Energy and Manufacturing in Manitoba

A Report of the Economic Development Advisory Board April 1978

PREFACE

Until recently society operated under the assumption energy resources were unlimited. Then in 1973 the cost of energy, which for many years had declined relative to other resources, rose sharply, causing widespread economic dislocation. Many of the current economic problems faced by the Canadian and Manitoba economies can be traced, in part, to the fundamental changes in the cost and availability of energy resources.

The energy crisis, aside from imposing new imperatives upon business and government, also highlights our ignorance of the role energy plays in economic welfare. Although the initial predictions of widespread and severe depression have proved to be premature and alarmist, energy supply security is essential for economic activity, especially industrial growth. While it is true that the economy displays an inherent resilience to structural changes such as energy price inflation, it is also critical that government monitor the impact such changes have upon economic activity and particularly the viability of the small indigenous enterprise.

I am pleased to see published this final report by the Economic Development Advisory Board. It is a useful contribution to the ongoing activity by the government to formulate an energy policy that encourages the economic welfare of Manitobans.

R.D."Bob" Banman
Minister
Industry and Commerce

FOREWORD

During the past few years the attitude of government and the population has profoundly shifted from a belief the public sector ought to actively manage the economy to a perception that greater reliance upon private enterprise is necessary to promote the economic well being of Manitobans. The change is characteristic not only of Manitoba, but is pervasive throughout North America. As government responds to these political imperatives, it is inevitable that public programs are rationalized to better allow the public service to fulfill these new obligations.

The Economic Development Advisory Board (EDAB), created in 1969 to assist in policy formulation and to provide a link between the private and public sectors, will be discontinued this fiscal year as part of this rationalization. It should be stressed that the activities of research and policy formulation with respect to economic development will not be forsaken by the government; increasingly economies are to be sought by incorporating these activities into existing government departments.

This report, Energy and Manufacturing in Manitoba will be the last report of EDAB. Certainly this is a topical issue but as indicated in the text it is easy to lose sight of the essential questions. The forecasts of doom and gloom have not materialized and in the short run - say ten years-there appears to be no need for radical and draconian conservation measures at the provincial level. In the longer run though, all but the chronically myopic agree that government must intercede to ensure energy supply security. As the report notes, there are comparatively few degrees

of freedom for the government to develop broad brush energy policies significantly divergent from the measures taken in other provinces and the nation. The only energy which the province does supply, and hereto this has been a comparatively inexpensive form of energy, is hydro electric power. Recent events indicate that the price of hydro is going to rise dramatically in the near future; the government ought to ensure that this price truly reflects the social cost involved in producing this energy. The report argues for a system of marginal cost or peak load prices to ensure the optimum use of present and future infrastructure. There is little doubt that such policies have the potential for substantial dislocation of certain income groups and sizes of firms and careful implementation is needed. It is felt, however, that there are substantial long term benefits to all Manitobans from a rate structure that encourages rational use of the existing hydro capacity and delays the costly exploitation of the northern river system or even nuclear technology. More research is critically needed and the government is strongly encouraged to pursue this area.

This research was conceived and implemented by Dr. Greg Mason of the Department of Economics at the University of Manitoba. For the initial phases of data collection he was ably assisted by Mr. George Manning. Finally, Mrs. Edna Magel provided expert and cheerful editorial assistance throughout the project and considerably contributed to its successful conclusion.

In closing I would like to express my appreciation for having been granted the opportunity to work as Chairman of the Board for the past four years. Also my sincere thanks to the many board members and staff who have so ably and freely given of their time and effort during this period.

L. Remis
Chairman

Acknowledgements

The preparation of reports such as this requires the cooperation of many who too often go unnoticed. First, I wish to express my appreciation to Mrs. Edna Magel who proved to be a cheerful, professional editor and typist of this manuscript. Also, in the initial stages of this work, Mr. George Manning, was instrumental in assisting in the preparation of the data and did much of the preliminary work on Chapter III.

Mr. Robin Chesters of I.P. Sharp Associates was very helpful in the assembling and preparation of a large databank and for his competent assistance I am most grateful. Mr. Al Macatavish, Mr. John Siemans and Mr. R. Northcott of Manitoba Hydro gave unceasingly of their time and assisted greatly in the development of the database for the hydro demand forecasting model. Mr. Bud Hample of Statistics Canada also assisted in obtaining some unpublished information and suggested data sources which were unknown to myself.

An early version of Chapter II was presented to the Department of Economics at the University of Manitoba and I am grateful to those faculty who freely criticised that paper.

Finally I wish to express my appreciation to the Economic Development Advisory Board for assisting and encouraging me through this year.

Greg Mason
Research Director and
Executive Secretary

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CHAPTER I

INTRODUCTION AND OUTLINE

This report investigates the energy consumption of Manitoba manufacturing with a view to assessing the potential impact of the energy crisis on the viability to this critical sector. In recent years, the Economic Development Advisory Board has concerned itself with the manufacturing sector of Manitoba, for as with Canada, it appears that this aspect of economic activity is becoming increasingly threatened. The desultry performance of manufacturing in Manitoba reflects general trends throughout the country, however in Manitoba the combination of distance, economies of scale, freight rate structures, and so on appear to conspire against success.

Energy too, may be an important determinant of manufacturing success; certainly many economists have argued that rapidly increasing energy prices foreshadow significant economic dislocation. At this moment the protracted coal strike in the United States underscores the pivotal role of energy supply in determining economic welfare.

This report consists of three separate, but related sections.

First, in Chapter II the role of energy prices in manufacturing is examined from two perspectives. The relation between energy prices, wage costs, shipments and manufacturing employment is examined using a straight-forward model which has successfully been employed elsewhere to examine the role of factor prices on manufacturing. As is demonstrated, energy price[s] have substantially altered compared to other inputs of production; this in tu[rn] induces a realignment of the technology employed and the output produced.

Also, firms in different activities have unique constraints on their use of energy. Some, because of recent capital intensive investments, may find it very difficult to alter the mix of inputs. The rapid appreciation in energy prices may work significant hardship on firms which are energy intensive and unable to shift these costs forward to consumers or backward to suppliers. Technology, seemingly a rubric under which all unknown change occurs, plays a key role in determining the adjustment by industry to a new price regime. Some industries have a malleable technology and a realignment of relative prices such as the rise in real price of energy can be accepted relatively easily, while others are burdened with a energy intensive technology incapable of easy adjustment.

Chapter III is an examination of the electricity consumption of manufacturing in Manitoba. Since hydro electricity is the energy sources most abundantly produced by Manitoba it is appropriate that this report consider in some detail the determinants of electricity consumption. Although data is difficult to obtain at a disaggregate level, it is possible to construct demand forecasting models with a reasonable level of accuracy using the commercial and power accounts in Manitoba hydro. The models are tested and the basic theory and problems involved in conducting such inquiries presented in some detail.

Chapter IV, is a brief synopsis of the major issues involved in electricity pricing. Economists have increasingly advocated the use of marginal cost or peak load pricing and this chapter evaluates the alleged

superiority of such a pricing scheme. As is demonstrated, while a marginal cost pricing approach has potential for imposing correct social costs upon the users of electricity, their potential for altering wealth distribution must not be ignored. For this reason, careful experimentation and research is mandatory before such a scheme is implemented.

CHAPTER II

EMPLOYMENT, OUTPUT AND ENERGY PRICES IN MANUFACTURING

INTRODUCTION

The reversal in the historic relationship between energy prices and other inputs to the productive process (labour, materials, and equipment) has prompted concern that the energy crisis will produce significant economic dislocation. This chapter examines the changing relationship between energy prices, the price of various inputs and the resultant impact on employment and output in manufacturing, with special emphasis on manufacturing in Manitoba.

I AN OVERVIEW OF ENERGY CONSUMPTION IN MANUFACTURING

From Table 1, which presents the indexes for petroleum products and average hourly earnings in Canadian manufacturing, it is apparent that both have experienced a substantial increase for the period 1970 to 1977. Table 2 presents the ratio between average hourly earnings in manufacturing and petroleum prices for Canada for the major regions.[1] In general, all regions have experienced the same phenomenon; from the first quarter of 1970 to about the third quarter of 1973 wages rose faster than petroleum prices, a trend which was sharply reversed in the three Eastern regions in the second quarter of 1973 and in the Western regions during the third quarter. Since then, the ratios have persistently declined indicating that energy prices have risen faster than wages. In 1977 there has been a stabilizing of the trend with perhaps a suggestion of a mild reversal, nevertheless the impact of the 'energy crisis'of 1973 is quite clear.[2]

1 all footnotes are to be found at the end of the chapters

TABLE 1

Petroleum Prices and Average

Hourly Earnings in Canadian Manufacturing

		Petroleum Prices	Average Hourly Earnings, Canada	Average Hou Earnings, Manitoba
1970	I	90.4	2.90	2.60
	II	90.4	2.94	2.61
	III	90.4	2.99	2.69
	IV	90.4	3.01	2.75
1971	I	92.1	3.10	2.81
	II	96.3	3.20	2.81
	III	100.8	3.26	2.87
	IV	101.2	3.29	2.95
1972	I	101.5	3.37	3.01
	II	102.2	3.43	3.03
	III	102.8	3.50	3.13
	IV	102.8	3.56	3.19
1973	I	102.8	3.65	3.22
	II	108.8	3.73	3.29
	III	112.1	3.82	3.41
	IV	119.2	3.87	3.50
1974	I	128.6	3.99	3.59
	II	139.7	4.10	3.67
	III	156.5	4.26	3.82
	IV	170.4	4.45	4.07
1975	I	170.7	4.67	4.23
	II	172.9	4.83	4.35
	III	178.1	5.01	4.56
	IV	185.4	5.09	4.70
1976	I	198.4	5.28	4.84
	II	200.6	5.50	4.88
	III	203.2	5.72	5.11
	IV	210.8	5.82	5.27
1977	I	225.9	5.97	5.39
	II	230.2	6.16	5.51

Data sources for this and all other tables are described in Appendix IV

TABLE 2

Ratio of Average Hourly Earnings

To Petroleum Prices

Canadian Manufacturing

		Canada	Atlantic	Quebec	Ontario	Prairies	British Columbia
1970	I	1.00	1.00	1.00	1.00	1.00	1.00
	II	1.020	.975	1.022	1.025	1.027	1.011
	III	1.026	.986	1.028	1.034	1.048	1.009
	IV	1.038	1.040	1.037	1.036	1.052	1.043
1971	I	1.023	1.013	1.015	1.024	1.016	1.018
	II	.996	.954	.990	1.001	1.005	1.00
	III	1.00	.957	.986	1.00	1.018	1.031
	IV	1.023	1.031	1.006	1.020	1.029	1.048
1972	I	1.034	1.049	1.017	1.036	1.028	1.050
	II	1.049	1.030	1.039	1.052	1.059	1.056
	III	1.066	1.033	1.044	1.066	1.086	1.111
	IV	1.092	1.118	1.064	1.092	1.094	1.135
1973	I	1.054	1.082	1.025	1.056	1.051	1.081
	II	1.048	1.041	1.024	1.049	1.067	1.077
	III	.998	.998	.974	.998	1.020	1.031
	IV	.956	.992	.937	.953	.965	.986
1974	I	.904	.964	.889	.897	.905	.931
	II	.837	.901	.834	.826	.842	.862
	III	.804	.854	.801	.788	.830	.854
	IV	.842	.930	.839	.822	.860	.891
1975	I	.860	.983	.864	.834	.879	.909
	II	.866	.939	.875	.837	.900	.909
	III	.846	.919	.867	.827	.885	.872
	IV	.820	.881	.827	.797	.857	.860
1976	I	.844	.920	.850	.820	.860	.889
	II	.867	.936	.875	.843	.887	.906
	III	.849	.918	.855	.818	.886	.913
	IV	.813	.900	.821	.783	.845	.865
1977	I	.824	.926	.831	.793	.847	.868
	II	.823	.893	.837	.793	.854	.858

TABLE 3

Ratio of Average Hourly Earnings
To Petroleum Prices

Prairie Region, Manufacturing

		Manitoba	Saskatchewan	Alberta
1970	I	1.00	1.00	1.00
	II	1.029	1.010	1.031
	III	1.053	1.027	1.048
	IV	1.056	1.036	1.048
1971	I	1.009	1.012	1.023
	II	.983	.999	1.010
	III	1.009	1.001	1.025
	IV	1.026	1.028	1.031
1972	I	1.026	1.037	1.028
	II	1.052	1.038	1.067
	III	1.072	1.047	1.101
	IV	1.084	1.074	1.099
1973	I	1.044	1.018	1.062
	II	1.051	1.026	1.081
	III	1.013	.975	1.029
	IV	.966	.927	.966
1974	I	.907	.874	.907
	II	.844	.808	.846
	III	.825	.797	.836
	IV	.857	.831	.863
1975	I	.869	.859	.886
	II	.885	.886	.909
	III	.875	.856	.891
	IV	.843	.837	.864
1976	I	.840	.843	.872
	II	.869	.881	.891
	III	.864	.866	.894
	IV	.824	.830	.852
1977	I	.827	.831	.852
	II	.828	.852	.858

TABLE 4

Ratio of Average Hourly Earnings
To Petroleum Prices
Manitoba Manufacturing

		Food & Beverages	Clothing	Printing	Metal Fabric.	Trans. Equip.
1970	I	1.00	1.00	1.00	1.00	1.00
	II	1.028	1.010	.990	1.060	1.027
	III	1.050	1.026	1.040	1.122	1.044
	IV	1.046	1.041	1.068	1.074	1.078
1971	I	.992	1.044	1.053	1.038	.996
	II	1.021	.986	1.045	.962	1.00
	III	1.028	.986	1.059	.981	.991
	IV	1.039	1.032	1.078	1.009	.996
1972	I	1.036	1.060	1.062	1.020	1.009
	II	1.080	1.085	1.072	1.028	1.010
	III	1.095	1.116	1.068	1.029	1.039
	IV	1.104	1.114	1.104	1.067	1.062
1973	I	1.051	1.060	1.093	1.030	1.034
	II	1.073	1.031	1.095	1.051	1.009
	III	1.030	.982	1.017	1.047	.968
	IV	.973	.941	1.010	.956	.940
1974	I	.914	.915	.950	.895	.861
	II	.823	.850	.875	.825	.801
	III	.821	.805	.878	.833	.764
	IV	.847	.822	.875	.840	.810
1975	I	.867	.867	.881	.864	.843
	II	.900	.859	.843	.887	.849
	III	.898	.823	.842	.890	.845
	IV	.854	.824	.826	.841	.815
1976	I	.847	.849	.835	.824	.815
	II	.865	.865	.888	.861	.845
	III	.857	.834	.903	.851	.827
	IV	.817	.794	.827	.817	.805
1977	I	.833	.812	.843	.790	.816
	II	.825	.812	.840	.812	.818

Within the Prairie region the tale is similar (Table 3). The indexes for the second quarter of 1977 (1977 II) indicate that average hourly earnings in Manitoba manufacturing have lagged behind those of Saskatchewan and Alberta.

Table 4 presents the ratio of earnings to petroleum prices for selected manufacturing industries in Manitoba with the differences in the indexes reflecting differences in the rate of increase in the average hourly earnings.

In summary, the relationship between wages and energy costs is quite clear; for the past three or four years energy price increases have tended to outstrip wage increases in all regional and industrial sectors of manufacturing. What is true nationally and regionally also holds for Manitoba.

Energy Prices and Materials, and Equipment Input Prices

A very similar picture emerges when the relationship between energy prices (petroleum prices) and input prices (other than labour) is investigated. Table 5 indicates that the ratio of materials input prices to petroleum prices has followed much the same pattern as the ratio of wages to energy prices, except that the decline is more substantial; materials input prices have tended to increase more slowly than wages. This data is for Canada as a whole, but the regional or industrial sector differences are unlikely to be significant.

Finally, in Table 6, the ratio of equipment prices to petroleum prices is presented. Once again, it can be seen that equipment prices have not kept pace, either with wage increases or energy prices.

TABLE 5

Ratio of Materials input prices to Petroleum Prices

Canada

		Thirty Industrial Materials Prices	Industry Selling Price	Wholesale Selling Price	Primary Metals Price
1970	I	1.00	1.00	1.00	1.00
	II	.998	1.001	.996	.997
	III	.983	.993	.986	.958
	IV	.957	.977	.965	.926
1971	I	.918	.941	.928	.876
	II	.881	.909	.896	.846
	III	.875	.913	.901	.846
	IV	.878	.914	.905	.840
1972	I	.927	.924	.924	.843
	II	.948	.928	.928	.843
	III	.969	.937	.946	.845
	IV	1.036	.949	.984	.861
1973	I	1.059	.928	.990	.849
	II	1.076	.934	1.008	.878
	III	1.137	.917	1.031	.862
	IV	1.155	.870	.996	.830
1974	I	1.132	.849	.979	.838
	II	1.050	.800	.913	.818
	III	.981	.763	.861	.752
	IV	.993	.788	.888	.765
1975	I	.947	.796	.872	.778
	II	.895	.786	.849	.761
	III	.870	.770	.840	.740
	IV	.807	.729	.793	.707
1976	I	.797	.727	.788	.696
	II	.808	.727	.789	.704
	III	.784	.709	.765	.694
	IV	.713	.668	.715	.663
1977	I	.727	.675	.738	.687
	II	.719	.672	.739	.693

* Each column presents the ratio of a materials input price index to petroleum price index

TABLE 6

Ratio of Equipment Input Prices

to Petroleum Prices

Canada

		Motor Vehicle Prices	Pulp and Paper Equipment Prices	Boiler and Plate Works Prices	Electrical Equip Prices
.970	I	1.00	N.A.	N.A.	1.00
	II	1.00	N.A.	N.A.	1.015
	III	1.00	N.A.	N.A.	1.022
	IV	1.00	N.A.	N.A.	1.010
.971	I	.964	1.031	1.029	.975
	II	.923	.986	.992	.935
	III	.919	.984	.988	.939
	IV	.920	1.00	.992	.954
.972	I	.933	1.00	1.025	.953
	II	.927	1.00	1.020	.944
	III	.927	1.018	1.024	.937
	IV	.908	1.039	1.025	.937
.973	I	.867	.995	1.064	.885
	II	.843	.985	1.045	.867
	III	.794	.943	.988	.827
	IV	.740	.892	.918	.795
.974	I	.697	.850	1.071	.770
	II	.637	.809	.968	.729
	III	.594	.769	.899	.716
	IV	.631	.777	.906	.775
.975	I	.624	.800	.911	.795
	II	.607	.787	.884	.793
	III	.586	.773	.846	.774
	IV	.568	.744	.796	.730
1976	I	.565	.742	.801	.710
	II	.559	.744	.794	.695
	III	.540	.725	.769	.665
	IV	.505	.692	.718	.622
1977	I	.524	.690	.714	.616
	II	.514	.678	.695	.605

* Each column presents the ratio of an equipment price index to the petroleum price index

N.A. means [illegible]

Energy Costs and Total Production Costs

While energy prices have indeed risen relative to the prices of other factors, this tells only part of the story; equally important is the proportion of total costs comprised by energy. As shall be demonstrated, energy does not bulk large in the costs of most firms, although recently this situation has begun to change.

From the Census of Manufacturing,a fairly complete picture of the costs of production may be obtained, except for capital formation and other capital related expenditures. First, to place energy within a perspective,it is useful to examine energy costs as a percent of value added. From Table 7, it is apparent that there is great regional diversity in the energy cost per dollar value added, with the Atlantic Provinces exhibiting a much higher than average ratio. This reflects the generally higher unit prices of energy in this region and perhaps, the legacy of underinvestment in energy efficient technology. To a large extent,the consumption of energy by manufacturing as a whole reflects the currently installed vintage of equipment (technology), capacity utilization of that equipment, the prices of energy and the mix of manufacturing industries. Within manufacturing there exists a diversity of activities with dramatically different energy consumption levels; the separate influences on energy use must be kept in focus to obtain an accurate picture of energy consumption.

Generally speaking,the energy cost of value added (Table 7) remained stable or declined for all regions during the period 1961 - 1974. Since 1974 there has been a clear reversal of this situation; given more recent data, this picture would probably be reinforced.

TABLE 7

Energy Cost of Value Added*

Manufacturing

	Can.	Nfld.	P.E.I.	Nova Scotia	N. B.	Quebec	Ontario	Manitoba	Sask.	Alberta	B. C.
1961	4.94	10.15	5.56	6.23	9.83	4.91	4.52	5.59	6.89	5.04	5.59
1965	4.52	10.55	5.94	6.16	10.88	4.63	3.99	5.12	6.67	4.72	5.46
1971	4.60	10.18	5.01	8.84	12.43	4.78	3.97	5.30	5.79	4.09	5.86
1972	4.44	9.94	4.10	7.88	11.83	4.65	3.51	5.16	5.41	3.99	5.31
1973	4.26	9.34	4.19	6.75	10.76	4.58	3.69	4.76	4.75	3.83	4.68
1974	4.62	10.14	5.46	8.64	12.96	5.11	3.82	4.39	4.86	3.63	5.41
1975	5.00	12.57	6.55	7.60	13.34	5.39	4.31	4.95	5.17	4.16	5.48

* Dollars of energy costs per dollar valued added

Table 8 presents an industry breakdown for energy per value added for several regions in Canada. Four industries emerge as significantly energy intensive. Paper and Allied Products, Primary Metals, Non-Metallic Minerals and the Chemical industry all have energy cost to value added ratios in excess of 6%. Subsequently it shall be demonstrated that these industries also have higher ratios of energy costs to wage and materials costs.

Generally, the energy intensity of Manitoba industry reflects overall national and regional levels. In some instances, the energy cost of value added is lower for Manitoba industry, however in the case of Primary Metals and Chemicals, Manitoba seems to have a significantly higher ratio. This could reflect a different, more energy intensive technology, or that Manitoba industry in these sectors is not particularly successful.

Table 9 and 10 summarize the energy intensive industries in Manitoba. Overall, these industries account for about 15% of total manufacturing employment and 20% of the total value added for the province. There appears to be some indication that these industries are becoming more important to the Manitoba economy. If this is the case, then sharp increases in the price of energy could conceivably further compromise the growth of manufacturing in the province.

When the energy costs per employee are examined (Table 11), the increasing importance of energy costs is emphasized, although care must be taken not to misinterpret this data. Really, all that is illustrated

TABLE 8

Energy Cost As A

Percent of Value Added

Manufacturing

		Canada	Ontario	Manitoba	Saskatchewan	Alberta
Food & Beverages Industries	1971	3.46	3.18	4.01	4.64	3.01
	1975	3.85	3.27	4.55	4.55	2.69
Tobacco Ind.	1971	.96	1.19	-	-	-
	1975	.98	1.06	-	-	-
Rubber & Plastics Industries	1971	2.78	2.73	1.75	x	2.67
	1975	3.60	3.36	x	x	3.00
Leather Industries	1971	1.42	1.89	1.74	x	1.04
	1975	1.51	1.93	2.07	x	1.66
Textiles Ind.	1971	3.65	3.24	1.70	2.37	5.74
	1975	4.82	4.36	1.64	2.00	2.96
Knitting Ind.	1971	1.72	2.20	1.51	x	x
	1975	2.15	2.69	1.44	x	x
Clothing Ind.	1971	.64	.58	.63	x	x
	1975	.71	.68	.73	x	
Wood Industries	1971	4.33	3.99	3.19	4.74	4.15
	1975	4.79	4.32	2.32	5.96	3.85
Furniture & Fix. Industries	1971	1.78	1.77	1.66	1.24	1.14
	1975	1.67	1.64	1.43	.44	1.23
Paper & Allied Prod. Ind.	1971	13.75	10.55	7.62	x	6.39
	1975	12.32	9.73	13.90	x	5.45
Printing & Pub. Industries	1971	.61	.95	.89	1.16	.71
	1975	.85	.88	1.03	8.88	.69

TABLE 8 (cont'd)

Energy Cost As A

Percent of Value Added

Manufacturing

		Canada	Ontario	Manitoba	Saskatchewan	Albert.
Primary Metals Industries	1971	10.12	8.49	29.82	x	7.7
	1975	11.03	9.58	18.04	x	4.8
Metal Fabric. Industries	1971	2.03	2.09	1.77	1.81	1.3
	1975	1.94	2.04	1.67	1.04	.9
Machinery Ind.	1971	1.64	1.55	1.83	1.61	2.2
	1975	1.55	1.51	1.57	1.54	1.6
Transport Equip. Industries	1971	1.94	1.99	2.13	1.21	1.3
	1975	2.28	2.34	2.19	1.84	1.0
Electrical Prod. Industries	1971	1.52	1.47	1.79	x	1.6
	1975	1.48	1.40	1.76	1.31	.8
Non-Metallic Min. Prod.Ind.	1971	9.72	10.10	9.41	10.45	5.0
	1975	12.05	11.18	16.44	8.55	5.5
Petroleum & Pet. Prod. Ind.	1971	4.99	5.97	x	4.19	5.9
	1975	5.80	6.57	x	3.05	12.0
Chemicals Ind.	1971	7.76	7.33	11.12	23.46	11.9
	1975	8.94	9.84	7.74	14.76	12.9

Not applicable

x confidential

TABLE 9

The Energy Intensive
Industries of Manitoba
: A Profile

	Employment	% of Total*	Valued Added	% of Total*	Establishments
		SIC 10 (Paper and Allied Products)			
1971	1,902	3.94	$31,930,000	5.71	25
1975	2,284	4.15	$59,624,000	5.51	26
		SIC 12 (Primary Metals)			
1971	2,552	5.28	$35,320,000	6.32	19
1975	2,916	5.30	$79,712,000	7.37	16
		SIC 17 (Non-Metallic Minerals Products)			
1971	1,227	2.54	$28,077,000	5.02	41
1975	1,526	2.77	$45,280,000	4.19	41
		SIC 19 (Chemical and Chemical Products)			
1971	918	1.89	$18,119,000	3.24	32
1975	1,083	1.96	$43,397,000	4.02	28

TABLE 10

The Energy Intensive Industries
vs. all of Manitoba Manufacturing

	Precent Total Employment*	Percent Value Added*
1971	13.65	20.29
1975	14.18	21.09

* Represents percent of total employment and value added in the manufacturing sector.

