\tilde{D} \ \tilde{D} \ \tilde{Q} = \Lambda \tilde{Y} + \tilde{E} \\ &\tilde{Q} = &[I - \Lambda \tilde{B}\tilde{D} \ \tilde{D} \]^{-1} \Lambda \tilde{Y} + \tilde{E} \end{split}$$

which is a commodity based MRIO model - in this case for a two region system. By substituting this expression for \tilde{Q} in the industry balance equation in 5.20 above, an industry based MRIO model is the result.

$$\tilde{\mathbf{X}} = \tilde{\mathbf{D}}' \left[\mathbf{I} - \Lambda \tilde{\mathbf{B}} \tilde{\mathbf{D}}' \right]^{-1} \Lambda \tilde{\mathbf{Y}} + \tilde{\mathbf{E}}$$
 5.29

Given the definition of the trade share coefficients in 5.17 above, it is clear that the contribution of foreign sectors to the domestic supply of commodity i is netted out when the flows are apportioned to both regions. Since this is the case, competitive imports from abroad are not removed from the final demand matrix.

To this point then, a commodity by industry based I-O model which is closed with respect to interregional commodity flows has been derived. This model is actually a commodity by industry variant of the basic MRIO model since it makes use of the provincial export columns found in each region's final demand matrix to develop trade shares (λ_i 's) which, in combination with the single region technical coefficients (elements of BD'), allow for an approximation of the technical coefficients of the true survey based interregional I-O (IRIO) model. The following discussion will focus on closing this MRIO system to personal consumption.

The commodity balance equation shown in equation 5.20 can be extended further to make personal consumption expenditures endogenous as well. The procedure begins with a re-specification of the commodity balance equations shown above in equations 5.18 and 5.19, where this re-specification is analogous to that used to endogenize consumption in the single region case. A commodity balance equation for region L could be written as shown in equation 5.30.

$$\lambda_{i}^{LL} \left[\sum_{j=1}^{n} \mathbf{b}_{ij}^{L} \mathbf{X}_{j}^{L} + \tilde{\mathbf{Y}}_{i}^{L} \right] + \lambda_{i}^{LM} \left[\sum_{j=1}^{n} \mathbf{b}_{ij}^{M} \mathbf{X}_{j}^{M} + \tilde{\mathbf{Y}}_{i}^{M} \right] + \mathbf{E}_{i}^{L} = \mathbf{Q}_{i}^{L}$$

$$\lambda_{i}^{LL} \sum_{j=1}^{n} \mathbf{b}_{ij}^{L} \mathbf{X}_{j}^{L} + \lambda_{i}^{LM} \sum_{j=1}^{n} \mathbf{b}_{ij}^{M} \mathbf{X}_{j}^{M} + \lambda_{i}^{LL} \tilde{\mathbf{Y}}_{i}^{L} + \lambda_{i}^{LM} \tilde{\mathbf{Y}}_{i}^{M} + \mathbf{E}_{i}^{L} = \mathbf{Q}_{i}^{L}$$

$$\lambda_{i}^{LL} \sum_{j=1}^{n} \mathbf{b}_{ij}^{L} \mathbf{X}_{j}^{L} + \lambda_{i}^{LM} \sum_{j=1}^{n} \mathbf{b}_{ij}^{M} \mathbf{X}_{j}^{M} + \lambda_{i}^{LL} \tilde{\mathbf{Y}}_{i}^{L} + \lambda_{i}^{LL} (\mathbf{e}_{i}^{L} \boldsymbol{\beta}^{L} \mathbf{N}^{L}) + \lambda_{i}^{LM} \tilde{\mathbf{Y}}_{i}^{M} + \lambda_{i}^{M} (\mathbf{e}_{i}^{M} \boldsymbol{\beta}^{M} \mathbf{N}^{M}) + \mathbf{E}_{i}^{L} = \mathbf{Q}_{i}^{L}$$

$$\lambda_{i}^{LL} \left[\sum_{j=1}^{n} \mathbf{b}_{ij}^{L} \mathbf{X}_{j}^{L} + \mathbf{e}_{i}^{L} \boldsymbol{\beta}^{L} \mathbf{N}^{L} + \tilde{\mathbf{Y}}_{i}^{T} \right] + \lambda_{i}^{LM} \left[\sum_{j=1}^{n} \mathbf{b}_{ij}^{M} \mathbf{X}_{j}^{M} + \mathbf{e}_{i}^{M} \boldsymbol{\beta}^{M} \mathbf{N}^{M} + \tilde{\mathbf{Y}}_{i}^{M} \right] + \mathbf{E}_{i}^{L} = \mathbf{Q}_{i}^{L}$$

$$\lambda_{i}^{LL} \left[\sum_{j=1}^{n} \mathbf{b}_{ij}^{L} \mathbf{X}_{j}^{L} + \mathbf{e}_{i}^{L} \boldsymbol{\beta}^{L} \mathbf{N}^{L} + \tilde{\mathbf{Y}}_{i}^{T} \right] + \lambda_{i}^{LM} \left[\sum_{j=1}^{n} \mathbf{b}_{ij}^{M} \mathbf{X}_{j}^{M} + \mathbf{e}_{i}^{M} \boldsymbol{\beta}^{M} \mathbf{N}^{M} + \tilde{\mathbf{Y}}_{i}^{M} \right] + \mathbf{E}_{i}^{L} = \mathbf{Q}_{i}^{L}$$

$$\lambda_{i}^{LL} \left[\sum_{j=1}^{n} \mathbf{b}_{ij}^{L} \mathbf{X}_{j}^{L} + \mathbf{e}_{i}^{L} \boldsymbol{\beta}^{L} \mathbf{N}^{L} \right] + \lambda_{i}^{LM} \left[\sum_{j=1}^{n} \mathbf{b}_{ij}^{M} \mathbf{X}_{j}^{M} + \mathbf{e}_{i}^{M} \boldsymbol{\beta}^{M} \mathbf{N}^{M} \right] + \lambda_{i}^{LL} \tilde{\mathbf{Y}}_{i}^{L} + \lambda_{i}^{LM} \tilde{\mathbf{Y}}_{i}^{M} + \mathbf{E}_{i}^{L} = \mathbf{Q}_{i}^{L}$$

It is important to note that the final demand vector referred to in the third, fourth and fifth equations in 5.30 above (\check{Y}) is now devoid of interregional imports and

exports as well as personal consumption.

In matrix notation, the commodity and industry balance equations for the system shown in 5.30 above can be expressed as follows;

$$\begin{split} \ddot{\Lambda}\breve{B}\breve{X}+\breve{\Lambda}\breve{Y}+\breve{E} &= \breve{Q} \\ \breve{X} &= \breve{D}^{\,\prime}\breve{Q} \end{split}$$
 5.31

As before, the commodity and industry balance equations can be manipulated to yield commodity and industry based models as follows;

$$\begin{split} \ddot{\Lambda} \breve{B} \breve{D}' \breve{Q} + \breve{\Lambda} \breve{Y} + \breve{E} &= \breve{Q} \\ \breve{Q} - \breve{\Lambda} \breve{B} \breve{D}' \breve{Q} &= \breve{\Lambda} \breve{Y} + \breve{E} \\ \breve{Q} &= \begin{bmatrix} I - \breve{\Lambda} \breve{B} \breve{D}' \end{bmatrix}^{-1} \breve{\Lambda} \breve{Y} + \breve{E} \\ \breve{X} &= \breve{D}' \begin{bmatrix} I - \breve{\Lambda} \breve{B} \breve{D}' \end{bmatrix}^{-1} \breve{\Lambda} \breve{Y} + \breve{E} \end{split}$$

$$5.32$$

the internal structure of each of these matrices had to be altered to allow the expanded commodity balance to be maintained. Structurally, the requisite matrices are defined as follows;

$$\tilde{\Lambda} = \begin{bmatrix} \lambda_1^{LL} & 0 & 0 & \lambda_1^{LM} & 0 & 0 \\ 0 & \lambda_2^{LL} & 0 & 0 & \lambda_2^{LM} & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ \lambda_1^{ML} & 0 & 0 & \lambda_1^{MM} & 0 & 0 \\ 0 & \lambda_2^{ML} & 0 & 0 & \lambda_2^{MM} & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$
5.33

$$\tilde{\mathbf{Q}}^{\prime} = \begin{bmatrix} \mathbf{Q}_{1}^{L} & \mathbf{Q}_{2}^{L} & \mathbf{N}^{L} & \mathbf{Q}_{1}^{M} & \mathbf{Q}_{2}^{M} & \mathbf{N}^{M} \end{bmatrix}$$
 5.38

$$\tilde{E}' = \begin{bmatrix} E_1^{L} & E_2^{L} & N^{EXPT^{L}} & E_1^{M} & E_2^{M} & N^{EXPT^{M}} \end{bmatrix}$$
5.37

$$\tilde{\mathbf{X}}^{\prime} = \begin{bmatrix} \mathbf{X}_{1}^{L} & \mathbf{X}_{2}^{L} & \mathbf{N}^{SCTR^{L}} & \mathbf{X}_{1}^{M} & \mathbf{X}_{2}^{M} & \mathbf{N}^{SCTR^{M}} \end{bmatrix}$$
 5.35

$$\breve{B} = \begin{bmatrix} b_{11}^{L} & b_{12}^{L} & \beta^{L} e_{1}^{L} & 0 & 0 & 0 \\ b_{21}^{L} & b_{22}^{L} & \beta^{L} e_{2}^{L} & 0 & 0 & 0 \\ \mu_{1}^{L} & \mu_{2}^{L} & \mu_{e}^{L} \beta^{L} & 0 & 0 & 0 \\ 0 & 0 & 0 & b_{11}^{M} & b_{12}^{M} & \beta^{M} e_{1}^{M} \\ 0 & 0 & 0 & b_{21}^{M} & b_{22}^{M} & \beta^{M} e_{2}^{M} \\ 0 & 0 & 0 & \mu_{1}^{M} & \mu_{2}^{M} & \mu_{e}^{M} \beta^{M} \end{bmatrix}$$
5.34

it is important to note that the matrix structure used earlier for the single region case has been extended to allow for interregional linkages. By expanding this system and focussing on the third row of each block matrix, the following balance equation for total personal income earned in region L can be defined;

$$\sum_{j=1}^{n} \mu_{j}^{L} X_{j}^{L} + \beta^{L} \mu_{e}^{L} N^{SCTR^{L}} + N^{EXOG^{L}} + N^{EXPT^{L}} = N^{L}$$
5.39

and similarly for region M. Therefore, the model shown in 5.32 above represents an I-O model that is closed with respect to interregional imports and exports, and personal consumption.

5.5 Building the Effects of Capacity Expansion into the Exogenous Vector

In the models discussed thus far, the technical coefficients were derived from measurements of flows of commodities between sectors reflecting purchases for *current period production needs*. That is, each of the commodity flows (elements across each row of the Use matrix - u_{ij}) is viewed as serving as an input for current output, and these relationships are fixed in the technical coefficients (b_{ij}'s). However, with many commodities it maybe the case that they are not completely consumed for current production, but rather contribute to the capital stock in each sector (e.g., plant and equipment). The dynamic I-O model serves to differentiate between these two types of input requirements, and makes the

capital input requirements of the various sectors in the model endogenous. The process of endogenizing investment amounts to assuming that investment, as in the case of personal consumption discussed above, can be split into endogenous and exogenous portions. Endogenous investment is that portion of the total which represents the capital stock augmentation requirements of the various sectors in response to demands for sectoral outputs, while exogenous investment represents that portion which is determined by investment decisions on behalf of private and public agencies (e.g., a \$300M investment in exploratory drilling in the NWT). Like the personal consumption case, this endogenization procedure requires that the investment vector be removed from the final demand matrix, and that it be replaced by modifications to the commodity balance equations making investment levels a function of sectoral output levels. The exogenous investment component only enters the framework if the dynamic model is used to assess the impacts of a delta investment vector, where this vector represents exogenous investment (i.e., the outcome of decisions unrelated to sectoral capital stock requirements).

The Duchin and Szyld (1985) reformulation of the dynamic I-O model, as discussed in chapter 4, is no different in this regard; the investment vector is removed from the final demand matrix and replaced by an investment term which reflects the capacity augmentation behaviour of all sectors in response to output demands. Duchin and Szyld (1985) noted that their admittedly arbitrary method of making sectoral capacity adjustments endogenous could be superseded by

a set of ex ante scenarios. In such a case, sectoral capacity adjustments would no longer be "endogenous" since the model itself would not be generating the capacity adjustment information, but they could be taken to represent the "endogenous" investment portion of the total investment vector referred to earlier. That is, insofar as endogenous investment is defined as that investment which is directly related to sectoral output levels, the Duchin and Syzld investment term could be retained to reflect the capital input requirements of sectors in an economy in response to an exogenous shock. For example, in the case of an Arctic Oil development project in the NWT, the associated investment profile would represent the perceived needs of those attempting to exploit the resource (exogenous investment). The associated capacity adjustments required in the NWT in response to such a plan however, would be endogenous to the extent that they would be a function of the required sectoral output levels in the NWT. Based on this logic then, the scenario driven Duchin and Szyld model would also require that the investment vector be removed from the final demand matrix, and be replaced by the suggested investment term. The investment term is placed "outside of the model" with the exogenous final demand vectors which drive the system (see chapter 4). This arrangement allows for the simultaneous representation of current period investment expenditures (exogenous investment) and the associated sectoral capacity expansions (endogenous investment) in one drive mechanism.

To build such a model, initially for the single region case, the commodity balance equation shown in 5.1 above needs to be altered to reflect the fact that some of the commodity i available for use in the region will be used by sectors to expand their capacities. To do this, an expansion investment term must be added to the LHS of the commodity balance equation to account for this capital formation activity as follows;

$$\sum_{j} b_{ij}(t_0) X_j(t_0) + \sum_{\theta=1}^{\tau} \sum_{j=1}^{n} K_{ij}^{\theta}(t_0) o_j(t_0 + \theta) + \mathring{Y}_i(t_0) = Q_i(t_0)$$
 5.40

where;

Ϋ́,	=	denotes a final demand vector which has had the investment vectors removed,
τ	≡	denotes the lag time required for an expansion plan to be realized (defined as the maximum gestation period associated with a plan's capital input requirements
k _{ij}	=	capital expansion coefficient - the amount of capital produced in period t_0 by sector i to increase the capacity of sector j by one unit in period ($t_0 + \theta$), and
o _j (t₀+€	9)≡	the capacity adjustment that must take place in sector j between periods $(t_0 + \theta - 1)$ and $(t_0 + \theta)$.

If, for a specific year no expansion is called for, the investment term drops out of equation 5.40, and a commodity balance equation identical to the one displayed in equation 5.1 remains. The commodity and industry balance matrix equations for such a system could be expressed as follows;

$$B(t_{0}) X(t_{0}) + \sum_{\theta=1}^{\tau} K^{\theta}(t_{0}) o(t_{0} + \theta) + \mathring{Y}(t_{0}) = Q(t_{0})$$

$$X(t_{0}) = D(t_{0})^{2}Q(t_{0})$$
5.41

it is important to note that all matrices and vectors have been time indexed. This set of equations can be solved to yield the expressions for Q and X as follows;

$$Q(t_{0}) = \left[I - B(t_{0}) D(t_{0})^{\prime}\right]^{-1} \left[\sum_{\theta=1}^{\tau} K^{\theta}(t_{0}) o(t_{0} + \theta) + \mathring{Y}(t_{0})\right]$$
5.42
$$X(t_{0}) = D(t_{0})^{\prime} \left[I - B(t_{0}) D(t_{0})^{\prime}\right]^{-1} \left[\sum_{\theta=1}^{\tau} K^{\theta}(t_{0}) o(t_{0} + \theta) + \mathring{Y}(t_{0})\right]$$

the investment terms presented here mirror those used by Duchin and Szyld (1985) in that the lag for the representation of various gestation periods appears in the equation. If we assume, in lieu of better information, that expansion related capital goods can be produced, delivered and integrated with existing stock in 1 period, the investment term appears very similar to the form used originally by Leontief (1953). Even if a gestation period of 1 is used, this model still retains the positive qualities espoused by Duchin and Szyld (1985). What remains is to extend the model derived earlier in equation 5.32 in this manner.

When the commodity balance equation in 5.30 was derived, the final demand vector was split into that portion which was labelled endogenous

consumption, and that portion which represented all other exogenous final demand categories, one of which was investment. The addition of the investment term to equation 5.30 essentially amounts to splitting the investment vector, like the consumption vector, into "endogenous" and exogenous parts. Based on this, equation 5.30 (the commodity balance for region L) is redefined as follows;

$$\lambda_{i}^{LL}(t_{0}) \left[\sum_{j=1}^{n} \mathbf{b}_{ij}^{L}(t_{0}) \mathbf{X}_{j}^{L}(t_{0}) + \mathbf{e}_{i}^{L}(t_{0}) \boldsymbol{\beta}^{L}(t_{0}) \mathbf{N}^{SCTRL}(t_{0}) \right] + \lambda_{i}^{LM}(t_{0}) \left[\sum_{j=1}^{n} \mathbf{b}_{ij}^{M}(t_{0}) \mathbf{X}_{j}^{M}(t_{0}) + \mathbf{e}_{i}^{M}(t_{0}) \boldsymbol{\beta}^{M}(t_{0}) \mathbf{N}^{SCTRM}(t_{0}) \right] + \lambda_{i}^{LM}(t_{0}) \left[\dot{\mathbf{Y}}_{i}^{L}(t_{0}) + \sum_{\theta=1}^{\tau} \sum_{j=1}^{n} \mathbf{k}_{ij}^{\theta^{L}}(t_{0}) \mathbf{o}_{j}^{L}(t_{0}+\theta) \right] + \lambda_{i}^{LM}(t_{0}) \left[\dot{\mathbf{Y}}_{i}^{M}(t_{0}) + \sum_{\theta=1}^{\tau} \sum_{j=1}^{n} \mathbf{k}_{ij}^{\theta^{M}}(t_{0}) \mathbf{o}_{j}^{M}(t_{0}+\theta) \right] + \mathbf{E}_{i}^{L}(t_{0}) \left[\mathbf{Y}_{i}^{M}(t_{0}) + \sum_{\theta=1}^{\tau} \sum_{j=1}^{n} \mathbf{k}_{ij}^{\theta^{M}}(t_{0}) \mathbf{o}_{j}^{M}(t_{0}+\theta) \right] + \mathbf{E}_{i}^{L}(t_{0}) \left[\mathbf{Y}_{i}^{M}(t_{0}) + \sum_{\theta=1}^{\tau} \sum_{j=1}^{n} \mathbf{k}_{ij}^{\theta^{M}}(t_{0}) \mathbf{n}_{j}^{M}(t_{0}+\theta) \right] + \mathbf{E}_{i}^{L}(t_{0}) \left[\mathbf{Y}_{i}^{M}(t_{0}) \mathbf{n}_{i}^{M}(t_{0}) \mathbf{n}_{j}^{M}(t_{0}+\theta) \right] + \mathbf{E}_{i}^{L}(t_{0}) \left[\mathbf{Y}_{i}^{M}(t_{0}) \mathbf{n}_{i}^{M}(t_{0}) \mathbf{n}_{j}^{M}(t_{0}+\theta) \right] + \mathbf{E}_{i}^{L}(t_{0}) \left[\mathbf{Y}_{i}^{M}(t_{0}) \mathbf{n}_{i}^{M}(t_{0}) \mathbf{n}_{i}^{M}(t_{0}) \mathbf{n}_{i}^{M}(t_{0}+\theta) \right] + \mathbf{E}_{i}^{L}(t_{0}) \left[\mathbf{Y}_{i}^{M}(t_{0}) \mathbf{n}_{i}^{M}(t_{0}+\theta) \mathbf{n}_{i}^{M}(t_{0}+\theta) \right] + \mathbf{E}_{i}^{L}(t_{0}) \left[\mathbf{Y}_{i}^{M}(t_{0}+\theta) \mathbf{n}_{i}^{M}(t_{0}+\theta) \right]$$

where;

 $\dot{Y} \equiv$ represents a final demand vector which is devoid of consumption, investment, and interregional imports and exports.

Furthermore, if we assume that the expansion related investment activities are to be allocated across regions in a manner distinct from that for current period investment expenditures then the equation 5.43 could be re-written as follows;

$$\lambda_{i}^{LL}(t_{0})\left[\sum_{j=1}^{n} \mathbf{b}_{ij}^{L}(t_{0}) \mathbf{X}_{1}^{L}(t_{0}) + \mathbf{e}_{i}^{L}(t_{0}) \boldsymbol{\beta}^{L}(t_{0}) \mathbf{N}^{SCTRL}(t_{0})\right] + \lambda_{i}^{LM}(t_{0})\left[\sum_{j=1}^{n} \mathbf{b}_{ij}^{M}(t_{0}) \mathbf{X}_{1}^{M}(t_{0}) + \mathbf{e}_{i}^{M}(t_{0}) \boldsymbol{\beta}^{M}(t_{0}) \mathbf{N}^{SCTRM}(t_{0})\right] + \mathbf{5.44}$$

$$\left[\lambda_{i}^{LL}(t_{0}) \dot{\mathbf{Y}}_{i}^{L}(t_{0}) + \mathbf{Y}_{i}^{LL} \sum_{\theta=1}^{\tau} \sum_{j=1}^{n} \mathbf{k}_{ij}^{\theta^{L}}(t_{0}) \mathbf{o}_{i}^{L}(t_{0} + \theta)\right] + \left[\lambda_{i}^{LM}(t_{0}) \dot{\mathbf{Y}}_{i}^{M}(t_{0}) + \mathbf{Y}_{i}^{LM} \sum_{\theta=1}^{\tau} \sum_{j=1}^{n} \mathbf{k}_{ij}^{\theta^{M}}(t_{0}) \mathbf{o}_{j}^{M}(t_{0} + \theta)\right] + \mathbf{E}_{i}^{L}(t_{0}) = \mathbf{Q}_{i}^{L}(t_{0})$$

where γ denotes a modified trade coefficient for expansion activities which may be defined as a weighted version of the observed trade shares (λ).¹⁴ The modified commodity balance equation for region L may be written as follows;

$$\begin{split} \check{\Lambda}(t_0) \check{B}(t_0) \check{X}(t_0) + \check{\Lambda}(t_0) \dot{Y}(t_0) + \check{\Gamma}(t_0) \sum_{\theta=1}^{\tau} \check{K}(t_0)^{\theta^{\perp}} \check{o}(t_0 + \theta) + \check{E}(t_0) &= \check{Q}(t_0) \\ \check{X}(t_0) &= \check{D}(t_0)^{\prime} \check{Q}(t_0) \end{split}$$
5.45

where each of the matrices has the same structure as that shown in equations 5.32 to 5.38. The final demand vector, \dot{Y} , was distinguished with a different overstrike to reflect the fact that, in this case, it is devoid of investment as well as consumption and interregional trade (the overstrike "breve" denotes the block matrix setup for a closed MRIO model). The modified trade share matrix, $\check{\Gamma}$, has a structure identical to the observed trade share matrix, $\check{\Lambda}$. By solving for \check{X} and \check{Q} in the usual fashion, an I-O model which is closed to personal consumption,

interregional commodity flows, and which is able to accommodate capacity expansion effects is obtained. The final form of the model appears as follows;

$$\begin{split} \check{\mathbf{Q}}\left(t_{0}\right) &= \left[\mathbf{I} - \check{\mathbf{\Lambda}}\left(t_{0}\right)\check{\mathbf{B}}\left(t_{0}\right)\check{\mathbf{D}}\left(t_{0}\right)^{\prime}\right]^{-1} \left(\check{\mathbf{\Lambda}}\left(t_{0}\right)\dot{\mathbf{Y}}\left(t_{0}\right) + \check{\mathbf{\Gamma}}\left(t_{0}\right)\sum_{\theta=1}^{\tau}\check{\mathbf{K}}\left(t_{0}\right)^{\theta}\check{\mathbf{o}}\left(t_{0}+\theta\right) + \check{\mathbf{E}}\left(t_{0}\right)\right) \\ &\therefore \\ \check{\mathbf{X}}\left(t_{0}\right) &= \check{\mathbf{D}}\left(t_{0}\right) \left[\mathbf{I} - \check{\mathbf{\Lambda}}\left(t_{0}\right)\check{\mathbf{B}}\left(t_{0}\right)\check{\mathbf{D}}\left(t_{0}\right)^{\prime}\right]^{-1} \left(\check{\mathbf{\Lambda}}\left(t_{0}\right)\dot{\mathbf{Y}}\left(t_{0}\right) + \check{\mathbf{\Gamma}}\sum_{\theta=1}^{\tau}\check{\mathbf{K}}^{\theta}\check{\mathbf{o}}\left(t_{0}+\theta\right) + \check{\mathbf{E}}\left(t_{0}\right)\right) \end{split}$$
5.46

where each represents a MRIO model that is closed with respect to personal consumption and which is driven by an exogenous vector which combines the current period final demand vectors and an investment term which quantifies the effects of capacity expansion activities.