TABLE 11

Energy Cost Per Employee

Manufacturing

	Canada	Nfld.	P.E.I.	N.S.	N.B.	Quebec	Ontario	Manitoba	Sask.	Alberta	B.C.
1961	381.78	713.92	280.78	361.22	664.35	346.31	371.67	380.52	574.84	434.49	467.28
1965	430.26	831.59	344.56	427.66	849.60	399.44	405.84	401.97	618.64	494.07	558.81
1971	614.24	979.33	441.05	824.46	1219.78	569.47	569.11	571.69	834.54	595.92	846.17
1972	643.69	1058.21	409.01	837.26	1357.02	599.79	598.51	565.23	850.06	626.39	855.83
1973	697.79	1226.30	465.83	856.99	1562.95	652.14	643.67	596.63	907.35	684.69	938.26
1974	909.09	1939.44	719.16	1424.37	2566.10	901.71	783.88	703.67	1012.73	788.76	1241.01
1975	1036.81	2011.46	949.43	1373.79	2654.88	1008.84	930.85	913.65	1177.43	1017.78	1312.97

* dollars energy cost per employee

is that the percentage change in energy costs has outstripped the percentage change in employment.

A more meaningful picture can be obtained by examining the relation between energy costs and the costs of materials and labour inputs. Table 12 presents this information for each of the provinces with little regional diversity evident. From 1961 to 1974 energy costs diminished in relation to materials costs, however in 1974 the situation reversed except for Nova Scotia and New Brunswick which registered declines. Manitoba and Prince Edward Island especially, seem to have experienced sharp reversals in the previously declining trend of energy costs relative to materials cost

A similar story emerges with respect to the energy costs as a percentage of wages. Table 13 presents this information for manufacturing for provinces and except for Saskatchewan, energy costs as a percentage of wage costs (manufacturing activity) declined throughout the sixties and early seventies, however in 1974 and 1975 this trend reversed. There is some indication of resumption of the decline in 1975 for Nova Scotia and New Brunswick, however it should be noted that the increase of petroleum prices relative to wages accelerated after 1975,suggesting that this is a temporary statistical artifact.

In summary, energy costs have increased in their share of total production costs for all regions. Although the data extends to 1975, it is likely that the trend has continued.

TABLE 12

Energy Costs as a Percentage of

Materials Costs

Manufacturing

	Canada	Nfld.	P.E.I.	N.S.	N.B.	Quebec	Ontario	Manitoba	Sask.	Alberta	B.C.
.961	4.10	11.69	2.19	4.76	6.81	4.22	3.87	3.79	3.64	3.05	4.74
.965	3.63	10.29	2.51	4.18	7.26	3.92	3.26	2.04	3.35	2.81	4.41
.971	3.61	9.40	2.60	5.47	7.00	3.85	3.19	3.50	3.41	2.39	4.75
.972	3.46	9.22	2.09	4.85	6.81	3.78	3.06	3.19	3.39	2.18	4.33
.973	3.24	9.10	2.04	4.01	6.69	3.55	2.91	2.81	3.07	2.00	3.95
.974	3.41	11.32	2.48	4.83	8.29	3.81	2.93	2.75	2.71	1.89	4.45
.975	3.51	11.95	3.01	4.50	7.47	3.93	3.10	3.26	3.14	2.10	4.63

TABLE 13

Energy Costs as a
Percentage of Labour Costs in
Manufacturing

	Canada	Newfound-land	Prince Edward Is.	Nova Scotia	Newbruns-wick	Quebec	Ontario	Manitoba	Saskatche-wan	Alberta	British Columbia
61	14.61	26.37	16.00	15.14	28.55	14.41	13.65	16.20	23.46	16.79	15.03
65	13.47	27.43	17.22	15.07	30.82	13.91	12.02	14.79	23.46	16.55	14.46
71	12.79	22.28	13.42	20.39	28.13	13.35	11.34	13.34	17.51	12.30	14.00
72	12.30	21.53	11.61	19.05	29.39	12.94	10.91	12.13	16.47	12.02	13.08
73	12.13	21.83	11.93	17.49	30.18	12.96	10.60	11.65	15.93	11.99	12.75
74	13.94	28.87	14.42	24.57	41.61	15.46	11.71	11.71	15.81	11.97	14.68
75	14.24	26.93	17.06	20.78	36.74	15.27	12.55	13.47	15.73	13.38	14.35

Energy Consumption and Concentration in Industry

During periods when relative prices alter or some other structural change occurs (such as the introduction of new technology), concern is often expressed over the ability of the small firm to weather these changes. Price increases are either absorbed by the firm or they are passed forward to consumers and backward to suppliers ,depending upon the monopoly and monopsony power of the firm. While the literature is divided, few economists would state unequivocally that no relation exists between price setting power and the average size of firms within a particular industry. Although it is true that a single-firm industry (monopoly) would exercise considerable price setting power, it is not certain that an industry composed of a few large firms necessarily is any less competitive (in terms of price and non-price competition) than an industry composed of many small firms. Also, the conduct and performance within an industry is never static; during one epoch an industry may exhibit intense price competition, while in subsequent periods price competition may give way to non-price competition in the form of advertising or technical change, or competition may subside completely and the industry act to maximise the joint profit of the group (i.e. form a cartel).

Changes in relative prices are usually borne best by firms with price making power since the price increase is either passed forward to the consumer or discounted backward into the prices offered for various supplies. As outlined above there is no unambiguous relation between the concentration of an industry (i.e. the degree to which output is concentrated into the hands of a few firms) and monopoly power, however some light may be shed on the potential impacts of energy price increases on small firms by examining the relation between energy intensity and concentration ratios. If energy intensity and concentration are positively related, energy price increases impinge most on concentrated industries. If there is a negative relation between energy intensity and concentration, energy price increases may impact upon smaller firms with a restricted ability to pass on the cost increase. Finally, if there is no relation, energy cost increase will not be passed on in a way systematically related to firm size.

There are a wide array of concentration measures, however the Herfindahl index is used here;[3] first because it is a pure ratio, second because it is easily available for industry groups where energy intensities may also be calculated. Fig. 1 shows the relation between two energy intensity measures for industrial subgroups of the four energy intensive industry groups (paper and allied products (SIC 10), Primary Metals (SIC 12), Non-Metallic metals (SIC 17) and Chemicals (SIC 19)). There is little systematic relation obvious from the figure - a supposition borne out by the correlation coefficient which turns out to be .081.

It is interesting to pursue the relation between the various measures of energy intensity. Figs. 2 and 3 present scattergrams of energy intensity (energy costs/wage costs, and energy costs/wage costs) plotted against employees per establishment. What these figures indicate is that the energy intensive industries tend to be very significantly different from the other 15 industrial groups. Care should be taken not to interpret employees per establishment as a measure of firm size since one firm may have a few or many establishments.

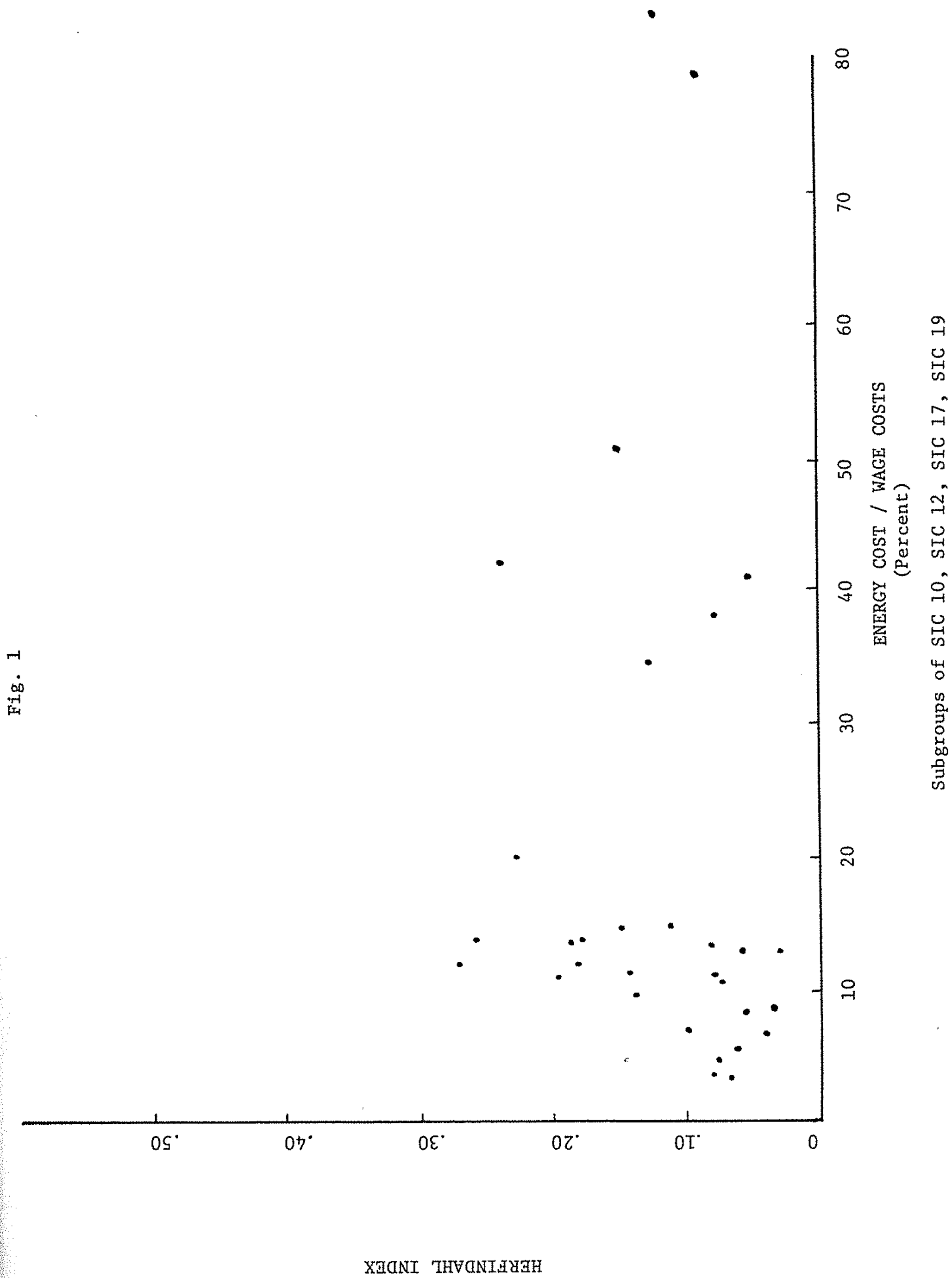
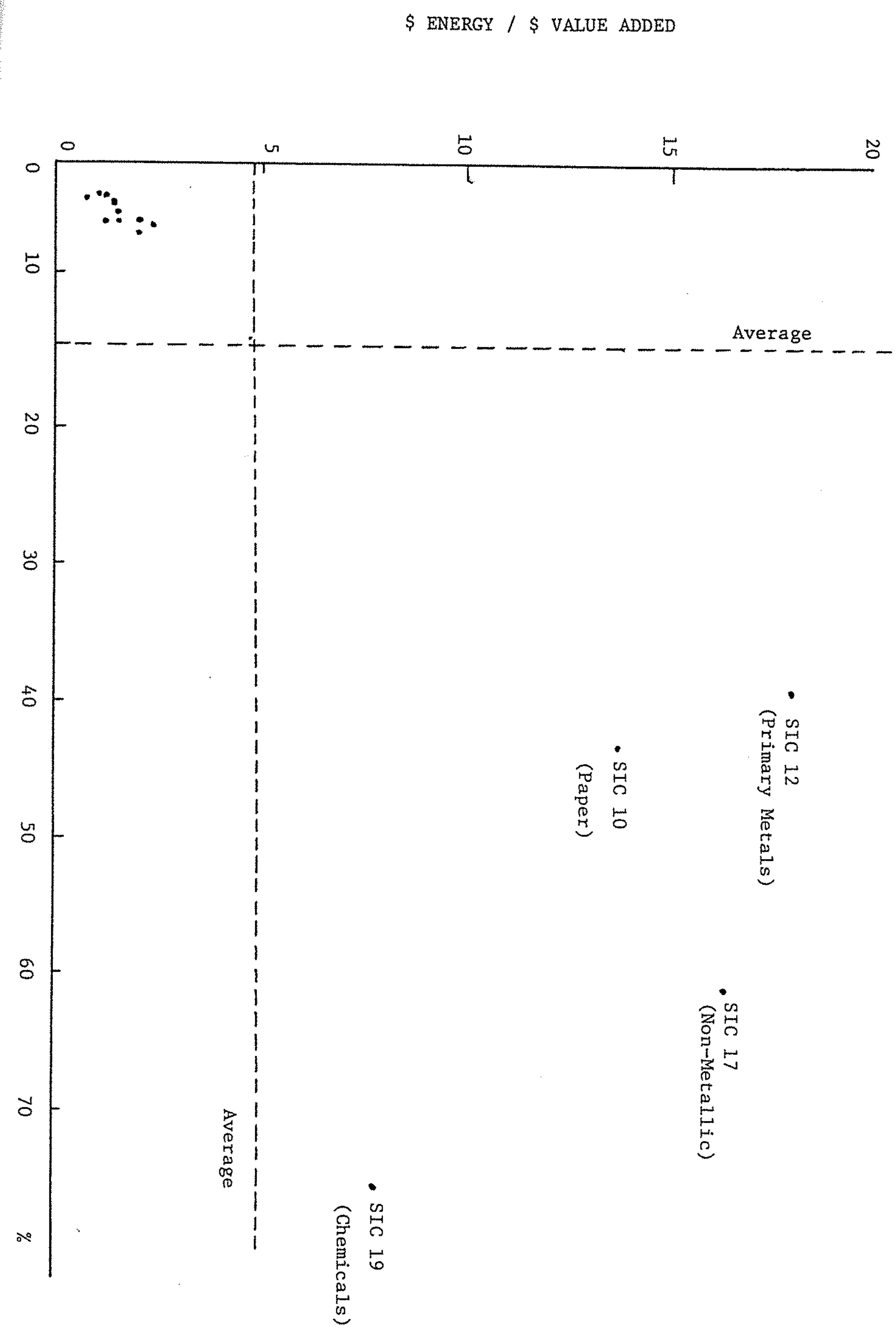
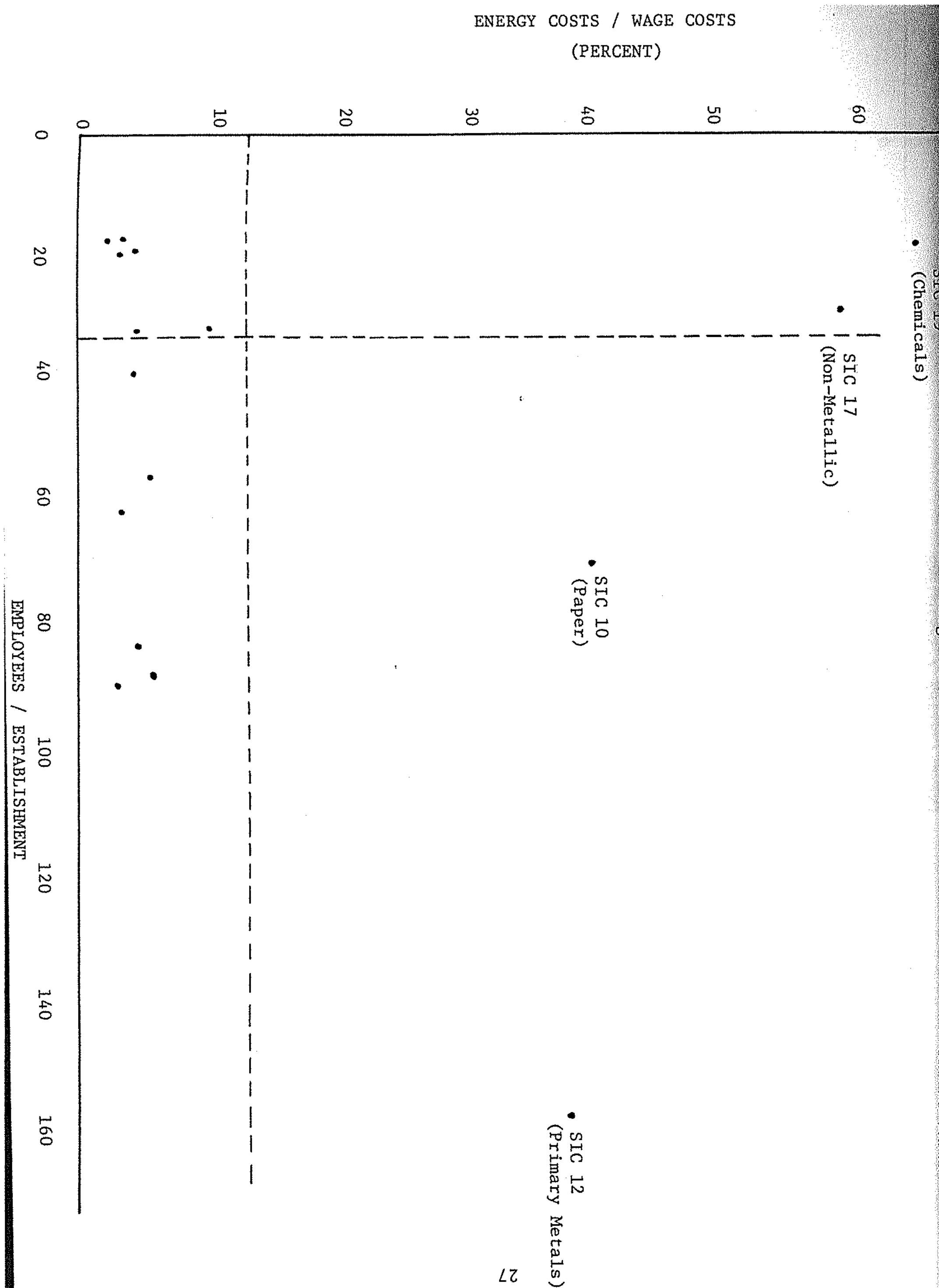


Fig. 1


$ ENERGY / $ VALUE ADDED
0
5
10
15
20
10
20
30
40
50
60
70
%
Average
Average
SIC 12
(Primary Metals)
SIC 10
(Paper)
SIC 17
(Non-Metallic)
SIC 19
(Chemicals)


ENERGY COSTS / WAGE COSTS
(PERCENT)
0
10
20
30
40
50
60
20
40
60
80
100
120
140
160
EMPLOYEES / ESTABLISHMENT
SIC 19
(Chemicals)
SIC 17
(Non-Metallic)
SIC 10
(Paper)
SIC 12
(Primary Metals)

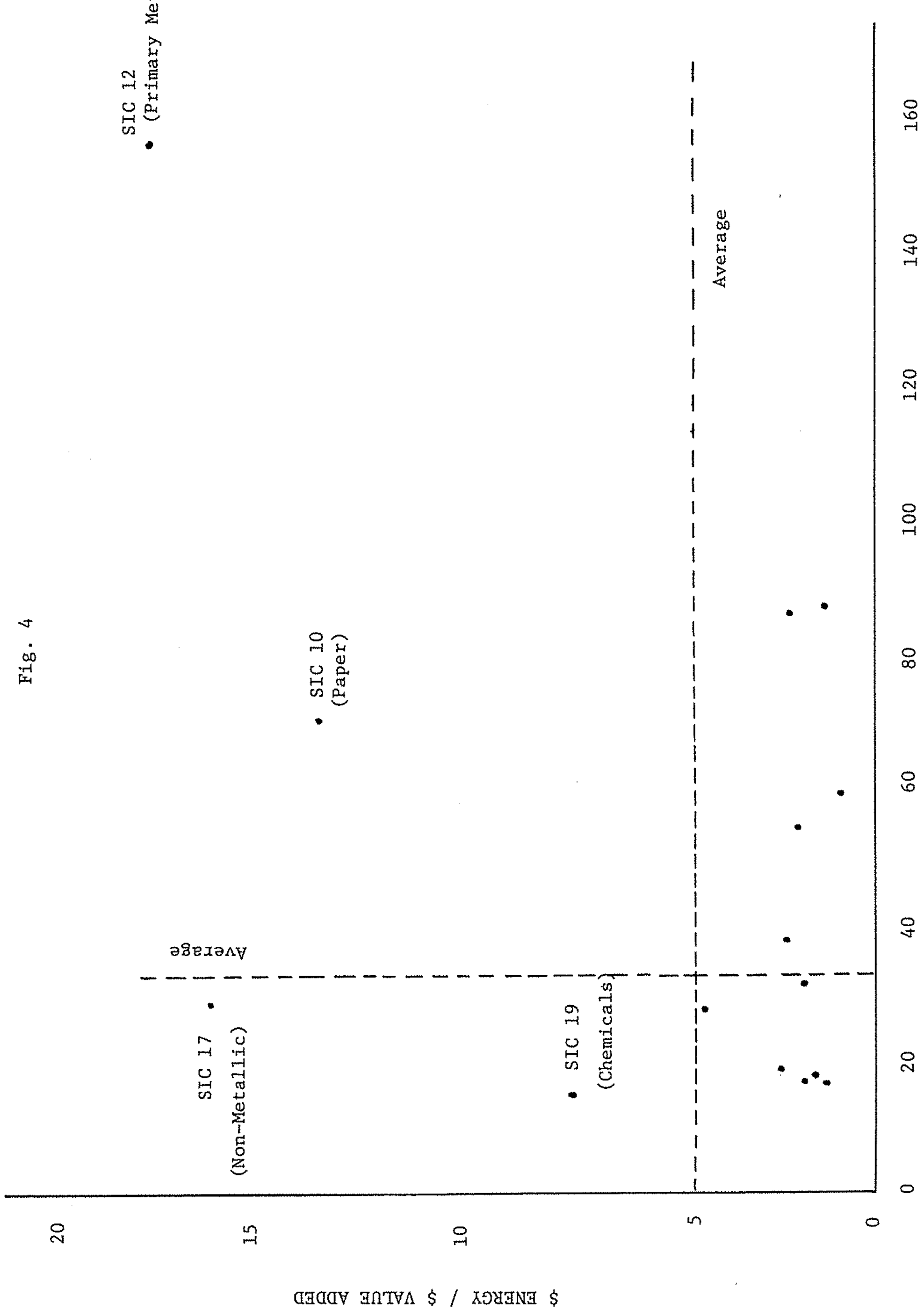


Fig. 4

II EMPLOYMENT IMPACTS OF ENERGY PRICES

A change in relative prices (the price of energy relative to the price of labour as shown in tables 1 to 4) tends to produce two effects which can either reinforce or counteract each other.

First, there is the substitution effect where the firm is hypothesized to react to changing prices (in its inputs) by replacing the expensive input, assuming the technology permits such substitution. To analyze the substitution between factors of production, it is sufficient to investigate the form of the production function without regard to what has happened in the short run with respect to prices. In the long run, a persistent change in prices, (for example, the post war period in which energy prices fell relative to labour prices) will induce changes in technology and consequently changes in substitution possibilities; however in the short run (perhaps less than five years) the form of industry production functions generally remain stable. Appendix III contains an elementary exposition on production functions and the measurement of elasticities of substitution - a measure of the ease with which inputs are interchangeable.

Second, as relative prices change, the firm finds profit margins falling, especially when inputs in general have been increasing in price. Consequently, investment declines, job creation slows and output falls. This response is termed the income or output effect.

Most often the two effects counteract each other. For example, in the case of energy prices increasing relative to wages, a typical response is to attempt to replace an energy intensive process with a labour intensive method of production. Thus, the demand for labour rises. On the other hand the increased costs imposed by energy price increases causes a costly conversion of technology and the use of higher priced labour (presumably the labour intensive process was more expensive prior to the change in energy prices) all of which reduces profit margins. The firm attempts to seek new market alternatives and reduce its hiring and output. Which effect predominates is difficult to judge a-priori.

Certain aspects of the adjustment process (that is, the adjustment to new price regimes) can be analyzed. The next section examines the relation between employment changes and changes in output in the relative prices of labour and energy. The subsequent section investigates the technology of production in various industries, and especially the substitution possibilities between energy and labour.

Energy Prices, Wages and Employment in Manufacturing

The determinants of employment in the manufacturing sector are important to identify and quantify. On the whole, manufacturing has had a sketchy performance both nationally and provincially, yet most analysts feel that stimulation of this sector, which produce 'hard' goods as opposed to 'soft' services, is an important priority. Three factors have been identified as affecting employment in manufacturing; first, changes

in the level of current output are obviously going to have an important impact on employment. Second, expected profit levels condition investment behaviour and consequently job creation. Third, changes in the relative price structure of the factors of production alter employment decisions.

The literature in this area, best represented by the works of Nadiri (1968), Phipps (1975) and Schaafsma (1977) commences with a general specification of the production function

$$q = f(K,L) \qquad \ldots. \; 1$$

which states that output q is some function of capital or labour. Through the appropriate manipulation (see Schaafsma for details) it is possible to derive an employment function such as

$$\ln E_t = A + B_1 t + B_2 \ln Q + B_3 \ln (w/C) + B_4 \ln E_{t-1} \qquad \ldots. \; 2$$

and

$$\ln E_t = A + B_1 t + B_2 \ln Q + B_3 \ln (w/C) + B_4 \ln E_{t-1} + B_5 \ln E_{t-2} \qquad \ldots. \; 3$$

where E_t is the employment in period t, t is time, Q is output, w is wages, C is the marginal cost of capital and E_{t-1} and E_{t-2} are employment levels in the previous 2 periods; note that ln denotes the natural logarithm of the variable.

Measurement of the Variables

The above equations are linear relationships in which changes in the independent variables ($t, Q\ w/c, E_{t-1}, E_{t-2}$) are supposedly reflected by changes in the dependent variable (E_t). The estimation of equation 1 and 2 through regression techniques requires the careful specification of the form of the relationship, the variables to be considered, and especially the measurement of the variables.

Q_t is measured by current shipments. In a sense the level of shipments does not accurately reflect current output, since shipments differs from output by the accumulation or disaccumulation of inventories. Presumably either some physical measure or real value added would be superior,but since it is most important to analyze the impact of factor prices on employment during a period when relative prices did alter substantially, namely the period 1970 to 1977, the choice of the measurement procedure is conditioned by the data availability. To obtain adequate data to perform the regression (i.e. degrees of freedom, see Appendix III) quarterly data must be used; value added is computed annually, consequently current shipments (real dollar value) must be used.

In the literature, analysts have concentrated on production function which specify capital and labour as the prime inputs to the productive process. Natural resources and in particular energy are usually ommitted. Recently, there have been attempts (see Taylor 1968, Moody 1974 and Mason 1978) to incorporate energy into the production function as a surrogate or proxy for capital services. In effect the production function is rewritten as

$$Q = f (E,L)$$

This procedure avoids the many complicated problems of deriving the marginal cost of capital. Specifying energy as an input into the production function does not remove all the problems, for a price index is not available for all energy, let alone price indexes relative to fuels used in manufacturing. The petroleum products price index is used as a proxy for energy costs in general but it is acknowledged that some specification error could be introduced, especially for manufacturing processes which employ fuels with divergent price trends than petroleum. The error may be somewhat minimized by considering that petroleum prices were the first to rise significantly, and other fuels have increased in price to capture the economic rent. Therefore C is replaced by a petroleum price index.[4]

Average hourly earnings are used as the measure of w. Although fringe benefits, featherbedding, misallocation etc. all serve to remove the equality between the marginal cost of labour and average hourly earnings, there is no closer proxy.

Equations 2 and 3 were estimated with regional data for the manufacturing sector as a whole. It is also possible to obtain data to perform these estimates for some industries within the twenty industry group, but these for the most part tend to be industries not characterized by high energy intensities. The time period is quarterly from 1970 to 1977 (second quarter) which permits a total 31 observations.

TABLE 14a

Output, Factor Prices and Employment

ependent ariable mployment)	Constant	Wages / Energy	Shipments	E_{t-1}	E_{t-2}	Time	R^2	't'[2]	D.W.
tlantic OLS) egion	-.2915 (-.196)	-.1314 (-.407)	.2724* (2.372)	.2418 (1.214)			.6233	.953	
tlantic OLS) egion	-.6271 (-.4037)	-.1577 (-.4684)	.3762* (2.887)	.2860 (1.441)	-.2921 (-1.343)		.6680	-.481	
tlantic egion 1 corrected)		-.1787 (1.252)	.2531 (1.405)	.2437 (.451)			.6398		2.02
tlantic egion 1 corrected)		-.310 (-.122)	.260** (1.723)	.2181 (.483)		.0016 (.690)	.6459		2.02

1) The presence of the lagged dependent variable, requires that the variance covariance matrix be corrected

2) The Durbin Watson statistic is meaningless when there is a lagged dependent variable (uncorrected). The t test is the t statistic produced by $e_t = Be_{t-1}$ and may be interpreted as usual. Note that e_t is the vector of residuals.

* signigicant at .05
** significant at .10

TABLE 14b

Output, Factor Prices and Employment

Dependent Variable (Employment)	Constant	Wages / Energy	Shipments	E_{t-1}	E_{t-2}	Time	R^2	't'[2]	D.W.
Quebec (OLS)	-.362 (-.1737)	.0349 (.7221)	.0841 (.7879)	.7884* (5.196)			.5286	1.01	
Quebec (OLS)	.369 (.1536)	-.0247 (-.2256)	.7471 (.6404)	.8615 (4.08)	-.1943 (-.863)		.5485	.844	
Quebec 1 (corrected)		.029 (-.297)	.213* (4.072)	.266** (1.479)			.6102		1.76
Quebec 1 (corrected)		-.1115 (-.8365)	.2207* (3.37)	.247 (1.231)		(-.0018) (-.984)	.6251		1.77

1) see table 14a
2) see table 14a

TABLE 14c

Output, Factor Prices and Employment

Dependent Variable (Employment)	Constant	Wages/Energy	Shipments	E_{t-1}	E_{t-2}	Time	R^2	't'^{2}	D.W.
Ontario (OLS)	-2.44** (-1.89)	.051* (1.46)	.145* (2.642)	.994* (8.265)			.7809	.672	
Ontario (OLS)	-2.33* (-1.45)	.024 (.347)	.158* (2.147)	1.198* (5.84)	-.268 (-1.33)		.7939	.309	
Ontario 1 (corrected)		-.005 (-.10)	.095* (2.542)	.668* (5.11)			.7735		1.77
Ontario 1 (corrected)		.026 (.287)	.869* (2.187)	.696* (5.06)		.0005 (.374)	.7744		1.78

1) see table 14a
2) see table 14a

TABLE 14d

Output, Factor Prices and Employment

Dependent Variable (Employment)	Constant	Wages/Energy	Shipments	E_{t-1}	E_{t-2}	Time	R^2	't'^{2}	D.W.
Prairies (OLS)	-1.127 (-1.64)**	-.104** (-1.38)	.262* (4.78)	.415* (3.33)			.924	2.69*	
Prairies	-1.38 (-.518)	-.141** (-1.63)	.282* (2.331)	.538* (3.19)	-.131* (.536)		.945	2.49*	
Prairies 1 (corrected)		-.169** (-1.79)	.314 (9.96)	.201 (.204)			.949		1.99
Prairies 1 (corrected)		-.162** (-1.46)	.313* (9.57)	.023 (.227)	.0005 (.247)		.949		1.95

1) see table 14a
2) see table 14a

TABLE 14e

Output, Factor Prices and Employment

Dependent Variable (Employment)	Constant	Wages / Energy	Shipments	E_{t-1}	E_{t-2}	Time	R^2	't',2	D.W.
British Columbia (OLS)	-.479 (-.634)	-.019 (-.290)	.152* (2.66)	.624* (4.91)			.754	.478	
British Columbia (OLS)	-.441 (-.385)	-.082 (-.662)	.164* (2.12)	.723* (3.74)	-.143 (-.784)		.738	-1.08	
British Columbia 1 (corrected)		-.027 (-.411)	.128* (2.44)	.601* (3.67)			.727		1.99
British Columbia 1 (corrected)		-.0366 (-.329)	.129* (2.32)	.599* (3.46)		.0001 (-1.09)	.728		1.99

1) see table 14a
2) see table 14a

The main results for regional manufacturing are presented in Table 14 with several alternative specifications. In some instances the equation was amended by omitting t from the specification, in others the second order lagged variable (E_{t-2}) was omitted.

For the most part the results fail to confirm the hypothesis that changes in the relative price of energy have had a major impact on employment in manufacturing. By far and away employment appears to be determined by changes in the level of output (shipments). Even the lagged variables have a mixed effect, with the second order term rarely attaining a coefficient significantly different from zero. What this implies is that employment adjustments to changes in shipments are usually accomplished quickly within one quarter. Given the generally sketchy performance of manufacturing along with low levels of capital formation it is not surprising that the labour force appears to be adjusted with some dispatch.

While there is little regional variation, one finding appears to be of some significance, and that is the coefficient on the factor price ratio (Wages/Energy) for the Prairie region. Unlike other regions where employment appears to have weak (low valued) and insignificant responses to factor price changes, the coefficient for the Prairies (see Table 14d) is around .16 and is significant at the .10 in a two tailed test. The sign is in the appropriate direction and suggests that for Prairie manufacturing as a whole, a 10% change in the ratio of wages over energy prices produces about 1.44% fall in employment in the current period. Since 1970 there has been a 15% decrease in the ratio of wages to energy prices in Prairie manufacturing (see Table 2).

It would be easy to make too much of these results. While the relationship is clear and significant, shipments still account for the bulk of the variation in current employment. In addition, it should be noted that a clear possibility of specification error exists in the form of simultaneous equation bias. The causal relationship between changes in factor prices and current employment is probably more complex than specified equations 2 and 3. A more satisfactory specification would involve the creation of a two equation system involving investment as a function of expectations, (formed as a function of previous behaviour in shipments and factor prices) and then the specification of employment as a function of shipments, inventories and past investment. Unfortunately the data for such an exercise, while available nationally, is time consuming to obtain at the regional and provincial level.

III ENERGY USING TECHNOLOGY OF MANUFACTURING

As outlined in Appendix II the elasticity of substitution is a measure of the ease with which one factor may be substituted for another. Generally this substitution is motivated by changes in the relative prices of the factors. Thus, increases in energy prices relative to labour and other inputs is presumed to induce a shift away from energy intensive technologies. By estimating a production function from data on output production and input consumption it is possible to calculate the elasticity of substitution. This procedure is discussed in some detail in Appendix III, however the basic idea is simple.

First, one assumes some specified form of the production function, usually a Cobb Douglas or Constant Elasticity of Substitution. This algebraic form is then fitted to the data points by least squares and the various coefficients may be obtained.[5]

The production function which is estimated is the non-homogeneous production function recently developed by Sato (see Sato, 1977). In its linearized form it appears as

$$\ln (K/L) = A_1 \ln C + A_2 \ln (W/L) + A_3 \ln (Q) + t + e_t \qquad \ldots\ldots 4$$

where various measures of energy consumption are substituted for K in the present analysis, C is the constant, W/L is the wage rate, Q is output, t is time and e_t the error. To account for regional variation, because pooled data must be used, dummy variables are introduced; this is explained in Appendix II. The parameter of interest is A_2 which is the elasticity of substitution between energy and labour. Once the form has been specified (eqn. 4), the measurement of data is the most important issue.

Measurement of Data

Data can condition the results of production function estimation to a considerable extent. The same function with time series data will yield an estimate of the elasticity of substitution quite different from cross sectional data. Pooling cross section and time series of course generates, parameter estimates distinct from either cross section and time series. As Bosworth (1976) cogently outlines, cross section data produces a short run production function parameter at the micro or macro level, while time series data tends to produce long run macro production function parameters. Pooling cross section time series data probably produces intermediate run results, however the bias is difficult to determine.

Labour

Labour services are measured as the number of production worker hours in each twenty industry group as presented in the yearly census of manufacturing. Hoarding, or underemployment of labour is partly, although not completely, resolved by using an hourly measure since slowdowns, featherbedding and management induced misallocation can obscure the relationship between labour inputs and output.

The use of production worker time is somewhat arbitrary for it seems to imply that administrative personnel have no relationship to productivity. One of the very important issues in empirical production analysis centers on aggregating first various sub-categories of inputs into a consistent aggregate and then in turn, transforming these inputs to an output. To perform this aggregation requires the assumption that the inputs are

separable. As Berndt and Christiansen (1973) have shown the choice of whether to aggregate labour inputs actually depends upon the use to which the estimation is to be put.

Energy Measures of Capital Services

The overwhelming majority of empirical investigations of production relationships employ two factor models with capital and labour as the inputs. Because of the difficulty in securing capital services and stock data at regionally and industrially disaggregate levels, analysts have searched for proxies of capital services. Energy, particularly a flow energy, is a potential proxy for capital utilization. In addition, total energy consumption could be useful, since for many of the fuel types hoarding may not be a major problem.

A-priori, a flow energy such as electricity has several attractive features. First, as mentioned above hoarding is avoided since the storage is difficult. In addition, the product is homogeneous, and the problem of aggregating is avoided. Third, as Moody (1974) and Taylor (1968) have shown, electricity consumption is closely related to capacity utilization. One of the problems with using electricity consumption as a proxy for capital services is the requirement that some measure of the capacity utilization of electrical equipment be established before electricity utilization could be unambigously related to capital services. Moody (1974) has demonstrated, for United States data, that the inclusion of an electrical consumption potential adds little to the specification of production functions both cross sectionally and for time series. A problem could exist however where, as in Canada, energy is used for space heating in addition to motive and process requirements. In that event a similar problem to labour hoarding could exist; i.e. there may be periods where there is no output yet energy consumption persists at high levels. Obviously this would change from industry to industry as the share of end use in energy altered.

Output

The measure of output is the real value added as defined by Statistics Canada in the Census of Manufacturing. There is considerable debate over the appropriate measure of output; as the data becomes more disaggregated, actual physical units of production become available. At aggregate levels, however real value added appears to be the best indicator of output.

Empirical Results

The sample data consists of a cross section of time series for five regions (Atlantic Provinces, Quebec, Ontario, the Prairie Provinces and British Columbia) for the period 1962 - 1974. Data on value added, total wage costs, hours worked and fuel useage for seven fuel types (electricity, natural gas, gasoline, fuel oil, diesel fuel, liquid petroleum gas (LPG) and coal was compiled from various Statistics Canada publications described in Appendix IV.

The first section of the analysis concentrates upon the calculation of energy/labour substitution for manufacturing as a whole for various fuel types. Table 15 presents the results for equation 4 when various fuel types are used; note that energy consumption is measured in BTU equivalents. From this table it can be seen that the elasticity of substitution (the column headed by WAGE RATE) varies considerably from a low of 1.277 to a high of 9.231. The negative value for coal is the result of a long term interfuel substitution away from coal and toward other fuel types, in particular heavy fuel oil. In addition, the high elasticity of substitution for diesel fuel reflects a comparatively recent surge in the use of diesel fuel in the manufacturing sector.

The values of the elasticities of substitution are generally significantly different from 1 which indicates that the Cobb Douglas functional form is not appropriate. Also the frequency with which the coefficient of VALUE (the homotheticity coefficient) is significantly different from zero strongly suggests the validity of some non-homogeneous functional form as is used here.

TABLE 15

Substitution between energy
and labour, Manufacturing
(All regions)

DEPENDENT VARIABLE ln (E/L)	CONSTANT	WAGE RATE[2] (ln W/L)	VALUE	DUM 1[1]	DUM 2	DUM 3	DUM 4	R^2
Electricity	17.99*	1.769**	-.7319*	-.018	1.052*	.7832	.181	.7351
	(6.29)	(6.59)	(-3.27)	(-.07)	(2.97)	(1.76)	(1.54)	
Natural Gas	7.023	2.082*	1.208	-8.008*	-2.208	-1.949	2.523*	.9710
	(.71)	(2.26)	(1.57)	(-8.77)	(-1.82)	(-1.28)	(6.26)	
Gasoline	32.04*	1.277**	-.817*	-.105	.985*	1.317*	.436*	.9080
	(19.88)	(8.44)	(-6.48)	(-.70)	(4.94)	(5.26)	(6.61)	
Fuel Oil	32.12*	1.455**	-.477*	1.248*	.946*	.279	-1.49*	.9622
	(13.68)	(6.61)	(2.60)	(5.72)	(3.26)	(.76)	(-15.55)	
Diesel	-165.2*	9.231	20.54*	34.77*	-19.80*	-35.96*	10.86*	.4162
	(-2.36)	(1.41)	(3.75)	(5.32)	(-2.29)	(-3.31)	(3.77)	
LPG	26.41*	3.44**	.0224	2.623	.842	.583	-.095	.8123
	(5.30)	(7.36)	(.06)	(5.66)	(1.37)	(.75)	(-.47)	
Coal	41.80	-1.073	-2.35*	-2.349*	3.150*	5.601*	.079	.5108
	(4.18)	(-1.14)	(-3.01)	(-2.53)	(2.55)	(3.61)	(.19)	

(-t values in brackets)

1) DUM 1 - Atlantic
DUM 2 - Quebec
DUM 3 - Ontario
DUM 4 - Prairies

2) ln refers to logarithms

* significantly different from 0 at .05 level

** significantly different from 1 at .05 level

TABLE 16

Substitution Between Energy
Aggregates and Labour
Manufacturing

DEPENDENT VARIABLE (ln E/L)	CONSTANT	WAGE RATE ln (W/L)	VALUE	DUM 1	DUM 2	DUM 3	DUM 4	R^2
E2[1.]	17.61	2.226	.1679	-5.204	-.919	-.044	2.118	.959
	(5.06) *	(6.82)**	(.62)	(-16.09)*	(-2.13) *	(-.08)	(14.84) *	
E4[2.]	33.89*	-.334	1.192*	-4.30*	1.529*	2.823*	-.098	.802
	(9.58)	(-1.01)	(4.30)	(-1.31)	(3.49)	(5.14)	(-.68)	

1. E2 (Electricity and Natural Gas) in BTU equivalents

2. E4 (Gasoline and Fuel Oil and Diesel and LPG and Coal) in BTU equivalents

* significantly different from 0 to .05 level

** significantly different from 1 to .05 level

TABLE 17

Interindustry Variation in

Substitution Elasticities Between

Energy Aggregate (E2)

and Labour

DEPENDENT VARIABLE (E2/L)	CONSTANT	WAGE RATE ln (W/L)	VALUE	DUM 1	DUM 2	DUM 3	DUM 4	R^2
SIC 1 (Food)	35.36 * (3.16)	2.039 * (2.07)	-2.100 (-2.12)	-7.816 (-14.97)	1.476 (1.05)	3.456 (1.94)	1.750 * (3.16)	.972
SIC 2 (Tobacco)	18.97 (1.74)	.898 (.85)	-.941 (-.88)		.141 (.37)			.038
SIC 3 (Rubber)	-6.987 (-.96)	-.5512 (-.38)	1.922 * (6.17)		-.051 (-.22)			.931
SIC 4 (Leather)	32.37 (6.28)	5.104 ** (5.15)	-1.368 (-1.95)		4.261 * (1.54)	5.893 * (2.19)	4.223 * (5.96)	.906
SIC 5 (Textiles)	7.103 (17.18)	.128 (.79)	.908 * (6.25)	-6.982 (-25.41)	-6.153 * (-10.12)	3.114 * (5.21)	1.932 * (7.52)	.972
SIC 6 (Knitting Mills)	18.20 (3.54)	3.076 ** (5.58)	.6793 (1.41)		-3.180 * (-9.54)			.976

* significantly different from 0 at .05 level

** significantly different from 1 at .05 level

TABLE 17 (cont'd)

DEPENDENT VARIABLE (E2/L)	CONSTANT	WAGE RATE	VALUE	DUM 1	DUM 2	DUM 3	DUM 4	R^2
SIC 7 (Clothing)	2.463 * (5.26)	.511 ** (3.29)	1.690 * (12.65)	-3.371 * (-7.10)	-8.758 * (-19.24)	-4.739 * (12.89)	-2.344* (-9.31)	.9664
SIC 8 (Wood)	-17.41 * (-4.23)	.100 (.60)	3.288 * (6.87)	.408 (.35)	-.109 (-.19)	3.283 * (5.56)	7.378 * (7.50)	.9615
SIC 9 (Furniture)	24.55 * (6.40)	4.283 ** (6.09)	.067 (.22)	-4.828 * (-8.32)	.3520 (-.47)	.6580 (.87)	1.479 * (5.82)	.9759
SIC 10 Paper)	-5.845 * (-7.18)	.7821 * (2.18)	2.598 * (12.20)	-4.085 * (-9.84)	-4.601* (-23.40)	-1.114 * (-5.58)	5.936 * (9.71)	.9759
SIC 11 (Printing)	2.237 (1.45)	.9761 ** (8.31)	1.517 * (7.12)	-4.864 * (-18.74)	-2.395 * (-7.93)	-2.564 * (-5.89)	.976 * (6.93)	.988
SIC 12 (Primary Metals)	23.08 * (7.39)	3.637 ** (6.65)	.1226 (.46)	-2.385 (-1.69)	-.1421 (-.39)	.5073* (.85)	2.237* (9.82)	.991
SIC 13 (Metal Fabricating)	.257 (.77)	.382** (4.01)	1.66* (26.43)	-5.22* (-26.18)	-2.676* (-19.01)	-3.10 (-17.09)	.139 (1.08)	.987

* significantly different from 0 at .05 level

** significantly different from 1 at .05 level

TABLE 17 (cont'd)

DEPENDENT VARIABLE (E2)	CONSTANT	WAGE RATE	VALUE	DUM 1	DUM 2	DUM 3	DUM 4	R^2
SIC 14 (Machinery)	22.27*	2.856**	-.436		.704	1.780*	1.974*	.854
	(8.27)	(5.88)	(-2.17)		(1.88)	(2.99)	(9.20)	
SIC 15 (Transport Equipment)	31.77*	4.521*	-1.139	-4.941*	1.871	4.968*	3.087*	.886
	(2.91)	(2.64)	(-1.37)	(-9.07)	(1.16)	(1.92)	(5.62)	
SIC 16 (Electrical Products)	3.209*	-.525*	.885	-6.550*	-3.084*	-2.983*	.246	.937
	(4.75)	(-2.35)	(5.27)	(-15.30)	(-5.84)	(-4.51)	(.63)	
SIC 17 (Non-Metallic Indus.	17.38*	1.314**	.055	-8.358*	-.533	.444	1.06*	.994
	(6.93)	(3.50)	(.25)	(-49.64)	(-1.30)	(-.86)	(4.15)	
SIC 19 (Chemicals)	16.28*	1.205	.200		-2.450	-1.057	2.006*	.936
	(2.55)	(1.78)	(.30)		(-1.85)	(-.60)	(7.16)	

* significantly different from 0 at .05 level

** significantly different from 1 at .05 level

These technical matters aside, it is apparent that the elasticity of substitution varies considerably among fuel types. It is also possible to consider the various fuel types as either 'flow' energies as in the case of electricity and natural gas or 'stock' energies as in the case of the remainder. Stock energies are typified by a relative difficulty and cost of their storage. Table 16 presents the elasticities of substitution for equation 4 when the fuel types are aggregated into these two general categories (E2 and E4). The elasticity of substitution still varies between the various fuel aggregates, reflecting the fact that the substitution of labour for energy varies when energy is aggregated, although the coefficients are considerably moderated compared to the individual fuel types.

Industry Variation in Substitution Elasticity

Table 17 presents the results for equation 4 for E2 the aggregate of electricity and natural gas. Other energy aggregates could have been chosen; most likely this aggregate is not of uniform importance for all industries, however to present the entire regression analysis would occupy too much space with comparatively little return. Some industries such as Textiles, Clothing, Wood, Paper, Printing and Metal Fabricating have comparatively low elasticities of substitution (i.e. elasticities less than 1.00), indicating that these industries, of which only paper is an energy intensive industry, have limited options to replace energy with labour. Of the remaining energy intensive industries (Primary Metals, Non Metallic Fabricating and Chemicals), only Primary Metals has an elasticity very much greater than 1, which indicates that prolonged energy price increases could have substantial impacts on employment in Paper, Non-Metallic Fabricating and Chemicals. Of course other factors of production are used in all these processes and much of the impact higher energy prices could be mitigated by a retooling of the industry with more energy efficient capital. Unfortunately the paucity of reliable capital data at the regional and twenty group level precludes any examination of this effect.

One final test was performed. The sample was split into two segments by specifying a dummy variable which equalled 1 for the years 1962 – 1969 and 0 for the remainder of the time period. When this dummy was included to test for the possibility that there has been a structural shift over time, it proved to be quite insignificant in explaining the variation. Consequently, pending further and more recent data, it must be concluded that the technology of production in manufacturing changes slowly.

To conclude this section it should be noted that there is little relationship between the elasticity of substitution and the energy intensity of various industrial groups. This is shown in fig. 5.