5.6 Discussion

The previous exposition detailed the development of a stylized dynamic MRIO model which is also closed to consumption. The most interesting part of this exercise is the use of Duchin and Szyld's investment term to represent "endogenous investment" in the commodity balance equation for the closed MRIO model. In a strict sense, something is only "truly" endogenous if the item is removed from the final demand matrix and replaced by mathematical relationships in the fabric of the model which generate these missing values in response to industry output impacts (e.g., see the derivations for closing the model to

consumption). In this light, the model shown above in 5.56 does not truly endogenize investment since the capacity adjustment vectors are the outcome of ex ante scenarios, and not some internal mechanism as in the original reformulation offered by Duchin and Szyld (1985). As mentioned above however, insofar as the word "endogenous" in this context implies that an item is a function of industry output levels, and not the result of forces completely external to the model (e.g., decisions to conduct exploratory drilling in the NWT), the investment term used above approximates a purely endogenous treatment of investment expenditures. As such, this expression was used in place of the investment vector in the final demand matrix.

As chapter 6 will discuss, each of the oil development scenarios provided by Croasdale and McDougall is accompanied by a capital investment time-line which reflects how each project will be constructed over time in the NWT. These investment expenditures represent the exogenous investment component referred to above since they are in no way determined by sectoral activity in the NWT, but rather they are a function of hypothetical decisions taken by industry to exploit the hydrocarbon reserve base of the NWT.

This model is appropriate to the task of assessing how the NWT and the rest of Canada could be affected by such projects since it is able to capture the combined effects of current period investment expenditures and the subsequent capacity augmentation expenditures for certain NWT sectors (the 2 effects

mentioned in the introduction). Chapter 6 explains exactly how this model was applied using a combination of published I-O data and unpublished expert information furnished by the Government of the Northwest Territories Bureau of Statistics, and the authors of the scenarios described in chapter 3.

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ENDNOTES

1. All of this will be conducted in a commodity by industry framework since this is how Canada's regional and national I-O data sets are compiled.

2. See Leontief, W.W. (1953). Dynamic Analysis, in W. Leontief, et al., (eds.) <u>Studies in the</u> <u>Structure of the American Economy</u>, Oxford University Press, New York.

3. "...The information collected from a particular establishment is assigned to an industrial category according to it's primary product. For example, suppose a manufacturer of fabricated metal products makes both steel casings and steel rods; if the manufacturer produces more steel casings than steel rods, the entire value of output of the manufacturer is assigned to the industrial category - steel casings. Hence, the total output of an industry is recorded as the sum of the outputs of all establishments assigned to that industry, including both the establishment's characteristic or primary product output and its secondary product output. Such a procedure, of course, can create misleading results in economies where significant secondary production occurs, for example, in the United States." (Miller, R.E., and P.D. Blair, 1985. p. 159.)

4. Rectangular refers to the fact that most often it is the case that the number of commodities (rows - m) exceeds the number of sectors (columns - n) and, as a result the Make, Use and Final demand matrices are rectangular, dimension (mxn), as opposed to being square, dimension (nxn), in the industry by industry case.

5. The B matrix is formed by dividing each element of the Use matrix by the corresponding column total. The term b_{\parallel} therefore represents the amount of commodity i used by sector j per dollar of sector j output. The product $b_{\parallel}X_{\parallel}$ therefore represents the total amount of commodity i required, or used, to make this level of sector j output possible. In matrix terms then, the BX term represents the product of a (43 commodity by 16 sector) B matrix and a (16 sector by 1 column) vector of gross sectoral output values (in the Canadian S level Provincial I-O data). The product therefore is a (43 commodity by 1 column) vector showing the total amount of each commodity used as an input into domestic production.

6. Where these are matrix equations: Q=mx1, X=nx1, B=mxn, D'=nxm, and F=mx1, where m denotes commodities and n denotes sectors.

7. This term represents the use of all commodities by the various final demand categories (e.g., personal consumption, government consumption, exports, etc.). The sum of this term and the BX term represents the total usage of all 43 commodities in the economy.

8. The D matrix is formed by dividing each element in a row of the Make matrix by the corresponding row sum (e.g., $d_{12}=v_{12}/Q_1$), Each d_{ij} coefficient therefore represents the share of each commodity produced by each sector. By using this technique to build a commodity by industry I-O model we are assuming that each sector produces a constant share of the total supply of commodity i - the <u>constant market share assumption</u>. Given this interpretation, pre-multiplying a vector of gross commodity outputs, Q, by a transposed D matrix provides an estimate of the total output of each sector. In future derivations any pre-multiplication by a D' matrix converts from commodity to industry space.

9. The other procedure would entail pre-multiplying the commodity balance equation by D' which allows for an immediate solution for X. This expression for X could then be substituted into the commodity balance equation to yield a model in commodity space.

10. An alternative approach would involve the use of an integrated econometric - I-O approach where the induced effects of industry output changes were estimated via the econometric portion of the model. An example of this approach can be seen in a recent report submitted to the Department of Transportation, Government of the Northwest Territories by the Custom Economic Services Branch of the Conference Board of Canada. The report was entitled "Economic Impacts from Implementing the NWT Transportation Strategy", and it was submitted to the GNWT in 1991.

11. Clearly, $\beta \Delta N$ represents that portion of additional personal income that will be spent on consumption. Therefore $e_i \beta \Delta N$ denotes that portion of additional personal income that will spent on commodity i.

12. Note that in this case we are dealing with one region only so only the region L elements of the vectors and matrices shown in equations 5.35, 5.36, 5.37, and 5.39 apply here.

13. The same logic applies to the case of endogenizing consumption.

14. This weighting scheme would be designed to make certain regions account for a larger or smaller proportion of the available supply of certain commodities in certain regions. See chapters 6 and 7 to see how this was done.

Chapter 6

Model Implementation

6.0 Introduction

Chapter 3 presented three scenarios of how the onshore and offshore oil reserves of the Mackenzie Delta/Beaufort Sea region of the Northwest Territories (NWT) could be developed in an economically feasible manner given current economic and technological conditions. These scenarios represent a subset of possible scenarios designed by two experts in the engineering-economics of oil development projects in Arctic regions - Croasdale and McDougall (1992). These authors were commissioned by the Federal Panel on Energy and Research and Development (PERD) to assess Canada's Frontier energy options. The report submitted by Croasdale and McDougall to the Federal PERD in 1992, along with the details behind the scenarios evaluated within it, has undergone a series of revisions since 1992 based on feedback from experts in the public and private sectors. The revised report, which has yet to be released, included several more scenarios than the original report, and these revised scenarios along with the detailed capital investment time-lines upon which they were based, form the basis for this analysis.

As discussed in chapter 5, the impact assessment tool thought to be most appropriate to the task of assessing how such oil development projects could affect the economies of the NWT and the remaining regions of Canada is a dynamic multiregional input-output model. It is the case that when capital intensive projects are initiated in a region which is relatively underdeveloped, one of the major impacts will be the exceedance of certain sectoral capacities as a result of the direct, indirect, and induced effects of the investment plan. The model developed in chapter 5 allows the effects of this capacity augmentation process to be assessed.

The purpose of this chapter therefore, is to describe in detail how the capital investment time-line information which underlies the scenarios designed by Croasdale and McDougall could be used in conjunction with the model derived in chapter 5 to assess how each oil development scenario would impact the economies of the NWT and the rest of Canada. In terms of structure, this chapter begins by reviewing the basic tenets of the model derived in chapter 5 as they relate to the implementation of the model in this context. Following this, the capital investment time-lines used by Croasdale and McDougall to assess the economic feasibility of each of the scenarios discussed in chapter 3 are presented and discussed. Following this, the chapter will proceed to discuss how this information was translated into a form which is amenable to the model derived in chapter 5. The chapter ends by discussing the implementation of the model. The

results of these computations are presented and discussed in detail in chapter 7.

6.1 Reviewing the Basic Requirements of the Extended Dynamic MRIO Model

The model developed in chapter 5 was inspired by the pioneering work of Duchin and Szyld (1985). The Duchin and Szyld reformulation was inspired by the desire to develop a dynamic I-O model that was amenable to practical application as an impact assessment tool as the following quote indicates;

"The mathematical properties of the dynamic model have been extensively studied but the model has not been used in empirical work because it produces implausible results. This paper <the Duchin paper > indicates the nature of the difficulties, describes the new formulation (first used in Leontief and Duchin, 1986), and presents some empirical results. Hopefully this work will stimulate the transition from a static toward a dynamic framework for applied input-output analysis." (Duchin and Szyld, 1985: pp. 270).

The fact that the model derived in chapter 5 includes an *investment term* as part of the exogenous vector means that the I-O system can be solved for that vector of gross outputs (in sector or commodity space) which satisfies all final demands, as well as all demands associated with an expansion plan. In the Duchin and Szyld reformulation, the model was driven solely by sector specific capacity adjustments. In the context of assessing how a massive capital intensive project undertaken in an underdeveloped region could affect that regional economy, it is important to realize that current period investment expenditures and capacity expansion activities would undoubtedly take place concurrently. The model derived in chapter 5 was designed to operate in this manner. The final form of the model, shown in equation 5.46, is driven by an exogenous vector which is actually the sum of current period investment expenditures in the NWT (where this information is obtained from the investment time-lines which are discussed below) and a capacity expansion vector which represents the product of a capacity adjustment vector (showing any capacity shortfalls found to exist in the NWT in the face of any investment plan) and an expansion capital input coefficient matrix (which details the capital inputs required by each sector in the NWT per dollar of expansion in that sector). The following sections will discuss the information needed to form this exogenous vector for each scenario.

6.2 The Input-Output Data

The input-output model derived in chapter 5 was implemented using the 1984 **(S)**mall Level Provincial Input-Output Accounts. These data sets, while somewhat dated, represent the most current set of Provincial Input-Output Accounts available in Canada. Like most developed countries, Canada uses a "*Commodity by Industry*" or rectangular framework for the compilation of its I-O accounts. Commodity by Industry Input-Output Data has the advantage of allowing for a better representation of the secondary products produced by the various industrial sectors of an economy as opposed to the "*Industry by Industry*" or square framework which requires that establishments, along with the total value

of their output, be allocated to industrial aggregates based on their principal product. This results in some inaccuracy due to the fact that a steel sheet manufacturer for example, may also produce a significant output of galvanized nails and screws - a commodity entirely distinct from steel sheets - but the total output of this establishment would be allocated to the aggregate sector responsible for steel sheet manufacture. In the rectangular system, this establishments' output would be tracked over each commodity it produces, and hence a better picture of the true nature of that establishment or sector is gained. The price of this added precision is the fact that any economy which has been mapped in this fashion will have a set of three primary transactions tables associated with it, as opposed to a single square transactions table in the industry by industry case. In the commodity by industry system, a "Use Matrix or Absorption Matrix tracks the commodity inputs to each sector while a "Make Matrix" tracks the commodities produced by each sector in the economy. A "Final Demand Matrix^{*} tracks the use of each commodity produced in the economy by final demand or "end-user" categories.

Each of the Provinces and Territories of Canada has a set of commodity by industry accounts compiled for it by Statistics Canada. These accounts are publicly available for all regions in Canada at the **(S)**mall level which consists of 16 industrial and 43 commodity aggregates, and at the **(M)**edium level (50 sectors and 100 commodities) for the 10 Provinces only. The S level tables include

detailed information on the flow of each commodity from each region in the system to every other region in the system, and this is the information needed to create the interregional trade matrix which is a fundamental component of the Multiregional I-O model (see Appendix 6a at the end of this chapter for detailed notes on the construction of an interregional trade coefficient matrix from the data available in the S level Provincial I-O accounts). The M level data, while disqualified from consideration based on the fact that such tables are not publicly available for the NWT (for reasons of confidentiality), do not include this detailed interregional trade information. Instead, the M level tables include an interregional trade balance figure for each commodity. Based on these considerations, it was decided that the model developed in chapter 5 be implemented using the 1984 S level Provincial I-O accounts published by Statistics Canada - Input-Output Division.¹

6.3 Capital Investment Time-lines for Each NWT Oil Development Scenario

As mentioned earlier, the scenarios described in chapter 3 represent the most current and highly regarded scenarios of the future of oil development in the Mackenzie Delta/Beaufort Sea region of the NWT. The capital investment time-line information upon which these scenarios were based were generously provided by Croasdale and McDougall (the authors of the scenarios). These investment time-line lines are displayed for all three scenarios discussed in chapter 3 in tables 6.1, 6.2,

and 6.3. These time-lines, for each scenario, specify the temporal distribution of investment expenditures, by 5 categories of investment, required to complete each type of development in the NWT. As such, impacts associated with operations, maintenance, or future expansion contingencies are not considered, and only the interregional economic impacts of the construction phase of each project will be examined. The following sections will describe exactly how this information was used to form the exogenous vectors needed to drive the model derived in chapter 5.

6.3.1 Scenario 1: 100M Bbl. Onshore Field - Small Pipeline Option

The first scenario focusses on the main onshore potential of the NWT - the oil and gas discoveries in the Mackenzie Delta and shallow Beaufort Sea region. Specifically, this scenario focusses on the development of an as yet undiscovered 100M Bbl. field near North Point on Richards Island in the Mackenzie Delta. This area yielded a number of smaller finds in the exploration boom of the 1970s and early 1980s, and it is considered to be a potentially rich oil producing region in the NWT. A variety of pipeline options for tapping this region's oil potential have been reviewed by the Canadian Oil and Gas Lands Administration, but the most economically attractive option involves extending the existing Norman Wells Pipeline (NWP - which is owned and operated by Interprovincial Pipelines Ltd. - IPL) north to a system of gathering lines in the Delta region with a concurrent

Table 6.1

Capital Investment Time-line: Scenario 1

Yr	Exploratory Drilling	Development Drilling	Gathering & Production Facility Construction	Pipeline Construction	Compressor Station Construction	Arctic Tanker Constru ction			
All Figures in Millions of 1984 Dollars									
1	19	19	0	0	0	0			
2	0	19	0	0	0	0			
3	0	63	32	38	0	0			
4	0	63	63	154	52	0			
5	0	63	127	154	65	0			
6	0	63	32	38	13	0			
7	0	63	0	0	0	0			
8	0	6	0	0	0	0			

(Source: Croasdale, 1994)

expansion of the capacity of the existing portion of the NWP.

At present, one major impediment to developing any of the smaller pools in the region is the lack of one large field - called an *anchor field* - which would make the investment in the pipeline attractive at which point the smaller pools could be tapped to maintain or increase the productive capacity of the system. Scenario 1 represents just this sort of development.

Croasdale and McDougall (1992), in developing a cost profile for this project, assumed the following; a total of 61 wells would be drilled of which 2 would be for delineation purposes, 40 would be producers, 13 would be water injectors, 4 would be gas injectors and one well would be dry. They also noted that the 100M Bbl. field would be tapped by a 12 inch diameter pipeline extending from North Point to Norman Wells (see figures in chapter 3). The pipeline specifications also included the construction of 4 compressor stations between North point and Norman Wells, and 3 additional stations between Norman Wells and Zama Alberta.² The facility would designed to produce oil at the rate of 35,000 barrels per day (bpd) over a period of 20 years.

The capital investment time-line information displayed in table 6.1 translates this general description of the development into a series of investment expenditures over a period of years which culminates in year 8 with a complete facility. The first two years consist of exploratory and development drilling only. The first year expenditure on exploratory drilling represents the fact that the 100M
Bbl. field is as yet not officially discovered, but sufficient geophysical and seismic evidence exists to suggest that the probability of such a field existing in the region is very high. This one time expenditure for exploratory drilling embodies the assumption that the field is discovered in one year, and partially delineated, while the development drilling in year 2 accounts for the final delineation and the beginning of the development drilling which aims to vent and pressurize the field in a manner which yields optimal production characteristics. It is important to note that this development drilling continues for every year in the construction phase of the project. In year 3, the field has been sufficiently delineated and studied to allow for the siting and initial construction of the platform facilities which will be used to house both the producing wells as well as the pressurizing water and gas injector wells. Year 3 also calls for the beginning of the pipeline construction phase. The expenditures tracked for pipeline construction include the purchase of 12 inch diameter pipe, the construction of the right-of-way for the pipeline, and the actual pipeline construction activities. Table 6.1 indicates that the pipeline construction expenditures extend over a period of 4 years with the compressor station construction and integration phase beginning in year 4, and continuing through year 6. By the end of year 6, both the well-head facilities and the pipeline are complete and production begins, with years 7 and 8 calling for expenditures for continued development drilling only.

6.3.2 Scenario 2: 350M Bbl. Offshore Field - Large Pipeline Option

Scenario 2 represents one of the most elaborate Arctic Oil development options available for the NWT. It focusses on the development of the 350M Bbl. offshore field discovered by Gulf Canada Ltd. in the Beaufort Sea. This large reservoir was initially thought to rival the Prudhoe Bay field discovered off Alaska's North Slope in the early 1970s (which has been conservatively estimated to contain over 1.2B barrels of oil). Delineation drilling and flow tests in the mid to late 1980s led to a revised estimate of approximately 350M Bbls. The discovery of this *elephant field* spawned many elaborate proposals for the extraction and transportation of Beaufort oil to southern markets. Specifically, scenario 2 called for a dedicated large diameter pipeline (16 inches) running from a gathering facility on Richards Island south to Zama Alberta where it would connect with IPL's existing pipeline network for transportation to the U.S. and to central and eastern Canada. The capital investment time-line information for this scenario is displayed in table 6.2.

Table 6.2 indicates that the first 4 years of the project would be devoted to the construction of the gathering and production facilities on Richards Island (which includes expenditures for the construction of sub-sea gathering lines and other offshore facilities), along with significant investment expenditures for the construction of the pipeline and the compressor stations. The facility would be designed to produce at a rate of 80,000 bpd over a period of 20 years. The

Capital Investment Time-line: Scenario 2

Yr	Exploratory Drilling	Døvelopment Drilling	Gathering & Production Facility Construction	Pipeline Construction	Compressor Station Construction	Arctic Tanker Construction	
All Figures in Millions of 1984 Dollars							
1	0	0	95	0	0	0	
2	0	0	190	0	0	0	
3	0	0	507	192	65	0	
4	0	0	696	230	65	0	
5	0	127	412	230	97	0	
6	0	127	70	230	97	0	
7	0	158	44	38	65	0	
8	0	158	0	0	0	0	
9	0	127	0	0	0	0	
10	0	63	0	0	0	0	

(Source: Croasdale, 1994)

significant expenditures for development drilling in years 5 through 10 represent efforts to maintain pressure in the reservoir, as well as efforts to link smaller nearby pools to the pipeline to allow the production rate of 80,000 bpd to be maintained for 20 years. The maintenance of maximum flow for the life-span of the facility is imperative since the per barrel pipeline tariff (the price per barrel after being transported to market) increases sharply as the flow of oil through the pipeline declines below its capacity. In this scenario, production begins in year 6 even though significant investment expenditures for gathering and production facilities are called for in years 6 and 7. Again, the incentive to produce oil as soon as possible is omnipresent, and the investment time-line information suggests that the facility is nearly complete by the end of year 5, and that the gathering and production facility investments in years 6 and 7 act to transform the facility from a marginal operating form to a completed facility by the end of year 7.

6.3.3 Scenario 3: 350M Bbl. Offshore Field - Tanker Option

Scenario 3 represents a more conservative form of development focussed on the Amauligak field in the Beaufort Sea. Specifically, scenario 3 calls for the development of the same 350M Bbl. offshore field over a 20 year period at a much reduced rate of 35,000 bpd with the oil delivered to southern markets via Arctic tankers. The capital investment time-line information for scenario 3 is

Capital Investment Time-line: Scenario 3

Yr	Exploratory Drilling	Development Drilling	Gathering & Production Facility Construction	Pipeline Construction	Compressor Station Construction	Arctic Tanker Construction
		All F	igures in Millions	of 1984 Dollars		
1	0	32	63	0	0	0
2	0	63	190	0	0	130
3	0	63	127	0	0	86
4	0	0	32	0	0	0
5	0	10	0	0	0	0

(Source: Croasdale, 1994)

displayed in table 6.3. The scenario also differed from the previous one in that the facilities at the well-head would be significantly less grand with the bulk of the offshore work based on a refurbished version of Gulf's floating platform facility, *Moliqupaq*, with approximately \$150M invested in storage facilities on Richards Island which would interact with the Arctic Tankers. The scenario called for the construction of one new Arctic tanker, and this investment is spread over years 2 and 3.³ Economically speaking, the tanker scenario appears to be a *cheaper* option, but politically speaking it likely represents one of the least likely options given heightened environmental concerns and an increasing awareness of the fundamental relationship between the Northern environment and the Aboriginal people who depend on it. The *true cost* of the tanker option is far greater when the potential for environmental and social upheaval in the event of an accident is taken into consideration. This assessment however made no attempt to figure such costs into the analysis.

6.4 Implementing the Model

Implementing the model developed in chapter 5 required the use of published Canadian Input-Output data in conjunction with the investment expenditure data provided by the authors of these scenarios. The following sections will describe exactly how these disparate data types were married, and how the results discussed in chapter 7 were generated.

6.4.1 Allocation of Investment Expenditures to "Small" Level Commodities

As mentioned earlier, the capital investment time-lines provide a picture of how each of the scenarios would be phased in over a period of years. The model derived in chapter 5 was designed to be driven by a dichotomous delta final demand vector (the exogenous vector referred to above). The first argument in the exogenous vector, a delta investment vector, captures all current period investment activity which would be directed toward the NWT (referred to as exogenous investment in chapter 5), and an *investment term* which allows the effects associated with capacity adjustments in any NWT sectors as a result of this investment activity, to be included (referred to as "endogenous" investment in chapter 5). This investment term portion of the final demand vector is non-zero in years when the investment plan - outlined year by year in each of the time-lines presented in tables 6.1, 6.2, and 6.3 - causes the capacity of certain sectors in the NWT to be exceeded.