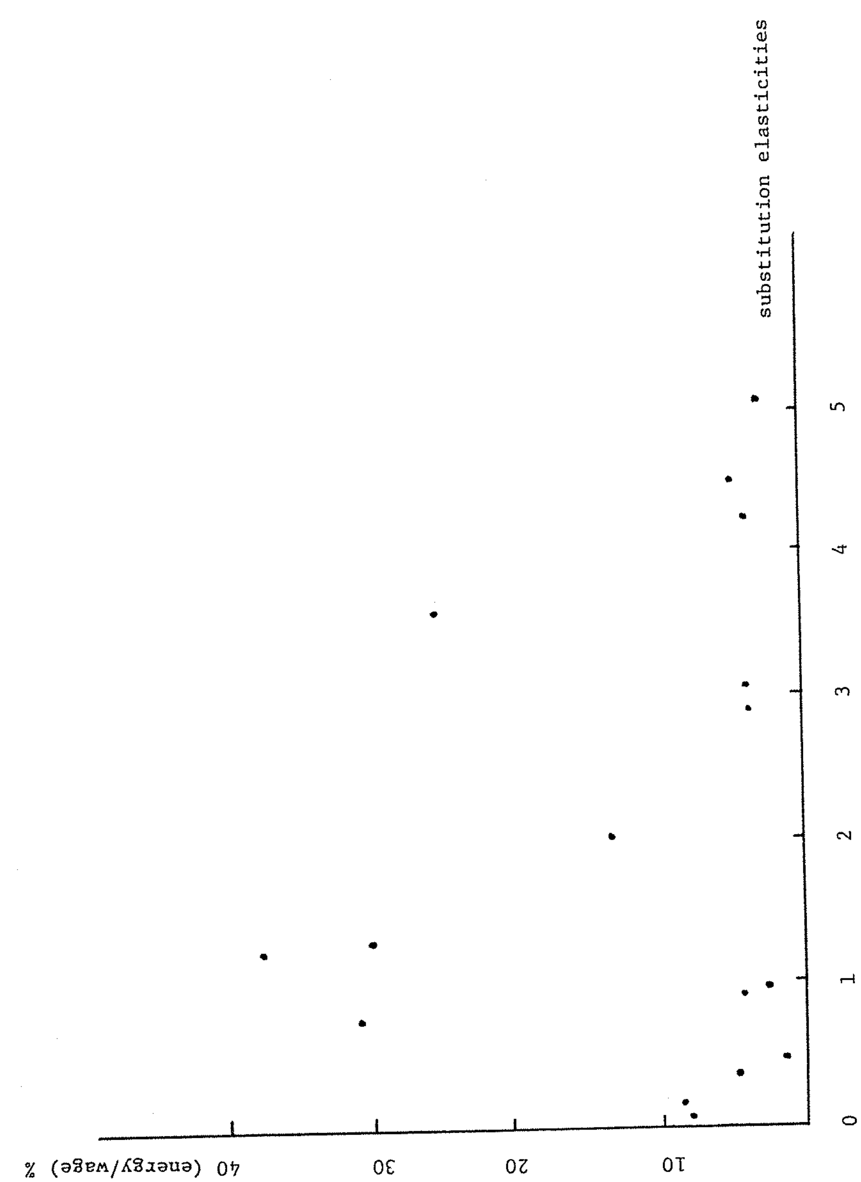


Fig. 5

IV SUMMARY

This chapter has investigated the consumption of energy in the manufacturing sector with a view to quantifying the relationship between energy prices and changes in output and employment. In general, energy remains a relatively small expenditure in all but four industrial groups. Paper and Allied products (SIC 10), Primary Metal Industries (SIC 12), Non-Metallic Fabricating Industries (SIC 17) and Chemical Products Industries (SIC 19) all have substantial expenditures on energy, and consequently are likely to be the most affected by continued increases in the price of energy. These four industries account for a small but growing share of value added and employment, and for Manitoba especially. with its heavy public investment in the Paper industry, the continued change in energy prices relative to other inputs, bears close scrutiny.

As for the relationship between employment and energy prices, it was seen that for manufacturing as a whole and across all regions in Canada, the change in relative prices (wages rates to energy prices) have only an insignificant impact in determining employment levels in manufacturing; other factors such as current levels of investment and output are probably most significant. This is not the case of Prairie manufacturing employment which appears to be quite sensitive to changes in the ratio of wages to energy prices. This finding is of some significance in appraising the design of an energy policy for Manitoba.

Finally, the technology of production in manufacturing was investigated. Unfortunately, the data does not permit the analysis of the Prairie economy separate from that of the rest of Canada, however some inferences

NOTES

1. It is difficult to develop an aggregate index of energy prices and consequently the price of petroleum is used as a surrogate for much of the analysis. Other energy types will parallel oil prices as long as there is comparative ease of substitution between the energy types, oil is a significant input in the production of that energy (eg. electricity) or the other energy source faces approximately similar demand and supply conditions as oil.
2. Data may often be misleading. The decline in the ratio of oil to wages may not be reflected by other energy types such as electricity.
3. A Herfindahl index is a measure of concentration. First a measure of size is selected (such as number of employees, value of sales etc.) and each firm's share of the industry total is computed. These shares are then squared and summed. Specifically the index appears as

$$H = \sum_{i=1}^{n} \left(\frac{X_i}{X} \right)^2$$

where X_i is the firm's share of the total and X is the industry total. H may vary between 1 indicating monopoly and 1/n (n the number of firms) which indicates complete equality of firm sizes. Of course concentration is only imperfectly measured by this index, but very crudely, the closer H is to zero the greater is the number of small, equally sized firms.

4. A more detailed explanation of energy as a proxy for capital services may be found in Mason (1978), Moody (1974) and Taylor (1967).
5. Recently the use of multiple input production functions has been advanced by Fuss (1977) and others. The lack of regionally specific data at the twenty group level, especially capital flows, precludes their application here.

CHAPTER III

THE DEMAND FOR HYDRO BY MANUFACTURING IN MANITOBA

INTRODUCTION

This chapter investigates the demand for electricity by the commercial and power accounts of Manitoba Hydro. The manufacturing sector i.e. the twenty industry group analyzed in other sections of this report, comprise a significant fraction of the total electrical consumption by the commercial and power accounts of Manitoba Hydro. Ideally, the analysis should be conducted at the twenty industry group level or lower, however disaggregate data is available only for the last three years. Consequently the demand forecasting will be performed for a higher level of aggregation than is truly desirable.

The first section presents an overview of electricity demand studies and surveys the results which have been obtained by researchers in other areas. Special problems exist in the estimation of demand for electricity which have prevented analysts from developing a concensus of research conclusions.

The second section specifies some econometric models for electricity demand in the commercial and power sectors. The elasticity of demand with respect to average electricity price and the elasticity of demand with respect to natural gas prices are investigated in some detail.

The third and final section tests the estimation equations and analyses their ability to forecast. As is demonstrated these models are a useful predictive device. Caution must be exercised in using these models however, because;

1. They are single equation forecasts and as such are prone to an econometric error known as simultaneous equation bias;

2. Any forecasts are also conditional in that electricity demand is projected based on other economic variables themselves forecast with error.

However such econometric forecasts do provide valuable insights into the determinants to electricity consumption and are indispensible tools for planning the capacity expansion of an electrical generating system.

I ELECTRICITY DEMAND: ISSUES AND PROBLEMS

Most econometric modelling proceeds by specifying a functional equation in which the dependent variable (electricity consumption) is algebraically related to various independent variables (such as population, incomes and indicators of economic activity). As explained in appendix 1 the existing data is generally 'fitted' to a functional form and the resultant econometric relationship can then be used for prediction and explanation of the movements in the dependent variable.

Electricity demand models are very similar in approach and style to other demand studies, however two important problems have inhibited their full development. These problems are very important and critically alter the interpretation that may be given to the econometric results; failure to recognize this can result in serious errors in the forecasting process.

Basically the demand for electricity differs from other demand studies in two ways;

a. The price schedule does not permit the specification of a demand relationship which is 'theoretically plausible' (see Taylor, 1975; p. 76). The consumer does not face a single price, but a price schedule characterized by blocks where the unit price declines. In other words, where the economics literature indicates that consumers will decide upon the quantity based upon price, in electricity consumption the price per unit depends upon the quantity consumed.

b. It is also critically important to recognize that electricity is a derived demand. Thus, the consumption of electricity is usually involved with the decision to procur capital equipment implying that a distinction must be made between short and long run hydro demand.

1. Electricity Demand and the Pricing Issue

Most electrical utilities use some variant of the Hopkinson rate scheme. The costs of providing service may be broken into a demand component and an energy component. The demand component reflects what economists usually term the fixed costs; while the energy charge relates to the variable costs associated with providing service.

A typical electricity price schedule appears in fig. 1. For the first Q_1 units the consumer is charged a fixed charge (demand charge) and an energy charge of ∅ per unit (intramarginal price), subsequent consumption is charged at a rate of θ per unit (marginal price).

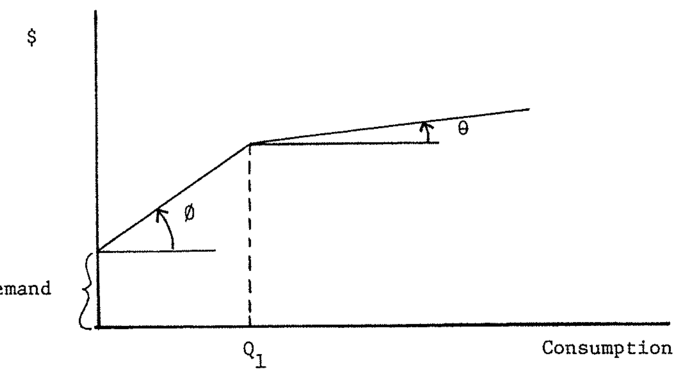


Fig. 1

Translated into neoclassical economics, for a consumer of two commodities, a composite good (x_1) and electricity (x_2), the consumer budget constraint appears as in fig. 2

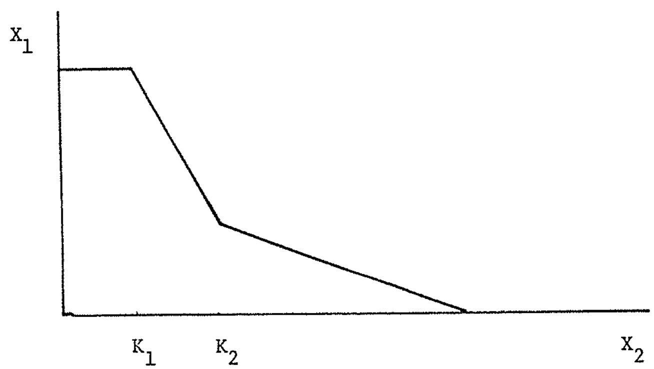


Fig. 2

The budget constraint merely shows the universe of possible consumption alternatives (combinations of x_1 and x_2) which are available given a total income of Y and prices p_1 and p_2 corresponding to x_1 (composite good) and x_2 (electricity). With the usual situation, i.e. the absence of declining block rates, the budget frontier (line XY in fig. 3) is straight, however the fact that p_2 follows a declining block schedule implies that the budget frontier will generally become less steep as more electricity (x_2) is consumed. Normally the position of equilibrium is found by a position of tangency between the consumer indifference curve and the budget constraint as shown in fig. 3 , however where the budget frontier is distorted (made non-convex) by a declining block rate for one of the commodities, the usual graphical and analytical techniques for specifying equilibrium fail. In other words, conventional analysis seems to imply the possibility of two or more equilibrium positions, as shown in fig. 4.

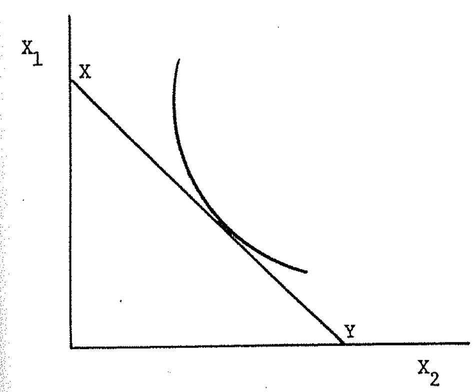


Fig. 3

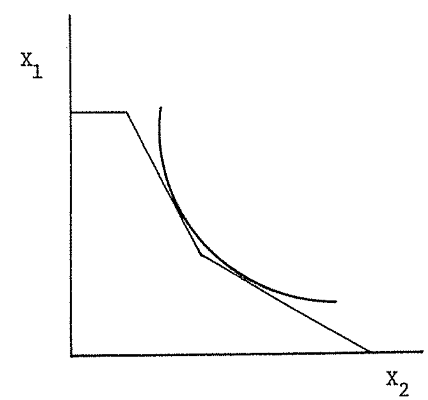


Fig. 4

Following Taylor (1975; pp. 76-80)it is apparent that rate changes alter the usual conclusions about income and substitution effects. He considers three changes;

1. an increase in the demand (or customer charge) with both the intramarginal and marginal charges constant;
2. an increase in the intramarginal charge, everything else constant;
3. an increase in the second marginal charge, everything else constant.

An increase in the demand charge produces a parallel shift downward of the entire budget contract, which reduces the consumption of electricity. This reduction is due to solely the reduction in income occasioned by the increased in the demand or fixed portion of the electricity price, i.e. it is a pure income effect.

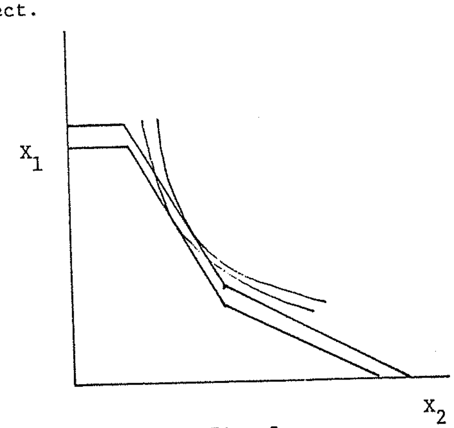


Fig. 5

Change in Demand Charge

The same is true for an increase in the intramarginal rate as demonstrated in fig.6, however for an increase in the marginal rate, in addition to income effects, there is also a substitution effect as demonstrated in fig. 7.

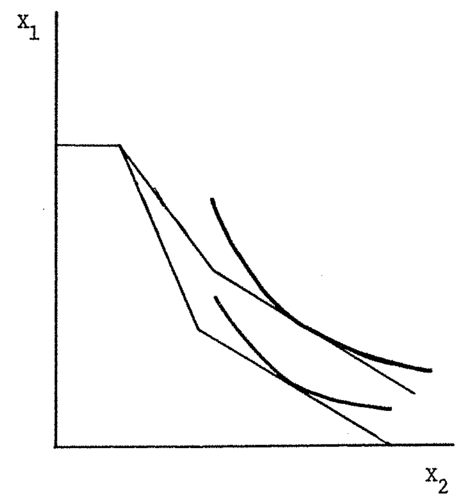


Fig. 6

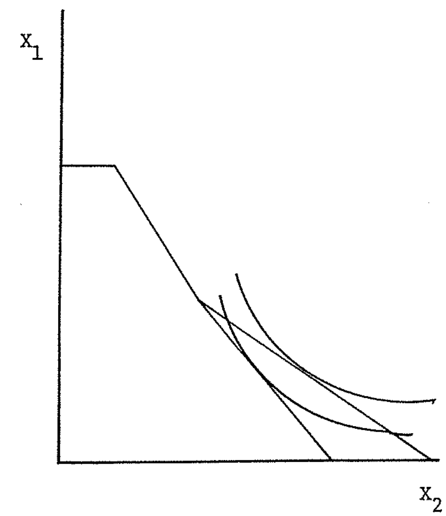


Fig. 7

The upshot of this is to indicate that for studies in the demand for electricity, the marginal price,in addition to the average price is important. Unfortunately developing the marginal price is frequently a difficult exercise, especially for economists with limited access to detailed rate statements and detailed individual accounts. This point, so critical to any econometric study of demand,will be re-examined later.

2. Short and Long Run Demand

Electricity is a derived demand. Variation in the electrical consumption is pursued, first by varying the intensity with which the capital stock (motors, processing and heating equipment) is employed, and second by investing and disinvesting in electricity consuming equipment. The first is a short run response, with the consumption theoretically varying between zero and the maximum capacity of the capital stock. Long run demand is more complicated and relates to the investment policy of the firm. In addition to price and other short run economic indicators such as seasonal retail sales, long run demand is greatly conditioned by overall investment policy within the manufacturing sector and hence is tied to basic economic variables such as demographic change. Thus, electricity demand in the long run is closely related to the demand for capital equipment.

II SPECIFYING THE COMMERCIAL DEMAND FOR ELECTRICITY

The distinction between industrial and commercial demand is difficult to align with Statistics Canada data. For the most part, the commercial accounts in Manitoba Hydro are not part of the manufacturing sector as defined by the Standard Industrial Classification.

Historically the construction of accurate demand forecasts for commercial consumption of electricity has been plagued by the usual econometric problems mentioned above. Certainly the declining block structure in rates is important, and to a lesser extent so is the problem of differentiating between short and long run demand. However, perhaps the most important difficulty lies in the extreme diversity of operations typically contained in the commercial accounts. Inevitably this indicates that there will be difficulty in isolating significant relationships in the load growth of this sector.

A Survey of Previous Studies

Most of the investigation into electricity consumption has concentrated upon the demand for residential consumption. However, some studies of the commercial sector do exist.

1. Mount, Chapman and Tyrell (1973)

This study employed pooled cross section and time series data from the United States (47 states, 1947 - 1960) in a specification which permitted regional and temporal variation in the various elasticities of demand. The functional form of the specification is straightforward, a combined linear and log linear specification.

$$\ln Q_{it} = a + C/D_{it} + b\ \ln Q_{it-1} + \sum_{j=1}^{N} B_j \ln V_{jit} + \sum_{j=1}^{N} c_j \frac{\ln V_{jit}}{D_{it}} + \sum_{j=1}^{N} d_j \frac{1}{V_{jit}} + e_{it} \qquad \ldots\ldots \quad 1^*$$

where, Q_{it} is the consumption of electricity (KWH) by state i in time t, D_{it} the value of a shift variable, (in this case the mean January temperature in state i and in time t), V_{jit} the value of the jth. independent variable, and e_{it} the error term.

For commercial demand the dependent variables chosed are population, income, the average price of electricity, the average price of gas (lagged one year) and the average price of appliances. The presence of the lagged dependent variable (Q_{it-1}) is of concern since autocorrelation will be difficult to detect. No indication is given by the authors about this potentially serious problem.

2. Lyman (1973)

The other recent study of commercial electricity consumption which is relatively accessible is the work of R.A. Lyman (1970). Several innovations are attempted including the specification of non-linear functional forms, the use of data disaggregated to the firm and the specification that not average income, but some measure of distribution be used. The general results for the commercial sector are that the price elasticities are typically high while income elasticities tend to be regionally specific.

* ln refers to the natural logarithm of the variable.

3. Halvorsen (1974)

Both previous studies use ex-poste average prices as the price variable, which Taylor indicates is actually the average revenue to the utility. This implies that the average price variable is an income variable. Strictly speaking, the marginal price calculated from actual rate schedules should also be included in the specification, however, given the inter-regional and inter-temporal variation in the rate schedules, the calculation of a marginal price is extremely time consuming. Also the declining block structure has the potential for introducing simultaneous equation bias in that quantity consumed is assumed to be determined by price, yet in electricity consumption price per unit is also determined by quantity consumed. To use one equation to estimate the demand relationship is, strictly speaking, impossible.

Halvorsen attempts to skirt this problem by using a two equation model which involves the specification of a price equation using both cost and typical electricity bills as independent variables, and a demand equation with conventional independent variables.

The results obtained by Halvorsen and the others is summarized in table 1.

TABLE 1

	Price Elasticity		Income Elasticity	
	Short Run	Long Run	Short Run	Long Run
Mount, Chapman and Tyrell	-.17	-1.36	.11	.86
Lyman	approx - 2.10			
Halvorsen		-1.57 (Cost)* - .562 (TEB)		1.376 (Cost) 1.154 (TEB)

* Note; Cost refers to cost elements in the price equation, TEB to typical electricity bill data.

III SPECIFYING THE INDUSTRIAL DEMAND FOR ELECTRICITY

Aside from the issues (discussed above) of properly calculating price and the distinction of short and long run demand, three additional matters are of particular importance in demand studies of industrial electricity consumption:

1. What is the response of electricity consumption to changes in the price of other fuels, namely natural gas, oil, coal and liquid petroleum?

2. To what extent can electricity be interchanged (substituted) with other fuels?

3. How responsive is the price of production to an increase in electricity?

There are also some data methodology problems which can substantially affect the measurement of demand. First, it is apparent that models which view the manufacturing (industrial) sector as a whole are misleading; within manufacturing there is great diversity of electricity intensity among sub industries. Second, interfuel substitution affects the impact of price. There is some possibility of substitution between electricity and other fuels with respect to heating and motive requirements, but little alternative to electricity when lighting is considered. In all likelihood, the importance of light is minor, especially for energy intensive industries such

as primary metals. Third, within manufacturing subgroups, say the twenty industry level, there exists a substantial variation in electricity intensity. Furthermore, the impact of geography cannot be ignored.

As mentioned in the initial chapter the nature of the relation between energy and other factors of production is vital to an appreciation of how energy prices affect growth. This interfactor and interfuel substitution has been discussed (see Fuss 1977), however, it is well to reiterate that there is considerable possibility for interchanging fuel types in the production process. In addition, it is apparent that this substitutability varies considerably among industries and is a major aspect of any demand study.

Aside from the Fuss (1977) study and the Berndt and Wood (1975) analysis described earlier, most demand studies estimate the cross elasticity of demand (the coefficient which directly measures interfuel substitutability) econometrically through cross section or time series analysis in which electricity consumption is the dependant variable. Some of the more important analyses are now summarized.

1. <u>Fisher and Kaysen</u> (1959)

This study remains an important contribution to the literature despite the passage of almost twenty years. The basic industrial demand equation is

$$KWH = KX_{it}^{B} P_{it}^{a} + e \qquad \ldots . 2$$

where KWH is electricity consumption, X_{it} is output by the i th. industry in time t, P_{it} the average price of electricity, B is the elasticity of output and 'a' the price elasticity of electricity consumption. Taking logarithms and using a cross section sample from 1956 the following results were obtained for various manufacturing industries;

	Price Elasticity (a)	Output Elasticity (B)
Food	-.78	.66
Textiles	-1.62	1.00
Pulp and Paper	-.974	.72
Chemicals	-2.59	.62
Stone, Clay	-1.78	1.027
Primary Metals	-1.28	.44
Fabricated Metals	+.55	1.10
Machinery (except electrical)	-1.33	.90
Electrical Machinery	-1.82	.37
Transportation Equipment	+ .687	1.05

Most valuable about the Fisher and Kaysen study is not the actual estimates, but rather the excellent discussion of the nature of electricity consumption and the demand for the final product. For example, if the price of electricity rises, consumption could fall for two distinct reasons. First, assuming a single product firm, if the price is passed onto the consumer, the demand for the product may fall reflecting a less than completely

inelastic demand function. As a result the demand for electricity falls as production is cut back in the face of inventory accumulation. Alternatively, instead of substitution on the demand side, increased electricity prices could reduce profit margins and the firm could reduce the production of the commodity. In the case of multiproduct firms, increased electricity prices, which may or may not be passed on to the consumer, induces substitution both in consumption and production. Output need not be affected in the instance where an alternate fuel may be substituted without any significant increase in cost, but this is very unlikely. In any event, the price elasticity of electricity is negative, first because the demand for electricity is derived from the demand for the output reflecting substitution in consumption and second, because of the impact changes in price have upon profit margins reflecting substitution in production.

2. Rees and Baxter (1968)

Rees and Baxter attempt to specify a multi-input Cobb-Douglas production function from which they derive the following demand function,

$$X = B_0 p_1^{B_1} \cdot p_2^{B_2} \quad \ldots . p_6^{B_6} Q^{B_{6+1}} \qquad \ldots . \; 3$$

where Q is output, X the consumption of electricity and $p_1 - p_6$ the prices of various fuels. The main conclusion is that output rather than price changes is the key determinant of consumption levels in industrial electricity for most industry groups. Only in a few instances did they discover significant price elasticities of demand.

3. Anderson (1971)

In general this study follows the work of Fisher and Kaysen but makes several important modifications. First, he focuses on the total demand for energy of which electricity is only a fraction. Second, the declining block rate is incorporated into the price structure. Third, simultaneous equation bias is also acknowledged. The results obtained tend to confirm the findings of Fisher and Kaysen, except that the price elasticity of electricity is high and very significant.

$$\ln E = -.35 - .061 \ln PC + .22 \ln PK - .32 \ln PO - 1.94 \ln PE - 1.07 \ln W. \qquad \ldots . 4$$

where E is the consumption of electricity and PC, PK, PO and PE are the prices (adjusted for quantity discounts) for coal, coke, oil and electricity, while W is the industrial wage rate.

A summary table of price elasticities for the industrial sector appears in table 2. As can be seen the price elasticity of electricity consumption in this sector generally is negative, greater than one and in most studies statistically significant. Also the price elasticity in the short run is much lower than the long run.

TABLE 2

	Price Elasticity	
Fisher and Kaysen	-1.25	long run
Baxter and Rees	-1.50	long run
Anderson	-1.94	long run
Mount, Chapman and Tyrell	-1.82	long run
Lyman	- .140	long run
Fuss	- .43	short run
NERA*	-.56 to - .98	short run

* National Electricity Research Association

IV THE DEMAND FOR ELECTRICITY IN THE COMMERCIAL SECTOR

The single equation model presented in this section is the first step toward a forecasting demand model for the commercial sector. It should be emphasized that these demand studies can be used to give unconditional forecasts of future trends, however the quality of the forecast is dependent upon the quality of the projections of the independent variables.

The structure of the estimating equation appears in two forms;

$$\ln KWH = b_0 + b_1 \ln P_e + b_2 \ln P_e/P_g + b_3 \ln R + b_4 \ln CP + b_5 \ln W + b_6 D + e \qquad \ldots . 5$$

$$\ln KWH = b_0 + b_1 \ln P_e + b_2 \ln P_{g-1} + b_3 \ln R + b_4 \ln CP + b_5 \ln W + b_6 D + e, \qquad \ldots . 6$$

where, KWH = commercial consumption of hydro electricity in kilowatt hours,

P_e = the average ex-poste price of electricity,

P_g = the price of natural gas for consumption greater than 2 MCF/annu

R = the value of Manitoba retail trade deflated by the consumer price index,

CP = the ratio of commercial accounts to total population,

D = dummy variable (D = 1 in the first quarter and 0 otherwise),

W = the average quarterly wage deflated by the consumer price index,

e = a random error term.

The data set consists of quarterly observation from 1971 (I) to 1977 (II) and were derived from information provided by Manitoba Hydro and

Statistics Canada as outlined in Appendix IV. The price of natural gas was calculated from the Public Utilities Board tariff schedules and reflects the cost of consuming 2,000,000 cu. ft. of gas per annum.

The results from the commercial sector are not encouraging (see Table 3). The only significant variable is the seasonal dummy while the sign for the elasticity of electricity consumption with respect to the price of natural gas is in the wrong direction for the first two specifications. When this variable is lagged one period, the sign becomes correct (positive) however it remains insignificantly different from zero, that is the price of electricity is an insignificant explanator for electricity consumption in the commercial sector.

The basic problem with estimating demand in this sector is that the data reflects an extreme diversity of economic activity. Gasoline stations, department stores and medical offices are all included under the rubric of commercial accounts. This alone precludes the possibility of estimating the fluctuation in load growth with any degree of sophistication.