The first step in creating these final demand vectors required that, for each scenario, the yearly investment plans be translated into a commodity classification which matched that used in the I-O data. This translation was performed primarily by an officer of the Government of the Northwest Territories (GNWT) Bureau of Statistics (Mr. Roy Ellis) whose job it is to assess how various proposed projects could affect the economy of the NWT. The decision to seek expert advice in making this allocation ensured that the investment expenditures associated with

Directory of Small Level Industry Aggregates

1.	Agriculture and Related Service Industries
2.	Fishing and Trapping Industries
3.	Logging and Forestry Industries
4.	Mining, Quarrying and Oil Well Industries
5.	Manufacturing Industries
6.	Construction Industries
7.	Transportation and Storage Industries
8.	Communication Industries
9.	Other Utility Industries
10.	Wholesale Trade Industries
11.	Retail Trade Industries
12.	Finance, Insurance, and Real Estate Industries
13.	Community, Business, and Personal Services Industries
14.	Operating, Office, Cafeteria, and Laboratory Supply Industries
15.	Travel, Advertising and Promotion Industries
16.	Transportation Margins

Directory of Small Level Commodity Aggregates

#	Commodity Label
1	Grains
2	Other Agricultural Products
3	Forestry Products
4	Fishing & Trapping Products
5	Metallic Ores & Concentrates
6	Minerals Fuels
7	Non-metallic Minerals
8	Services Incidental to Mining
9	Meat, Fish & Diary Products
10	Fruit, Vegatables, & Miscellaneous Food Products
11	Beverages
12	Tobacco & Tobacco Products
13	Rubber, Leather & Plastic Fabricated Products
14	Textile Products
15	Knitted Products & Clothing
16	Lumber, Sawmill & Other Wood Products
17	Furniture & Fixtures
18	Paper & Paper Products
19	Printing & Publishing
20	Primary Metal Products
21	Metal Fabricated Products
22	Machinery & Equipment
23	Autos, Trucks & Other Transportation Equipment

Table 6.5 - Continued

#	Commodity Label
24	Electronic & Communictions Products
25	Non-metallic Mineral Products
26	Petroleum & Coal Products
27	Chemicals & Chemical Products
28	Miscellaneous Manufactured Products
29	Residential Construction
30	Non-residential Construction
31	Repair Construction
32	Transportation & Storage
33	Communication Services
34	Other Utilities
35	Wholesale Margins
36	Retail Margins
37	Imputed Rent of Owner Occupied Dwellings
38	Other Finance, Insurance & Real Estate
39	Business Services
40	Personal & Other Miscellaneous Services
41	Transportation Margins
42	Operating, Office, Laboratory & Cafeteria Supplies
43	Travel, Advertising & Promotion

each of the scenarios were impressed on NWT sectors in a manner which best represented how these investment expenditures would enter the NWT economy. Tables 6.9, 6.10 and 6.11 display percent profiles of how the various types aggregate investment expenditures related to the development of oil and gas reserves in NWT can be disaggregated based on experience with such projects in the NWT. The profile in table 6.9, for example, shows how a dollar spent on "exploratory drilling" actually involves a very complex web of goods and services. Tables 6.10 and 6.11 display the same percent profiles for investment expenditures on gathering and production facility construction and pipeline related activities respectively.

The procedure used to allocate these aggregate investment expenditures to commodities tracked in the I-O system involved the use of percent profiles like those discussed above to allocate each type of investment across commodities at the **(W)**orksheet level. The worksheet level represents a very disaggregate commodity and industry classification scheme used in building the Provincial and National Input-Output Tables. Worksheet level tables are almost always restricted from public access due to the fact that single firms may be identified at this level of disaggregation. In the case of the NWT, the worksheet level tables are almost always restricted tables for the NWT are also restricted, and they represent only a moderate increase in sectoral and commodity disaggregation relative to the **(S)**mall level

tables used here. Once the aggregate investment expenditure data for each scenario was translated to worksheet level commodities, aggregation parameters used by Statistics Canada to aggregate up from the worksheet level to the small level were used to create a set of S level commodity specific investment profiles. These profiles are displayed in tables 6.6, 6.7, and 6.8 (see tables 6.4 and 6.5 for directories of the various sector and commodity titles). This aggregation revealed that the investment expenditures associated with each oil development scenario were allocated to 4 S level commodities. Specifically, all activity related to the provision of exploratory drilling, development drilling, and gathering and production facility construction was allocated to commodity 8 at the S level. Commodity 8, as table 6.5 indicates, is "Services Incidental to Mining". This commodity group subsumes all of the activities displayed in table 6.9. All activity related to the construction of the pipeline - see table 6.11 - after aggregation and some expert judgement, was allocated to commodity 30 which is "Non-residential Constructionth (see table 6.5). All compressor and pumping station related activity referred to in table 6.11 was allocated to commodity 22 - "Machinery & Equipment, while all of the tanker investment called for in scenario 3 was allocated to commodity 23 - "Autos, Trucks & Other Transportation Equipment". Each row in tables 6.6, 6.7 and 6.8 therefore, represents the required investments in each commodity to complete the investment plan for that year. Each row was taken and the non-zero elements were added to the proper row of a null vector

Commodity Allocation of Investment Expenditures Scenario 1

Yr.	Commodity 8	Commodity 22	Commodity 23	Commodity 30					
	All Figures in Millions of 1984 Dollars								
1	38	0	0	0					
2	19	0	0	0					
3	95	0	0	38					
4	127	52	. 0	154					
5	190	65	0	154					
6	95	13	0	38					
7	63	0	0	0					
8	6	0	0	0					

(Source: Ellis, 1994)

Commodity Allocation of Investment Expenditures Scenario 2

Yr.	Commodity 8	Commodity 22	Commodity 23	Commodity 30					
	All Figures in Millions of 1984 Dollars								
1	95	0	0	0					
2	203	0	0	0					
3	507	65	0	192					
4	·697·	65	• • • •	230					
5	538	97	0	230					
6	196	97	0	230					
7	203	65	0	38					
8	158	0	0	0					
9	127	0	0	0					
10	63	0	0	0					

(Source: Ellis, 1994)

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Commodity Allocation of Investment Expenditures Scenario 3

Yr.	Commodity 8	Commodity 22	Commodity 23	Commodity 30			
	All Figures in Millions of 1984 Dollars						
1	95	0	0	0			
2	253	0	79	0			
3	190	0	52	0			
4	32	0	0	0			
5	13	0	0	0			

(Source: Ellis, 1994)

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Aggregate Investment Expenditure Decomposition Scheme Exploration Drilling

Category	Sub-category	Offshor e	Onshor e
	A Parcent Distribution		
Construction			
	Eqpt. & Camps	2	10
	Artifical Islands	51	0
Transport Eqpt.			
	Ground Support (trucking)	2	29
	Air Support	2	7
	Support Vessels	4	2
Supervision & Support Base		7	10
Drilling			
	Drilling Rig	8	7
	Camp Catering	2	2
	Drill Bits	0	1
	Cementing	2	1
	Logging & Evaluation	2	2
	Testing	5	2
	Drilling Fluids	1	2
	Casing	1	1
	Downhole Tools	2	4
	Support Eqpt.	4	3
	Rentals	2	0
	Comm. & Weather Forecasting	1	1
Fuel		2	17
Total	ъ -	100	100

(Source: Ellis, 1994)

Table 6.10Aggregate Investment Expenditure Decomposition SchemeGathering & Production Facility Construction

Materials		%	Services		%
	Gravel	1		Land-Rent, Fees, Claims	1.5
	Pipe	9.3		Fees, Permits	0.3
	Fittings & Fab. Pipe	1.9		Camp	2.1
	Tanks	6.1		Equipment Rentals	0.5
	Boilers	0.5		Location Prep. & Cleanup	0.9
	Steel - Piles & Structural	1.5		Transportation	1
	Structural Steel & Bidgs.	1.8		Engineering & Drafting	2.9
	Fencing	1.1		Inspecting & Expediting	2
	Heating & Ventilating	1.1		Quality Control	1.2
	Valves	8.2		Surveying	1.5
	Pumps & Compressors	11		Dirtwork	1.4
	Treaters	4.6	Installation		
	Vessels (process)	2.2		Civil	2.1
	Flare Stack	1.4		Mechanical	4.6
	Engines & Motors	0.8		Electrical	2.8
	Electrical Eqpt. Misc.	1.2		Equipment	0.4
	Panels - Control, Alarm	1.6		Environmental	0.3
	Insulation	1.3		Install Pipeline	7.2
	Pipe Coating	0.6		Road Construction	4.3
	Paint, Coating, Insulation	1.2		Testing Eqpt.	0.9
	Instr Elec.& Pneum.	1.4	Sub-tot. Services	•	37.9
	Safety Eqpt.	0.7			
	Power line	1			
	Communications Eqpt.	0.7			
Sub-total		52.1	Total		100.0

(Source: Ellis, 1994)

Table 6.11Aggregate Investment Expenditure Decomposition SchemePipeline Construction

Component		%	Cont'd		%
Pipeline Materials			Logistics Eqpt.		
	Right-of-way Cost	0.18		Camp & Bldgs	0.1
	Pipe	25.4		Equipment	0.8
	Int. Coatings	0.45		Miscellaneous	0.2
	Ext. Coatings	2.37	Sub-totai	· ·	1.13
	Valves & Fittings	1.61	Logist. Operations		
	Miscellaneous	4.61		Fuel	0.2
Sub-total		34.7		Tools	0.04
Pipeline Installation				Labour	0.70
	Equipment	9.60		Catering	0.06
	Fuel	2.50	Sub-total		1.01
	Expendables	0.40	Transportation		7.60
	Tools	0.40	Logk	atics Total	9.70
	Labour	16.4	Other Facilities	M&E	
	O.H. & Profit	4.40		Buildings	0.30
	Catering	1.30		Maint. Eqpt.	0.90
Sub-total	-	35.0		Aircraft	0.40
	Pipeline Total	69.6		Communications Costs	0.80
Station Materi	ial		Sub-totai		2.30
	Compressor Assly.	1.10		Construction	
	Refrig./Htg. Assly.	1.0		Equipment	0.03
	Meter Assemblies	0.1		Fuel	0.004
	Miscellaneous	0.04		Expendables	0.025
	Building	1.60		Tools	0.006

Table 6.11 Continued

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Component		%	Cont'd		%
	Utilities	0.04		Labour	0.21
Sub-total		3.90		O.H. & Profit	0.08
Station Construction				Catering	0.03
	Equipment	0.34	Sub-total	·	0.39
	Fuel	0.05	Engineering		6.22
	Expendables	0.28	Inspection	_	3.31
	Tools	0.09	Other F	acilities Total	12.22
	Labour	2.52	Gra	and Total	100.0
	O.H. & Profit	0.98			
	Catering	0.34			
Sub-total		4.58			
	Station Total	8.46			

(Source: Ellis, 1994)

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forming the delta investment vector referred to above.

6.4.2 The Capacity Adjustment Model

The first step in determining whether or not any NWT sectors would require additional capacity to satisfy demands associated with an investment plan for a specific year involved running this delta investment vector through the MRIO model developed in chapter 5. Clearly, the model developed in chapter 5 can be run with or without an investment term present in the final demand vector. The resulting gross output vector represented the impacts on all sectors in all regions as a result of the investment plan for that year in the NWT. To determine whether or not sufficient capacity existed in the NWT sectors to meet all of the requirements associated with this investment plan, the following comparison was made;

$$\begin{array}{rl} X_{j}^{84} + \Delta X_{j}^{t} \leq CP_{j}^{84} \\ \forall_{i} \end{array}$$
 6.1

where CP_j^{84} denotes the potential output in sector j in the NWT in 1984. As long as this the potential output figure for any sector j in the NWT was not exceeded by the investment plan, then no capacity adjustment was necessary. If however, an investment plan did cause the potential output of certain NWT sectors to be exceeded, then the amount by which the capacity was exceeded was recorded and added to the capacity adjustment vector portion of the investment term for this year (the $\check{o}(t_0+\theta)$ vector in equation 5.46). In subsequent years, the sum of the base period output vector and the delta X vector were compared to the sum of the potential output figure and any capacity additions made since the beginning of the project.⁴ This procedure was followed for every year in each scenario Tables 7.1, 7.5, and 7.6 in chapter 7 display the results of these comparisons for each scenario over all years. It was assumed that only sectors in the NWT would be subject to capacity shortfalls as a result of these investment plans. As such, the previously discussed capacity adjustment procedure was performed for NWT sectors only.

The actual investment term, as shown in chapter 5, is the product of the capacity expansion vector just discussed, and an expansion capital coefficient matrix. This capital coefficient matrix was also provided by the GNWT Bureau of Statistics. Specifically, the investment columns at the worksheet level were taken and, based on internal information, split to represent the commodities purchased by each sector in the NWT as capital. The capital coefficient matrix was created by dividing each capital input by the total output of the respective sector. The resulting coefficients represent the purchases of each commodity as capital per dollar of expansion in each sector j in the NWT. The product of the capital coefficient matrix and the expansion vector just discussed represents the

commodity specific requirements associated with the expansion plan.

6.4.3 Allocating NWT Expansion Related Activities Across Regions and Sectors

As shown in chapter 5, both the delta investment vector and the investment term are pre-multiplied by interregional trade coefficient matrices. Prior to running the model for any year in any scenario, the delta investment vector was premultiplied by the *observed* trade coefficient matrix (Λ). Pre-multiplying any final demand vector by this matrix acts to allocate the final demands across all regions in the system. For example, the product of a delta investment vector denoting a single \$100M shock to sector 4 in the NWT and the observed trade share matrix suggests that only 71 percent of this shock is actually allocated to sector 4 in the NWT, with the remainder allocated to sector 4 in the western and central regions (see technical appendix 6a for details behind this concept). In the case of expansion activities however, the observed interregional trade pattern for intermediate inputs was modified to reflect the fact that while the manufacturing sector in the NWT may provide a percentage of all direct input demands for manufactured goods in the NWT, it will not produce manufactured capital inputs. The same may be said of the mines, quarries & oil wells sector in the NWT. While this sector may produce the bulk of the direct inputs to its own production in the NWT, certain capital inputs required to expand the capacity of this sector in the NWT will not come from sector 4 in the NWT, but rather from sector 4 production in Alberta. An example may be added seismic surveying crews and equipment, added drilling rigs, etc. This realization meant that the expansion vector (the product referred to above) had to be pre-multiplied by a trade coefficient matrix which reflected the fact that certain types of capital goods will not be produced by sectors in the NWT, and this meant that the observed trade coefficient matrix had to be modified to reflect these altered trade relationships.

The modification of the observed interregional trade coefficient matrix involved reducing the size of specified interregional trade coefficients for commodities in the NWT and adding the removed magnitudes to commodities in Alberta. The modification scheme is displayed in table 6.12. The procedure for modifying the trade shares involved extracting the NWT and Alberta blocks from the full interregional trade matrix (Λ) and importing the main diagonals from each into a spreadsheet where the modifications indicated in table 6.12 were performed. These diagonals were then exported, run down the diagonals of null matrices of the proper dimensions, and then inserted into the full block trade matrix and saved as a separate trade matrix (Γ) for use with expansion vectors only. These modifications represent judgements, but they were made after considerable consultation with the GNWT Bureau of Statistics. The concern on behalf of the GNWT Bureau of Statistics was focussed on the issue of producing a realistic picture of where this expansion activity would be routed to, and the modifications displayed in table 6.12 address these concerns. It should also be

noted that the shares of all commodities used in the NWT which come from other regions were left unchanged.

6.4.4 Running the Model

For years where the investment plan did not call for capacity expansion in the NWT, the investment term component of the final demand vector dropped out, and the model was driven entirely by the delta investment vector (a static model). The model pre-multiplied the delta investment vector by the observed trade matrix for reasons discussed above, and then pre-multiplied the resulting product by the full multiregional Leontief Inverse matrix as shown in chapter 5. The result was a gross output vector showing how each of the 16 sectors in each of the 12 regions in the model would be affected. For years where the investment plans did cause the capacities of certain NWT sectors to be exceeded, the expansion vector was pre-multiplied by the modified trade matrix (Γ) and then added to the product of the delta investment vector and the observed trade matrix (Λ), and this final demand vector was used to drive the model (a dynamic model). In this case, the effects of the expansion activities in the NWT on sectors in all regions were added to the effects of the delta investment vector.

The program used to generate these results included a regional aggregator which served to aggregate the output from the model to conform with a 6 region scheme displayed in table 6.13. This 6 region aggregation scheme was used to

Table 6.12						
Modifications	to	the	Observed	Interregional	Trade	Matrix

Comm.#	Change to NWT Coefficient	Allocated to	Alberta Sector Affected
8	decreased by 100%	commodity 8 in Alberta	sector 4
20	decreased by 100%	commodity 20 in Alberta	sector 4
21	decreased by 100%	commodity 21 in Alberta	sector 5
22	decreased by 100%	commodity 22 in Alberta	sector 5 - 90% sector 4 - 10%
23	decreased by 100%	commodity 23 in Alberta	sector 5 - 81% sector 7 - 16%
24	decreased by 100%	commodity 24 in Alberta	sector 5 - 74% sector 8 - 21%
28	decreased by 100%	commodity 24 in Alberta	sector 5
32	decreased by 50%	commodity 32 in Alberta	sector 7
33	decreased by 100%	commodity 33 in Alberta	sector 8

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group similar Provinces together thereby making the presentation of the output less cumbersome.⁵

6.5 Analysis of Model Output

In each case, the investment plans for each year were first subjected to the capacity analysis routine, and then the final demand vectors for each year were compiled. The main program computed total impact vectors as discussed above, and then proceeded to decompose this vector into direct, indirect and induced effects, and these helped explain the total impact patterns revealed for each year in each scenario. The purpose of this sub-section is to describe how these constituent effects were computed and what they mean.

6.5.1 Direct Effects

Direct effects are defined as the output impacts on sectors in an economy due to the direct input requirements of those sectors experiencing increased final demand for their outputs. For example, if the final demand for manufacturing sector output in a region were to increase by \$100M, this sector would have to draw inputs from all suppliers (including the household sector) to meet this additional demand. These impacts on all sectors which supply direct inputs to the manufacturing sector represent the direct effects. Technically speaking, the direct effects are computed by pre-multiplying any vector representing desired or forced

	Table 6.13	
Regional	Aggregation	Scheme

Reg.#	Title	Composition	
1	Eastern Region	Newfoundland Prince Edward Island Nova Scotia NewBrunswick	
2	Central Region	Ontario Quebec	
3	West-Central Region	Manitoba Saskatchewan	
4	Western Region	Alberta British Columbia	
5	Yukon Region	Yukon Territory	
6	Northwest Territories (NWT)	NWT	

output levels in certain sectors, or a delta final demand vector, by the technical coefficient matrix as follows;

$$DE = (A \cdot \Delta FD) + \Delta FD$$

where 6.2
$$A = [a_{ij}]$$

where a_{ij} denotes a *technical coefficient* which represents the dollars worth of sector i output required per dollar of sector j output. It should be noted that the direct effects in this case will include the initial final demand shock as well as the incremental *first round effects*. If the final demand shock is not included in the direct effect then the direct effects represent the output required in all sectors over and above the output required to satisfy the initial shock only. As will be clear in the section on indirect effects, if the initial final demand shock is not included with the direct effect then they will be included with the indirect effects.

6.5.2 Indirect Effects

Indirect effects are defined as the sum of the direct effects on all sectors as a result of satisfying the direct input requirements of the sectors that supply inputs to the initially stimulated sectors. Technically, the indirect effects represent the sum of all rounds of spending from round 2 through ∞ . For example, a mining sector may experience a direct effect of \$40M in response to a \$100M

increase in the final demand for the output of a manufacturing sector. The \$40M direct impact to the mining sector represents additional output which must be produced to meet the demands of the manufacturing sector (the first round), and to produce this extra output the mining sector will require additional inputs from all of it's input suppliers (the second round). Each input supplier would also have to purchase additional inputs (the third round), and so on. This round by round approach to assessing the impact of a final demand shock approximates the total effect computed using a Leontief Inverse Matrix. Indirect effects are usually computed as the difference between the total impact vector and the direct impact vector as follows;

$$IE = ((I - A)^{-1} \cdot \Delta FD) - ((A \cdot \Delta FD) + \Delta FD)$$
 6.3

where the use of the Leontief Inverse means that all rounds 2 through infinity are included.

6.5.3 Induced Effects

Induced effects are defined as the extra output caused by the fact that payments to labour result in a consumption stimulus which must be satisfied by extra sectoral activity. That is, if the output level of sector j (mining for example, to continue the previous example) were to increase then payments to labour (as one input to sector j production) would also increase, and a portion of this added

personal income would be spent on consumption (in a manner dictated by the marginal propensity to consume). The additional stimulus to consumption (a final demand item) would have to be satisfied by additional current period production in those sectors which produce consumer goods, as well as in those sectors which provide direct inputs to them and so on. To capture induced effects, the basic I-O model must be closed to personal consumption. The model derived in chapter 5 was closed with respect to personal consumption, and as a result the induced effects across sectors and regions could be assessed.

The computation of induced effects involves computing gross output vectors from two models using the same final demand vector, where one model is closed to households and the second is not. The difference between the total impact vectors generated by these 2 models, given the same delta final demand vector, could only be due to induced effects. This was done for every final demand vector for each scenario, and the results are discussed in detail in chapter 7.

6.6 Discussion

The purpose of the previous discussion was to provide a bridge between the analytical model developed in chapter 5 and the results discussed in chapter 7. It should be stressed that the implementation of this model was facilitated, to a significant degree, by the provision of expert judgement and unpublished data

by Croasdale and McDougall (the authors of the scenarios) and the GNWT Bureau of Statistics. The results presented in chapter 7 represent the outcome of this marriage between published I-O data and the additional information mentioned above. As is mentioned in so many I-O studies, the integration of such expert information can only add to the usefulness of the results of an I-O application.

ENDNOTES

1. A considerable percentage of the resources of Statistics Canada is directed toward the compilation of the I-O accounts for Canada since they are used as benchmarks for the National Accounts. New Provincial and Territorial tables for 1990 are due to be released this coming fall. Unfortunately, early access to this more recent data was not granted. In fact, the release of the 1990 tables has been pushed back several times, and they may not be seen before December 1995.

2. The added compressor stations between Norman Wells and Zama Alberta represented the fact that this section of the pipeline would have to be able to handle the current output from the Norman Wells field as well as the oil from the Delta. The pipeline from the delta to Norman Wells would transport 35,000 bpd while the section from Norman Wells to Zama would have to handle 60,000 bpd (35,000 bpd from the delta + 25,000 bpd from the Norman Wells field).

3. Note that while this tanker construction related investment gets allocated later on to NWT commodity groups, the interregional trade coefficient matrix allocated nearly 100 percent of it to sector in the western and central regions and abroad.

4. The GNWT Bureau of Statistics provided estimates of capacity utilization rates and potential output figures for all S level sectors in 1984 using the standard Statistics Canada methodology;

> $CUR_t = \left(\frac{P_t}{CP_t}\right) * 100$ 6.4

where:

 $CP_{t} = \frac{K_{t}}{\left(\frac{K_{o}}{P_{c}}\right)}$ 6.5

and where:

- K, = fixed capital stocks at time t,
- $P_{t} = actual output at time t (1984),$
- K_t/P_t = capital-output ration at time t,
- $K_0/P_o =$ minimum or capacity capital-output ratio (minimum through 1984 to 1990), $CP_t =$ estimated capacity or potential output at time t.

5. If the output vectors were not aggregated then each output file for each year of every scenario would consist of 12(regions)x16(sectors in each) = 196 data points. Dropping to 6 regions cuts this by 50% and results in no lack of clarity in the output. Graphing 196 data points would require twice as many figures to display the output relative to the significant number of figures displayed in chapter 7.

Chapter 6 Appendix

Computing the Trade Coefficient Matrix from Data Available in the Canadian Small Level Provincial Input-Output Accounts

6a.0 Introduction

The Multiregional I-O approach differs from the pure Interregional I-O approach in that the former does not require the collection of detailed interregional sectoral transactions. That is, the interregional model requires data showing how much of region L sector i output is purchased by sector j in region M. The multiregional approach requires that detailed inter-sectoral flow data for the host region be collected as well as data on the exports by sectoral output category from this region to all others in the system with no sectoral destinations specified. The advantages of this approach over the pure interregional approach are clear a significant reduction in the level of effort, time and money required to compile regional I-O data. The multiregional I-O (MRIO) model still makes these interregional linkages endogenous by virtue of an interregional trade share matrix. The elements of this matrix denote the proportion of the total amount of each commodity (or sectoral output category) used in a region which comes from each other region and from the region itself. These elements can transform a set of single region technical coefficient matrices into an approximation of the true

survey based interregional technical coefficient matrix.

The Canadian S Level Provincial Input-Output Accounts are compiled with this approach in mind. Specifically, the detailed interregional export and import data for each Province and Territory is embedded in the final demand matrix of each region, and it is this data which is used to create the trade matrix required to mobilize a MRIO model of the Canadian Multiregional system. It is the purpose of this appendix to discuss how this data can be used to create the trade share matrix referred to above. Chapter 4 provides the technical details behind the MRIO approach.

6a.1 The Final Demand Matrices in the S Level Provincial I-O Accounts

As mentioned above, the final demand matrices included with the S level Provincial commodity by industry I-O accounts include detailed information on the interregional exports and imports of each commodity tracked in system. That is, for any commodity i in region L, data exists to show how much is exported from region L to each other region in the system and how much is imported by region L from each other region in the system.

Chapter 5 refers to the procedure used to create a MRIO model using this information as the *endogenization of interregional trade*. That is, when the MRIO model is solved given any exogenous vector, the output levels in each region are determined by final demand levels in each other region (i.e., a *portion* of final

demand for commodity i in region L is satisfied by production in region M, and this *portion* is specified by the trade share matrix). The first step involved in the construction of a MRIO model of the Canadian system involves the extraction and manipulation of the interregional export vectors and the subsequent development of an interregional trade share matrix.

6a.2 Understanding the Interregional Import and Export Data

The interregional export(import) data, as mentioned, is nested in the S level final demand matrices for all Provinces and Territories. These data show the dollar value of exports(imports), by commodity, from(to) each region to(from) each other region (see table 6a.1). For example, in Ontario's final demand matrix, 12 columns track the exports from Ontario of each of 43 commodities to each other region. It is important to note that the intraregional flow elements are reported as zeros in each regions interprovincial import and export columns. The first step in computing the interregional trade share matrix for the entire system requires that these columns be extracted from each regions' final demand matrix.

6a.3 Computing the Trade Shares

The first step in computing the trade shares involves the creation of an interregional trade table, or shipments matrix, for each commodity produced in the system. An example of such a table is displayed in table 6a.2. Specifically, for

each commodity i, trade flows from a particular region to all others are tracked in each row of the shipments matrix. In table 6a.2, z_i^{LM} denotes the dollar flow of commodity i from region L to region M irrespective of the sector of destination in the receiving region. These flows will include shipments to producing sectors in region M as well as to final demand categories in region M. Thus, for each commodity, a shipments matrix of the sort displayed in table 6a.2 must be created from the interprovincial export figures discussed above.

It was mentioned above that the intra-provincial flows are not tracked in the export columns in each regions' final demand matrix. These elements are required to fill in the on-diagonal elements in table 6a.2. To compute these on-

$$z_i^{1,1} + z_i^{2,1} + ... + z_i^{P,1} + ... + M_i^1 = U_i^1 + FD_i^1$$
 6a.1

where M¹_i represents the imports of commodity i from abroad into region 1, U¹_i represents the respective row total from region 1's Use matrix, and FD¹_i represents the respective row sum from region 1's Final Demand matrix. Equation 6a.1 simply represents the sum of elements down the first column of a shipments matrix like the one displayed in table 6a.2. The only difference is that the contribution of commodity i from sectors abroad is included. This acts to net out the contribution of foreign imports as discussed in chapter 5. All of the items in equation 6a.1, with the exception of the on-diagonal term, can be obtained directly
Table 6a.1

Simplified Representation of a Final Demand Matrix in the S Level Provincial I-O Accounts: Region L

Co mm	Domestic FD	Exports to L	Exports to M	Imports from L	Imports from M	Inter-reg. Trd. Bal	Rest of the FD items	Total FD
1	Y ₁	0	ÈE,	0	M,	ITB ₁	F ₁	TFD,
2	Y ₂	0	E ₂	0	M ₂	ITB ₂	F ₂	TFD₂
:		÷		÷	:			-
i	Y	0	E,	0	M	ITB,	F,	TFD,
:		`	ŧ	ŧ	;			:
n	Y _n	0		0	M _n	ITB _n	F _n	TFD
V.A.	VA	VA	VA	VA	VA	VA	VA	VA
Tot al	тот	тот	τοτ	тот	тот	тот	тот	GTO T

Table	6a.2
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Shipments	Matrix for	^r Commodit	уi
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Receiving Region								
Shipping Region	1	2	3	<i></i>	N	EXPORTS	тот	
1	Z ^{1,1}	Z, ^{1,2}	Z, ^{1,3}		Z _i ^{1,N}	E,1	Q _i ¹	
2	Z ₁ ^{2,1}	Z _i 2,2	Z ^{2,3}		Z, ^{2,N}	E ²	Q ₁ ²	
3	Z ^{3,1}	Z, ^{3,2}	Z ^{3,3}		Z _i ^{3,N}	E'3	$Q_{_{I}}^{_{3}}$	
ŧ.,	÷	÷	:	×.	÷	:	:	
N.	Z ^{N,1}	Z ^{N,2}	Z ^{N,3}		Z ^{N,N}	E, ^N	Q, ^N	
IMPORTS(M)	M ,1	M,2	M,³		M _i ∾			
тот	T _i 1	T ,2	T _i ³		T _i N			

from the I-O data available for region 1, in this case, leaving the on-diagonal term to be derived by re-arranging terms and solving for $z_i^{1,1}$. This procedure must be performed for each of the 43 commodities in each of the 12 regions in the Canadian system to complete the system of 43 shipments matrices.

Once these shipments matrices are completed, the next step involves computing the column sums for all columns in all 43 shipments matrices (where the contribution from foreign sectors is part of this sum). These sums represent the total shipments of commodity i into each region. For example, summing down column 1 in table 6a.2 provides the total amount of commodity i available in region 1 both from production in region 1 and from production in regions 2, 3 & N (as well as from foreign sectors). This total for a region N may be expressed as follows;

$$T_i^N = z_i^{1,N} + z_i^{2,N} + ... + z_i^{N,N} + M_i^N$$
 6a.2

where M_i^N represents the contribution to the total supply of commodity i in region N from foreign sectors. If each element in each shipments matrix is divided by the respective column sum $(T_i^N, \forall N)$, the result is a set of coefficients denoting the proportion of all of commodity i used in each region N that comes from each region L (where L & N = 1, 2, 3, ..., 12 in the Canadian interprovincial case), and these proportions are defined to be the interregional trade shares (coefficients), and are denoted as c_i^{LN} .

To construct the interregional trade share (coefficient) matrix, the coefficients in each column of each shipments matrix are rearranged so that all coefficients corresponding to each trading pair are grouped in one 43x1 column vector. Once this rearrangement is performed, these vectors must be run down the main diagonals of 43x43 null matrices. Each matrix therefore will show, for each trading pair, the proportion of each of the 43 commodities used in region N that comes from region L. In the Canadian case, 12 regions interacting through trade translates into 144 possible trading pairs, and therefore 144 of these trade coefficient matrices. The full MRIO trade coefficient matrix is constructed by stacking all of these matrices, row by row, reflecting the same "from-to" structure displayed in table 6a.2. The resulting block matrix will consist of 516 rows and 516 columns (43 commodities * 12 regions = 516 rows and columns).

The 516x516 trade coefficient matrix is the matrix required to transform the system of S level Provincial and Territorial tables into a Multiregional Input-Output model of the Canadian economy. This matrix was the basis for the modifications discussed in chapter 6. Software was developed to compute this trade matrix (and variants of it) from the raw Provincial and Territorial S level Final Demand matrices.

Chapter 7

Analysis of Model Output

7.0 Introduction

The purpose of this chapter is to present, and to discuss output generated by the model which was derived earlier in chapter 5, and implemented as discussed in chapter 6. Specifically, three scenarios of the way the oil reserves of the NWT - both onshore and offshore - may be developed were analyzed in terms of how each could affect the economies of the NWT and the rest of Canada. Each of these scenarios represents a general picture of how the onshore and offshore reserves of the region could be developed in an economically feasible manner.¹ As discussed earlier, these scenarios are based on the experience and expertise of two noted specialists in the engineering-economics of such projects. These specialists (Croasdale and McDougall, 1992) were commissioned by the Federal Panel on Energy and Research and Development (PERD) to assess Canada's Frontier energy options². These scenarios represent the most current and respected *professional opinion* regarding how the reserves of Canada's North could be developed.

In terms of structure, this chapter will discuss model output for each

scenario in turn focussing on summary figures which are provided within the main body of the chapter. The actual sector specific impact patterns for each year of each scenario (figures 7.52 to 7.127) have also been included in the **graphical appendix at the end of the thesis.** The fact that the model produces output in 3 dimensions (time, space and sectors) means that the output is difficult to present in a compact form. The figures in the graphical appendix, while large in number, represent the best presentation format found. The number of figures was also minimized by excluding impact patterns which were qualitatively identical to those for other years, but the number of figures is still quite large. Reference will continually be made to the figures in the main body, as well as to the figures in the graphical appendix in an effort to present the key findings. The summary figures included in the main body of the chapter were formed by aggregating over all sectors in each region. When sectoral impacts are discussed in the main body of this chapter, the figures in the graphical appendix have to be consulted.

7.1 Scenario 1: 100M Bbl. Onshore Field - Small Pipeline Option

Scenario 1, as described in chapter 3, represents one generic scenario of onshore oil development in the NWT. The scenario, as devised by Croasdale and McDougall (1992), was based on the discoveries made in the Mackenzie Delta and in the very shallow Beaufort Sea off Richards Island in the 1970s and 1980s. The scenario was based on a 100M Bbl. field located on Richards Island which

is, as yet, not discovered. Scenario 1 therefore, represents a generic picture of how this could happen.

The capital investment time-line for scenario 1 discussed in chapter 6 (see table 6.1) shows how such a development could come to pass, with all of the cost elements based on conservative estimates from industry sources.

7.1.1 Pre-Capacity Adjustment Years - 1, 2 & 3

The first 2 years of scenario 1 called for \$38M and \$19M respectively of drilling activity, with the drilling program for year 1 split evenly between exploratory and development drilling (see table 6.1). Based on the investment allocation parameters discussed in chapter 6 (see table 6.6), this drilling activity was allocated to commodity 8 in the NWT (services incidental to mining - see table 7.3 for a listing of all commodity titles) which, according to the sectoral share matrix for the NWT in 1984, was entirely allocated to sector 4 in the NWT (see table 7.2 for a listing of all S level sector titles). The observed interregional trade coefficient matrix for 1984 also indicated that of all commodity 8 used in the NWT, 71% was produced in the NWT, 13% was produced in the western region, and 16% was produced in the central region. The structure of the MRIO model therefore allocated this direct final demand shock to sector 4 in each of these regions based on these percentages. The full MRIO final demand vector was then run through the capacity adjustment model described in chapter 6, and the results

Table 7.1

NWT Sectoral Capacity Adjustment Profile - Scenario #1

Sector	Cap. Adj. Yr.1	Cap. Adj. Yr.2	Cap. Adj. Yr.3	Cap. Adj. Yr.4	Cap. Adj. Yr.5	Cap. Adj. Yr.6	Cap. Adj. Yr.7	Cap. Adj. Yr.8
		All F	lgures in l	Millions of	1984 Dolla	urs ·		
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	54.3	47.6	0	0	٥
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0.3	0	0	0
9	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0

indicated that the drilling programs for years 1 and 2 could take place without any capacity augmentation in the NWT. Therefore a *static version* of the model derived in chapter 5 was used to assess the interregional economic impacts of these investment plans (see table 7.1).

Figure 7.1 presents a summary of the interregional impacts associated with the investment plans for each year in the development of this onshore project. Clearly, the impacts of the drilling programs in years 1 and 2 were relatively small (relative to subsequent impacts) with the NWT, and the central and western regions capturing the bulk of the effects. Figure 7.52 in the appendix presents this information in a sectorally disaggregate manner for year 1 (note that the impact patterns for year 1 and year 2 are qualitatively identical given that the exogenous vector for each year consisted of a single shock to sector 4 in the NWT). As was expected, sector 4 in the NWT experienced the largest total impact, followed by sectors 4 and 5 in the western and central regions. The total impacts on sectors 4 and 5 in the western and central regions represented a combination of the direct sector 4 shocks which were transmitted to these regions by virtue of the interregional trade matrix, the backward linkages from sector 4 in the NWT to these sectors, as well as the intrasectoral backward linkages of these sectors in the western and central regions. Figure 7.2 clearly shows that the total effect of the drilling programs in each of the first two years was captured largely by the NWT (37%), followed by the central region (36%) and the western region

(24%). Figure 7.52 also suggests that the total effects in the western and central regions were concentrated in sectors 4 and 5 respectively, with substantial effects also exhibited by sectors 12 and 13 (finance, insurance & real estate, and community, business & personal services). Figures 7.3, and 7.52 show that the personal income effects were largest in the central region, followed by the NWT and the western region in years 1 and 2. Figure 7.4 shows that the central region captured approximately 41% of the system-wide personal income effect in years 1 and 2, while the NWT captured approximately 34% in each of these years, followed by the western region which captured a far smaller share of approximately 22%. All other regions captured less than 5% of the system-wide personal income effect.

To better understand exactly how these total impacts were manifested, they were dissected into their constituent direct, indirect, and induced effects. Figure 7.53 in the appendix, presents the sectoral and regional distribution of the direct impacts associated with the investment plan for year 1 (identical to the pattern for year 2). It is clear that sector 4 in the NWT captured the largest direct effect, followed by sectors 4 and 5 in the western and central regions. This impact pattern suggests that, aside from the initial final demand shock which was included as part of the direct effect, sectors in the NWT were not stimulated to supply direct inputs to sector 4 in the NWT. The sector 5 impacts in the western and central regions were the result of the backward linkages from sector 4 in the

NWT, as well as from sector 4 in the western and central regions to the manufacturing sectors of these regions. The fact that the manufacturing sector in the NWT was not directly affected suggests that, as expected, this sector did not have the structure required to satisfy the demands of sector 4 in the NWT. Figure 7.7 suggests that the NWT captured the bulk of the system-wide direct effect associated with these NWT drilling programs (62%), with the central and western regions accounting for a much smaller share of the system-wide direct effect (19% and 18% respectively). Given that the initial final demand shock values were included as part of the direct effect, the direct effect exhibited by sector 4 in the NWT represented almost no direct input production (the final demand shock accounted for nearly 100% of the direct impact to sector 4 in the NWT). In the western region however, approximately 20% of the direct effect to sector 4 represented the production of direct inputs, while the remainder was accounted for by the initial final demand shock. In the central region, the direct impact exhibited by sector 4 was 120% of the original final demand shock to sector 4. Based on this, even though the NWT appears to capture the largest share of the system-wide direct effect (see figure 7.7), if the contribution of the original final demand shock to sector 4 is removed, the NWT sectors actually experience a far smaller direct impact than do sectors 4 and 5 in the western and central region. This implies that sector 4 in the NWT purchases very few direct inputs from sectors in the NWT. It also implies that the intraregional output

multiplier in the NWT for sector 4 is much smaller than it is the western and central regions.

Figure 7.54 in the appendix suggests that the western and central regions captured the bulk of the indirect effects associated with these drilling programs. The indirect effects in the western region were concentrated in sectors 4 and 5, with most other sectors exhibiting significant but smaller impacts. In the central region, the indirect effects were overwhelmingly concentrated in the manufacturing sector, and again, the indirect effects exhibited by most other sectors were significant but much smaller. The dominance of the indirect effect exhibited by sector 5 in the central region suggests that this sector was far more important as a supplier of inputs to all sectors in all regions in than was sector 5 in the western region. The fact that sector 4 in the central region did not exhibit a large indirect effect, while sector 4 in the western region did speaks to the fact that these two sectors in these two regions were structurally distinct (I will return to this issue later in this section of the chapter). Figure 7.8 suggests that indirect effects, as a contributor to the total effect, were most important in the eastern and west central regions, followed by the western region, the Yukon and the central region. Figure 7.9, however, shows that the presence of the eastern, west-central and Yukon regions in the upper portion of figure 7.8 was more a manifestation of the fact that the total effects in these regions were relatively insignificant, with the central region capturing the bulk of the system-wide indirect effect, followed by the western region and the NWT.

Figure 7.55 in the appendix, indicates that the induced effects of the drilling programs were also concentrated in western and central regions. Specifically, the induced effects in the western region were concentrated in sectors 4, 5 and 12 with all other sectors exhibiting substantial but smaller effects. In the central region, the induced effects were similarly scattered across most sectors, but the induced effect exhibited by sector 5 (manufacturing) overshadowed all others. The lack of an induced effect to sector 4 in the central region speaks, yet again, to the fact that there is a significant difference between what has been classified as sector 4 in the western region versus the central region. Figure 7.11 shows that the central region captured the bulk of the induced effects (50%-55%) in these years, with the western region accounting for a significant but smaller share (30%-33%). The NWT, and all other regions cumulatively accounted for less than 20 percent of the induced effects in these years.

To this point then, the effects of two years of exploratory and development drilling activity in the NWT have been assessed. It appears that the economic benefits of this activity would accrue largely to Ontario, Quebec, Alberta, British Columbia and the NWT, with relatively little direct, indirect or induced effect filtering through to the Yukon, and the west-central and Atlantic Provinces. This spatial impact pattern is consistent with what Douglas and MacMillan (1981) found when assessing the effects of developing the Alsands Project in Alberta (using a 1974 MRIO model). It would seem, from what can be discerned at this level of sectoral aggregation, that the interregional trading patterns did not change measurably over this decade.

Year 3, as discussed in chapter 6 (see table 6.1), consisted of a significantly greater amount of development drilling activity in the NWT, along with the beginning of the well-head facility and pipeline construction phases. Table 6.6 shows that, as in years 1 and 2, the development drilling translated into a \$63M direct shock to commodity 8 (services incidental to mining) in the NWT, which translated into a direct \$63M shock to sector 4 in the NWT, which was apportioned to the NWT (71%), the western region (13%), and the central region (16%). The gathering and production facility construction activity (\$32M) was also allocated to sector 4 in the NWT on the recommendation of the Government of the Northwest Territories (GNWT) Bureau of Statistics, and it was apportioned as discussed above (refer to chapter 6 for details regarding the allocation of expenditures to S level commodities). The pipeline construction related activity was allocated to commodity 30 (non-residential construction) in the NWT, again based on the recommendations of the GNWT Bureau of Statistics. The NWT sectoral share coefficients indicated that commodity 30 in the NWT was produced entirely by sector 4 in the NWT, and the trade share matrix showed that all of this activity was allocated to production in the NWT.³ As in years 1 and 2, the capacity adjustment model indicated that this activity could take place in the NWT

without the addition of any capacity to any NWT sectors (see chapter 6 for details regarding this calculation).

The total impacts of this investment plan in year 3 are displayed in figure 7.1, and in detailed sector specific terms in figure 7.56 in the appendix. Figure 7.1 suggests that the increase in the overall level of investment in the NWT in year 3 caused a significant increase in the total impacts captured by the NWT, the central region and the western region. The remaining regions exhibited less sensitivity to this increased activity in the NWT, with the west-central region exhibiting a noticeable increase over previous years. Figure 7.2 shows that the NWT's share of the system-wide total impact increased substantially in year 3, to the detriment of the central region primarily, with the western region also showing a slight decline. The fact that the construction sector impacts associated with the beginning of the pipeline construction phase in the NWT were allocated entirely to sector 6 production in the NWT, with no concurrent direct shock to sectors in the western and central regions, accounted for this effect. The NWT absorbed all of the construction sector activity in year 3, and, as a result, only the drilling activity in year 3 resulted in direct shocks to the western and central regions. As a result, the NWT increased it's share of the system-wide total impact in year 3. The fact that the central region lost a greater share of the system-wide total impact in year 3 than did the western region suggests that the western region was picking up some spin-off from the added pipeline construction activity in the NWT

which was not being transmitted proportionately to the central region. Figure 7.8 confirmed this hypothesis by showing that the indirect effects as a percentage of the total effects in the western region increased by a greater margin than did the same quotient for the central region over years 2 and 3. Clearly, the pipeline construction activity in the NWT had a greater impact on the importance of the indirect effects in the western region than in the central region. This caused the central region to lose a greater share of the total effect in year 3 to the NWT than did the western region. It should be clear however, that the central region still received a larger total impact in year 3 than did the western region. Figure 7.56 presents the total impact pattern by sector, as well as, by region for year 3. Relative to the total impact patterns for years 1 and 2 (see figure 7.52), the total impacts in the NWT in year 3 were focussed in two sectors, 4 and 6. The total personal income earned in the NWT (sector 17 in these figures) also increased substantially in year 3 with the addition of pipeline construction investment. In the western and central regions, the sector 5 total impacts appeared to increase as a percentage of the total impact to sector 4 in each region, relative to the same comparison in earlier years. Comparing the indirect impact patterns for years 1 and 3 (figures 7.54 and 7.58 in the appendix) shows that the bulk of this additional manufacturing sector impact, especially in the central region, was largely due to the added indirect effects caused by the pipeline construction activity in the NWT.

As noted above, the increased level of investment in the NWT caused a

significant increase in the amount of personal income earned in the NWT, as well as in all other regions. Figure 7.3 shows that the central region experienced the greatest increase in personal income effects, followed by the NWT and the western reaion. This was interesting in light of the pipeline construction investment in the NWT in year 3. The fact that the personal income generated in the central region in year 3 represented a greater percentage increase over year 2 levels relative to the NWT was due primarily to the indirect and induced effects which were captured by the central region. Figure 7.4 shows that, while the central region still captured the bulk of the system-wide personal income effect in year 3, it did lose a small portion of it's share to the western region in year 3. The fact that the western region captured a larger share of the system-wide personal income effect in year 3 than it did in year 2, reinforces the earlier contention that the western region was slightly more sensitive to pipeline construction activity in the NWT, than was the central region, even though the magnitude of the impacts felt by the central region were larger than those felt by the western region in year 3. The fact that the NWT's share of the system-wide personal income effect did not change given the pipeline construction investments in year 3 was surprising. This could only be explained by subsequent direct, indirect and induced effects in other regions which caused these regions to generate enough personal income to maintain their shares in year 3. This suggests that while 100% of all NWT construction sector impacts were allocated to production in the NWT, substantial

interregional backward linkages caused a considerable portion of the direct effects of this activity to be spun-off to other regions. Figure 7.61 confirms this by showing that nearly 100% of the direct sector 6 impact in the NWT was accounted for by the initial \$38M final demand shock for pipeline construction. The decline in the relative importance of the personal income effects in the NWT in year 3 shown in figure 7.5 was due to the fact that the total effects in the NWT had increased substantially, and due to the fact that the pipeline construction activity, as well as the drilling activity, resulted in substantial direct impacts in other regions, principally the western region (see figure 7.4).