Of course other explanators may have been chosen to specify the model, however these are difficult to generate and the data is frequently unreliable. Also, most of the significant indicators are annual, however the data base developed by Manitoba Hydro is of limited usefulness prior to 1971 a fact which severely constrains the demand estimation process.

TABLE 3

Regression Coefficients[1] for the Commercial Sector

Constant	Pe	Pe/Pg	R	CP	W	D.	R^2	D.W.	N
16.21	-.26	.06	-.14	2.14	.04	.38	.714	1.73	26
(1.56)	(-.86)	(.29)	(-.22)	(.63)	(.58)	(5.30)*			

Constant	Pe	Pg	R	CP	W	D	R^2	D.W.	N
15.82	-.20	-.29	-.14	1.98	.03	.37	.714	1.73	26
(1.53)	(-.84)	(-.22)	(-.19)	(.59)	(.54)	(5.31)*			

Constant	Pe	P_{g-1}**	R	CP	W	D	R^2	D.W.	N
16.77	-.24	.05	-.17	2.41	.03	.37	.703	1.65	25
(1.43)	(-.88)	(.28)	(-.22)	(.61)	(.61)	(5.30)*			

* Significant at .01 level

** P_{g-1} refers to the price of natural gas lagged by one period

1. all of these coefficients may be interpreted as elasticities. For example in the second column -.26 is the elasticity of electricity consumption with respect to a change in average ex-poste electricity rate, and so on.

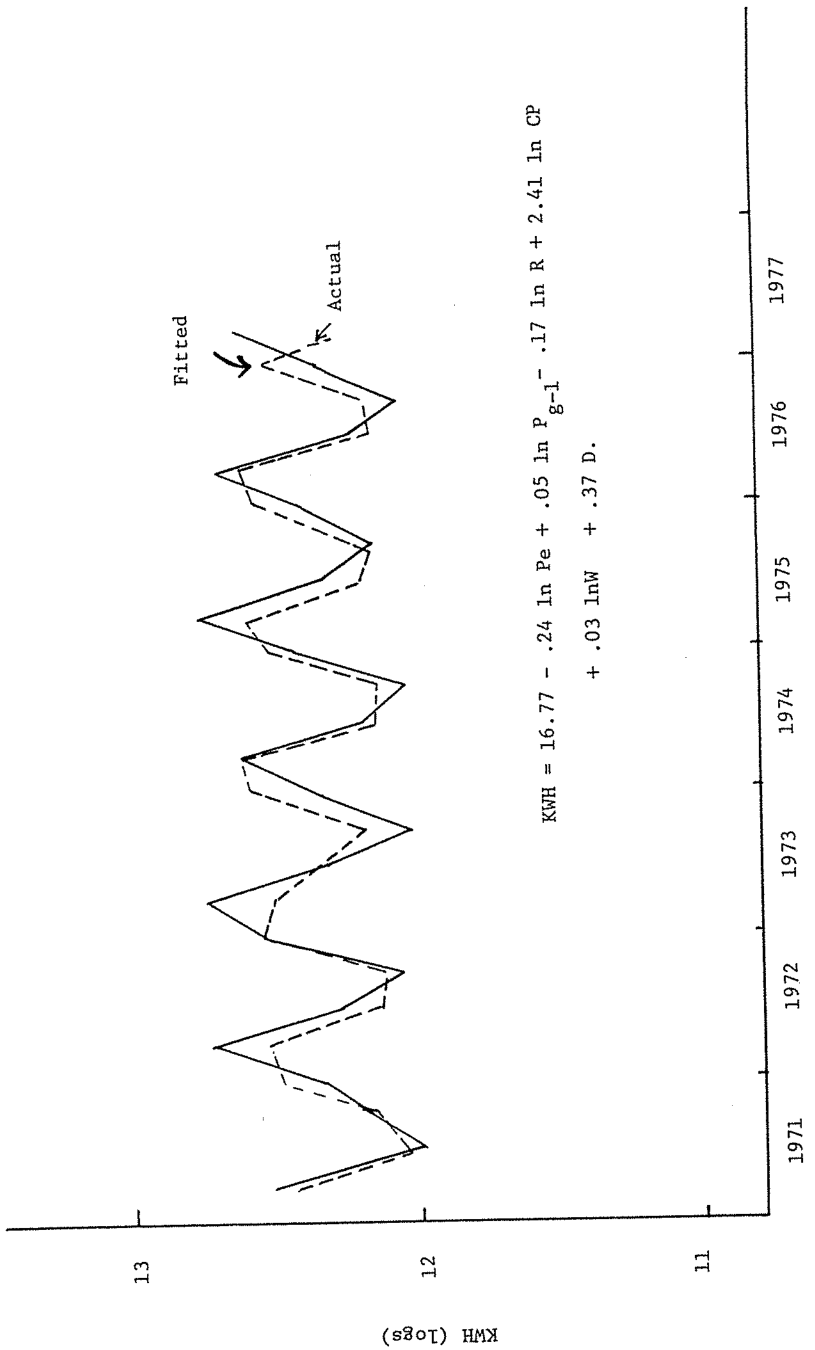


Fig. 8

V THE DEMAND FOR ELECTRICITY IN THE INDUSTRIAL SECTOR

The basic structure of the estimating equations for industrial hydro demand is similar to the commerical sector;

$$\ln KWH = b_0 + b_1 \ln P_e + b_2 \ln P_g + b_3 \ln W + b_4 \ln W + b_5 \ln SHP + b_6 \ln E + b_7 D + e, \quad \ldots . 7$$

$$\ln KWH = b_0 + b_1 \ln P_e + b_2 \ln P_{g-1} + b_3 \ln W + b_4 \ln W + b_5 \ln SHP + b_6 \ln E + b_7 D + e, \quad \ldots . 8$$

where P_e, P_g, P_{g-1}, and D are as defined before, and

W = the average wage in the manufacturing sector,

E = the employment index in the manufacturing sector,

SHP = the value of shipments in 1971 dollars.

Ideally a measure of value added should be used for an indicator of output in the industrial sector, however this information is available only on an annual basis. Real shipments however, is available quarterly and can be used as a proxy for output.

Table 3 presents the results of estimating the models above. In general it can be seen that the explanatory power of the industrial demand estimating model is superior to the commercial sector, undoubtedly due to the less heterogeneous nature of the data. Also, from fig. 9 it can be seen that industrial demand is much less seasonal, suggesting that the consumption of electricity in this sector reflects underlying economic and technical forces rather than changes in the season.

TABLE 4

Regression Coefficients for the Industrial Sector

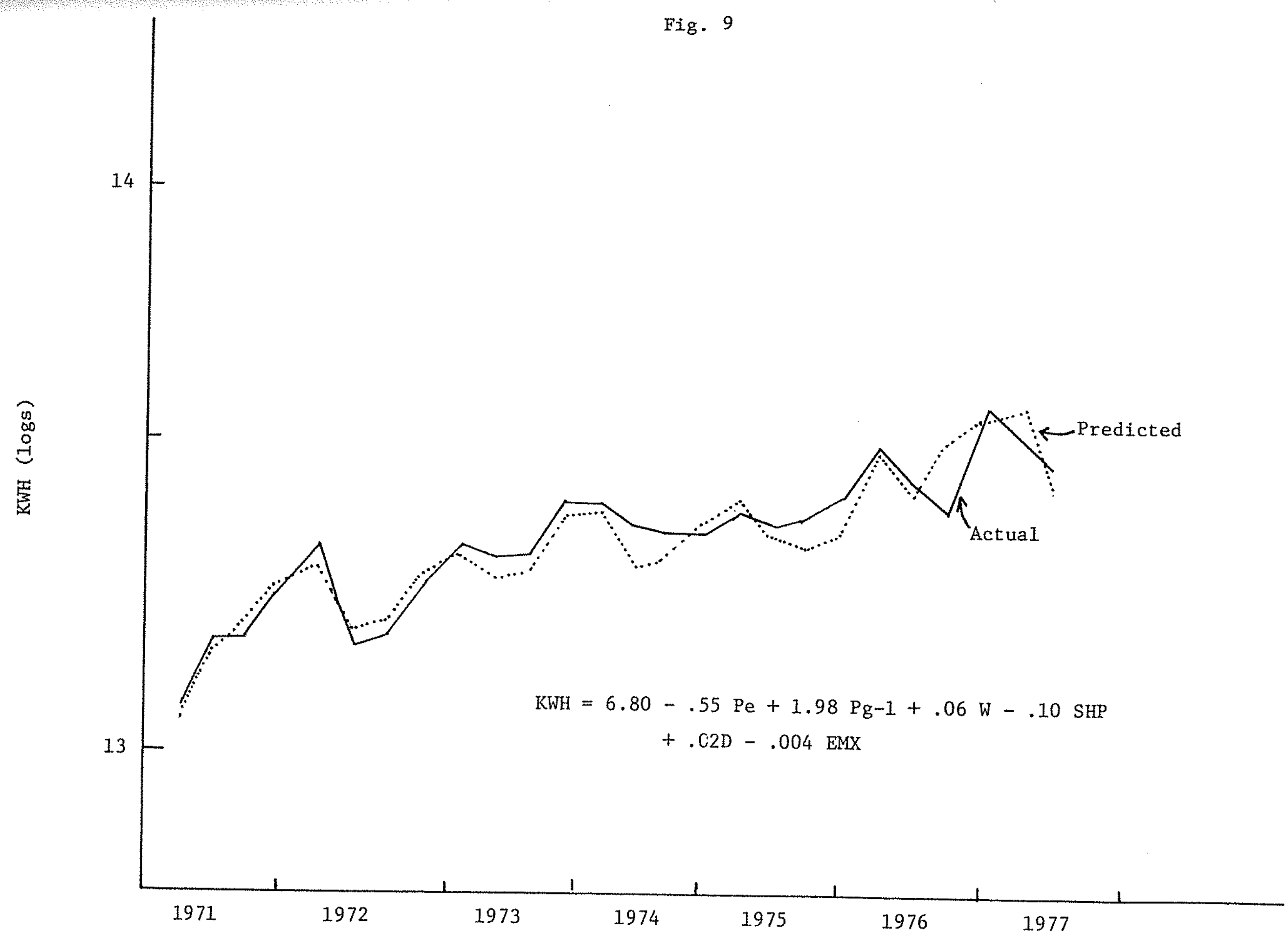
Constant	Pe	Pg	W	SHP	Dummy	EMX.	R^2	D.W.
6.80	-.55	1.98	.056	-.10	.02	-.004	.867	1.56
(1.98)*	(-2.48)**	(3.05)**	(3.29)**	(-.24)	(.84)	(-.96)		

Constant	Pe	P_{g-1}	W	SHP	Dummy	EMX.	R^2	D.W.
11.48	-.04	.09	.061	-.17	.08	.002	.823	1.36
(3.42)*	(-.27)	(3.71)**	(3.08)**	(-.34)	(2.32)*	(.60)		

* Significant at .05 level ** significant at .01

1. Note that all variables are measured in logarithms and consequently the coefficients may be interpreted as elasticities.

Fig. 9



The results in table 4 clearly indicate that lagging the price of natural gas is unproductive; the coefficients for electricity prices (P_e) and the dummy variable become quite unstable. Concentrating on the first equation reveals that the elasticity of demand (short run) for electricity is about - .5 and is significant at the .01 level. In addition, the cross elasticity of demand with respect to natural gas prices is also substantial (1.98) and significant at the .01 level. Surprisingly there appears to be little systematic relation between current shipments and the consumption of electricity, however the wage rate appears to be significantly associated. More than likely this is spurious, reflecting merely a common direction and rate of growth. Overall manufacturing shipments in Manitoba have been very sketchy indicating the underlying precariousness of the manufacturing and industrial base. Finally, the Durbin-Watson test is unable to accept or reject the null hypothesis that serial correlation is present.

VI FORECASTING THE DEMAND FOR COMMERCIAL AND INDUSTRIAL CONSUMPTION OF HYDRO

The demand models developed in the previous two sections may be used for unconditional prediction which refers to the procedure of estimating the structural coefficients of demand over a restricted sample (say first quarter 1971 to first quarter 1976) and then extrapolating the dependent variable (kilowatt hours of consumption) using the actual values of the various independent variables. In this manner the actual values may be compared with the predicted values and a good idea of the basic value of the model thereby obtained. Once the unconditional testing has been accomplished it is then possible to use the estimated model over the entire sample set for conditional prediction, provided of course that the coefficie of the demand model over restricted and full sample sets are sufficiently comparable. A more complete explanation of prediction and forecasting is in Appendix V.

Conditional forecasting is more problematic than unconditional projections, since in the latter, history is replicated, while with the forme forecasts are made into the future and based upon projections of the indepen variables, themselves subject to forecast error. For this reason, forecasti is at best a precarious exercise and should not be extended for more than the reasonably foreseeable future; generally no longer than five years. In this paper, only unconditional forecasts are developed to provide the basic equations upon which conditional forecasts may be made.

Forecasts of Commercial Consumption

The demand model for the commercial sector proved to have relatively low explanatory power. If the estimating is performed for the first 19 quarters the following results are obtained

$$KWH = 21.19 - .185\ P_e + .069\ P_{g-1} + .081\ W - .767\ R + 3.04\ CP + .415\ D$$
$$(1.67)\ (-.64)\quad (.38)\quad (1.05)\quad (-.75)\quad (.71)\quad (4.74)$$
$$R^2 = .733 \qquad D.W. = 1.71 \qquad F = 5.51 \qquad \ldots .\ 9$$

and compared to the estimated equation over all 26 observations they are quite similar;

$$KWH = 16.77 - .23\ P_e + .051\ P_{g-1} + .029\ W - .171\ R + 2.41\ CP + .37\ D$$
$$(1.42)(-.88)\quad (.28)\quad (.61)\quad (-.22)\quad (.611)\quad (5.31)$$
$$R^2 = .703 \qquad D.W.\ 1.65 \qquad F = 7.09 \qquad \ldots .\ 10$$

The only significant changes are in the coefficients on the wages (W) and retail trade (R). The R^2's are hardly disturbed as are the Durbin-Watson statistics.

Fig. 10 shows the actual and fitted data over the first 19 quarters. Using equation 10 and the values of the independent variables it is possible to project KWH for the remaining 7 quarters until 1977 (2) as indicated by the dotted line.

The quality of the prediction may be tested by a variety of summary measures.* For example, Theil's inequality coefficient is very low (.0059) while the mean square error is .1465. Most of the error in the forecast is understandably caused by the exclusion of other variables. For the most part the dummy variable (D) is the prime determinant of consumption in this sector and no claim can be made that the model is a truly satisfactory forecasting device.

* See Appendix V for an explanation of these terms

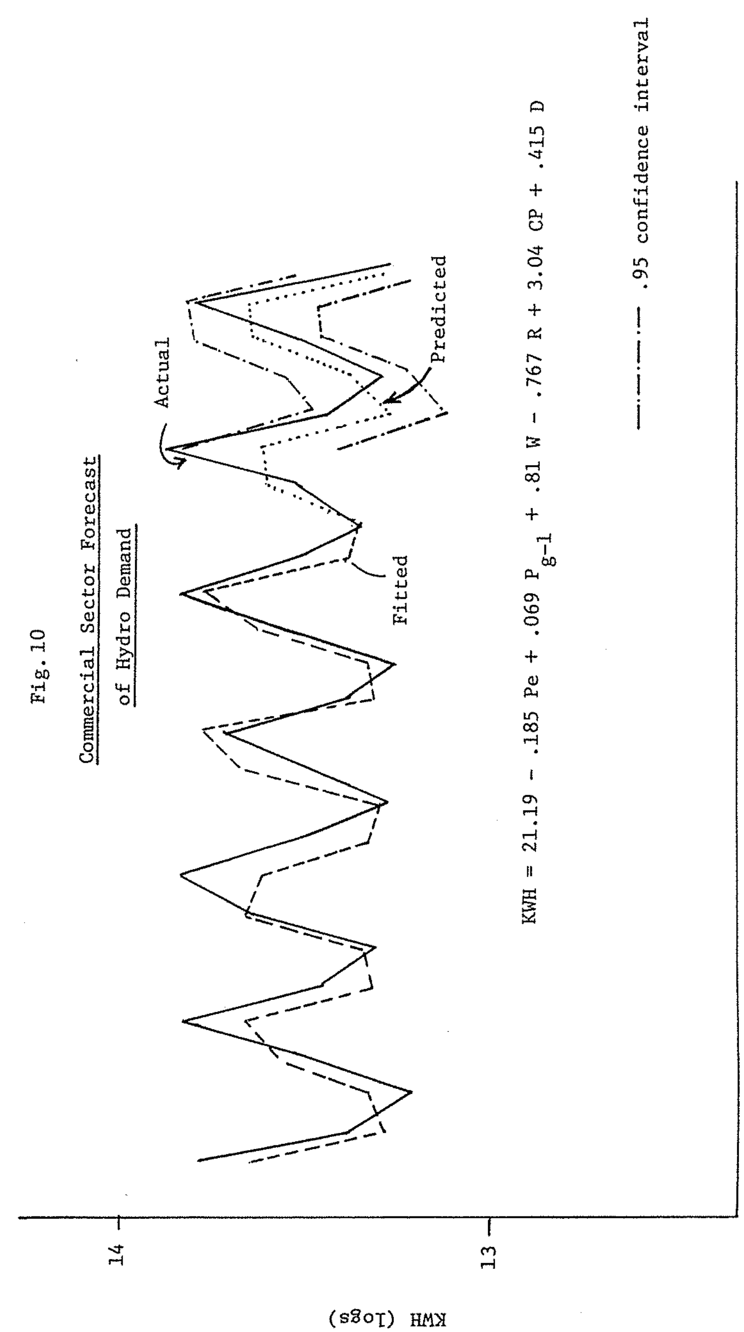


Fig. 10

Commercial Sector Forecast

of Hydro Demand

Nevertheless this is an excellent cast study of a regression equation with relatively low explanatory power, but which seems to have an acceptable predictive ability. It should be stressed, that the commercial sector is, by virtue of the data on power consumption, very heterogeneous and improvement in the model lies in the direction of first developing more homogeneous classes of power users. Next, data on typical power consumption for various classes of users must be developed so that more precise measures of marginal prices may be obtained. This point is also relevant for natural gas prices. Finally, the seasonality of the data strongly suggests that the commercial sector will be difficult to model econometrically in the sense that economic and social forces may have little bearing upon power consumption. In this case, time series analysis such Box-Jenkins procedures could be employed.

Forecasting Industrial Consumption

The specification and testing of a forecasting model for the industrial sector is somewhat more difficult. The estimation over the first 19 quarters yielded the following result;

$$KWH = 10.56 - .62\,P_e + .032\,P_g + .047\,W - .37\,SHP - .004\,D + .0003\,EMX$$
$$(3.99)\ (-3.06)\ (1.07)\ (3.12)\ (-1.03)\ (-.16)\ (1.18)$$
$$R^2 = .904 \qquad D.W.=.89 \qquad F = 18.8 \qquad \ldots.\ 11$$

compared to the estimation over the entire sample;

$$KWH = 6.80 - .55\,P_e + 1.98\,P_g + .056 - .10\,SHP + .02D + .004\,EMX$$
$$(1.98)\ (-2.48)\ (3.05)\ (3.29)\ (-.24)\ (.84)\ (-.96)$$
$$R^2 = .867 \qquad D.W. = 1.56 \qquad F = 13.8 \qquad \ldots.\ 12$$

The comparatively recent movement of natural gas prices, fails to be reflected in the smaller sample; this is a typical problem in testing forecasting models. A less restricted sample, say the first 23 observations would undoubtedly force the coefficient in P_g to converge to the result obtained in equation 11, however it then becomes difficult to evaluate the quality of the prediction.

Another problem is that the smaller sample introduces positive serial correlation into the results (DW = .89). A Cochrane-Orcutt procedure successfully removes this but there is evidence of a certain instability in the coefficients especially in Pe and Pg;

$$KWH = -.85\,P_e + 1.62\,P_g + .022\,W + .91\,SHP + .044\,D - .005\,EMX$$
$$(5.21)\ (1.29)\ (1.11)\ (3.15)\ (1.26)\ (-.87)$$
$$R^2 = .899 \qquad D.W. = 1.36 \qquad F = 21.3 \qquad \ldots.\ 13$$

The increase in the price elasticity of electricity and the significance of the coefficient on natural gas suggests that the data support quite different models depending upon the sample size chosen.

Recent experience in the past two years are especially important to explain the movement of consumption in the industrial sector. An examination to the actual growth of demand in this sector suggests that there has been a significant variation in the rate of increase in the past few years. A forecasting model at this level of aggregation is unable to determine or predict such changes; only more comprehensive techniques using disaggregated information on individual sectors within the industrial accounts have any hope in accomplishing a more sensitive prediction.

Fig. 11 indicates the actual load growth, along with the fitted values for quarters 2 to 19 (Cochrane-Orcutt procedures eliminate the first observation). The predicted values for quarters 20 to 25 are indicated by the dotted line.

The quality of the prediction as measured by Theils inequality coefficient (.0408) and the mean square error (1.062) indicate that this too is an acceptable predictive tool over the past two years, although it is not as good as the commercial sector model. From fig. 11 it is apparent that the industrial sector model does not 'track' the actual data as well as the commercial sector model (fig. 10).

Fig. 11

Industrial Sector Forecast of Hydro Demand

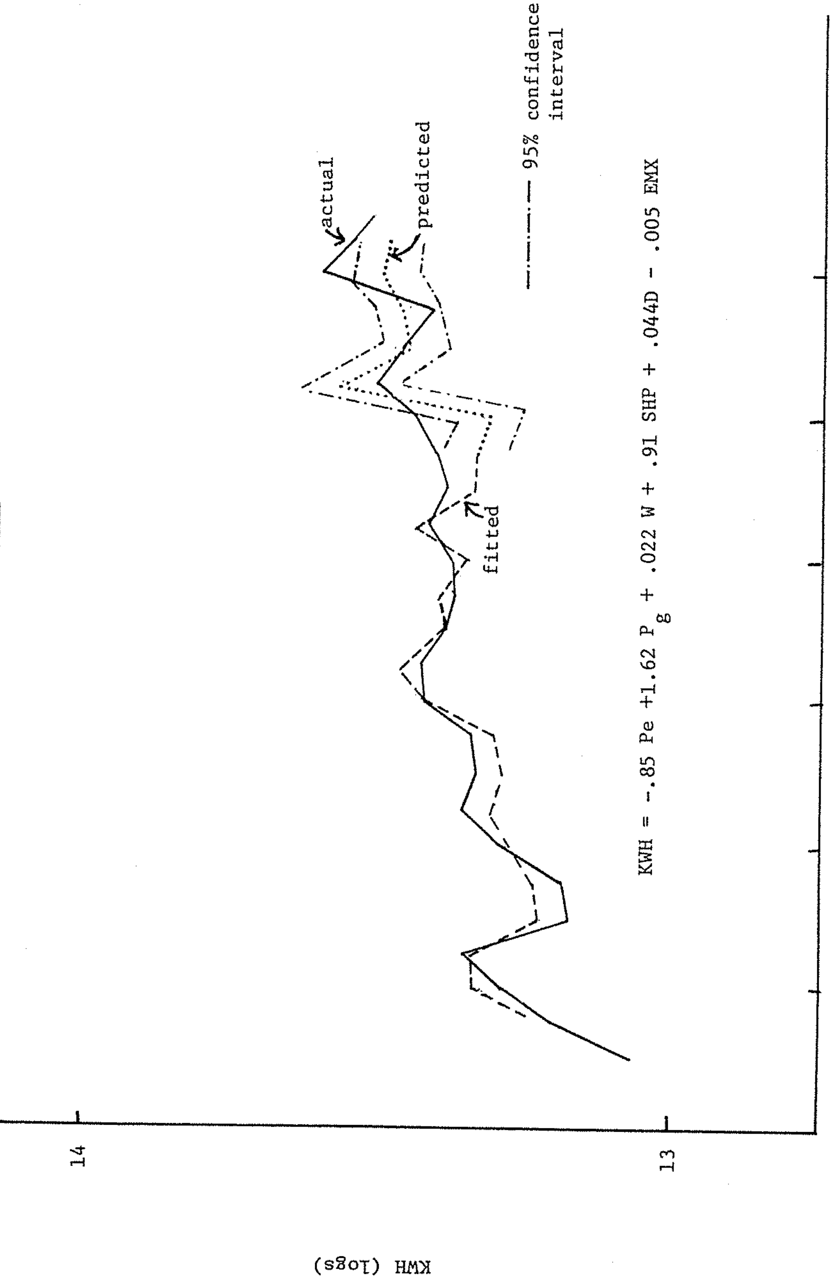


TABLE 5

Summary Of The Predictive Power

Of The Forecasting Models

COMMERCIAL SECTOR

(Quarters 1 - 19)

Coefficient	Value	't' Statistic
P_e	-.18	-.64
P_{g-1}	.07	.36
W	.08	1.05
R	-.76	-.75
CP	3.04	.71
D	.42	4.74

(P_e = average price of electricity (ex poste), P_{g-1} = lagged value of natural gas prices, W = average wages, R = retail sales, CP = consumer price index, D = seasonal dummy).