The pattern of direct effects for year 3 are displayed in figure 7.57 in the appendix. Clearly, the pipeline related investment resulted in a substantial direct impact to sector 6 in the NWT. In year 3, the direct effect to sector 4 in the NWT was 126% of the initial shock, compared to 104% in year 2. This implies that the direct effect exhibited by sector 4 in year 3 included the added effects of producing direct inputs for sector 6 in the NWT. The direct effect exhibited by sector 6 in the NWT was approximately 101% of the initial sector 6 impact implying that sectors 4 and 6 in the NWT drew relatively few direct inputs from sector 6 in the NWT, as discussed above.⁴ Figure 7.6 indicates that the majority of the total effects in the NWT continued to be accounted for by direct effects (approximately 88%), while in most other regions, the importance of the direct effects declined slightly. This decline was sharpest in the western and central

regions in year 3. Figure 7.8 shows that this was offset in these regions by a concurrent increase in the importance of indirect effects in most regions, with the western region experiencing the greatest increase, followed by the central region. As noted above, the majority of this indirect effect was caused by the pipeline construction activity in the NWT in year 3. Figure 7.7 suggests that the NWT gained a larger share of the system-wide direct effect in year 3 to the detriment of the central and western regions. This was due to the fact that the initial sector 6 shock in the NWT was not shared with these regions, and this acted to increase the NWT's share of the overall direct effect. It was also the case that the pipeline construction activity in the NWT actually generated a significant amount of direct input production in the NWT (e.g., the direct impact on sector 4 in the NWT was 126% of the final demand shock to sector 4 in year 3) unlike previous years where the direct effects in the NWT were almost entirely accounted for by the direct final demand shocks.

The pattern of indirect impacts for year 3, across sectors and regions, is presented in figure 7.58 in the appendix. Relative to the earlier patterns, the interregional indirect effects associated with the investment plan for year 3 did not appear to change in any overt qualitative way. One noticeable change, relative to earlier patterns, was the disproportionate growth of sector 5 in the central region relative to all other sectors in that region. Clearly, the pipeline construction activity in the NWT resulted in a preferential indirect effect to this sector in the

central region. The same disproportionate increase in the magnitudes of the indirect effects was witnessed in sectors 4 and 5 in the western region. Figure 7.9 shows clearly that the central region captured the bulk of the system-wide indirect effect in year 3 (43%), followed by the western region (36%), and the NWT (14%). It also shows that in year 3, the central region's share declined somewhat to the benefit of the western region and the NWT. This, as mentioned above, was due largely to the extra indirect effects captured by the western region as a result of the pipeline construction activity in the NWT. Despite the fact that the central region lost some of it's share of the system-wide indirect effect to the NWT and the western region, figure 7.8 clearly shows that all regions experienced an increase in the relative importance of indirect effects. The western region clearly stood out as that region to which indirect effects became more important in year 3. Once again, this was due entirely to the pipeline construction activity in the NWT.

The pattern of induced effects associated with year 3's investment plan is displayed in figure 7.59 in the appendix, and, in this case, the pattern was qualitatively indistinguishable from earlier patterns. Figure 7.11 shows that each region's share of the system-wide induced effect remained relatively constant over all years in this scenario. The dominance of the central region in terms of capturing induced effects was clear with over 50% of all induced effects taking place in the central region in all years. The western region, while experiencing a

slight increase in year 3, consistently captured between 30% and 34% of the system-wide induced effect, followed by the NWT which consistently captured between 7% and 10%.

7.1.2 Capacity Adjustment (Peak) Years - 4 & 5

Years 4 and 5 of scenario 1, as discussed in chapter 6 (see table 6.1) represented years of peak investment in the NWT. Years 4 and 5 called for continued development drilling (\$63M & \$63M), along with accelerated gathering and production facility construction (\$63M & \$127M), pipeline construction (\$154M & \$154M), and the beginning of compressor station construction and integration (\$52M & \$65M). The compressor station investments, as discussed in chapter 6 (see table 6.6) were allocated to commodity 22 (machinery & equipment - M&E) based on recommendations from the GNWT Bureau of Statistics. The interregional trade share matrix indicated that of all commodity 22 used in the NWT, only 0.01% was produced in the NWT with 47% produced in the western region, 38% produced in the central region, and 4% produced in the west-central region (with the remainder coming from foreign sources). The capacity adjustment model indicated that the final demand vectors for these years would result in the exceedance of existing capacity in sector 4 in the NWT (by \$54M) in year 4 and in sectors 4 (by \$48M) and 8 (by \$0.3M) in the NWT in year 5 (see table 7.1). The massive investments in these years, combined with the effects of

adding the required capacity, made these years the peak years for all impacts, and these will be discussed below. The fact that capacity adjustments were required for these years meant that the investment term in the final demand component of the model derived in chapter 5 became non-zero, and as a result a *dynamic version* of the model was used to assess the interregional economic impacts for years 4 and 5.

Figure 7.1 shows clearly that these years were the peak impact years for all regions. The NWT captured the largest total effect in years 4 and 5, followed by the central and western regions. Due to the fact that the expansion investments required in year 5 were smaller than those in year 4, the increase in all regions from year 4 to year 5 was substantially smaller than what was observed in going from year 3 to year 4. Figure 7.2 shows that in these capacity adjustment years, the NWT's share of the system-wide total impact declined steadily, while the shares captured by the western and central regions increased. The share of the system-wide total impact captured by the western region increased sharply in year 4 and subtly in year 5, while the share captured by the central region remained at its year 3 level in year 4, and increased subtly in year 5. The NWT lost ground in these years for two reasons; firstly, the compressor station investments in years 4 and 5 resulted in almost no impact in the NWT while the manufacturing sectors in the western and central regions essentially split these shocks between them, and secondly, the investment term in the dynamic version of the model acted to translate the capacity adjustments required for sector 4 in the NWT into large manufacturing and other demands which were satisfied largely by sectors in the western and central regions (see table 7.4 for a listing of sector 4's capital input requirements). As discussed in chapter 6, the investment term made use of a modified trade share matrix which acted to ensure that any manufacturing sector impacts of the capacity adjustment profiles, along with any commodity 8 required as capital, which would have been allocated to production in the NWT, were allocated to sectors in Alberta. All other interregional and intraregional trading patterns were unchanged. This was done, under the guidance of GNWT Bureau of Statistics officials, to reflect the fact that the manufacturing sector in the NWT would not provide items such as fabricated metal products and electronic equipment, for example, which would be needed to expand the capacity of sector 4 in the NWT. The GNWT Bureau of Statistics felt that the role of Alberta in the development of the Beaufort reserves would likely be more substantial than it was in the early 1980s, and as such these adjustments were made. This modified trade share matrix therefore, acted to lessen the demands placed on the NWT for capacity adjustments and to exaggerate the demands placed on Alberta (which is half of the western region). This explains why the western region's share of the system-wide total impact increased sharply in year 4, while the central region's share remained at its year 3 level.

Figures 7.60 and 7.68, in the appendix present the total impact patterns for these years disaggregated by sector, as well as by region. Figures 7.64 and 7.72 present the same patterns for the capacity adjustment vectors alone. Relative to the total impact patterns seen for previous years, the total impact patterns displayed in figures 7.60 and 7.68 indicate that the capacity adjustment activities in years 4 and 5, in conjunction with the compressor station investments in these years, not only caused the general magnitude of the impacts to increase substantially, but they also caused the sector 6 impact in the NWT to be larger than any other. Figures 7.64 and 7.72 suggest that nearly 25% percent of this was due to the expansion of sector 4 capacity in the NWT. The fact that the sector 4 impact in the NWT was smaller than seen previously, as a percentage of the sector 6 impact, was the result of the fact that all commodity 8 called as capital, which would normally have been produced by sector 4 in the NWT, was allocated to sector 4 production in the western region. The fact that all manufacturing related capital inputs required for the expansion plans in years 4 and 5 were allocated to sector 5 production in the western region explained why the sector 5 impact in the western region was uncharacteristically large, relative to earlier years. The larger than normal total impact exhibited by sector 4 in the central region also reflected the added boost from the expansion plans for years 4 and 5. The manufacturing sector in the central region also experienced a significant impact as a result of the sector 4 expansion in the NWT in years 4 and 5. Sector

5 in the western and central regions also received the bulk of the compressor related production in years 4 and 5. These findings provided some explanation for the trends shown in figure 7.2.

Figures 7.60 and 7.68 also indicate that the western region captured more personal income in years 4 and 5, relative to the shares captured by the NWT and the central regions, as compared to previous years. Figures 7.64 and 7.72 show that the expansion plans resulted in significant personal income effects in all three of these regions, with the effect in the western region being much closer to the effects exhibited in the NWT and in the central region. This was due to the extra sector 4 and 5 activity which was routed to the western region by the modified trade share matrix. Figure 7.4 suggests that the western region definitely increased it's share of the system-wide personal income effect in year 4 (relative to year 3), but as figure 7.3 suggests, the central region and the NWT still captured the bulk of these effects. The sharp drop in the share captured by the NWT coincided exactly with the gain in the western region in years 4 and 5, with the central region showing more modest increases in these years. Figure 7.5 shows that in year 4, the relative importance of the personal income effects in the NWT reached a global minimum, while the relative importance of these effects in the western and central regions experienced slight declines. This sharp drop in the relative importance of the personal income effects in the NWT was due largely to the fact that the bulk of the effects experienced in the NWT were attributable to

the direct final demand shocks with the bulk of the true direct effects taking place in other regions. The slight rebound in year 5 was due mainly to the increase in gathering and production facility investment in year 5, 71% of which was allocated to production in the NWT. The significant rebounds in years 6 and 7 were due largely to the tapering off of pipeline construction investment in these years, which not only meant that the personal income generated in the NWT became a larger proportion of the total effect, but it also meant that the magnitude of the total effect in the NWT was declining. These two forces acted to increase the relative importance of personal income effects in the NWT in these later years.

Figures 7.61 and 7.69 present the direct impact patterns, by sector and by region, for years 4 and 5 respectively, and figures 7.65 and 7.73 present the direct effects of the capacity adjustment vectors alone. Relative to previous years, the large direct sector 6 impact in the NWT stood out as a major qualitative change. The large direct impacts to sector 5 in the western and central regions, which exceeded the direct sector 4 impacts in these regions in these years, also acted to distinguish these impact patterns. Figure 7.7 shows that over years 4 and 5, the NWT's share of the system-wide direct impact declined steadily from a global maximum in year 3, while the shares captured by the central and western regions the fact that the western region actually gained a larger share of the system-wide direct effect than did the central region, a trend which reversed itself immediately

after the capacity expansion period. Even in light of this finding, figure 7.6 suggests that this had no effect on the relative importance of direct effects in the NWT. The relative importance did however increase steadily over the capacity adjustment period in the western and central regions. Clearly, the loss of the sector 4 and 5 activity in the NWT in years 4 and 5 was more than compensated for by the expansion related direct effects which remained in the NWT, and by the massive sector 4 impacts in the NWT for drilling and well head activity.

As for the indirect effects, figures 7.62 and 7.70 present the indirect impact patterns for years 4 and 5, while figures 7.66 and 7.74 present the indirect impact patterns associated with the expansion activities only for these years. A comparison of these patterns with those for earlier years revealed no noteworthy qualitative changes. Figure 7.9 suggests that in the capacity adjustment period, the share of the system-wide indirect effect accounted for by the central region declined to the benefit of the western region and the NWT. The fact that the western region captured a larger share, while the central regions' share declined was the result of two factors; firstly, the western region, by virtue of the observed trade share matrix received larger share (47%) of the M&E shock to the NWT for compressor stations than did the central region (37%), and secondly the western region, by virtue of the *modified trade share matrix* received all sector 5, and some sector 4 production that would have resulted in the NWT in response to the expansion activities. Together these effects gave the western region a larger

share of the system-wide indirect effect in years 4 and 5, to the detriment of the central region. The increase in the NWT's share of the system-wide indirect effect was due mainly to the large pipeline construction investments which began in year 3 and ended in year 7.

Figures 7.63 and 7.71, in the appendix, present the induced impact patterns for each of the capacity adjustment years, and figures 7.67 and 7.75 present the induced impact patterns associated with the NWT expansion plans alone for these years. Comparisons of these figures with those observed for previous years vielded no significant qualitative differences. Even the induced impact pattern associated with each of the capacity expansion plans appeared indistinguishable from earlier, non-capacity adjustment years. Figure 7.11 shows that the share of the system-wide induced effect captured by each region varied little over the entire time period. A slight increase in the share captured by the western region, and a concomitant drop in the share captured by the NWT was exhibited in the capacity adjustment years, with shares returning to pre-capacity expansion levels by year 6. The increase in the western region's share of the induced effect was due primarily to the sector 5 impacts diverted there in the capacity adjustment Figure 7.10 suggests that the relative importance of induced effects vears. dropped slightly in years 4 and 5 in all regions, with the decline in the western region being most noticeable. This was a reflection of the fact that, in most regions, the importance of the direct effects increased steadily through years 4

and 5, and the importance of the indirect effects peaked in year 4, and began to decline in year 5. These simultaneous effects coincide with the oscillations shown in figure 7.10.

The capacity adjustment years then, were characterized by exaggerated sector 4 and 5 impacts in the western and central regions, and by very substantial sector 4 and 6 impacts in the NWT. Also, the western region, in these years, captured more personal income per dollar of total effect than in any other year due largely to the characteristics built into the modified trade share matrix. As with earlier years, the structural difference between sectors 4 and 5 in the western and central regions was striking. This was especially clear in the induced impact patterns for the capacity adjustment vectors alone (see figures 7.71 and 7.79). Sector 5 in the central region exhibited a substantial induced effect as a result of the expansion plans, while sector 4 in the central region exhibited almost no induced effect. Sector 4 in the western region however exhibited a substantial induced effect, while sector 5, even though it had been allocated all manufacturing demands associated with the expansion that would have been allocated to the NWT, exhibited a substantial but relatively small induced effect. This will be discussed further in the discussion for scenario 1.

7.1.3 Post-Capacity Adjustment Years - 6, 7, & 8

The capital investment time-lines for the final 3 years of scenario 1 (see

table 6.1) called for a gradual reduction in all investment categories as the project was nearing completion. In fact, the authors of the scenarios noted that by the end of year 6 the facility would start producing oil at the desired rate. The investment plans for years 7 and 8 therefore consisted of continued development drilling activity only. By the end of year 6 then, the well head facilities and the pipeline were completed, and the drilling programs in the final 2 years represented the installation of additional water and gas injection wells designed to enhance the productive efficiency of the field.

The level of development drilling slated for year 6 remained at its year 5 level, but the gathering and production facility (well-head) construction investment was significantly reduced (\$32M), as was the investment in pipeline construction (\$38M), and compressor station investment (\$13M) (see table 6.1). The capacity adjustment model indicated that the final demand vector for year 6 could be satisfied without the need for any capacity augmentation in the NWT, and ,as a result, a static version of the model was used.⁵ In fact, given the sizeable capacity adjustments of years 4 and 5, considerable excess capacity would exist, and if this project were to be implemented in isolation from any other developments, year 6 would undoubtedly be one of considerable unemployment in the NWT as the pipeline neared completion. This has been the experience with such projects in the past, and this speaks to low potential which exists in such regions for the retention of long-term economic benefits from such projects.

The delta final demand vector for year 6 was identical structurally to the one used in year 3 with the exception of the \$13M shock to commodity 22 in the NWT (see table 6.6). Based on this, the only element of year 6's final demand vector which could act to differentiate the impact pattern for year 6 from that seen for year 3 is this \$13M shock to commodity 22 in the NWT. The final demand vectors for years 7 and 8 were identical in structure to those used in years 1 and 2, and as a result a detailed discussion of these impacts would be redundant.

Figure 7.1 indicates that by year 6, the total impacts in all regions had decreased significantly relative to years 4 and 5 as a result of the general drop in the level of investment in the NWT and the cessation of capacity expansion activities in the NWT. In year 6 the NWT still captured the greatest total impact, followed by the central and western regions. The cessation of pipeline construction activities however acted to significantly narrow the gap between the NWT and central region, and between the central region and the western region in terms of total impacts, and this trend continued through year 8. Figure 7.2 indicates that by year 6 most regions had returned to their pre-capacity adjustment shares of the system-wide total impact, with the western region experiencing a steady decline from year 5 (a year of maximum investment and capacity adjustment in the NWT) through to year 7 where it's share stabilized at it's year 1 share. The central region experienced a significant drop in it's share of the system-wide total effect in year 3 (the first year of pipeline construction

activity), this increased steadily thereafter reaching its year 2 level by year 7, the first year after the completion of the pipeline. The NWT exhibited an opposite but very similar pattern over this period. Figure 7.76 presents the total impact pattern for year 6, and relative to year 3, the effect of the \$13M shock to M&E in the NWT for compressor station investment was clearly visible in exaggerated sector 5 impacts in the western and central regions, along with an increase in the amount of personal income generated in the western region. Figure 7.4 shows that in year 6 the western region's share of the system-wide personal income effect was larger than it was in year 3, even though this share steadily declined from year 5 through year 7. Also, like years 4 and 5, the pipeline construction activity in the NWT in year 6 resulted in a large impact on sector 6 in the NWT, although, due to the absence of the investment term in year 6's final demand vector, the total effect exhibited by sector 6 in the NWT was more like that seen in year 3. That is, the capital input matrix used in the investment term indicated that sector 4 in the NWT required a significant sector 6 input for each dollar of capacity expansion, and this augmented the total sector 6 impact in the NWT in years 4 and 5. The construction sector impact in the NWT in year 6 was entirely the result of pipeline construction activity.

Figure 7.77 presents the direct impact pattern for year 6, and comparison with the same figure for year 3 (figure 7.57), made it clear that the M&E shock in the NWT caused significant increases in the direct effects exhibited by sector 5 in

the western and central regions. Relative to years 4 and 5, the effect of the investment term was clear; the direct effect to sector 6 in the NWT in year 5 was far greater than that seen in year 6 as a result of pipeline construction alone, and the direct impacts on sector 5 in the western and central regions were substantially larger, not only in absolute terms but relative to the direct effect exhibited by sector 4 in each of these regions, in year 5 than in year 6. Since the only difference between year 5 and year 6 was a \$48m expansion plan for sector 4 in the NWT, these differences could be attributed to the effects of the investment term (see table 6.6). Figure 7.7 shows that the share of the system-wide direct effect captured by the NWT declined steadily from year 3 through year 6 returning to it's year 2 share in year 7. This pattern coincided with the pipeline construction phase in the NWT which began in year 3 and ended in year 6. The western and central regions had been steadily increasing their share of the system-wide direct effect since year 3, again following the trajectory of the pipeline construction phase in the NWT. In fact, after year 3 the western region captured a larger share of the system-wide direct effect than the central region did, and this reversed after year 6, the last year of pipeline activity in the NWT. At year 6 however, each of these regions captured an equal share of the system-wide direct effect.

Figure 7.78 presents the indirect input pattern for year 6, and a comparison with the same figure for year 3 (figure 7.62) suggested that the effect of the M&E investment in year 6 was largely accounted for by the direct manufacturing

impacts discussed above, since the two patterns appeared to be very similar (meaning the M&E shock did not affect the indirect impact pattern, only the direct impact pattern). Figure 7.9 shows that the share of the system-wide indirect effect captured by the central region steadily increased after year 4 reaching it's year 2 level by year 7. Over the same period, the western region and the NWT had been capturing a steadily decreasing share, and by year 7 they to returned to their initial shares.

The induced impact pattern for year 6 (see figure 7.79) revealed no differences relative to previous years, suggesting that the bulk of the factors which acted to differentiate each years' total impact pattern affected the direct impact patterns primarily.

By the beginning of year 7 the facility is complete, and oil is being produced at the desired rate. The investment plans for years 7 and 8 call for development drilling only, and as a result all impact patterns reflect those reviewed earlier for year 1.

7.1.4 Discussion of Scenario 1 Results

Scenario 1 represents one generic scenario of the way in which a lead field in the Mackenzie Delta region could be developed. The project is phased in over a period of 8 years with the majority of the investment and associated impacts taking place in the 4th and 5th years. Some interesting trends were observed in

the interpretation of the model results for this scenario. To begin, there appeared to be a trade-off between the NWT and the western region in terms of personal income effects. When investment was at it's peak in years 4 and 5, the NWT lost some of it's share of the system-wide personal income effect to the western region, and to the central region to lesser degree. This was largely attributable to the pipeline construction phase in the NWT which caused a significant spillover effect in the western region. As noted above, this was also a manifestation of the investment term used for the dynamic analysis which used a modified trade share matrix to apportion all manufacturing sector capital inputs that would have been allocated to the NWT by the observed trade share matrix to Alberta. This modification was made based on guidance from GNWT Bureau of Statistics officials which noted that the NWT would not manufacture such inputs, and that the western region would certainly play a more important role in the development of oil in the western Beaufort than it had in the developments of the 1970s and 1980s.

Another interesting finding was the apparent structural difference between sectors 4 and 5 in the western region and their counterparts in the central region. Specifically, sector 5 in the western region often appeared to exhibit more of its total effect as a direct effect, with a smaller portion accounted for by indirect and induced effects. Sector 5 in the central region appeared to do the opposite, having the bulk of its total effect accounted for by induced effects. To highlight

these two sectors, the direct, indirect and induced effects exhibited by each were graphed in a manner that would clearly show the contribution of each type of effect to the total exhibited by each over all years. Figures 7.15 and 7.16 clearly show that sector 5 in the central region had a far greater share of its total effect contributed by induced effects in all years than did sector 5 in the western region. The contribution of direct effects to the total effect exhibited by sector 5 in the western region was far greater than in the central region. In fact, figure 7.17 suggests that the behaviour of the manufacturing sector in the western region, in terms of the distribution of its total impact across the three types of impacts, was more similar to the pattern exhibited by sector 5 in the NWT. The fact that sector 5 in the western region always displayed a substantial direct effect as a result of any sector 4 activity in the NWT speaks to an apparent resource processing bias in the manufacturing sector of the western region. The lack of a similar effect in the central region, combined with the fact that sector 5 in the central region always exhibited a large induced effect no matter what the final demand configuration, suggested that this manufacturing sector was more diversified and mature relative to the manufacturing sector in the western region.

Another apparent structural difference was encountered between sector 4 in the western and central regions. In the central region, sector 4 impacts were largely direct, with very small indirect effects, and no measurable induced effects. In the western region however, a significant percentage of any sector 4 total
impact was accounted for indirect and induced effects. An induced effect to sector 4 implied that the personal income earned in the system which was spent on consumption caused a feedback to sector 4 in the western region, and not to sector 4 in the central region (e.g. increased housing starts in all regions as a result of higher earnings in all regions would ultimately require more raw lumber from the Albertan forestry sector). This finding, based on knowledge of the Albertan economy makes intuitive sense as does the lack of such effects in sector 4 in the central region. Clearly, this suggests that the establishments gathered under the banner "Mines, Quarries & Oil Wells" in the western region, are different from those included in this sector in the central region. Figures 7.12 and 7.13 clearly show that the sector 4 impacts in the central region were almost entirely direct, whereas those in the western region were composed of substantial indirect and induced components. Figure 7.14 suggests that sector 4 in the central region appears to have more in common with sector 4 in the NWT than it does with sector 4 in the western region. These patterns are not manifestations of the scenario data but rather they are reflections of the aggregate regional structures embodied in the I-O data.

Scenario 1 therefore would have the greatest overall effect on the NWT with the central region being far more able to benefit over a longer period of time from the project. The western region would also receive a significant economic benefit from the development of this project, with a significant portion of the economic



Figure 7.1



Figure 7.2





Regional Share of the Total Personal Income Effect: Scenario #1

Figure 7.4



Personal Income Effects as a Percentage of the Total Effect: Scenario #1

Figure 7.5



Direct Impacts as a Percentage of Total Impacts: Scenario #1

Figure 7.6



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Figure 7.7



Figure 7.8



Figure 7.9



Figure 7.10



Figure 7.11

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Mines, Quarries & Oil Wells Impacts Western Region: Scenario 1

Figure 7.13



Mines, Quarries & Oil Wells Impacts NWT: Scenario 1

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Figure 7.14

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Figure 7.15



Figure 7.16



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Figure 7.17

benefit to the western and central regions being attributable to the pipeline construction phase. The NWT's benefits, barring any unforseen structural changes, would likely taper off quickly after the end of year 6, with much of the employment created in the early phase of the project released once the project reached a state of full production. If however, as Croasdale and McDougall suggest, this project acts as the lead development in the Mackenzie Delta/Beaufort Sea region, this labour may migrate from project to project in the NWT over a period of years.

7.2 Scenario 2: 350M Bbl. Offshore Field - Large Pipeline Option

Scenario 2 represents a generic scenario of one of the grandest development options available for Beaufort Oil. Specifically, the 350M Bbl. offshore oil reservoir, Amauligak, discovered by Gulf Canada in 1984 has been heralded as the field which could conceivably lead to the development of most of the known reserves in the Canadian Arctic, including the onshore field which was the focus of scenario 1. Croasdale and McDougall (1992) noted that a current industry supported view is that this field could justify the construction of a dedicated 16 inch diameter pipeline from Richards Island in the Mackenzie Delta to the northern terminus of the existing IPL pipeline network in northern Alberta. As noted in chapter 3 above, the Amauligak field does not have sufficient oil to maintain optimal flow rates in the pipeline for the requisite 20 years, and as a

result, the smaller fields in the Beaufort, along with the onshore reserves, could be tied into this system during the production life of the pipeline to maintain the required 80,000 bpd production rate. Hence, this field could conceivably lead to a full-scale development of many of the existing oil reservoirs in the Beaufort Sea and Mackenzie Delta regions. In what follows, the interregional economic impacts of this development scenario will be assessed using the model developed in chapter 5, and implemented as discussed in chapter 6.

7.2.1 Pre-Capacity Adjustment - Year 1

Table 6.2 suggests that the first year of this scenario called for \$95M of gathering and production facility investment. Given that the lead field has been discovered and well delineated, the exploratory and development drilling phase which was required in scenario 1 was not required in this case. This \$95M investment in year 1 represents the construction of offshore "top-sides" and the installation of a refurbished version of Gulf's floating caisson platform "Moliqupaq". As discussed in chapter 6, all gathering and production facility investment was allocated to commodity 8 (see table 7.3 for a listing of commodity titles) in the NWT, which, as discussed above, was allocated to sector 4 (see table 7.2 for a listing of sector titles) production in the NWT. The observed trade share matrix indicated that any sector 4 final demand shock in the NWT was apportioned to 3 regions with the NWT receiving 71%, the western region receiving 13% and the

Directory of Small Level Industry Aggregates

1.	Agriculture and Related Service Industries
2.	Fishing and Trapping Industries
3.	Logging and Forestry Industries
4.	Mining, Quarrying and Oil Well Industries
5.	Manufacturing Industries
6.	Construction Industries
7.	Transportation and Storage Industries
8.	Communication Industries
9.	Other Utility Industries
10.	Wholesale Trade Industries
11.	Retail Trade Industries
12.	Finance, Insurance, and Real Estate Industries
13.	Community, Business, and Personal Services Industries
14.	Operating, Office, Cafeteria, and Laboratory Supply Industries
15.	Travel, Advertising and Promotion Industries
16.	Transportation Margins

Directory of Small Level Commodity Aggregates

#	Commodity Label
1	Grains
2	Other Agricultural Products
3	Forestry Products
4	Fishing & Trapping Products
5	Metallic Ores & Concentrates
6	Minerals Fuels
7	Non-metallic Minerals
8	Services Incidental to Mining
9	Meat, Fish & Diary Products
10	Fruit, Vegatables, & Miscellaneous Food Products
11	Beverages
12	Tobacco & Tobacco Products
13	Rubber, Leather & Plastic Fabricated Products
14	Textile Products
15	Knitted Products & Clothing
16	Lumber, Sawmill & Other Wood Products
17	Furniture & Fixtures
18	Paper & Paper Products
19	Printing & Publishing
20	Primary Metal Products
21	Metal Fabricated Products
22	Machinery & Equipment
23	Autos, Trucks & Other Transportation Equipment

Table 7.3 - Continued

#	Commodity Label
24	Electronic & Communictions Products
25	Non-metallic Mineral Products
26	Petroleum & Coal Products
27	Chemicals & Chemical Products
28	Miscellaneous Manufactured Products
29	Residential Construction
30	Non-residential Construction
31	Repair Construction
32	Transportation & Storage
33	Communication Services
34	Other Utilities
35	Wholesale Margins
36	Retail Margins
37	Imputed Rent of Owner Occupied Dwellings
38	Other Finance, Insurance & Real Estate
39	Business Services
40	Personal & Other Miscellaneous Services
41	Transportation Margins
42	Operating, Office, Laboratory & Cafeteria Supplies
43	Travel, Advertising & Promotion

central region receiving 16%. The total, direct, indirect and induced impact patterns, given the configuration of the delta investment vector for year 1, were identical to those seen for year 1 of scenario 1. As such, the impact patterns for year 1 of scenario 2 were not included. The detailed interregional economic effects of a solitary shock to sector 4 in the NWT have been discussed in detail above, and to do so here would be repetitive. It should be noted that the impacts in this case were much larger than those for years 1 and 2 of scenario 1.

7.2.2 Capacity Adjustment (Peak) Years - 2, 3, & 4

Years 2, 3 and 4 of scenario 2 called for escalating levels of investment in gathering and production facility construction along with large pipeline construction and compressor station investments in years 3 and 4. The capacity adjustment model indicated that the delta final demand vectors created for years 2, 3 and 4 would result in the exceedance of capacity in a number of NWT sectors. In year 2, the capacity of sector 4 was found to be lacking by approximately \$49M (all \$ figures in 1984 dollars), and in years 3 and 4 massive gathering and production facility investments in the NWT resulted in further sector 4 capacity additions of approximately \$307M and \$158M respectively. The investment plans for these years also caused the capacities of several other NWT sectors to be exceeded with the adjustment to sector 6 in year 3 (\$27M) being most noteworthy after the sector 4 adjustments (see table 7.5). Given that

capacity adjustments were necessary in these years, a dynamic version of the model developed in chapter 5 was used to assess the interregional economic impacts in these years.

The total, direct, indirect and induced impact patterns, by sector and by region, for year 2 are presented in figures 7.80, 7.81, 7.82 and 7.83 in the appendix. The delta final demand vector for year 2 consisted of a large direct shock to sector 4 in the NWT combined with an investment term component which represented the expansion activities associated with sector 4 only (see table 7.4). Figure 7.18 shows that by year 2, the magnitude of the total impacts in all regions was beginning to increase sharply as a result of the combination of the current period investments and the expansion activities in the NWT. The NWT clearly captured the largest total impact in year 2 followed closely by the central and western regions. Figure 7.80 suggests that the bulk of the total impact of the investment and expansion plans for year 2 were captured by the NWT, with sectors 4 and 6 exhibiting the largest impacts. As seen in the early years of scenario 1, a final demand vector consisting of a single shock to sector 4 did not cause a significant impact to sector 6 in the NWT. This implies that sector 4 in the NWT did not purchase sector 6 commodities as a direct inputs. The large sector 6 impact in this case was caused by the fact that sector 4 did purchase sector 6 commodities as capital to increase its capacity (see table 7.4 for the capital input requirements of sector 4 in the NWT). The western and central regions also

Capital Input Requirements of the Mines, Quarries & Oil Wells Sector in the NWT

Cm .#	Capital Input per Dollar of Additional Capacity	Share Produced by the NWT (%)	By Sector (primarily)	Share Produced by the Western Region (%)	By Sector (primarily)	Share Produced by the Central Region (%)	By Sector (primarily)	
7	.003	72	4	11	4	4	4	
8	.045	71	4	13	4	16	4	
20	.022	0	4	67	5	17	5	
21	.001	0.3	10	15	5	77	5	
22	.022	0.01	4	47	5	38	5	
23	.003	3	7	10	5	32	5	
24	.005	5	8	6	5	78	5	
25	.009	5	5	21	5	70	5	
26	.,057	24	5	74	5	1.20	5	
.27	.018	` 1	4	24	5	59	5	
31	.007	100	6	0	6	0	6	
32	.018	38	7	36	7	21	7	
33	.003	86	8	12	8	0	8	
34	.021	90	9	2	9	0	9	
35	.022	55	10	22	10	20	10	
36	.0007	89	11	4	11	0	11	
38	.033	44	12	34	12	21	12	
39	.03	44	13	27	13	24	13	
40	.027	43	13	14	13	20	13	
41	.007	5	16	34	16	38	16	

(Source: Ellis, 1994)

received a significant total impact which was concentrated in sectors 4 and 5. Figures 7.81, 7.82, and 7.83 show that nearly 50% of the total impact exhibited by sector 5 in the central region was accounted for by induced effects, followed closely by indirect effects with the direct effects accounting for the smallest portion. These figures also show that the reverse was again true of the sector 5 impact in the western region. Relative to the total impact pattern for year 1 of scenario 1 (figures 7.52) which was generated using a final demand vector which was identical to the one used to generate year 2 impacts in scenario 2 with the exception of the investment term. Clearly, the exaggerated manufacturing sector impacts in the western and central regions in year 2 of scenario 2 were attributable to the expansion plan. The total, direct, indirect and induced effects associated with the expansion plan only are presented in figures 7.84, 7.85, 7.86, and 7.87 respectively. Clearly, the total impacts of the expansion plan for year 2 in the NWT and in the western region were largely direct, while in the central region more than 50% of the total effect was induced. This fact once again suggests the existence of a fundamental structural difference between these two sectors in the western and central regions.

Figure 7.19 suggests that by year 2, the NWT's share of the system-wide total effect increased markedly over year 1, while the share captured by the central region declined by a similar magnitude. The fact that the western region did not lose any of its share to the NWT in year 2 was due mainly to the compensatory action of the modified trade share matrix in the investment term of the dynamic model in year 2.

Figure 7.80 also shows that the central region captured the largest personal income effect followed by the NWT and the western region (see figure 7.20 for a clearer picture of this). The additional sector 4 and 5 activity in the western region, by virtue of the modified trade share matrix, acted to exaggerate the amount of personal income generated in this region in year 2 to the detriment of the NWT. This is shown clearly in figure 7.21. In year 2 the NWT's share of the system-wide personal income effect declined slightly to the benefit of the western region, while the central region retained it's large share. The fact that the bulk of the high labour income generating activities associated with the expansion in the NWT were being captured by sectors in the western and central regions was also clear in figure 7.22 which shows that in year 2, the relative importance of personal income effects in the NWT dropped substantially. This effect was also due to the fact that the large direct effects in the NWT greatly increased the magnitude of the total effect in year 2, thereby exaggerating this decline in the relative importance of the personal income effects in the NWT.

Years 3 and 4 were years of maximum investment and expansion activity in the NWT (see table 6.2 and table 7.5). Figure 7.18 shows that the total impacts in each region reached a maximum in years 3 and 4 with the NWT capturing the largest total impact, followed by the central and western regions. Figure 7.19 Table 7.5

NWT Sectoral Capacity Adjustment	Profile	- Scenario	#2
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Sector	Cap. Adj. Yr.1	Cap. Adj. Yr.2	Cap. Adj. Yr.3	Cap. Adj. Yr.4	Cap. Adj. Yr.5	Cap. Adj. Yr.6	Cap. Adj. Yr.7	Cap. Adj. Yr.8	Cap. Adj. Yr.9	Cap. Adj. Yr.10
,	All Figures in Millions of 1984 Dollars									
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	48.5	306.8	158.3	0	0	0	0	0	0
5	0	0	0	3.3	0	0	0	0	0	0
6	0	0	0	27.7	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	0	0	3.6	2.1	0	0	0	0	0	0
9	0	0	5.5	5.6	0	0	0	0	0	0
10	0	0	0	3.4	0	0	0	0	0	0
11	0	0	0.7	4.2	0	0	0	0	0	0
12	0	0	0	3.8	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0

suggests that the NWT's share of the system-wide total impact reached a maximum in year 3 (a year of maximum expansion investment) and dropped slightly in year 4 (a year of maximum investment, but of declining expansion investment). The share captured by the central region reached a global minimum in year 3, and recovered slightly in year 4, while the western region's share increased steadily from year 2 through year 4, with the increase from year 3 to 4 being almost imperceptible. Once again, this was due to the fact that in these years of maximum expansion activity in the NWT, the sheer magnitude of the direct effects in the NWT caused the NWT to increase it's share of the system-wide total impact to the detriment of the central region and, as discussed above, the compensating action of the modified trade share matrix acted to route a larger share of these direct effects to the western region thereby shielding it's share from a similar reduction.

The investment time-lines indicated that year 3 would see a substantial increase in the level of gathering and production facility construction along with the beginning of the pipeline construction phase, and the compressor station investment phase (see table 6.2). Table 7.5 indicates that this investment plan for year 3 required that the capacity of sector 4 be augmented by \$307M, along with a number of smaller capacity adjustments (see table 7.5). The total, direct, indirect and induced impact patterns for years 3 and 4 are presented in figures 7.88 to 7.91 and 7.96 to 7.99 respectively, with the same patterns for expansion

plans only presented in figures 7.92 to 7.95 and 7.100 to 7.103 (all of these figures are in the appendix). Figure 7.88 suggests that in year 3, the bulk of the total impact in the NWT was concentrated on sectors 4 and 6. Relative to year 2, the exaggerated sector 6 impact was the result of massive current period investment expenditures for pipeline construction along with a substantial level of expansion in sector 4. In the western region, the total impacts were concentrated in sectors 4 and 5. In fact, for the first time in this scenario sector 5 in the western region exhibited the largest total impact, followed closely by sector 4. The exaggerated sector 5 impact in the western region was caused by a combination of factors; firstly, the investment time-line for year 3 called for a significant commodity 22 (M&E) investment in the NWT for compressor station equipment, and the observed trade share matrix acted to apportion 47% of this to the western region, and 37% the central region. Secondly, the modified trade share matrix acted to augment the manufacturing sector impact in the western region by routing all manufacturing impacts to the western region which would have been allocated to the NWT as a result of the expansion investment. The western region's sector 4 impact was also due to a combination of factors; firstly, the observed trade share matrix acted to allocate 16% of all sector 4 final demand in the NWT to sector 4 in the western region, and the modified trade matrix in the investment term allocated all commodity 8 required as capital by sector 4 in the NWT to sector 4 in the western region. The total impacts in the central region were also

concentrated in sectors 4 and 5, with sector 5 exhibiting the largest impact. Figures 7.89 to 7.91 suggest that nearly 50% of the sector 5 impact in the western region was direct (approximately 20% was induced) whereas in the central region, nearly 50% of the total impact on sector 5 was induced (approximately 30% was direct). These figures also suggested that approximately 66% of the total impact exhibited by sector 4 in the western region was direct, with the remainder being accounted for indirect and induced effects. In the central region however, over 90% of the total impact on sector 4 was direct, with almost 0% accounted for by induced effects. As discussed previously, these differences speak to substantial differences between sectors 4 and 5 in the western region and sectors 4 and 5 in the central region.

Figures 7.93 to 7.95 suggest that the indirect and induced effects on sector 5 in the central region, as a result of the expansion plan alone, accounted for approximately 30% percent of the total sector 5 impact seen in figure 7.88, with less than 10% attributable to the direct effects of the expansion plan. Less than 20% of the full sector 4 impact in the central region was attributable to the expansion plan. In the western region, the expansion plan for the NWT accounted for approximately 40% of the full effect exhibited by sector 5, while approximately 30% of the full effect exhibited by sector 5, while approximately 30% of the full effect exhibited by sector 5, while approximately 30% of the full effect exhibited by sector 6 was attributable to the expansion plan, while less than 25% of the total effect exhibited by sector 6 was attributable to the expansion plan, while less than 25% of the total effect exhibited

by sector 4 in the NWT was due to the expansion plan. Clearly the expansion plan had a significant effect on all regions with the NWT and the western region having larger portions of their total effects accounted for by expansion related industrial activity.

Also evident in years 3 and 4 was the fact that the western region appeared to earn a greater amount of personal income, over previous years, relative to the NWT and the central region (see sector 17 in figure 7.88). A comparison with figure 7.92, which presents the total impact pattern associated with the expansion plan alone, suggests that nearly 50% of the total personal income earned in the western region was directly attributable to the expansion plan for year 3. A similar comparison for the central region suggested that the expansion plan accounted for approximately 34% of the personal income earned in the central region. Figure 7.20 suggests that the personal income effects in all regions increased substantially over their year 2 levels. It was interesting to note that while the central region experienced the largest increase in personal income earned between years 2 and 3, it had a smaller share of it's total personal income effect accounted for by the expansion plan in year 3 than did the western region. Figure 7.21 shows that in year 3 the NWT's share of the system-wide personal income effect declined to the benefit of the western region, while the central region retained it's year 2 share. The drop in the NWT's share in year 3, and the subsequent gain by the western region, was due to the combined effects of the

modified trade share matrix which acted to route all manufacturing sector capital input demands away from the NWT to the western region, and the significant M&E investment in the NWT in year 3 of which 47% was allocated to sector 5 in the western region. So, even though in absolute terms, the NWT generated more personal income in year 3 than did the western region, the rate at which the western region generated personal income in year 3 increased relative to year 2, while the same rate declined in the NWT. Figure 7.22 suggests that the massive direct impacts in the NWT in year 3 once again acted to reduce the relative importance of personal income effects there.

The direct impact patterns for years 3 and 4 are presented in figures 7.89 and 7.97 in the appendix. Relative to the same pattern for year 2 (figure 7.81), 2 major differences are clear. Firstly, the direct effects in the NWT were again concentrated in sectors 4 and 6, but in both years the direct effect on sector 6 was far greater than previously seen. In year 4, the direct effect on sector 6 in the NWT declined as a percentage of the sector 4 impact, but it was still far more pronounced than it was in year 2. As discussed above, this was due to the combined effects of massive pipeline construction investments in years 3 and 4, and the construction sector requirements of sector 4 for expansion. Secondly, the direct impacts exhibited by sector 5 in the western and central regions appeared to increase disproportionately relative to the sector 4 impacts in these regions. Clearly, each of these manufacturing sectors received a larger direct effect in

years 3 and 4 than in year 2. These exaggerated sector 5 impacts were largely caused by the compressor station investments in years 3 and 4 which were allocated to sector 5 in the western (47%) and central (37%) regions. The fact that figure 7.24 shows the NWT gaining a larger share of the system-wide direct impact over the capacity adjustment years while the shares captured by the western and central regions declined, speaks to the enormity of the direct effects in the NWT which were primarily caused by the pipeline construction activities. The fact that the NWT's share declined slightly in year 4 while the western and central regions' shares increased in year 4 was due to the fact that although year 4 was a year of maximum investment in the NWT, the level of the expansion activities declined significantly (see table 7.5).

Figures 7.90 and figures 7.98 present the indirect impact patterns for years 3 and 4. A comparison of these patterns with the same pattern for year 2 (figure 7.82) suggests that little in terms of qualitative change could be discerned. This suggests that the bulk of the effects which differentiated the total impact patterns for various years were direct. Figure 7.26 shows that over the capacity adjustment years, the central region, while capturing the bulk of the system-wide indirect effect, lost some of it's share to the western region and the NWT in year 3. However, the central region gained this share back in year 4 as a result of the significant decline in the magnitude of the sector 4 expansion in the NWT. Clearly, the expansion activities were causing substantial indirect effects in the

western region and the NWT which were not being transmitted, in a proportionate manner, to the central region.

Figures 7.91 and 7.99 present the induced impact patterns for years 3 and 4. A comparison of these figures with the same figure for year 2 (figure 7.83) suggests that, in a qualitative sense, the patterns did not change. Figure 7.28 suggests that the share of the system-wide induced effect did not change substantially over the capacity adjustment period, and in fact that these shares were stable over the length of the entire scenario. Clearly though, the central region captured the majority of the induced effects, followed by the western region and NWT. Figure 7.27 suggests that over the capacity adjustment years especially, the relative importance of the induced effects declined in all regions. Figure 7.25 suggests that this was the result of the growing importance of indirect effects in all regions over the capacity adjustment years.

7.2.3 Post-Capacity Adjustment Years - 5 through 10

The capital investment time-lines (see table 6.2) show that in years 5, 6, and 7 called for declining levels gathering and production facility investment and escalating levels of development drilling which begin in year 5 and continue through to the end of the development phase. The time-lines also called for continued but declining investments in pipeline construction and compressor stations through the end of year 7. By the end of year 7 the facility and pipeline
are essentially complete and production begins by the end of year 7. The final years (8, 9, and 10) consisted entirely of development drilling investments. The authors of the scenarios noted that this drilling was directed toward the installation of blow-out prevention devices and other systems meant to optimize the productive efficiency of the field. Given that the capacity adjustment model indicated that these investment plans could be carried out in the NWT without any capacity adjustment, a static version of the model was used to assess the interregional impacts in years 5 through 10.

The capital investment time-lines for years 5, 6 and 7 (see table 6.2) indicated that the final demand vectors for these years would be structurally identical to those for years 3 and 4 with the exception of the investment term (see table 6.7). The total impact patterns for years 5 through 7 are presented in figures 7.104, 7.108 and 7.112. The main difference between the investment plans for years 4 and 5 was the lack of an investment term in the final demand vector for year 5. Otherwise, the magnitudes of the various investment expenditures changed little. Figure 7.104 suggests that relative to year 4, the main change in the total impact pattern was the reduction in the total impact exhibited by sector 6 in the NWT. In the capacity adjustment years, sector 4 required substantial capital inputs from sector 6 (see table 7.4), and with the cessation of expansion investment in the NWT, the total effect exhibited by sector 6 in the NWT was significantly reduced. The sector 4 and 5 impacts in the western region did not

change radically even with the cessation of expansion investment in the NWT suggesting that pipeline construction investments in the NWT had a stronger effect on sector 5 in the western region than the investment term did. The total impact exhibited by sector 5 in the western did decline slightly, and this was entirely due to the cessation of the expansion investment phase in the NWT.