(Quarters 20 - 25)

Quarter	Actual (logs)	Predicted (logs)	% Error
20	12.35	12.48	+ 1.05
21	12.86	12.51	- 2.79
22	12.22	12.07	- 1.24
23	12.04	12.19	+ 1.24
24	12.34	12.55	+ 1.70
25	12.60	12.56	- .3

Theils inequality coefficient = .00591*
Mean Square Error .... = .1466
Bias Proportion .... = .024
Variance Proportion .... = .025
Covariance Proportion .... = .949

TABLE 5

(continued)

INDUSTRIAL SECTOR

(Quarters 1 - 20)

Coefficient	Value	't' Statistic **
P_e	-.85	-5.21
P_g	1.62	1.29
W	.02	1.11
SHP	.91	3.15
D	.04	1.26
EMX	-.005	-.87

(SHP = Shipments in manufacturing, EMX employment index in manufacturing, W = Average hourly wage in manufacturing)

(Quarters (21 - 25)

Quarter	Actual (logs)	Predicted** (logs)	% Error
21	13.53	13.48	-.29
22	13.48	13.42	-.44
23	13.42	13.48	+.44
24	13.70	13.45	+2.23
25	13.52	13.30	-1.65

Theils Inequality Coefficient = .0054*
Root Mean Square .... = .1467
Bias Proportion .... = .6581
Variance Proportion .... = .036
Covariance Proportion .... = .305

* see Appendix V for an explanation of these terms

** corrected for serial correlation.

VII SUMMARY

The estimation of demand elasticities and the construction of forecasting models is an ongoing process. The results presented in this chapter must be viewed as preliminary but also indicative that more work would be very beneficial in this crucial area. Table 6 presents a summary of the various elasticities estimated in the commercial and industrial sectors. It is difficult to interpret these estimates as either short or long run estimates since the data is quarterly from 1971 to 1977 indicating some capital adjustment response potential to changes in the price of electricity. However, as demonstrated in the previous section there is variation within the fuel use in manufacturing sectors, especially with regard to electricity.

TABLE 6

Estimated elasticities

Sector	Price of Electricity	Price of Gas	Output	Retail Sales
Commercial*	-.24	-.05		-.17
Industrial	-.55**	1.98**	-.10	

* all coefficient insignificant at .05 level

** significant at .01 level

Some main conclusions are possible at this stage.

1. The commercial and industrial sectors need to be considerably disaggregated. Work had begun in collecting data by SIC classification at

Manitoba Hydro, but this activity needs to be accelerated. Without better data (and this applies to estimating residential demand also) little improvement in forecasting can be expected.

2. These models are single equation forecasts. Ideally an energy consumption model should be constructed for the entire province including all energy types, not merely electricity. Interfuel substitution is an important element in the preparation of such a model. It is important, however, not to oversell such holistic exercises; large scale modelling must be disciplined and proceed sensibly and to that end, these single equation forecasts are an important first step. Experience in the United States has indicated that large scale energy modelling systems tend to be very expensive and, as yet, of limited value.

3. Typical consumption patterns are needed for various classes of users. A major shortcoming in the analysis presented here is that prices entered into the specification are ex-poste average prices when both the marginal and intermarginal prices are required for proper evaluation of demand.

4. The study has examined the consumption patterns of Manitoba Hydro alone. Certainly for completeness and accuracy the information obtainable from Winnipeg Hydro, and the electricity generated at the plant site is essential. Resource constraints preclude this research effort from pursuing these aims.

CHAPTER IV

PRICING OF HYDRO ELECTRICITY: A SYNOPSIS

INTRODUCTION

The pricing of electricity has occupied increasing attention both in the theoretical literature and in the deliberations of regulatory commissions. Electricity production has certain characteristics which make fair and efficient rates problematic. This chapter very briefly surveys some of the major issues involved in pricing electricity.

First, electricity invariably involves the use of capital intensive processes. Nuclear plants, dams, and thermal generating plants are large indivisible capital equipment usually with some debt or equity financing and requiring sufficient revenues to service these capital obligations.

Second, the generation of electricity is itself, frequently a fuel intensive process with coal, oil and to a small, but increasing extent, uranium required to produce electricity. Accordingly the costs of providi electricity can be very sensitive to the cost of other energy types. In Manitoba, the main source of electricity is hydro electric power which is not dependent upon fossil fuels, however during periods of high demand the utilities must rely upon thermal generating plants.

Third, electricity consumption is marked by significant temporal variation in consumption. Typically customers may be segregated into residential, commercial and industrial users although within each of these categories there may be additional classes of users. Each of these customers tend to have different demands both for power (peak kilowatts) and energy (duration of kilowatts) which produces a typical varying pattern of demand on the utility. For example, residential use peaks during the 5:00 p.m. to 8:00 p.m. period each day while industrial usage tends to be less cyclical following a weekly pattern of usage. This variation in demand generally necessitates the expansion of generating capacity to fill the peak demand.

Finally, and related to the above, is the existence of separate classes of customers based upon different demand elasticities for electricity and physically separate locations. These are the necessary and sufficient conditions for price discrimination and most electricity utilities actively employ a form of rate discrimination, in effect 'charging what the traffic will bear'. Often one class of customer may be charged in excess of the actual cost of service, thereby subsidizing the use of other customers.

Variations in Electricity Demand

Each of the three major classes of electricity customer exhibits unique cycles of demand. For residential consumers, the daily cycle is most pronounced, with peak demand occurring between 5:00 and 7:00 p.m. This daily cycle may be superimposed upon a more gentle weekly cycle in which demand peaks on the weekend. Finally, both the daily and weekly cycles are part of an annual cycle with the most dramatic peak occurring in the winter months of January and February and a second summer peak that has evolved recently due to airconditioning demands.

Commercial users have a peak which is spread throughout working and retail hours of the day, a decline in usage on the weekend, and an annual peak during the winter months and in the summer.

Industrial usage is less prone to cycles. Although there is weekly activity that declines on the weekend, industrial usage tends to conform to the workday and week; the existence of significant shifts in demand is most closely related to the general state of the economy. During periods of rapid expansion, plant and equipment is more likely to be fully utilized with around the clock production and cycles tend to become less pronounced. As economic activity slackens, shifts are reduced and industrial consumption ceases during the evening and weekends. While there is some seasonal variation due to weather and light changes, industrial consumption tends to be for process heating (smelting), direct use (electro-plating and other chemical processes) and motive power.

A significant difference exists between American and Canadian electricity consumption in that annual peaks tend to be in opposition to one another; summer airconditioning in the U.S. placed the peak demand on electricity utilities while in Canada the winter months are the peak. This fortuitous opposition may be and is exploited by utilities who arrange energy swaps throughout the year.

The existence of sharp variations in demand and the requirement that electricity be generated by capital intensive processes places significant constraints upon the design of efficient prices. In addition, if fairness is also added as a requirement for a pricing system, the problems of designing electrical rate structures can be severe. Finally, it is often argued that energy prices can be used as a tool to redistribute income and encourage manufacturing. The next section examines the basis for electricity rates and in particular the concept and measurement of marginal cost in electricity generation.

ELECTRICITY RATES

The purpose of any pricing mechanism, from the perspective of the utility is to fully recover all operating costs. Historically electricity rates have evolved in step with metering technology and increasing economic understanding of the basic notions of cost. The first rates were simply total costs divided by some standard such as square footage, number of rooms, number of customers etc. Such rates are appropriate where the demand is stable and unambiguously related to the standard; i.e. where actual consumption is a simple linear relation to number of rooms, customers, square footage etc.

As meters evolved,it becomes possible to measure the total energy consumed (kilowatthours) and subsequently the total demand (kilowatts). With the possibility of differentiating between those who used a small percentage of the total capacity for a long time, and those who used a significant percentage of capacity for a brief period, it became apparent that these two types of consumption contributed differently to the total costs of the system. Those with a high energy charge but low demand (the low capacity long duration user) contributed little to the need for expanded capacity, while those with high demand regardless of their energy requirements impelled the utility to make expensive additions to capacity.

In the late 19th century two rate structures to cope with this problem were developed. The Hopkinson rate consisted of a charge to cover the demand (maximum kilowatts consumed) and an energy charge for the duration of this consumption (kilowatthours). The Wright rate schedule was a scheme of dividing energy consumption into blocks which were porportionate to the demand

and charging a declining rate for successive levels of consumption. Both charges price the demand and energy portions of electricity consumption while recognizing the load factor aspect.[1] Customers with a stable demand for electricity have high load factors while those with significant variation in their demand have low load factors.

Most electricity utilities, and Manitoba Hydro is no exception, bas their rate structures on fully distributed historical costs. Recently the alternative scheme of marginal cost pricing has become widely discussed.

a. Fully Distributed Historical Cost (FDHC)

This procedure, also known as average cost pricing, calculates the average costs on the electrical generating system imposed by various class of customer and allocates rates according to use. Because of joint costs (costs borne jointly by all customers such as transmission lines and administrative overhead) divisions between customers are difficult to make but the most common procedure is to separate demand, energy and customer costs. A demand charge relates to the peak power demanded by the user, energy charges reflect the duration of any particular level of demand, whi customer costs are those costs (such as office labour and other administra expenses) associated with servicing the customer.

The general procedure is to first allocate total annual costs among various types of users based on consumption patterns, and then, within a class, allocate the costs according to demand, energy and customer charges

Allocating costs, especially demand costs, (peak kilowatts) is a difficult task and most utilities are confined to quite crude estimating procedures.

The main advantages of this pricing policy are alleged to be accounting convenience, avoidance of any surplus or deficit, fairness to consumers and possibly conservation of energy. The average cost pricing method is convenient and requires comparatively unsophisticated metering procedures. In addition, the rate structure appears to be fair and simple in that all overhead and joint costs are allocated according to use. Finally, since the rate structure is based upon historical costs, it can be argued that average cost pricing encourages the appropriate consumption patterns if average costs are projected into the future.

Several important weaknesses of an average costs pricing system relate to the use of historical accounting as a base for rates. Although historical costs reflect previous investment(and average cost pricing would certainly keep rates low during a period of gradual load growth given increasing costs), other pricing systems perform the same task. Historical average cost based rates do keep rates low when unit costs are increasing, but also increase the burden to the consumer should unit costs ever decline. Average cost pricing eliminates the impact of inflation, the use of different cost technologies (nuclear, hydro and thermal) and time varying costs; the cost of a small increase in capacity is under-stated with an average cost rate.

During periods of rapid load growth and inflation, historic costs are a poor guide to future expenditures required to service such growth. In addition to recovering costs, rates should serve as an indicator of appropriate consumption patterns. As average costs currently tend to be

considerably lower and lag marginal costs, (the incremental cost occasion by a small incremental increase in consumption) rates based upon average costs tend to encourage a consumption pattern greater than is actually warranted if the marginal users were charged the incremental costs of production. Under average cost rates, the customer does not receive the full information about the cost of production. Inevitably the utility, because of revenue requirements,must raise rates, however these rates wil always be below the cost of providing the extra consumption encouraged by the initially low rates. Consequently revenue requirements overtake rates. If rates reflected the cost of increased output, consumption woul be tuned to the cost of producing output and not the past costs.

Proponents of average cost pricing, rely primarily upon its inhere simplicity both in application and rate structure as the main advantage. Many view the arguments for a marginal cost pricing scheme as artificial and only of theoretical interest. Accordingly average cost pricing schem persist despite their almost universal condemnation by economists.

b. Marginal Cost Pricing

Although average cost pricing proponents agree that the allocation joint costs is arbitrary, they also alleged that the simplicity of the scheme compensates for any flaws. In the past twenty years economists ha become insistent that a marginal cost pricing policy not only makes super economic sense, but is workable. They also cite the use of such rates by the French electrical utilities which have pioneered several sophisticate rate structures. Before pursuing the mechanics of such a procedure, the concept of marginal cost in electrical utilities will be reviewed.

To fully appreciate the difference between the average cost price and the marginal cost price procedure it is important to examine the difference between average and marginal cost and how these two concepts apply to electricity production. Simply stated, the average cost is merely the total cost divided by the output, while the marginal cost is the extra cost due to increasing production by one unit. Theoretically the increase in output is supposed to be infinitesimally small, however for the purposes at hand no harm is done by examining the extra costs associated with producing one extra kilowatt or kilowatthour.

If total costs vary continuously with production, then a typical situation could appear as in fig. 1.

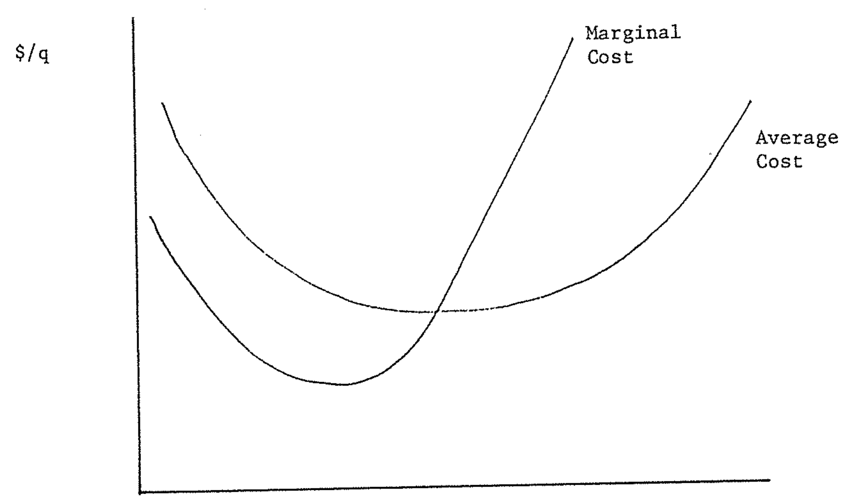


Fig. 1

Note that the marginal cost exceeds average cost when average costs are decreasing and vice versa. Also note that total costs are equal to the area ABCD and to the area under the marginal cost curve at the relevent level of output; in other words marginal cost is the first derivative of the total cost function.

In a perfectly competitive environment,[2] output will be pursued to the point where average cost is minimized and price is set equal to marginal costs of production. For this reason economists generally favour marginal costs as a basis for electricity pricing.

In electricity generation, the calculation of marginal cost may be difficult since a small increase in consumption could necessitate a dramati increase in costs through the construction of 'lumpy' capital intensive generating equipment. This assumes of course that increases in demand will not be met through a degredation in service such as brownouts. It is possible to isolate three general marginal production costs associated with electricity generation;

1. Marginal customer costs associated with providing a transmission network to fulfill customer demands;

2. Marginal demand costs caused by expansions to capacity to meet peal power requirements;

3. Marginal energy costs associated with what economists generally term variable costs of production such as fuel and maintenance.

Marginal customer and energy costs tend to be relatively stable, increa or decreasing in a predictable and incremental manner with output. Margina demand costs, however, either vary dramatically with small increases in output or are constant over wide ranges of output. Typically marginal costs increase with output at a relatively modest rate, and then quite suddenly may increase as capacity is exceeded, as shown in fig. 2.

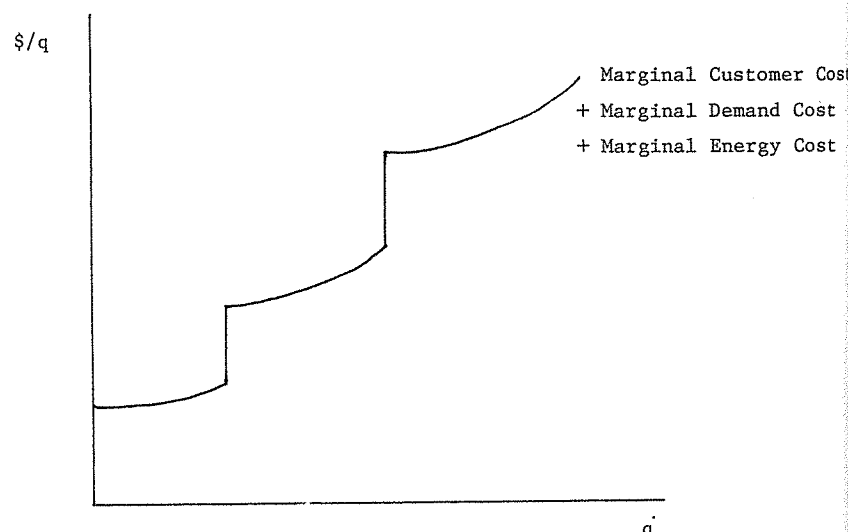


Fig. 2

An additional factor already mentioned is the existence of peak demands. At different times the generating system incurs different probabilities that demand will be exceeded and it seems intuitive that prices should reflect the degree of risk that capacity will exceed and consequently marginal costs may be firmly related to time of day variations in demand.

Marginal cost pricing rests upon three basic propositions;

1. Resource scarcity
2. Price responsive demand for electricity
3. Consumer sovereignty

The first proposition merely indicates that electricity production consumes resources which have positive real costs. The second, assumes that value of electricity production is neither zero or infinite, implying that consum will alter consumption patterns in response to price. Finally, consumer sovereignty recognizes that consumers are the best judge of what to consume and in what quantity. Although the literature on the effects of advertisin throws considerable doubt on the consumer sovereignty proposition especiall in the household, the commercial and industrial sectors are probably highly informed purchasers of electricity; consequently consumer sovereignty may safely be retained as an assumption.

Marginal cost pricing proceeds from the theorem, basic to modern exchange economics, that the marginal social gain from consuming should equ the marginal social cost of producing. One procedure of looking at the benefits from expanding capacity is to examine the foregone value added in industry should the increased capacity not be met. If this opportunity cos of expansion exceeds the direct costs of adding to capacity, then the expans is warranted.[2] For residential users, if the consumers are willing to pay the increased cost of production and if revenues are sufficient to permit construction, then expansion is warranted. In the absence of externalities (such as pollution) and income inequalities, the most accurate measure of social gain is price, while the measure of social cost of production is marginal cost. Basically, the price of electricity should be set equal to the cost of producing the last unit (kilowatt) of power.

APPLYING MARGINAL COST PRICING PRINCIPLES TO ELECTRICITY

Although the theory is clear, the application of marginal cost pricing to a particular situation can be troublesome. To many, the costs of such a pricing scheme can outweigh any benefits which accrue.

The main requirement,is of course, that a pricing system should provide the utility with sufficient revenues to cover costs; in addition to guiding consumption, to the least cost configuration. Marginal cost pricing, because it signals the extra cost (or saving) obtained from a small increase (or decrease) in output, effectively sets up an environment where consumers have accurate information about the cost of production. If external effects are also included in the cost structure of the utility, the price equal marginal cost rule becomes a socially optimum rule.[3]

Also, electricity rates must be fair, but it is important to note that fair is not the same as equal. Regulatory commission have generally interpreted fairness to be the following principles;

a. The sequence of consumption is irrelevant. All consumption in new and those who have been established customers have no more right to service than a new customer;

b. Price discrimination ought not to exist and rates should not vary with end use;

c. Price changes should be announced with sufficient forewarning;

d. If costs are increasing and a surplus accrues to the utility as a result of marginal cost pricing, this quasi-rent should be divided equally among all users.

Often the goals of efficiency and fairness are not compatible, and it becomes difficult to evaluate the superior course of action; that is, whether it is more desireable to sustain inequities in the name of efficien or vice versa. In some circumstances a marginal cost pricing scheme conver to an equitable system. For example, if native land settlements are includ as a cost of additional hydro expansion, electricity consumers will bear th increasing cost. Fairness relates, not only to equity within the set of electricity consumers,but also between consumers and non consumers of elect Legitimate costs of production are land settlement claims due to flooding a electricity rates should reflect this cost.[4]

Given that a utility has decided to adopt a marginal cost pricing form it becomes important to decide whether long or short run marginal costs are be used as the basis for prices. Short run marginal costs refer to the marg customer and energy charges, while long run marginal costs compute the extra cost of a unit of production when capacity is expanded. Most economists arg that prices should be based upon long run marginal costs, to impose upon current users the extra costs of their increasing demands. In addition, sho run marginal costs could easily fluctuate especially in a situation where a variety of plant and equipment was 'mixed' to service demand. Varying rate structures are extremely costly and lead to considerable emnity between cust and producer.

PEAK LOAD PRICING

Electricity is a flow energy not easily stored and subject to wide variations in demand. Consequently a utility usually maintains a portfolio production capability. Frequently advanced technology capital equipment (hydro generating stations) are in continuous use, and vintage generating plants (thermal stations) are introduced to service the peak demands. Often these vintage plants are considerably more expensive and impose significant cost burdens upon the utility.

Coupled with the decision to become connected to the utility (connect) and consume a maximum power level (demand) over a specified period of time (energy) entailing customer, demand and energy charges respectively, there is a decision about the time of use. As mentioned above, different customers have unique peak periods. Given that peak demand is generally met either by introducing older plants into the generating system or by expanding the system through new investment, the peak obviously imposes significant costs upon the utility.

The Hopkinson rate was originally designed to assist in peak load pricing by separating the rate into an energy charge to cover operating cost and a demand charge based upon the customer's peak demand. Most important from the point of view of the utility, however, is the coincident demand of many users, not the peak demand of a particular user. The usual utility rates do little to encourage the individual customer to rationalize total system costs unless the customer peak and system peak are closely aligned.

If, for the sake of simplicity, there are two periods, the peak and off-peak, with an off-peak short run marginal cost and a long run marginal cost (cost of adding one unit of production at the peak) and if these costs are constant, then there should be two prices charged to consumers. This also assumes that load growth occurs at the peak. The peak price would be the sum of marginal short run and marginal long run costs while the off-peak charge is merely the marginal short run cost. Note that only the peak

period consumer is charged with the expansion to capacity and that of peak users are charged only the marginal short run costs which are the custom, or connect charge and the energy charge.

Of course this is an extremely simplified version of the peak load pricing rule; many more sophisticated rules have been devised to account for several peaks of different amplitude and duration, uncertainty in the demand and the need to meet revenue requirements. Nevertheless the basic concept remains; charge capacity expansion to those who contribute to peak demand.

MARGINAL COST PRICING AND REVENUE REQUIREMENTS

For many years electricity production was believed to be characteriz economies of scale in which event a marginal cost pricing rule would have resulted in deficits. Recently, economists are coming to believe that the period of declining unit costs may be ending. It appears that the technology of electricity production is coming to a limit in providing lower unit costs. Also, the increased environmental awareness of most communitie internalizes to the utility many costs previously borne by the community at large. Finally, technical progress or its lack, coupled with inappropriate depreciation procedures may produce revenues in excess of requirements.

This last point bears some examination. Depreciation is a contribut for the use of capital and theoretically in any given year it ought to equa the loss in value sustained by a capital asset- a loss which may be in part attributable to physical wear and tear but is primarily the result of technological advances. In a period of rapid technical advance, capital assets rapidly lose value and, accordingly, depreciation charges should be high in the initial years. In many instances however, the current money costs of adding to capacity are significantly greater than historical costs and straightline depreciation could result in a revenue requirement considerably lower than obtained by marginal cost pricing. Alternatively, periods of slow technical advance may even enhance the value of the currently installed assets and revenue requirements based upon straightline depreciation may well overstate marginal costs and deficits ensue.

This abbreviated discussion should serve to highlight the critical importance played by the measurement of marginal cost in electricity rate-making. It is essential that an electrical utility be required to develop fully costing procedures and most desireability that these costs include all the external costs of production. Efficient price structures depend critically upon complete cost information.

Given that marginal cost pricing rules tend to produce surpluses or deficits (except where unit and marginal costs are equal), economists have devised some adjustments which approximate the optimal price structure. Specifically these include the a) inverse elasticity rule and b) multi-part tariffs.

The inverse elasticity rule involves explicit price discrimination among users and is immediately open to the objection that rather than the costs, the characteristics of the user determine price. The usual statement

of this rule is that customers should be separated into identifiable classes, usually based on an identifiable end use (e.g. residential, industrial, etc.). Once this has been accomplished any deviation from the marginal cost for a class is inversely proportional to the elasticity of demand for that particular class of customer.

One operational procedure for effecting this pricing procedure is for price to be set at marginal cost (assuming excess revenues) and then rate rebates returned to consumer based upon their respective demand elasticities; the markets with the highest elasticity of demand would receive the largest rebate. By adjusting the various proportionality factors (i.e. the factors by which the rates are adjusted) it is possible to exactly meet revenue requirements.

The multipart tariff examines the marginal cost in terms of componen sensitivity to consumption decisions. For the typical user the least sensitive component is the decision to become connected to the utility gri subsequent costs are related to consumption and consumption is in turn rel to price. Thus,the customer charge which reflects the initial decision to consumer,may be adjusted with greater freedom than the demand or energy charges while still maintaining the function of prices to signal efficient consumption.

The inverse elasticity rule has the weakness that elasticity demand studies are still very rudimentary and shares with multipart tariff the defect that wealth distributions can be considerably affected if electrici prices are adjusted. Also, the imposition of a multipart tariff requires a sophisticated measure of demand elasticity for various components of the electricity rate.

These shortcomings not withstanding, regulatory commissions, at the insistence of economists, are increasingly examining marginal cost pricing. With respect to the implementation of such pricing structures in Manitoba, it may be briefly noted that the commercial and industrial sectors are probably the best sectors to begin experiments with time of use pricing. These purchasers of electricity are generally more informed about options than residential customers and are likely to respond to time differentiated prices. Accordingly, as long as prices are not punitive and act to shift the peak completely, a time differentiated price could well moderate the variation in demand. Also because of capital cost allowances and technical change, a non residential user is better able to adjust energy technology.

The imposition of a marginal cost pricing scheme has many advantages to the utility and to society as a whole. Of course any significant departure in rate structure is constrained by the existence of long term constracts in supply and what may be widely perceived to be a historical rate structure. Since peak load pricing would tend to increase the electricity bill of those peak consumers unwilling or unable to modify their own consumption, considerable opposition to the scheme may be encountered unless the policy is introduced carefully. Most important is a detailed customer survey to evaluate consumption patterns and options and identify those customers who have few options in modifying their demand. Above all, care must be taken not to introduce a rate structure which either increases income inequalities and discriminates against small firms.