Year 6 saw a drastic decline in the level of gathering and production facility construction investment which acted to significantly reduce the direct final demand shock to sector 4 in the NWT, as well as in the western and central regions. Figure 7.108 presents the total impact pattern for year 6, and clearly the decrease in the sector 4 final demand shock caused a significant reduction in the total impact exhibited by sector 4 in the NWT, as well as in the western and central regions. The maintenance of pipeline construction investment at year 5 levels acted to maintain the large sector 6 impact in the NWT and the large (relative to year 1) manufacturing sector impacts in the western and central regions. The relative drop in the magnitude of the total impact to sector 4 in the western region was reflective of this sectors' sensitivity to sector 4 activity in the NWT. The relative insensitivity of sector 4 in the central region, speaks to the stark difference between these two sectors. By year 7 all investment categories showed significant decreases relative to year 6 levels. Most important was the sharp drop in the level of pipeline construction investment in the NWT in year 7 (down to \$38M in year 7 from \$230M in year 6). Figure 7.112 presents the total impact

pattern for year 7, and the effect of the declining pipeline construction investment in the NWT was clearly visible in the drastic drop in the total impact exhibited by sector 6 in the NWT. Relative to year 6, the manufacturing sector impact in the western region declined markedly relative to the sector 4 impact in that region. The sector 5 impact in the central region was also affected noticeably by the substantial drop in the level of pipeline related activity in the NWT. Figure 7.18 shows that since the end of the capacity adjustment period (the end of year 4), the total impacts in all regions declined substantially over years 5, 6 and 7 (e.g., down from \$1.4B in the NWT in year 4 to less than \$350M in year 7). Most noteworthy was the fact that in year 7, a year marked by an 84% decline in the level of pipeline construction in the NWT, the central region actually captured a larger total effect than the NWT did for the first time in this scenario. Clearly, the direct effects in the NWT had declined to the point where the indirect and induced effects of the central region allowed it to overtake the NWT. This was also due to the fact that since year 4, the M&E investment in the NWT for compressor stations declined at a much slower rate (only dropped by 33%) and the regional multiplier associated with this sector 5 impact in the western and central regions acted to shield these regions, to a small extent, from this drastic drop in pipeline investment in the NWT. Figure 7.19 shows that since year 4, the NWT's share of the system-wide total impact had been declining steadily, as did the central region's share. Interestingly, the western region's share was steadily increasing

over this period. In year 7, the NWT's share dropped drastically, while the central region's share increased sharply. The western region's share also peaked in year 7, but this peak represented the terminus of a gradual climb. The decline in the NWT's share over years 5 and 6 was gradual because gathering and production facility construction was gradually being reduced over these years. The fact that the western region was able to increase it's share over years 5 and 6 was due primarily to the fact that the M&E investment in the NWT increased significantly in year 5, and stayed at that level in year 6, providing a significant sector 5 shock to the western and central regions. The fact that the central region's share did not respond accordingly was due to the fact that the central region was losing significant indirect effects associated with this gathering and production facility construction over years 5 and 6 (see figure 7.26). The sudden upsurge in the central region's share of the system-wide total impact in year 7 was due to the drastic decline in the NWT's share, combined with the fact that the central region still received a significant M&E shock in year 7. Figure 7.24 shows that the NWT experienced a sharp drop in it's share of the system-wide direct effect in year 7. while the western and central regions increased their shares. Given the fact that nearly 90% of all NWT impacts were direct, this reflects the main cause of the decline in the total impacts in the NWT. Figure 7.25 shows that in year 6 most regions experienced an increase in the relative importance of indirect effects after a decline in year 5. This was due primarily to the increased level of compressor

station investment in the NWT which was satisfied primarily by sector 5 activity in the western and central regions, and these sectors, especially sector 5 in the central region, have far reaching backward linkages both across regions and across sectors. After year 6, the relative importance of indirect effects in all regions declined to their year 1 levels with the drastic decline in the level of pipeline construction in the NWT. Figure 7.26 shows that the western and central regions each gained a larger share of the system-wide indirect effect in response to the reduction in pipeline activity in the NWT in year 7, while the NWT's share declined. This however was not startling when one considers that nearly 90% of all impacts in the NWT were direct. Clearly, this gradual tapering off of investment in the NWT resulted, by year 7, in all regions experiencing significantly reduced economic impacts.

As noted above, the facility and pipeline began operating at full capacity at the end of year 7. The investments in years 8, 9 and 10 contained development drilling expenditures only. By year 10 even the level of development drilling was down nearly 70% relative to it's year 8 level. The total, direct, indirect and induced impact patterns for these years would be identical to those seen for year 1 of scenario 1 (a single shock to sector 4 in the NWT), and as such, figures for these years were not included. Summary figures 7.18 to 7.28 indicate that after year 7, all impact patterns return to their year 1 levels as would be expected. Figures 7.18 and 7.20 make clear the fact that after year 5, the total impacts and

the personal income effects in all regions decline sharply to year 10, the end of the development phase for scenario 2.

7.2.4 Discussion of Scenario 2 Results

The results discussed above represent the impacts associated with one generic scenario of the way Beaufort Sea Oil could be developed. Perhaps the most striking feature of this scenario is the fact that in a relatively short period of time (10 years) many billions of dollars of economic spin-offs will be generated over all the regions of Canada, with the impacts accruing to the NWT, one of Canada's least developed regions, being the greatest. The basic fact that the multiplier effects were seen to be greater in the western and central regions, combined with the fact that the NWT was unable to capture significant indirect and induced effects speaks to the relative immaturity of this region. The fact that 1 dollar of drilling investment in the NWT for example, had a much smaller effect on the NWT than it did on the western and central regions (once the magnitudes of the direct final demand shocks are removed) suggests that the structure of this region is very basic and local in focus. The extensive backward linkages to the more developed regions of Canada acted to transmit much of the economic benefit of this project to the central and western regions. This suggests that during the development of this facility the NWT would go through another significant boom-bust cycle which so often characterizes the resource experience

of underdeveloped regions. The fact that the central and western regions were able to capture significant indirect and induced effects implies that these regions, while certainly affected by the downturn, will be far more able to retain the economic benefits of this project for a longer period of time than would the NWT.

As mentioned above for scenario 1, a fundamental structural difference between the western and central regions was made clear in interpreting the results. Specifically, sectors 4 and 5 in the western and central regions behaved in markedly different ways to identical final demand shocks (sector 4 impacts in the NWT). The manufacturing sector in the western region exhibited large direct effects in response to drilling and gathering and production facility construction activities in the NWT, while this sector in the central region was exhibiting significant indirect and induced effects as well, with the direct effects accounting for a smaller share of the total impact. Figures 7.32, 7.33 and 7.34 suggest that there is indeed a substantial difference between what constitutes the manufacturing sector in the western region and in the central region. Clearly, sector 5 in the western region captures far fewer induced and indirect effects relative to sector 5 in the central region. In fact, figure 7.34 suggests that the manufacturing sector of the western region is more similar to the manufacturing sector in the NWT than it is to the manufacturing sector in the central region. Figures 7.29 to 7.31 suggest that sector 4 in the central region is also distinct relative to sector 4 in the western region.



Figure 7.18



Figure 7.19



Total Personal Income Earned Scenario 2

Figure 7.20



Regional Share of the Total Personal Income Effect: Scenario #2

Figure 7.21



Personal Income Effects as a Percentage of the Total Effect: Scenario #2

Figure 7.22



Direct Impacts as a Percentage of Total Impacts: Scenario #2

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Figure 7.23



Figure 7.24



Figure 7.25



Figure 7.26



Figure 7.27



Figure 7.28



Figure 7.29



Figure 7.30



Figure 7.31



Figure 7.32



Figure 7.33



These differences aside, it is clear to see that a development of this magnitude in the NWT would have substantial effects in the region, as well as in most other regions of Canada. The fact that a significant amount of capital stock would be added to the NWT economy over the life of this projects speaks favourably to the potential for other developments to follow. Conceivably, if the Amauligak field were to lead the region into an era of sustained oil and gas activity as the remaining (and perhaps new) fields in the Beaufort are tapped to lengthen the operating life of the pipeline, the NWT economy could begin to retain more and more of the economic benefits which spin off of such projects. It is likely that in this era of increased respect for Aboriginal rights to indigenous lands, the requirement for the training and use of local labour pools will become more extensive relative to past experiences which showed that the majority of the local employment benefits were short lived. This does not take into consideration the effects of possible royalty income which would be earned by NWT Aboriginal groups as a result of the various land claims which have already been settled, and those which will be settled shortly, in the NWT.⁶

7.3 Scenario 3: 350M Bbl. Offshore Field - Small Tanker Option

Scenario 3 represented a much more conservative approach to developing the offshore reserves of the Beaufort Sea. The previous scenario called for the development of these reserves with a dedicated large diameter pipeline at a rate

of 80,000 bpd. As noted in chapter 3, both of the previous scenarios which dealt with pipelines required that additional reserves be discovered during the operational life of the project to maintain peak flow through the pipeline. Such discoveries were essential if the favourable economics associated with the projects were to be maintained.⁷ Scenario 3 therefore represents one way of developing the offshore Amauligak field which would not absolutely require the discovery and development of additional fields. In this manner, the economic oil in the Amauligak field could be developed in a relatively low cost manner. Croasdale and McDougall (1992) also postulated a development scenario which saw this field tapped by a northern extension of the Norman Wells pipeline, one that would not only be less sensitive to the discovery of other fields, but which. would also act as the first step to a full-scale development of Beaufort reserves. For this analysis however, the tanker option was assessed for purposes of comparison with the previously discussed pipeline options.

7.3.1 Pre-Capacity Adjustment - Year 1

The capital investment time-line information for scenario 3 indicated that this project would require a period of 5 years to be developed (see table 6.3). For the first year of the project, the time-lines called for development drilling and gathering and production facility construction only (see table 6.3). As table 6.8 shows, this translated into a single final demand shock to sector 4 in the NWT in year 1. The

total, direct, indirect and induced impact patterns by region and by sector for year 1 are identical to those discussed for scenario 1, year 1, and as such these patterns were not included in the appendix. The interregional and intersectoral economic impacts of an isolated shock to sector 4 in the NWT have been discussed in detail above and to do so again here would be needlessly repetitive.

7.3.2 Capacity Adjustment - Year 2

The capital investment time-line information indicated that year 2 would see increased development drilling and gathering and production facility construction investment along with the beginning of the construction of one Arctic Class 2 Ice Breaking Tanker. It was assumed that only 1 additional tanker would need to be built to allow a production rate of 35,000 bpd, and that the tankers would be owned and operated by a third party. The tanker investment was allocated to commodity 23 (autos, trucks & other transportation eqpt.) in the NWT final demand vector, and the observed trade share matrix acted to allocate this to the NWT (3%), the western region (10%) and the central region (31%). In the central region, the sectoral share matrix indicated that this tanker related activity would be allocated to sector 5 (98%) with the remainder going to sector 7 (2%). In the remainder allocated to sector 7 (10%). Table 7.6 suggests that this investment plan for year 2 would result in the exceedance of capacity in sector 4 in the NWT

Table 7.6

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NWT Sectoral Capacity Adjustment Profile - Scenario #3

Sector	Cap. Adj. Yr.1	Cap. Adj. Yr.2	Cap. Adj. Yr.3	Cap. Adj. Yr.4	Cap. Adj. Yr.5
All Figures in Millions of 1984 Dollars					
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	86.7	0	0	0
5	0	0	0	0	0
6	0	0	0	0	0
7	0	0	0	0	D
8	0	0	0	0	0
9	0	0	0	0	0
10	0	0	0	0	0
11	0	0	0	0	0
12	0	0	0	0	0
13	0	0	0	0	0
14	0	0	0	0	0
15	0	0	0	0	٥
16	0	0	0	0	٥

by approximately \$87M. Therefore, a dynamic version of the model developed in chapter 5 was used to assess the interregional economic impacts of this investment plan.

As shown in table 6.8, the delta final demand vector for year 2 consisted of a \$253M shock to commodity 8 and a \$79M shock to commodity 23 with an investment term representing capacity augmentation in sector 4 in the NWT. Table 7.4 shows the commodity specific capital input requirements of sector 4 in the NWT. Figures 7.116, 7.117, 7.118 and 7.119 present the total, direct, indirect and induced impact patterns for year 2, and figures 7.120, 7.121, 7.122, and 7.123 present the total, direct, indirect, and induced effects associated with the expansion plan only. Relative to year 1, figure 7.116 indicates that, as with capacity adjustment years in previous scenarios, the addition of capacity in sector 4 in the NWT resulted in a substantial direct effect to sector 6 in the NWT since. as shown in table 7.4, sector 4 requires a significant input of construction activity to increase capacity. Comparison of figure 7.116 with the total impact pattern for year 2 in scenario 2 (figure 7.80) which was similar in every respect except for the commodity 23 shock for tanker construction, made clear the effect of tanker investment on the manufacturing sectors of the western and central regions. The same comparison also revealed that the western region, as a result of the tanker investment, generated more personal income (sector 17) relative to the central region and the NWT. Figures 7.117, 7.118, and 7.119 in combination with figures

7.46 to 7.51 suggest that the bulk of the sector 5 effects in the western region were direct, while in the central region the bulk of the sector 5 impact was accounted for by indirect and induced effects. These figures also showed that the sector 4 impacts in the central region were overwhelmingly direct, while in the western region indirect and induced effects accounted for a substantial share of the sector 4 impact.

Figure 7.35 shows that even in peak years, the total impacts in all regions were less than half as large as they were in scenario 2 (compare to figure 7.18). The combination of investment and expansion plans in year 2 resulted in a significant increase in the level of the total impacts in all regions. Relative to scenarios 1 and 2 however, the total impact exhibited by the central region was much closer to that exhibited by the NWT in the peak period. This was directly attributable to the fact no pipeline construction activity was called for in scenario 3. The pipeline construction phase in the earlier scenarios acted to significantly inflate the total impacts in the NWT, and since none of this activity resulted in direct shocks to other regions, it acted to greatly increase the gap between the total impacts experienced in the NWT, and those experienced by the western and central regions. Figure 7.36 confirms this fact by showing that in year 2, the peak year in scenario 3, the central region captured a larger share of the system-wide total impact than the NWT did. Comparison with the same figure for scenario 2 (figure 7.19) reveals that during the peak period, the NWT's share increased

substantially over the central regions' share, and the central region did not gain a larger share until the end of the pipeline construction phase in year 7.

In terms of personal income effects, the central region generated more than any other region, followed by the NWT, and the western region. The previously noted relative increase in the level of personal income generated in the western region was born out in figure 7.38 which confirms that the western region gained a slightly larger share of the system-wide personal income effect in year 2 as a result of the combination of the expansion plan and the tanker investment which was allocated to the western region. The central region however, retained the greatest share over the entire development period, but in year 2, it experienced a substantial gain to the detriment of the NWT. It is interesting to note that in year 4, the first year after the cessation of all tanker investments, the NWT regained it's year 1 share largely to the detriment of the central region. The fact that the western region's share did not decline substantially after the tanker investment ceased suggests that the slight increase in this regions' share in year 2 was the direct result of the expansion plan in the NWT. Figure 7.39 suggests that the expansion plan in the NWT, which resulted in significant manufacturing activity in the western and central regions (which was augmented in the case of the western region by the structure of the modified trade share matrix), acted to significantly reduce the relative importance of personal income effects in the NWT to the benefit of the western region. The fact that the relative importance of the personal

income effects also declined in the central region in years 2 and 3 (years of tanker investment) suggests that the total impacts grew at a faster rate than did personal income with the addition of these manufacturing sector impacts.

Figure 7.41 indicates that the central region's share of the system-wide direct effect increased noticeably in year 2 to the detriment of the NWT and the western region. The fact that the central region's share continued to increase until the cessation of tanker investment suggests that the direct effects associated with this activity in the central region caused this increase. Figure 7.43 indicates that in year 2, the western region and the NWT experienced an increasing share of the system-wide indirect effect to the detriment of the central region. Figure 7.42 suggests that the relative importance of indirect effects increase in year 2. As for induced effects, figure 7.45 shows that, like previous scenarios, the central region captured the bulk of all induced effects (over 50%) and that it's share increased steadily until the tanker investment phase ended. The shares held by all regions remained fairly stable over all years as they did in previous scenarios.

7.3.3 Post-Capacity Adjustment Years - 3, 4 & 5

In the years following the peak year, table 6.3 suggests that the investment plans began to decline steadily as the project was nearing completion. The authors of the scenario indicated the project is nearly complete by the end of year

3 and that production would begin in year 4 at the desired rate (35,000 bpd). For year 3, the time-line information (see table 6.3) indicated that the level of investment in gathering and production facility construction was beginning to decline as was the investment in tanker construction. The capacity adjustment model indicated that all investment plans for the remaining years could be accommodated without the need for capacity adjustment in the NWT (see table 7.6). The total, direct, indirect and induced impact patterns for year 3 are presented in figures 7.124 to 7.127. Years 4 and 5 were characterized by delta investment vectors with a single shock to sector 4. Since the pattern of impacts for such an investment plan has been discussed earlier, these years will not be discussed at length here, and the impact patterns for these years were not included in the appendix.

The effect of the cessation of expansion activity in the NWT in year 3 was clearly visible in the lack of a substantial sector 6 impact in the NWT, along with a significant drop in the relative magnitude of the sector 5 impact in the western and central regions (see figure 7.124). By year 4, the effect of the cessation of tanker investment, which was split between the western and central regions (10% and 31% respectively), was evident in the substantially reduced sector 5 impacts in these regions (see figure 7.124). The effect of the concurrent cessation of all development drilling was evident in the reduced sector 4 impact in the NWT, as well as in the proportionate drop in the total sector 4 impacts in the western and

central regions. After year 3, the facility was largely completed and operating at capacity. The investments in years 4 and 5 were consisted of relatively small investments in gathering and production facility construction and development drilling respectively. Figure 7.35 shows that by year 3, with the cessation of the expansion phase, the central region exhibited the largest total impact, followed by the NWT and the western region. By year 5, with the cessation of all tanker investment, and with significantly less sector 4 investment in the NWT, the total impacts exhibited by all regions declined substantially.

7.3.4 Discussion of Scenario 3 Results

Scenario 3, as mentioned above, represents a significant departure from scenarios 1 and 2 in that it focussed on a relatively low cost tanker based development of the Beaufort Sea Amauligak field. The fact that this represented a significant departure from earlier scenarios was evidenced primarily by the fact that the economic benefits to the NWT, and to all other regions, were substantially reduced relative to earlier scenarios, due to the lack of pipeline construction activity which is the only type of activity that would be captured 100% by the NWT. Without this pipeline activity, the personal income effects in the NWT, along with the associated induced effects, were significantly reduced. This option clearly may be optimal from the stand point of oil companies given the fact that the sunk costs involved are quite low (relatively speaking) and the fact that the favourable

economics of the project are not dependent on the discovery of additional reserves, which significantly lessens the risk involved with such a project. From the Territorial point of view however, this type of development would see the Federal Government and the oil companies extract significant value from the region with an absolute minimum of economic benefit remaining in the NWT, and, as such, this development option would be the least desirable. As mentioned earlier, the authors of these scenarios proposed a small pipeline scenario with an identical cost structure. They noted that such an option would still represent a least cost option for the oil companies, but it would allow for more economic benefit in the NWT. If such a project were to act as a staging point for an era of oil activity in the Beaufort Sea then such an option would be beneficial to all parties. Viewed in such a manner, this type of project would be beneficial in that it would gradually turn attention to the region, and facilitate future developments by virtue of the fact that much of the necessary physical and institutional infrastructure would be in place.

7.4 Discussion of Assessment Results

The previous pages have presented the results of an assessment of the interregional economic impacts associated with three distinct oil development options for the NWT. These scenarios were provided by 2 specialists in the engineering-economics of Arctic oil and gas projects, and they represent the most



Figure 7.35


Figure 7.36



Total Personal Income Earned Scenario 3

Figure 7.37



Regional Share of the Total Personal Income Effect: Scenario #3

Figure 7.38



Personal Income Effects as a Percentage of the Total Effect: Scenario #3

Figure 7.39



Direct Impacts as a Percentage of Total Impacts: Scenario #3

Figure 7.40



Figure 7.41



Figure 7.42



Figure 7.43



Figure 7.44



Figure 7.45



Figure 7.46



Mines, Quarries & Oil Wells Impacts Western Region: Scenario 3



Figure 7.48



Figure 7.49



Figure 7.50



Figure 7.51

current and respected opinion with regard to how the oil reserves of the Canadian Arctic could be developed. While these specialists (Croasdale and McDougall, 1992) postulated a number of scenarios that were not considered in this analysis, this subset represented three distinct types of projects that could occur in the NWT given current economic and technological conditions. In many cases, the economics of certain projects relied on the assumption that further reserves would be discovered during the life of the project, and given the size of the region and the favourable exploration results of the 1970s and 1980s, the probability of such additional reserves being found is considered to be high. The main factor influencing the probability of Arctic Oil being developed is not just the international price of oil, but rather the variance around the average yearly price. Oil companies have evolved over the past 3 decades to the point where they necessarily focus on short-term costs and profits. Given such an attitude, the price of oil would not only have to be considerably higher than the required prices for each of the developments discussed above, but this price would have to be perceived as stable at high levels for such Frontier projects to proceed. Therefore, in the absence of a Federal imperative to develop Frontier reserves to guarantee the supply of sovereign oil and gas, the likelihood of such projects taking hold in the present economic climate is not high.

The analysis was instructive however in that it clearly showed what types of developments would serve various objectives. As noted, from a territorial point

of view, a full blown Mackenzie Valley Pipeline development with large scale operations in the Beaufort would be desirable since such a project stands to have the greatest economic impact on the NWT. Such a project would also decrease the cost of marginal additions to the Beaufort Sea operation. The primary ingredient for ensuring large scale economic benefits in the NWT, based on the analyses conducted above, is pipeline construction activity. This is the only sort of economic activity generated by the various projects which stays largely in the NWT. The fact remains that the NWT's economic structure is such that the potential for generating a period of long term growth and development in the aftermath of such activity is low. The fact that all projects call for substantial additions to the NWT's capital stock base is encouraging and, as mentioned above, this could lead to continued resource activity in the region, and thereby contribute to some sort of longer-term economic benefit for the NWT.

The nature of the economic impacts exhibited by the western and central regions, were quite distinct. As discussed above, these two regions continually behaved in markedly different ways to identical final demand shocks in the NWT. The western region's manufacturing sector appeared to be very sensitive in a direct way to increased sector 4 activity in the NWT, with the indirect and induced effects of this activity accounting for less than 40% of the total impact exhibited by sector 5 in the western region. In the central region, the manufacturing sector was also sensitive to sector 4 activity in the NWT, but the bulk of the total effect

exhibited by sector 5 in the central region was accounted for by indirect and induced effects. Such a fundamental difference suggested that these two sectors, while both classified as manufacturing sectors, were quite different. The fact that the manufacturing sectors of Alberta and British Columbia, by virtue of a comparative advantage in renewable and non-renewable resources, are primarily focussed on processing primary materials (lumber, coal, oil, gas, fish, etc.) accounts for this finding. The refining bias of these economies also suggests that they would be more likely to be affected in a direct manner. The fact that the bulk of the total impacts exhibited by the manufacturing sector in the central region were accounted for indirect and induced effects speaks to the fact that the manufacturing base in Ontario and Quebec is more diversified and primarily engaged in the production of secondary manufactured goods (steel, automobiles, trucks, pipe, etc.). The fact that nearly 90% of the total impacts in the NWT were direct, in all years, suggests that this region is also oriented to the extraction and processing of renewable and non-renewable resources. In the case of the NWT however, the sheer lack of indirect and induced effects, relative to the western and central regions, was due to the immaturity of this economy. It is this lack of indirect and induced effects in the NWT which makes it a dependent region in Canada - one which relies extensively on imports from all other regions of Canada while exporting relatively low value goods - and it is this lack of a diversified economic structure which could cause the benefits associated with any oil

development project to quickly "slip through the hands" of the NWT.

The fact that the total impacts experienced by the NWT in the previous analysis accounted for a maximum of 37% of the total output of the NWT in 1984, while those experienced by the western and central regions accounted for a maximum of 0.5% of the total output in each of these regions, supports this view of the NWT undergoing another boom-bust cycle of economic growth and decline in the aftermath of such projects. This prospectus changes somewhat when the ramifications of land claim settlements and a Northern Accord are considered. A fundamental reason for the continued pressure for land claim settlements by various Aboriginal groups, and for continued negotiations on a Northern Accord between the GNWT and the Government of Canada, is this issue of benefit retention. A good example of this is the Inuvialuit Development Corporation (IDC) which represents the constructive use of proceeds from the settlement of the Inuvialuit Land Claim (more than \$50M was awarded to the Inuvialuit people). Specifically, the IDC represents a corporation formed by the Inuvialuit people of the NWT to establish a stable, long-term economic base from which the people of the region can contribute to and benefit from the regional and national economies (Bone, 1992). The IDC's plan is to accomplish this through the efficient deployment of it's assets. This deployment consists of partial or whole ownership of many northern and southern enterprises such as major ground, water, and air transportation firms, drilling contracting companies, real estate companies (in the NWT and British Columbia), construction companies, surveying companies, environmental services companies, and manufacturing firms in Alberta and British Columbia etc. Clearly, if such companies are owned and operated by Northerners, then the prospects for longer term economic benefits accruing to the NWT as a result of the aforementioned oil developments appear much improved. Also, a Northern Accord which would give the GNWT Province-like powers over the ownership of it's renewable and non-renewable resources, could only act to enhance the prospect for long term economic benefits in the NWT in the aftermath of any of the aforementioned oil development projects.