All electrical utilities must be encouraged to participate in such an exercise which should be adopted as a specific energy policy by the government. All electrical utilities must also develop accurate estimates of long run marginal cost consistent with alternate consumption growth

potentials. Coupled with these estimates must be rate structures which recover costs and signal efficient consumption. Since commercial and industrial users tend to be more sophisticated purchasers of electricity and possibly have more degrees of freedom in choosing energy sources, it is these sectors which should be considered as the initial targets for a time differentiated pricing policy.

NOTES

1. Load factor is merely the ratio of average demand to peak demand. A high load factor reflects a consumer with an even demand, while a low load factor indicates significant variation in the demand for power.

2. A critical assumption throughout is perfect competition. As is obvious, a regulated utility does not operate in a perfectly competitive environment and strict adherence to marginal costing is not warranted, in which case some departure from marginal cost prices is justified. See Baumol and Bradford (1970) and Lipsey and Lancaster (1956) for further discussion.

3. One has the option of interpreting external effects very liberally, however it seems most fruitful to consider only those externalities which are due to the generation of electricity and the wealth realignment induced by the rate structure. Market failure is also obviously important.

4. This point is crucial. To compensate land owners out of general taxes involves a subsidy from the taxpayers, who have quite varying hydro demands to the electricity consumer. It is much more equitable to make electricity consumers bear these costs through rates.

CHAPTER V

SUMMARY AND RECOMMENDATIONS

This report tends to raise more questions than it answers; this is partly because the resources at hand are somewhat limited, but more importantly because the questions are diffuse and difficult. The main purpose of the study is to explore some issues relevant to the consumption of energy by the manufacturing sector in Manitoba with a view to establishing whether or not the 'energy crisis' is inimical to the welfare of this sector. In addition, a demand forecasting model is presented for the commercial and industrial accounts which very roughly approximate the twenty group manufacturing sector.

In Chapter II, this report found some evidence that Prairie manufacturing employment is sensitive to the ratio of energy prices to wages cost: Since this is potentially an important finding it is recommended:

1. That the government monitor manufacturing energy consumption dissaggregated to the twenty industry group level. Information for this monitoring should be obtained from the accounts maintained by the utilities and energy supply companies. At this time Manitoba Hydro maintains consumption data for this level of disaggregation; all energy suppliers should be encouraged to maintain similar records.

2. The model specified in Chapter II which relates to the effect on employment had by energy prices and wage costs should be extended to more sophisticated specification and to Manitoba. Data is maintained by Statistics Canada which would support such a project, however it is somewhat time consuming to obtain. It must be stressed that different manufacturing groups react very differently to changes in the relative factor prices and any further work must move in the direction of greater specifici in the data.

Another important question relates to the ease with which energy may be substituted for other factors of production. The model presented in Chapter II relating energy and labour consumption by manufacturing firms is admittedly primitive. A multiple input production function is certainly superior, however it becomes very difficult to obtain sufficiently disaggregate data. Despite their importance however, at this time it is unlikely that further developments in this area will prove to be easy to obtain and the province is not encouraged to pursue this avenue.

Chapter III presented a demand forecasting model for the commercial and industrial accounts in Manitoba Hydro. The results were surprisingly good considering the paucity of data and the use of proxy variables.

3. It is strongly recommended that this forecasting activity be vigorously pursued by the government.

Specifically;

3a. The structural forecasting approach employed in this paper should be extended to more diverse and disaggregated levels. Within industrial activity there are many separated manufacturing activities each with unique consumption patterns and this needs to be more fully incorporated into the analysis.

3b. In sectors such as commercial accounts, where there is seasonality in consumption, the structural forecasting can be usefully complemented by time series analysis. In some instances, as the models become more refined it may be possible to combine both structural and time series forecasting techniques.

3c. All electrical and energy suppliers in the province ought to be required to maintain comprehensive and detailed records of consumption. Since billings are invariably computerized the creation of such a record should not be costly and the confidentiality of the individual customer can be easily maintained.

3d. The province is encouraged to explore a comprehensive energy planning model with a view to establishing the potential such as device has for assisting industry in planning technology adoption and investment activities. Ideally such a venture should be a joint project between the province, major supplier[s] and major consumers. It is vital to discipline such efforts though, and to resist the temptation to model for the sake of modelling. All projects, especially those 'in house' should b[e] thoroughly evaluated by independent appraisers outside the government to ensue cost effectiveness.

3e. The province is encouraged to adequately fund various agencies (such as the Manitoba Bureau of Statistics, or the Manitoba Energy Council) to ensure that accurage and usable data is available to sustain any comprehensive modelling effort.

3f. All agencies concerned with collecting energy related data should be coordinated, perhaps through the Manitoba Energy Council.

Another important area was investigated by Chapter IV, albeit the treatment is cursory. Economists are almost uniformly persuaded that marg[inal] cost or peak load pricing is superior to the present average cost rate structure. Therefore;

4. All utilities which supply a flow energy not capable of cheap storage (electricity, gas) should develop experiments to evalu[ate] the effect of peak load pricing upon

   a. consumption patterns
   b. income distribution
   c. profitability of firms in varying market structures.

These last two points are critical, for although a marginal cost pricing scheme has great potential to rationalize energy development, it a[lso] has the potential to substantially redistributed wealth.

APPENDICES

These appendices are to assist the general reader in understanding the techniques applied in the text.

APPENDIX I

Elasticity; Concepts and Measurement

Basic to both theoretical and policy economics is the concept of elasticity. There are a seemingly bewildering array of measures, but for the purposes of this report the most important are the elasticity of factor substitution, price elasticity and income elasticity.

1. Elasticity of Substitution

The process of production may be easily represented by an algebraic equation of the general form,

$$q = f(x_1, x_2, \ldots, x_n),$$

where q is the measure of output (most commonly real valued added), x_i the various factors of production (land, labour, capital, energy, etc.) and which is read 'real valued added is some single valued function of a specific combination of various inputs!

The elasticity of substitution is actually quite a subtle concept and is most easily approached using a two input production function of the form,

$$q = f(x_1, x_2).$$

It is defined as

$$\sigma_{12} = \frac{d \log(x_2/x_1)}{d \log(f_1/f_2)}$$

where f_1 and f_2 are the partial derivatives of the production function with respect to x_1 and x_2.

This algebraic formula may be interpreted graphically for σ varying between its limits of 0 and ∞. Fig. 1 demonstrates a production function which has no possibility for substituting various inputs while fig. 2 shows a production function with infinite substitution possibilities. With respect to interfuel substitution the development of such elasticity measures is basic to the formulation of an energy policy. More on this concept is presented in Appendix III.

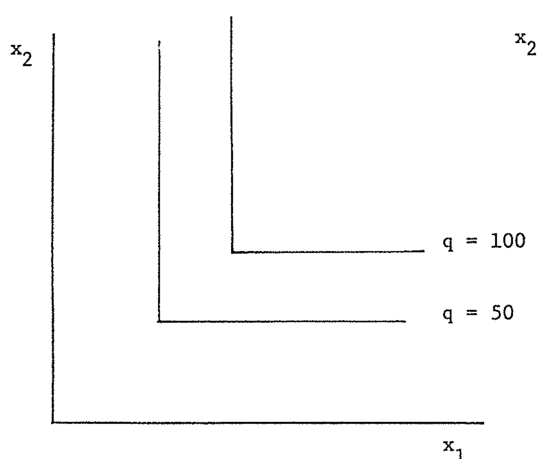


Fig. 1

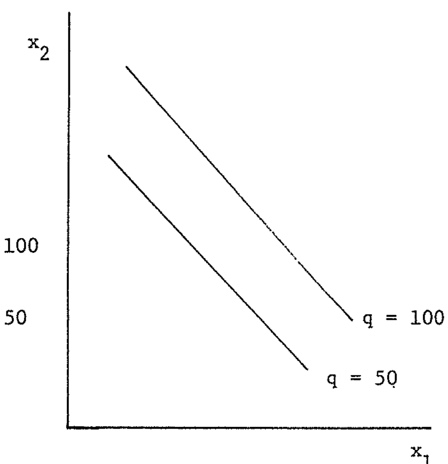


Fig. 2

2. <u>Price Elasticity</u>

Price elasticities may be divided into the 'own price' elasticity which indicates the responsiveness of the demand of a product to changes in its own prices and 'cross price' elasticity which indicates the responsiveness of the demand to changes in the prices of other products.

a. Own Price Elasticity

Formally the elasticity of demand is given by

$$\sigma = \frac{\%\ \text{in Quantity}}{\%\ \text{in Price}}$$

$$= \frac{dQ/Q}{dP/P}$$

Now, it is important to appreciate that the elasticity of demand varies along the demand curve as indicated by fig. 3.

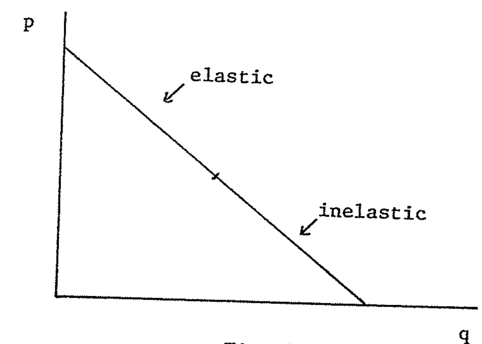


Fig. 3

In addition, shifts of the demand curve tend to alter the price elasticity for a given quantity demanded. For example, if income increases, the price elasticity of demand tends to increase, reflecting the fact that higher incomes permit the consumer to entertain the consumption of more diverse products. Advertising, in its attempt to shift demand curves outward, produces the seemingly contradictory result that for a given quantity the elasticity of demand increases. It is interesting to note also that if pric is held constant, these results are reversed; income increases and advertisi expenditures tend to produce lower own price elasticities of demand.

3. Cross Price Elasticity

The cross price elasticity reflects the degree to which various commodities are substitutes or complements for each other. A high cross price elasticity indicates close substitution between the two products; typically, for space heating, electricity and natural gas are considered to be close substitutes.

The formula for cross price elasticity is given by

$$\sigma_{12} = \frac{\%\text{ in Quantity of Good 1}}{\%\text{ in Price of Good 2}}$$

4. Measurement

The measurement of the various price elasticities is most directly accomplished by assuming a demand relation of the form,

$$q_1 = p_1^a p_2^b \cdot \cdot \cdot p_n^z$$

and taking logarithms to produce

$$\ln q_1 = a \ln p_1 + b \ln p_2 + \cdot \cdot \cdot \cdot + z \ln p_n$$

where the coefficients in a linear regression based upon this equation may be read directly as the elasticities of price. For example if q_1 is the consumption of electricity and p_1 its prices, then a is the 'own price' elasticity of electricity. If p_2 is the price of natural gas, then b is the cross price elasticity of electricity with respect to natural gas prices, and so on.

5. Income Elasticity

By now the basic form should be familiar. The income elasticit of a product, like the price elasticity is an attribute of a demand relationship which indicates the responsiveness of demand to changes in income. If income is included in the specification of a demand relatior ship as equation, then its coefficient from a regression estimation procedure may too be interpretated as the elasticity measure.

The importance of elasticity measures lies in their indication of potential responsiveness. Thus, low price elasticities of electricil indicate that a price increase will unlikely provoke any significant decrease in consumption, while high elasticities indicate that a public utility will face revenue declines if it attempts to increase price, because quantity will respond significantly to such increases. If the own price of elasticity is high, (greater than 1)price increases (decre tend to produce revenue decreases (increases), while if the own price elasticity is low (less than 1), price increases(decreases) will produc revenue increases (decreases). Since utilities typically employ price discrimination in their rate making, information on the price elasticit various users is important to the overall strategy of rate formation.

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APPENDIX II

Understanding Regression

1. The Basic Concept of Linear Least Squares:

Causality in the social sciences is difficult to demonstrate and researchers are usually required to combine logical a priori reasoning with statistical inference. Thus, the theory gives the direction of the causal relationship, while the statistical analysis enables one to evaluate to what degree the theory is supported by the available evidence.

Generally casual relationships between two variables, an independent variable (the cause) and a dependent variable (the effect) may first be examined using a simple scattergram. In fig. 1, a relationship between X the independent variable and Y the dependent variable is demonstrated.

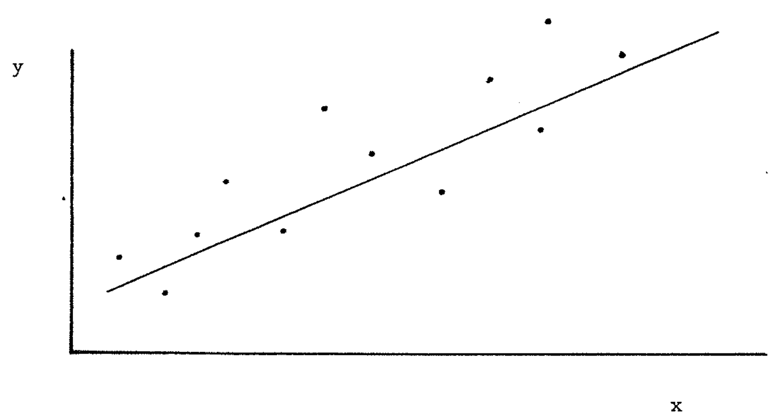


Fig. 1

For the most part the causal relation is assumed to be linear (a straight line) and the positioning of such a line within the cluster of points is called Least Squares Adjustment.

Each of the points in fig. 1 may be viewed as a pair of numbers (x,y) in the positive quadrant. In the same way any straight line is a pair of numbers (x',y'). For example consider the cluster of points given by the following collection of paired numbers

TABLE 1

x	1.2	3.5	1.6	2.7	5.7	3.9	1.1
y	2.3	2.9	1.4	3.9	4.9	5.0	.9

which may be plotted as shown in fig. 2. A straightline given by the

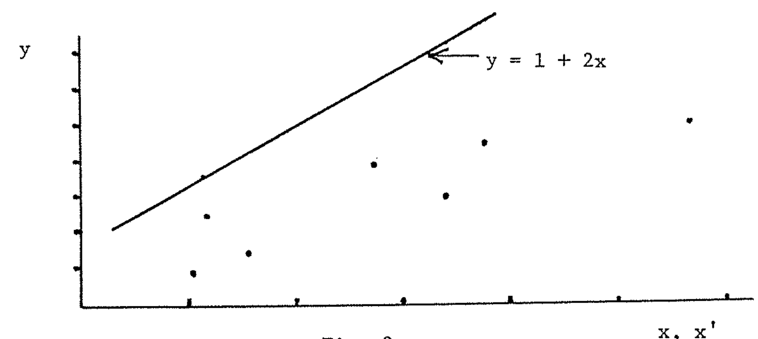


Fig. 2

equation $Y = 1 + 2X$ yields the following set of points with the x's matched for ease of comparison

TABLE 2

x'	1.2	3.5	1.6	2.7	5.7	3.9	1.1
y'	3.4	8.0	4.2	6.4	12.4	8.8	3.2

and may also be plotted as shown in fig. 2.

It is apparent that the linear relationship is not particularly close to the cluster of observed points. The rule for fitting or adjusting a given straight line to a cluster of points is the minimization of squared vertical deviations. Intuitively one could either move the line up and down parallel to itself or it may also be possible to adjust the line by pivoting it and changing the slope. Each x observation has two points corresponding to it; first there is the observed point as given in table 1 and then there is the 'fitted' point given by the equation and by table 2. The least squares adjustment rule states that <u>the line should be moved to reduce the sum of the squared differences between the observed and fitted values of y.</u> In the case at hand the sum of the squared deviations is given in table 3.

<u>TABLE 3</u>

	observed	fitted	deviations	squared deviations
x	y	y'	y-y'	$(y-y')^2$
1.2	2.3	3.4	-1.1	1.21
3.5	2.9	8.0	-5.1	26.01
1.6	1.4	4.2	-2.8	7.84
2.7	3.9	6.4	-2.5	6.25
5.7	4.9	12.4	-7.5	56.25
3.9	5.0	8.8	-3.8	14.44
1.1	.9	3.2	-2.3	5.29
				117.29 sum of squared deviations

Fortunately rather than experiment with different straightlines, it is possible to calculate the least squares line precisely using matrix algebra, a procedure now conveniently handled by computers. In this instance

the least squares line is given by the equation

$$Y = .706 + .832\ X$$

and is plotted fig.3.

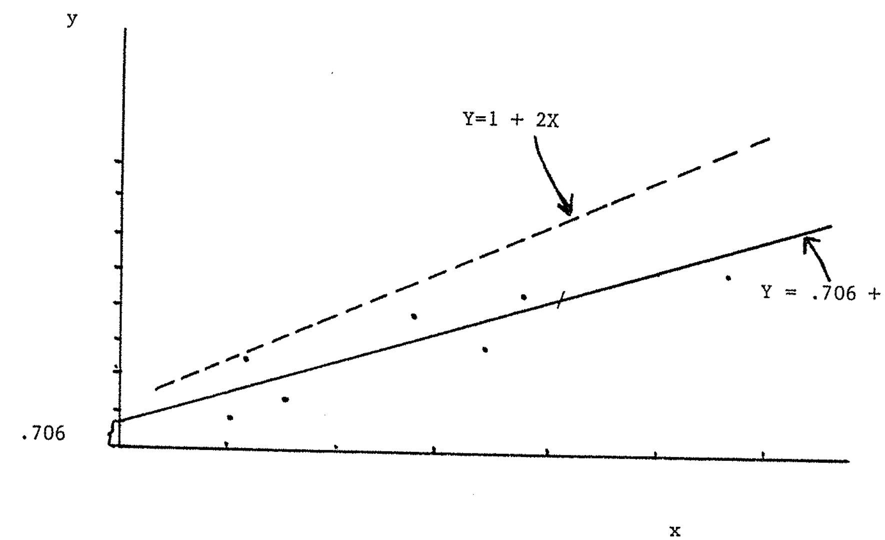


Fig. 3

2. <u>Evaluating the Fitted Line</u>

The least squares procedure is easily extended to several dimensions, and most computer routines have the capability of handling over 100 independent variables. Once the least squares line has been found, it is important to have measures for evaluating its quality or 'goodness of fit' and 'significant'.

a. Goodness of Fit

Consider the scattergrams in Figs. d and e.

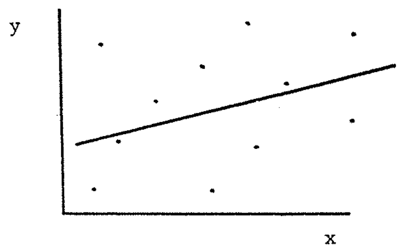


Fig. 4a

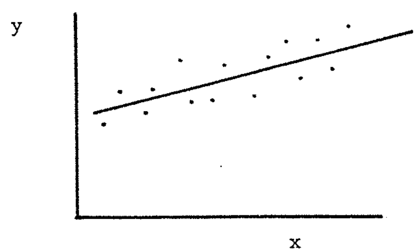


Fig. 4b

Intuitively the second figure is more satisfactory because the observed points cluster about the least squares line while in the first case the observed points are widely dispersed. The statistic used to measure the closeness of the clustering is the R^2 or correlation coefficient which varies between 0 for a least squares line fitted to extremely dispersed data and 1 for a least squares line fitted to data that itself is a straight line. Typically correlation coefficients in the range of .7 to .98 are considered desireable. In the equation above the R^2 is .74.

b. Significance

Goodness of fit is all too frequently taken to be the most important aspect of statistical evaluation; the significance of the constant term and slope term are equally,if not more important. In the case at hand

$$Y = .706 + .832X$$

the constant is .706 and the slope is given by .832

If we consider each point y in the observed pair (x,y) as a sample from a given population it is possible to visualize, not just one value,but many y values associated with each x. In other words the data may appear as

TABLE 4

x	y_1	y_2	y_3	y_4	.... etc.
1.2	2.3	3.1	1.9	2.2	....
3.5	2.9	3.1	3.3	1.9	....
1.6	1.4	4.2	1.1	2.6	....
2.7	3.9	3.1	1.8	4.2	....
5.7	4.9	6.6	2.9	5.2	....
3.9	5.0	3.7	6.3	4.2	....
1.1	.9	1.1	2.6	1.8	....

Thus, even though only one value of y is actually available (y_1), it is treated as if it were just one of a large sample of other observations corresponding to a particular value of x.

Assumed is that the population of y for each value of x is distributed normally; in other words the population of y is distributed as many natural phenomenona. Consider the distribution of y given that x = 1.2 which is indicated in row 1 of the above table. Fig. 5 portrays this situation and shows where the point $y_1 = 2.3$ lies in the distribution. Each observed y value may also be placed in such a distribution, relative to the given value of x.

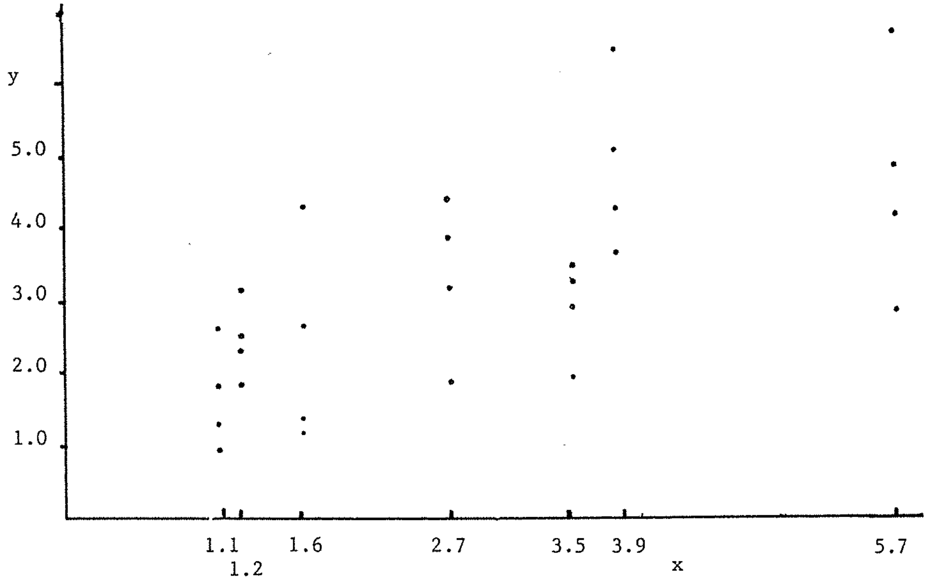


Fig. 5

If for each x there were many observed values it would be expected that on 'average' the values of y would tend to cluster around the least squares line, as below

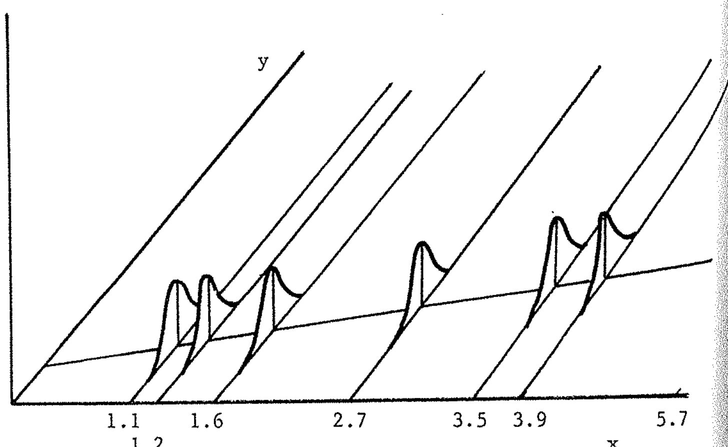


Fig. 6

The basis of tests of significance is the hypothesis, usually termed the null hypothesis. What is required is some measure that indica whether the coefficient (either the constant term or the slope term) is significantly different from zero. The null hypothesis is usually set up postulating that the particular coefficient in question is zero and then seeing with what risk this may be rejected. Statistical verification generally proceeds by calculating the probability of rejecting a hypothes that is true; if this probability (termed the probability of committing type I error) is sufficiently low (say less than 5%) then the hypothesis rejected and the coefficient as calculated is accepted as reasonably accu

The statistic used to evaluate the slope term (the constant ter are usually ignored) is the t statistic. It is calculated automatically l most regression routines and if it is greater than 2.5 it is usually safe to accept the coefficient with a 5% chance that the true value is actually equal to zero. In the regression equation calculated above the t statisti on the slope coefficient is 3.79241 which indicates a reasonable level of significance.

3. Assumptions of the Least Squares Model

Many things can disturb the calculation and interpretation of le squares coefficients and it is dangerous to perform regressions with impun Underlying linear regression are a set of quite strict assumptions.

a. Homoscedasticity

Until now the notion of error has not been mentioned, however in human endeavour, and especially social measurement errors abound. In this case, with one data point for each independent value (x value), the error is simply defined as the difference between the observed and the fitted values and is the same as the deviation discussed above. Fig. 7 clearly shows the errors associated with the above example.

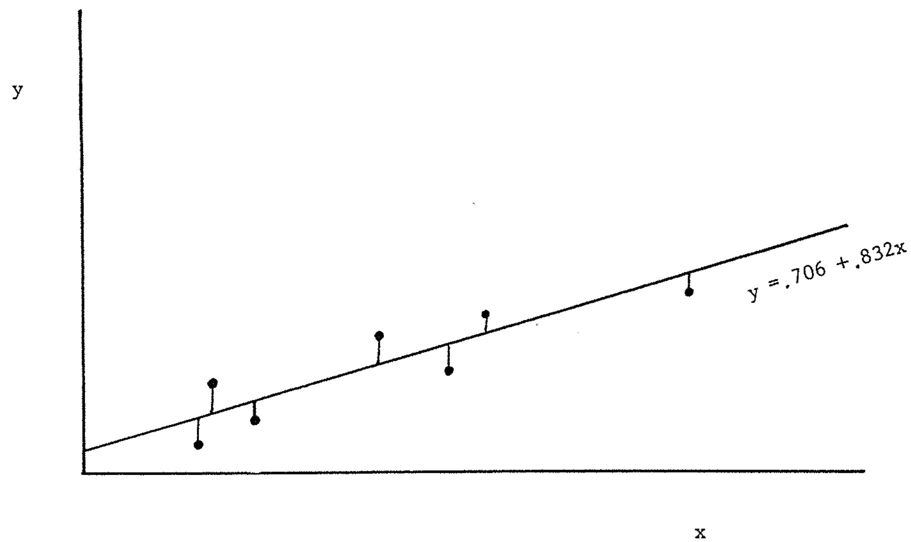


Fig. 7

An important assumption underlying the least squares model is that the error is not associated with the value of X. In other words large values of X are not associated with large errors. In fig. 8 an example of a heterscedastic error structure is demonstrated.

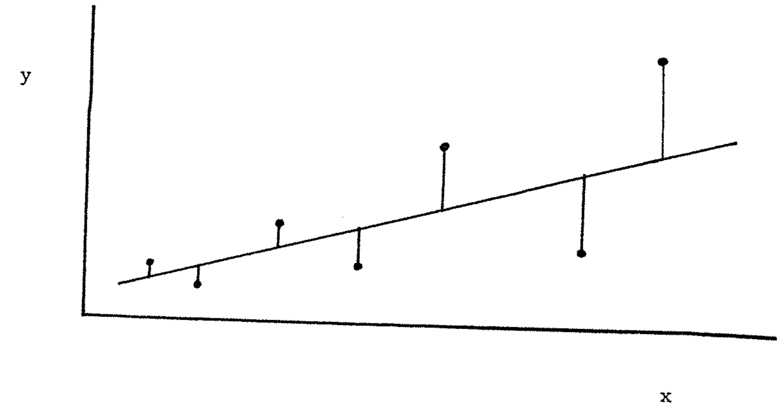


Fig. 8

It can be shown that heteroscedasticity leads to several undesirable consequences, the most important of which is that the t statistics would tend to lead one to reject the null hypothesis that a coefficient was zero (or any particular value) when in fact it should be accepted. In other words heteroscedasticity tends to produce estimates which are unjustifiably optimistic.

The general assumption behind least squares regression is that the data points (i.e. values of y) are drawn from normal populations which are invariant to the value of x. Referring to fig. 6 this means that each of the distributions of y (bell shapes curves) has exactly the same form.

b. Autocorrelation

In addition to a constant distribution (constant variance) of the errors, it is also required that the errors from one observation not be associated with the errors from other observations. Technically it is required that the covariance of the errors be zero, or,

$$E\ (u_i, u_{i+k}) = 0,\ i \neq k$$

The simplest case is when successive error terms are related according to the linear relation

$$u_i = pu_{i-1} + v_i$$

Autocorrelation has much the same consequences as heterscedasticity; the tests for significance are too optimistic. There are standard procedures for dealing with both heterscedasticity and autocorrelation which are generally available in most computer routines.

c. Multicollinearity

A more pervasive and important problem is that of multicollinearity. As mentioned above the least squares procedure is easily extended to multivariate situations. A typical equation would appear as

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 \quad \ldots. + e_i$$

where x_i $i = 1,2,3, \ldots.n$ are the independent variables. The only requirement is that the number of independent variables must be less than the number of data points. Thus given the data in table 1,with 7'y'observations,could only be used to support six independent variables (assuming a constant term is desired). Multivariate analysis is important,as generally more than one factor is thought to influence the movements of y. The regression equation, along with the goodness of fit measures and tests of significance enable to what extent each separate factor influences y.

The problem with multicollinearity arises when the supposed separate independent variables, are in fact not independent from each other.

For example if the dependent variable were the incomes in various rural municipalities and two of the several independent variables were the Canadian Wheat Board Price for wheat (x_1) and gross farm incomes (x_2), i is more than likely that these two variables are very closely associated

If this is the case the tests of significance tend to break down because the explanation is in effect'spread' out over several variat One is therefore led to the erroneous conclusion that a particular varia is not significant (i.e. its' value is not significantly different from zero) when in fact it could be highly significant.

The usual remedy for multicollinearity is obtaining more data and examining the list of independent variables and excluding those which may be redundant.

d. Specification Error

The theory leads one to both the form of the causal relation (i.e. straightline) and to particular independent variables which act upon the dependent variable. While the straightline is most common, it is quit possible that nonlinear relationships may in fact be the 'true' relationsh In addition, other factors, not developed by the theory, may also be important in explaining the movement of y. Both types of error are termed specification error and little can be done to eliminate that perhaps the form and the number of independent variables included are inappropriate.

4. Pooling Cross Section and Time Series Data

Not infrequently, econometric testing is impeded by the paucity of data. In this event pooling cross section and time series data can be an attractive alternative to tests under constrained degrees of freedom. However, the matter is not as straightforward as simply forming a larger matrix of pooled cross section and time series data.

Basically there are two approaches used in the pooling problem.

a) Covariance Analysis

This procedure uses dummy variables to isolate the effect of different cross sections and different years. The simple pooling of data assumes that the constant and slope coefficients are invariant with respect to time or cross section. The covariance model formally appears as

$$Y_{it} = a + \sum_{k=1}^{m} B_k X_{kt} + \sum_{i=2}^{l} C_i D_{it} + \sum_{j=2}^{r} E_j Z_{jt}$$

where B_k is a vector (k=1, ...m) of m regression coefficients, C_l(i=2, ...l) cross section dummy variable coefficients and E_j (j=2, ...r) a vector of time series dummy variable coefficients.

The choice as to whether to merely pool the data or use covariance analysis can be made on the basis of a Chow test; in the empirical testing to be presented shortly, the covariance procedure (or a limited version of it) is used on the basis of a Chow test on aggregate data.

Covariance analysis has several limitations. First, it can consume substantial degrees of freedom, especially if the full scale version is employed. A limited version where dummies are inserted only for cross section or time series data reduces this problem, however, at the expense of reducing the power of the Chow test. Furthermore, the inclusion of dummy variables does not permit any actual inferences about the behaviour by different cross section populations or different epochs. Accordingly, the most one can say in the event of statistical significance on the part of the dummy variables is that cross sectional or time series differences do exist.

b) Error Components

The error components model was first presented and tested by Balestra and Nerlove (1966). The basic idea may be illustrated by considering equation

$$Y_{it} = a + B_i X_{it} + e_{it}$$

$$e_{it} = u_i + v_t + w_{it}$$

where u_i is the error due to the cross section, v_t is the time series error and w_{it} is the combined component. Error components is related to the covariance model by making explicit assumptions about the errors are normally distributed and that there is no time series error, then it can be shown that

$$Var\ (e_{it}) = Var\ (u_i) + Var\ (w_{it}).$$

In the same way if the time series errors are normally distributed (V_t= N(0, $_v^2$)), the variance of the error term is equal to the sum of the individual variances of the cross section, time series and combined error components.

By employing two stage estimation process of first performing OLS on the entire pooled sample from which the residuals are calculated an estimate of the variance covariance-matrix is obtained. Then by performing a generalised least squares estimate, efficient estimators of B_i may be obtained.

Needless to say the covariance procedure is computationally simpler, and for the initial estimation is preferred.

APPENDIX III

Production Functions and their Empirical Implementation

1. Introduction

The firm, in its decisions about output and pricing, relies upo the idea of a production function. In the vast majority of cases where firms are of small or modest size, the decision maker may have only intuitive notions of the production function.

Basically a production function is a technical recipe which indicates the maximum output obtainable from given quantities of inputs. Economists have become accustomed to arbitrarily dividing factors of production into labour, equipment (capital), materials (natural resources and semifinished products) and land (in some cases a particular location) The production function may either be presented as an explicit technical recipe in much the same form as a cooking recipe; it may be a graph depicting the relation between output and one factor of production ; or it may be an algebraic expression in which all the factors of production may presented. The algebraic expression in its most general form is given by

$$Q = f\ (x_l, x_m, x_c, x_s)$$

which is translated into everyday language as output is a function of lab materials, capital and land. There may be as few as one factor, or many depending upon the particular process involved.

2. Elasticity of Substitution

Perhaps the most important aspect of production function theory the measurement of the elasticity of production, defined as,

" the proportionate change in the ratio of the amounts of the factors divided by the proportionate change in the ratios of their marginal physical productivities"

The marginal physical product of a factor is simply the extra production obtained from increasing the use of that factor by one unit. The marginal physical product of labour, for example, is the increased product obtained by increasing the workforce by one.

A useful device for examining production functions is that isoquant which indicates the combinations of factors required to yield the same level of output. For example, suppose the output of tractors is obtainable from two factors of production, labour and capital equipment. More than likely one can combine these factors in varying proportions to yield output; perhaps there is even a wide range of substitution where one tractor could be produced with a wide range of factor combinations. Ideally an isoquant may be represented as in fig. 1.

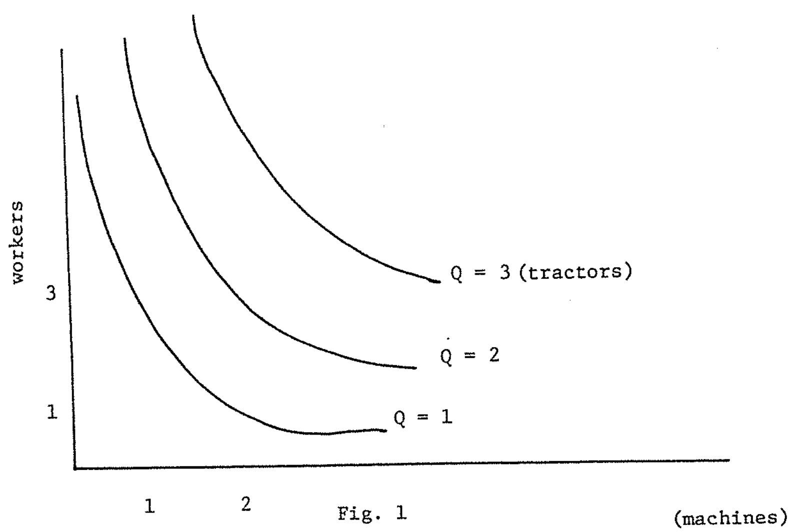


Fig. 1

From the above figure it is apparent that one tractor may be produced using either three workers and one machine or one worker and two machines in addition to many combinations in between. Production function which permit many factor combinations are said to be characterized by hig elasticities of substitution while production functions in which the technical recipe is rigid and invariant has low or even zero elasticities of substitution.

Formally the elasticity of substitution is found by calculating the following:

$$\sigma_{12} = \frac{d \log (x_1/x_2)}{d \log (f_1/f_2)}$$

for the two factor production function

$$q = q(x_1,x_2).$$

In general,as the isoquant becomes flatter the elasticity of substitution increases, while isoquants which resemble right angles have a low elastic The elasticity of substitution is a pure number ranging from 0 to infinit and may be interpreted as a measure of the ease with which the various inputs are interchangeable. As a result elasticities much greater than 1 (say 3 or 4) indicate the use of a fairly malleable technology, capable o: permitting the firm to incorporate changes in factor prices without substantially changing its profitability. Elasticities less than 1 (and grea than zero of course) indicate technologies with limited capacity to respor to significant changes in prices.

Some productive processes, most notably those characterized by capital intensity and high technology, tend to have low elasticities of substitution, while other productive processes appear to have much wider possibilities for combining factors of production. Where high elasticities prevail, the choice of technique depends on the relative prices of the inputs; high priced inputs tend to be eliminated in favour of cheaper alternatives. Changes in relative prices, as has characterized energy prices relative to other inputs would then be accompanied by changes in technique in those industries with a malleable technology. Industries which, for what ever reason, are 'locked' into energy intensive technologies do not have the option of altering their factor combinations and consequently face reduced profit margins, declining capital formation and eventually declining employment. as energy prices accelerate.

3. Empirical Implementation of Production Functions

For the most part econometricians have concentrated upon two factor production functions, although recently the estimation of multiple input production functions has been introduced. Several important issues are involved in the estimation of production functions and their attributes.

a. The first concerns the measurement of output and the variou inputs. For the most part real value added (value added deflated by an appropriate price index) is used for a measure of output, although in studies of particular activities, the actual physical units (tons of stee ingots, millions of board feet, number of buses) may be used. The measur ment of various inputs may be relatively straightforward such as number o worker hours in the case of labour. Problems of underemployment, differe in skills and other distortions exist, but are generally not important compared to the distortions that exist in the measurement of capital inpu Simply to compute dollar value of machinery, or the number of machines is quite insufficient. The fact that machinery is not constantly used or th capacity utilization varies not only with levels of economic activity, bu also expectations about imminent technological change or that technical change itself alters the contribution of capital equipment,all make the quantification of capital services problematic. The use of energy surroga as explained in the text, offers some promising alternatives in the measur of capital and also enables one to estimate directly the elasticity of substitution between energy and labour.

b. A second important question in the empirical verification of the production function is the precise algebraic form to be used. As outl in a previous appendix, it is most convenient if the form may be made line when least squares is to be employed. Economists have identified a wide variety of production functions all of which have different applications.

4. Types of Production Functions

a. Zero Elasticity Production Functions

The production process underlying the input-output model makes the assumption that there is absolutely no possibility of substituting factors. In other words, the isoquants appear as right angles.

b. Unit Elasticity

The Cobb-Douglas production function is perhaps the most widely used form, for both theory and econometric work and in its algebraic form appears as

$$Q = AK^{a}L^{b}, \quad \text{with } a + b = 1$$

By taking logarithms this function may be 'linearized' and regression techniques may be used to estimate A, a and b.

One of the drawbacks from this particular form is that by definition the elasticity of substitution is constrained to 1. This means that as one moves along an isoquant the ratio of the factor proportions to the slope of the isoquant at point is equal to 1. While this may have desirable theoretical properties in that simpler functions are developed,it is unduly restrictive for the purposes at hand.

c. Constant Elasticity of Substitution Production Functions (

This form of the production functions developed in the early 1 has become widely used, simply because the elasticity of substitution is necessarily confined to 1. However it is required that the elasticity o substitution not vary with levels of output. In other words,as one move outward across various isoquent,the elasticity must be constant.

The functional form of the CES production function appears as

$$Q = A\ (\emptyset \bar{K}^{p} + (1-\emptyset)\ \bar{L}^{p})^{\ u/p}$$

where p is termed the substitution parameter and is related to the elasticity of substitution by the expression

$$\sigma = 1/(1-p)$$

The estimation of the CES production function is difficult in t taking logs does not immediately result in a linearized form. Several procedures are available, most notably the Kmenta approximation which exp the CES functions in a Taylor's series about the point p=0 or the margina productivity relation developed by Arrow, Minhas Chenery and Solow which appears as

$$\ln(Q/L) = a + b\ \ln W,$$

where W is the wage,rate b the elasticity of substitution and Q/L the out per labour input.

d. Non Homogeneous Production Functions

The production functions b and c above all share one property in that an expansion in the use of each factor by z% leads to a z% increase in output. Recently a class of production functions have been developed by Sato (1977) which do not make this assumption. In effect this is one more step closer to reality.

In this linearized form, suitable for regression analysis, this function appears as,

$$\ln K/L = A_1 + A_2 \ln (W/L) + A_3 \ln Q + t + e_t,$$

if the production function is in two factors with labour (L) and capital (K). This functional form is used for the statistical analysis in chapter 2.

APPENDIX IV

Data Sources

Most data was obtained from Statistics Canada. The Province, either through the Manitoba Energy Council or the Manitoba Bureau of Statistics, keeps relatively little useful information on energy consump and prices. For Section I the CANSIM system was used to retrieve the various series. The information on value added, energy costs and the ot input costs was obtained from the Census of Manufacturing 31-203 for var years. Information on shipments and employment indexes used in Section were also obtained from the CANSIM system.

For the analysis of elasticities of substitution (Section III), Census of Manufacturing was used along with the Energy Bulletin (57-002) which gives information on energy consumption by fuel type for the twent industry group (1964-1972).

Data employed in the demand forecasting studies was obtained from the CANSIM data base (wages, shipments, retail trade etc.). The dat series on hydro consumption of commercial and industrial accounts was obtained from Manitoba Hydro and the natural gas prices index was develop from the Manitoba Public Utilities rate schedules (1970 - 77).

APPENDIX V

Forecasting; Methodology and Problems

1. Introduction

Econometric forecasting may be divided into two major categories; First, and most widely used are forecasts based upon a structural model of demand or supply. The dependent variable, in the case at hand the consumption of electricity, is related through multiple regression techniques to one or more independent variables, such as retail trade, prices, etc. Once the regression coefficients have been estimated, the equation can be used to project future values of the dependent variable given values of the independent variables. Second, there are time series forecasts which project movement in the dependent variable solely by inference from its past behaviour. No information on the movements of other variables is required.

2. Structural Forecasting

Once the econometric model has been specified and estimated its validity may be evaluated by performing an ex-poste analysis or unconditional forecast. Thus the model is not estimated for all the values at hand, but only for restricted periods as indicated in fig.1.

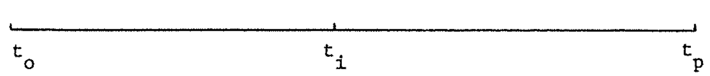


Fig. 1

The period t_0 to t_i is the estimation period and care should be taken that there are sufficient observations during this period to produce statistically valid estimations. Next, the period t_i to t_p represents a period in which the predictions of the model are compared with history. The ex-poste period (t_i to t_p) must be sufficiently long to produce enough data points to enable the calculation of various accuracy measures (discussed below), however, if t_i is too far into the past, the model may not reflect the structure of demand or supply as it presently exists. Care should be taken to ensure that the estimated mode with a restricted sample (on periods t_0 to t_i) does not deviate significa from the model when estimated for the entire sample (t_0 to t_p). Unfortuna little guidance can be given in the selection of appropriate ex-poste per and judgment is unavoidable.

3. Summary Measures of Predictive Accuracy

A variety of summary measures of predictive accuracy are possible Perhaps the most common are the calculation of confidence intervals.

a. Confidence Intervals

The design of the predictive model involves partitioning the time period and sample into two separate entities, the estimation period and the ex-poste period. A confidence interval is based upon certain assumpti about the behaviour of the errors from each of these two time periods. Calculated, is a band around the forecast values (see fig.10&11 Chapter II which indicates the region in which there is a (1-a)% chance that the forecasts do not belong to the same model as the actual values. If the actual values fall within say a 95% confidence interval, then the model is considered to be acceptably accurate.

b. Theil's Inequality Coefficient

This is a measure of the accuracy of the predicted versus actual values in a conditional forecast. It is given by the formula

$$U^2 = \frac{\sum (P_i - A_i)^2/n}{A_i^2/n}$$

and has values between zero and infinity; the closer the coefficient lies to zero the better the prediction. Note that P_i is the predicted value while A_1 is the actual value.

Is is possible to decompose the Theil inequality coefficient into three partial inequality coefficients;

1. Bias proportion which measures the differences between the mean of the predicted and actual values;

2. Variance proportion which compares the variances of the predicted and actual values;

3. Covariance proportion which indicates to what extent the predicted and actual values move in step.

In simple terms, the bias proportion measures and compares the 'averages' of the predicted versus actual values, the variance proportic measures to what extent the variables have different 'spreads' and the covariance proportion compares the extent to which the variables tend tc move in opposite directions. Of the three, the third is the most seriou since additional information cannot generally reduce the error due to covariation.

c. <u>Root Mean Square</u>

The Root Mean Square error is given by the formula;

$$\text{R.M.S.E.} = \left(\frac{1}{N} \Sigma (F_t - A_t)^2\right)^{\frac{1}{2}}$$

and it measures average forecast error (where F_t is the forecast value a A_t is the actual value at t).

3. Time Series Models

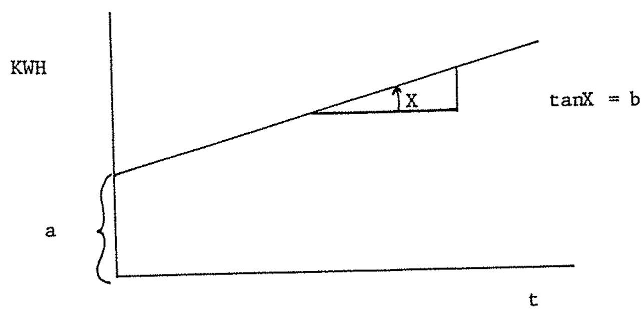
Time series models comprise both the simplest and most complex forms of econometric projection. The basis time series model is the straightline projection, while stochastic forecasting models such as autoregressive moving average (ARIMA) models have only recently become widely available.

a. Simple Extrapolation

The easiest forecast is obtained by a trend line through the data points. Usually this is obtained by regressing the dependent variable against time. By transforming the data into logarithms or other non-linear functions, this technique can be made to 'fit' a variety of data points. Typical functional forms used are demonstrated below:

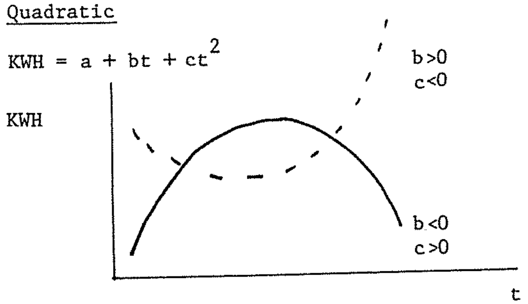
Linear

$KWH = a + bt$



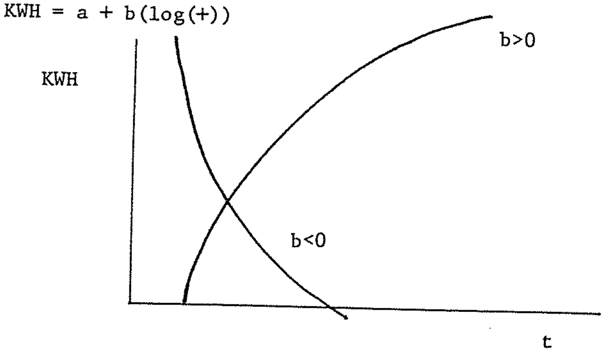
Quadratic

$KWH = a + bt + ct^2$



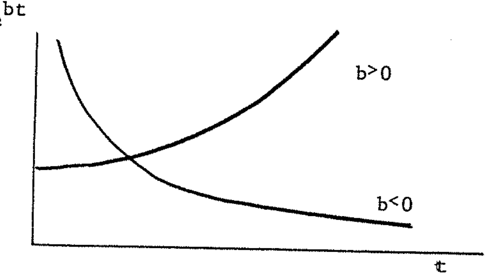
Semi-log

KWH = a + b(log(+))



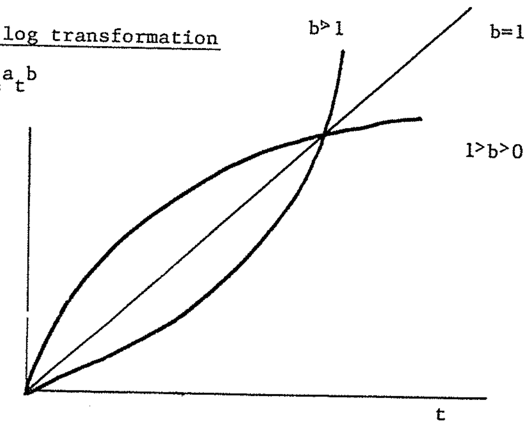
Semi-log transformation

$KWH = Ae^{bt}$



Double log transformation

$KWH = e^{a}t^{b}$



b. Exponential Smoothing (Moving Average)

The essentially naive extrapolation exercises implied by the previous models may be improved by adding some assumptions. One of the most common is to assume that current load growth is most affected by recent behaviour. The simplest situation occurs when only the previous period affects current consumption which is given by the equation

$$\widehat{KWH}_{t+1} = aKWH_t + (1-a)\ \widehat{KWH}_t$$

where $\widehat{KWH}_{t+1}$ and $\widehat{KWH}_t$ refer to the estimated values. Through some simple manipulation the following equation is obtained;

$$\widehat{KWH}_{t+1} = aKWH_t. + (a-a^2)KWH_{t-1} + (1-a)^2\ \widehat{KWH}_{t-1}$$

When a = .2 the result is

$$\widehat{KWH}_{t+1} = .2KWH_t + .08KWH_{t-1} + .64\ \widehat{KWH}_{t-1}$$

Note that some procedure for initializing the model is required; perhaps the result of a structural forecast could be used. The predicted load for t+1 ($\widehat{KWH}_{t+1}$) is based upon some fraction of the actual past periods consumption (KWH_t), a fraction of the actual consumption in the past period (KWH_{t-1}) and, finally, a fraction of the predicted consumption for the past period ($\widehat{KWH}_{t-1}$). As a approaches 1.0, the prediction relies increasingly more upon the actual past period consumption, and less on previous period forecasts and values.

c. Autoregressive Models

Given significant seasonality or trends, the simple curve fitting or exponential smoothing procedures are inappropriate. The autoregressive

model postulates that current levels of consumption are dependent solel on past values in the following fashion;

$$KWH_t = a_0 + a_1\ KWH_{t-1} + \ldots\ldots.a_n\ KWH_{t-n} + e_t$$

The objective of the autoregressive model is to discover the set of lag and the values of their weights which best fit the data.

d. Autoregressive-Moving Average Models

The autoregressive moving average model (ARIMA) combine the exponential smoothing and autoregressive model to form predictions base upon the past error terms and lagged values. A typical simple model is given by

$$KWH_t = a_1Y_{t-1} + b_1\ (KWH_{t-1} - KWH_{t-1})$$

The Box Jenkins technique is perhaps the most widely used method of estimating such models. Although ARIMA models can produce models of hig precision, especially on seasonal data (eg. commercial consumption of hydro), considerable skill is required in their specification and develo ment. A rough and ready ARIMA model is likely to be more inaccurate tha simple time series forecasts.

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