While useful information was undoubtedly generated by this analysis, this successful application immediately begs the availability of more disaggregate I-O data, along with more detailed information on what types of capital are required by sectors in the NWT for expansion and how this is integrated with existing capital stocks. Chapter 8 will discuss these issues in more detail and offer suggestions for refinements of this approach. While the results discussed above were difficult to present and even more difficult to discuss in a detailed fashion, this application represents a significant improvement over the static MRIO approach to assessing the interregional economic impacts of large scale capital intensive projects, especially when such projects are to be undertaken in small underdeveloped regions like the NWT.

ENDNOTES

1. The scenarios offered by Croasdale and McDougall (1992) have been found to be economic given current economic and technological conditions. In fact, the express purpose of their report was to highlight economically feasible options for the development of Frontier reserves.

2. Canada's Frontier Lands are defined as all acreage which lies offshore under Canadian jurisdiction as well as all Territorial acreage.

3. GNWT Bureau of Statistics Statistician, Mr. Roy Ellis indicated that Statistics Canada requires that all construction activities in any Province or Territory be allocated entirely to production in the in which it takes place, with no interregional trade in construction. They referred to this as a "work in place" convention.

4. The capital input matrix for the NWT revealed that sectors 4 and 6 drew heavily from sector 6 on capital account in 1984.

5. As discussed in chapter 5, when the capacity adjustment vector portion of the investment term becomes zero, the model defaults to a standard static MRIO model.

6. The land claims that have settled in the NWT do give considerable power to Aboriginal groups holding a claim to extract significant revenues from exploration, development and production activities which take place on their land. See Bone (1992) for a discussion of the past present and future of land claim negotiations in the NWT.

7. Croasdale and McDougall (1992) noted that the base-case economics for these projects were very sensitive to pipeline tariffs, and that these tariffs were very sensitive to pipeline throughput. If flow rates declined below those specified, the pipeline tariffs would significantly add to the per barrel oil price required to make each project feasible. This sensitivity and the concomitant reliance on continued discoveries seriously curtails the attractiveness of pipelines except in most stable of situations (i.e., the huge reserves of Alaska's North Slope).

Chapter 8

Discussion and Conclusions

8.0 Introduction

This dissertation has sought to both develop and apply a novel impact assessment framework to the task of assessing how a set of Arctic Oil development scenarios could affect the economies of the Northwest Territories (NWT) and the remaining regions of Canada. The model developed in chapter 5 was motivated by the desire to create an assessment tool which could represent the interdependent nature of the Provinces and Territories of Canada while also capturing the effects associated with capacity expansion in the NWT. That is, as noted in the introduction to chapter 5, large scale projects such as the Arctic Oil development scenarios discussed in chapter 3 would affect the economy of the NWT, and by extension the economies of all other regions of Canada, in two main ways. Firstly, the investment expenditures associated with such projects would have a significant effect on sectors in the NWT, even though a significant portion of these expenditures would leak to sectors in other regions. Secondly, and more importantly, these investment expenditures would cause the capacities of certain NWT sectors to be exceeded, and thereby cause capacity expansion investment in the NWT. A static Multiregional Input-Output (MRIO) model would not take this capacity exceedance into consideration, and would therefore generate NWT specific output impacts which, in some cases, would not be possible given existing capacity in the NWT. The extended dynamic MRIO model derived in chapter 5 represents a clear advance over the static MRIO model by virtue of the fact that it is able to simultaneously accommodate both the interregional interdependencies and expansion investment. The results discussed in chapter 7 were also made more credible due to extensive cooperation by the Government of the NWT Bureau of Statistics, as well as by Croasdale and McDougall (the creators of the scenarios discussed in chapter 3), in translating each of the generic scenarios described above into investment vectors which served to drive the assessment. While the model developed in chapter 5 does not represent the first attempt to blend the desirable features of the MRIO approach with those of the Dynamic I-O model, it does represent the first attempt to imbed Duchin and Szylds' reformulation of Leontief's dynamic model within a rectangular MRIO framework. Not only were Duchin's hopes of allowing the dynamic model to be useful in applied work realized here, but the utility of the approach was enhanced by allowing for the simultaneous endogenization of interregional trade flows.

This final chapter will briefly discuss the results presented in chapter 7, as well as the limitations of the approach taken. Following this, suggestions for future refinements will be made. The chapter ends with a discussion of

geopolitical change in the NWT and how such changes could affect the analysis.

8.1 Comparison of Results Across Scenarios

The scenarios evaluated in chapter 7 represent 3 distinct options for the exploitation of the Beaufort Sea Oil reserves. The first scenario focusses on the onshore reserves of the Mackenzie Delta and the offshore reserves of the shallow Beaufort Sea surrounding Richards Island in the Mackenzie Delta region. Specifically, scenario 1 called for a northern extension of the existing Norman Wells Pipeline from Norman Wells to Richards Island. Scenario 2 focusses on the 350M Bbl. field located in the deeper Beaufort Sea, and represents one of largest Arctic Oil development options currently under consideration. Specifically, scenario 2 called for large scale offshore platforms and a dedicated large diameter pipeline running from Richards Island, through the Mackenzie Valley, to a southerm terminus in Alberta. Scenario 3 also focusses on the 350 Bbl. offshore field, but with the use of tankers in place of a pipeline to transport oil to southerm markets.

The results discussed in chapter 7 indicate that the magnitude of the interregional economic impacts associated with each scenario varied considerably. Scenario 2 called for investment expenditures and capacity expansion investments which were far larger and more extensive than those associated with scenarios 1 and 3. The pipeline construction investments called for in scenarios 1 and 2 significantly increased the relative magnitudes of the total

impacts experienced in the NWT. In fact, in scenario 3 where no pipeline construction investment was required, the total impacts in the NWT were barely greater than those in the central region. A comparison of the total impact summary figures (figures 7.1, 7.18, and 7.35) with the capital investment time-lines for these projects (tables 6.1, 6.2 and 6.3), suggests that the years which contain pipeline construction investments coincide with those years when the difference between the total impacts experienced by the NWT and those experienced by the central and western regions are the greatest. Even in year 2 of scenario 3, a year of significant capacity expansion in the NWT, the total impact in the NWT was just barely greater than the total impact in the central region. This is consistent with the NWT's history with large scale resource projects where the majority of the territorial economic benefit came about as a result of the associated construction activity.

This analysis also revealed some interesting structural peculiarities in the 1984 I-O data with which the model was implemented. Firstly, the manufacturing sector in the western region exhibited a strong direct effect in response to any primary sector (sector 4 - Mines, Quarries, & Oil Wells) investment in the NWT. That is, drilling activity in the NWT for example, resulted in a strong direct effect in the manufacturing sector of the western region. The indirect and induced effects exhibited by this sector were significant but certainly smaller than the direct effects. The manufacturing sector in the central region however, while also

strongly affected by drilling activity in the NWT, exhibited a smaller direct effect and larger indirect and induced effects as a result. Also, the primary sector (sector 4) in the western region exhibited significant indirect and induced effects while the primary sector impacts in the central region were largely direct. As discussed in chapter 7, these distinct impact patterns suggest a fundamental structural difference between these 2 sectors in these 2 regions. That is, the manufacturing sector in the central region appears to be more diverse (and hence mature), while the manufacturing sector in the western region displayed a definite resource processing focus. Likewise, the primary sector in the western region appears to be much more responsive to the direct, indirect and induced effects associated with drilling activity in the NWT relative to the same sector in the central region.

Of the 3 scenarios considered, scenario 2 undoubtedly represents the most desirable option from the point of view of the NWT, given that environmental concerns related to such a large pipeline could be adequately addressed. This scenario results in the greatest economic impact to the NWT in terms of total effects, personal income effects and in terms of the amount of capacity which would have to be added to the NWT economy. The tanker option, while clearly the cheapest option, would likely receive the greatest opposition from territorial interest groups, both because of its lower economic impact and the potential for disruption in the event of a tanker accident. While Croasdale and McDougall

(1992) note that the bulk of the World's oil is moved by tankers, the likelihood of such an option being approved for the Beaufort Sea reserves would be small. The most likely scenario, combining the interests of the GNWT, Aboriginal groups in the NWT, and the oil industry, would be some variation of scenario 1. That is, a small pipeline could be built to tap the Amauligak field, and in the course of its productive life, the smaller offshore fields along with the small onshore fields could eventually be tied in to maintain a low pipeline tariff. The industry view, as espoused by Croasdale and McDougall (1992) is consistent with this phased approach to the development of these reserves, as opposed to the building of a huge project initially. This incremental approach would keep costs relatively low and significantly reduce the risk to the oil companies in terms of sunk costs, while at the same time avoiding the possibility of a tanker accident which would create unprecedented ecological and social devastation.¹

8.2 Limitations and Possible Refinements

The I-O data upon which this analysis is based, as mentioned earlier, is very aggregate both in terms of sectors and in terms of commodities. This meant that the investment expenditure profiles for each scenario had to be aggregated to match this level of sectoral detail and, as such, the expenditures required for each scenario were allocated to 4 commodity groups. While differences between scenarios and across years for each scenario were observed in chapter 7, the true

extent to which each of these scenarios would have differed in terms of their interregional economic impacts was blurred by this aggregate data. Clearly, one possible refinement would be to conduct this analysis with disaggregate I-O data.

Aggregation issues not withstanding, the extended dynamic MRIO model developed in chapter 5 represents a significant improvement over conventional approaches for assessing the interregional economic impacts of capital intensive projects. As mentioned, this model represents a hybrid formed by arouping the desirable features of the classic MRIO model with those of a reformulated dynamic I-O model. The reformulated dynamic I-O model upon which the investment term used above is based included a routine for the endogenous generation of capacity adjustment information, and in this way the model truly endogenized investment in a manner which is conceptually similar to the classic Leontief dynamic I-O model. The approach adopted here however superseded this capacity adjustment routine with a set of exogenously specified scenarios which, along with potential output figures for all NWT sectors, provided the capacity adjustment vectors used to drive the model in capacity adjustment years. This scenario approach has many benefits over the somewhat "ad-hoc" equations postulated by Duchin and Szyld (1985). In this fashion however, expansion investment is no longer purely endogenous since the model itself does not generate the adjustment vector. That is, when a final demand vector is removed from the final demand matrix in any endogenization procedure, it is usually

replaced by modifications to the commodity balance equations, based on theory, which make this dependent on the level of output being generated in the system. In this case, the final demand vector was removed, but the expansion investments were not represented in commodity balance equations by a functional relationship with gross output. Instead, the investment term was added to the right (exogenous) side of the commodity balance equation to represent an additional use of commodities, but it was not functionally tied to sectoral output levels. The result is a model which does not truly endogenize investment. As discussed in chapter 5 however, to the extent that endogenous investment can be defined as that investment which is related to sectoral output demands, then the investment term built into the commodity balance equations approximates truly endogenous investment, as distinct from exogenous investment which is in no way influenced by sectoral output levels in an economy, but rather is the result of external factors (e.g., an oil companys' decision to invest in drilling activity in the NWT is not dependent on the demands for sectoral outputs in the NWT). The scenario driven Duchin and Szyld approach does however offer an empirically tractable form of the dynamic I-O model which distinguishes between these two types of investment activity.

The approach taken here is also subject to the standard criticisms of I-O analysis. That is, the technical coefficients and trade shares upon which the model is based are invariant with respect to time, relative price changes in inputs,

and output levels in all sectors. This means that, like any I-O analysis, this analysis involves the implicit assumption that constant returns to scale prevail, and that technological change is assumed to be non-existent. The fact that this analysis was based on data for 1984 exacerbates the concern over using this approach to assess economic impacts over time. The results presented above therefore can be interpreted only as one possible picture of how such projects will actually affect the NWT and the remaining regions of Canada.

The quality of the results however was significantly enhanced by the provision of expert information both from the GNWT Bureau of Statistics and from Croasdale and McDougall (the authors of the scenarios). The detailed expenditure data provided by Croasdale and McDougall and the commodity allocations conducted by the GNWT Bureau of Statistics allowed this analysis to be based on a realistic portrayal of how such investments would enter the NWT.

The high degree of sectoral aggregation also affected the capacity adjustment analysis. In each case, these calculations were based on the potential output of a sector which subsumes all mining and oil and gas activities (sector 4). As such, the capacity reflected by these figures could not accurately reflect the true capacity in the NWT for exploratory drilling for example. If more disaggregate I-O data was available, the investment time-lines could be translated into much finer commodity classifications resulting in a clearer picture of how the capacities of NWT oil and gas related sectors would be affected. Specifically, given a finer

degree of sectoral detail, more NWT sectors would need to experience capacity expansion as a result of the investment plans for the scenarios evaluated above.

The Duchin and Szyld (1985) investment term allows for the fact that certain capital goods purchased for expansion may require more than one period before they could add to the effective capacity of the investing sector implying that such expansions would have to be planned a certain number of periods in advance. In this dissertation it was assumed, in lieu of better information, that expansion capital could be purchased, produced and integrated with existing stock in one period, as the Leontief dynamic model did. Given more disaggregate I-O data, precise information regarding the capital requirements for expansion in each sector and the lag times associated with the integration of this capital would allow for a more accurate reflection of the timing of the impacts.

The model used above was also closed to personal consumption and, as a result, the model was able to generate personal income effects in response to any final demand vector based on labour income and revenues earned by unincorporated business enterprises. The analysis could be extended to provide an occupationally specific impact pattern. Such an occupationally specific output format was used by Leontief and Duchin (1986) in assessing the effects of automation on the American work force.

8.3 Geopolitical Change in the NWT and Implications for the Analysis

The NWT can be best described as a resource hinterland. That is, the economy of the region is driven primarily by the international business cycle and the concomitant international demand for primary materials. Like other hinterlands, the future course of economic development in the NWT has little to do with the objectives of Northerners and everything to do with investment decisions made by Canadian and multinational corporations. The regions' relative inaccessibility and harsh climate combined with its small and dispersed internal market have hindered the evolution of this staple economy into a more diversified form focussed on secondary activities. Much of the Northern Development literature deals with the inability of this regional economy to diversify (Bone, 1984; Nassichuk, 1987; Quigley and McBride, 1987; Abele, 1987; Pretes, 1988; Huskey and Morehouse, 1992; Bone, 1992). It is precisely this lack of economic diversification which makes the NWT unable to capture any long-term economic benefit from projects aimed at exploiting its natural resource endowment. The regions' apparent inability to use its resource endowment to secure long-term economic good fortune for its residents is exacerbated by the fact that the bulk of the regions' population does not have the skills required to partake in many of the long term employment opportunities which accompany resource development. As a result of these factors, the NWT's past experience with resource activity has been one of short lived economic benefit, and long term economic hardship augmented by the fact that most projects irrevocably change the environment on

which traditional Aboriginal life is based. Bone (1992) and others have noted that the prospects for a diversified NWT economy, even in the wake of Beaufort Sea oil and gas operations, are not good.

While diversification may be too much to hope for in the NWT given the factors discussed above, Bone (1992) and others note that 2 concurrent forces could alter the way the NWT takes part in such projects in the future and benefits from them. Specifically, over the past 17 years since the Berger Inquiry, the issue of benefit retention in the North has gained importance both nationally and internationally, and negotiations for a Northern Accord between the GNWT and the Government of Canada, and the settlement of Comprehensive Land Claims typify this concern on behalf of the Government of Canada. These concurrent processes of geopolitical change could allow the NWT to take on a greater role in the development of its resource base, and derive royalty and taxation revenue from such activities. These changes could allow the NWT to retain some long-term economic benefit from the exploitation of its natural resource base.

Specifically, the Northern Accord would see the devolution of control over all onshore resources, and a portion of the offshore resources from the federal government to the GNWT. Such a devolution of powers would bring the NWT one step closer to Province-hood. Bone (1992) notes that Beaufort Sea oil and gas projects could trigger an economic boom in the NWT, under such a regime, which would generate significant resource royalties for the GNWT. In terms of the

results discussed above, such a devolution of powers would not alter the fact that a significant amount of the economic activity associated with such projects would leak out of the region, but it would shield the NWT, to some extent, from the boom-bust cycle of growth and decline alluded to earlier. Royalty and taxation revenues could be re-spent by the GNWT and thereby generate larger induced effects in the region as a result. The GNWT could also use some of this revenue to enhance the skills of Northerners preparing them to take advantage of some of the longer-term employment opportunities which would accompany such resource projects. In its current form however, the Northern Accord specifies that the federal government would scale back transfers proportionately with resource revenues. Many GNWT sources note that, in the short term at least, this would leave the NWT in a poorer financial position.² This issue of transfers is the main reason why this Accord has yet to be signed.

Comprehensive Land Claim settlements with Aboriginal groups is another manifestation of this heightened concern. The settlement reached with the James Bay Cree and Inuit peoples in 1975, and the Western Arctic Claim settlement with the Inuvialuit in 1984 are the most noteworthy to date. The James Bay Agreement called for \$225M to be paid to the Cree and Inuit people over a 10 year period, outright ownership of 13,300 km², and exclusive hunting rights over 155,000 km² (Bone, 1992). The Western Arctic Agreement called for \$45M to be paid to the Inuvialuit people, title to 11,000 km², exclusive hunting rights over 78,000 km², and

rights to sand and gravel (Bone, 1992). In each of these cases, the capital infusions were used to form Native Organizations which took on the responsibility of securing a future for their people. Specifically, the Inuvialuit Development Corporation used some of the cash from their settlement to acquire controlling interests in many strategic aspects of the Northern and southern economies. In the North, these investments included purchases of drilling contracting firms, surveying firms, ground, air and water transportation companies, real estate companies etc. Clearly, the Inuvialuit Development Corporations' objective was to take an active role in the Northern economy. Bone (1992) notes that many of the investment activities undertaken by the Inuvialuit represent training exercises which will allow the people of this region to be ready to take an active role in the development of the Beaufort Sea oil and gas operations. The apparent success of the Inuvialuit Comprehensive Land Claim settlement, and the fact that several remaining claims should be settled in a similar manner over the next decade, suggests that the people of the NWT will be in a better position to actively participate in and benefit from the next wave of large scale resource activity in the NWT.

The fact that Comprehensive Land Claim settlements and a Northern Accord could act to significantly increase the benefits to the NWT in response to the types of projects evaluated in chapter 7 is acknowledged. If these forces acted to decrease the amount of exploration crews imported from Alberta for
example, then these effects could be represented in the analysis by modifying the interregional trade share matrix. Likewise, the effects of some subtle diversification in the NWT, as a result of increased GNWT revenues (e.g., increased resource processing activity), could be represented by altered technical coefficients since such a change would represent a new input mix for the output of the GNWT sector selling processed natural resources. So a detailed analysis of exactly how these geopolitical reconfigurations in the NWT could affect the interregional backward linkage pattern of the NWT would provide useful information for conducting a sensitivity analysis for the results generated herein. My post-doctoral work, which has been funded by the Social Sciences and Humanities Research Council of Canada, will deal with such issues, and summer work with GNWT Bureau of Statistics in Yellowknife should provide some interesting insight into how such changes could alter the way the NWT would be affected by large scale resource projects (as well as access to disaggregate I-O data for the NWT and the remaining regions of Canada).

In any event, the changing geopolitical structure of the NWT could act to allow the region to both have more control over the scope and timing of resource developments, and to retain long-term economic benefits in the wake of the types of projects evaluated in chapter 7. Not only would increased participation of Northerners in the actual operation of these developments increase the benefit to the NWT, but the concomitant taxation and royalty revenues from these resources

would represent long-term economic benefits for the NWT. So, while a diversified NWT economy which captures many of the linkages to southern Canada may not be a realistic scenario, these geopolitical changes could act to lessen the regions' vulnerability to the boom-bust cycle of economic development which characterizes staple economies.

8.4 Conclusions

The previously discussed limitations and refinements aside, the approach developed herein represents a significant improvement over either of the parent approaches to the task of assessing the interregional economic impacts of capital intensive projects on a regional economy. The results presented in chapter 7 represent one useful picture of how Arctic Oil projects could affect the economies of the NWT and the rest of Canada. The fact that the usefulness of these results could only be enhanced with more disaggregate I-O data is acknowledged. These results, taken alone do not portray an optimistic picture for the future of the NWT. That is, in the absence of benefit retention mechanisms, the NWT would undoubtedly experience another boom-bust cycle of economic growth and decline in the aftermath of such developments. Past, present and ongoing geopolitical changes in the NWT however suggest that when these Arctic reserves are targeted, the NWT may be better able to capture long term economic benefits. This dissertation therefore, represents the first step of an ongoing research

agenda which aims to not only understand how the NWT, and the rest of Canada, could be affected by resource projects in the NWT, but more importantly how geopolitical change in the NWT could affect the structure of the regional economy, and its trading relationships with the remaining regions of Canada.

ENDNOTES

1. While large tanker accidents have been witnessed in the past and the damage caused was certainly grotesque, a tanker spill in ice covered waters represents an absolute worst case scenario for environmental and social damage. This is primarily due to the fact that oil beneath ice could not be reclaimed and the ecosystems of the Arctic environment, by virtue of a short growing season, are very vulnerable to ecosystem changes. An oil spill could devastate the food source for all Arctic mammals, including Humans.

2. That is, currently each dollar of transfers from the federal government costs relatively little in terms of administration. However, if for every dollar of resource revenue the NWT lost one dollar of transfers, the additional administration cost would result in a net loss for the NWT. This of course does not take into consideration the long-term benefits accruing from increased autonomy.

Graph Appendix

Sector and Region Specific Impact Patterns

(Figures 7.52 to 7.127 - Referred to in Chapter 7)



Figure 7.52



Figure 7.53



Indirect Effects by Region Scenario #1, Year #1

Figure 7.54





Figure 7.56



Figure 7.57





Induced Effects by Region Scenario #1, Year #3

Figure 7.59



Figure 7.60



Figure 7.61



Figure 7.62



Figure 7.63



Figure 7.64





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Figure 7.66



Figure 7.67



Figure 7.68



Figure 7.69



Figure 7.70





Figure 7.72





Figure 7.74





Figure 7.76



Figure 7.77





Figure 7.79



Figure 7.80



Figure 7.81



Figure 7.82


Figure 7.83



Figure 7.84



Figure 7.85



Figure 7.86



Figure 7.87



Figure 7.88



Figure 7.89



Figure 7.90

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Figure 7.92





Figure 7.94



Figure 7.95





Figure 7.97



Figure 7.98



Figure 7.99





Figure 7.100



Figure 7.101



Figure 7.102



Figure 7.103





Figure 7.105



Figure 7.106



Figure 7.107



Figure 7.108



Figure 7.109



Figure 7.110

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Figure 7.112



Figure 7.113





Figure 7.115



Figure 7.116



Figure 7.117



Figure 7.118


Figure 7.119



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Figure 7.120



Figure 7.121



Figure 7.122



Figure 7.123



Figure 7.124



Figure 7.125



Figure 7.126



Figure 7.127

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