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Input-Output Model for the Electricity Supply Industry in Iceland

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Abstract

This report presents a partial input-output model which links all output of the electrical supply industry to all its inputs. The independent variable is the output of the electricity supply industry and the model is called the Demand-Driven Input-Output Model (ADAF). It is constructed in a regular Leontief input-output framework and can be used to calculate the increased demand for inputs when a demand shock is applied to the model. Secondary effects are not estimated because we do not have a full input-output model.

Input and output development is followed over a period of four years in order to make an input-output model with technical coefficients that are an average of this time-period. An "input-output time series" analysis is possible with more data. The relationship established between input and output or demand for input and demand for output is used to forecast future demand for input and future demand for output. The increased demand for inputs in the electricity sector as a result of a large increase in the demand for electricity in a power-intensive industry is estimated.

Contents

Formáli

Skýrslan sem hér birtist er unnin fyrir styrk frá orkumálanefnd Norðurlandaráðs. Rannsóknir í orkumálum sem beinast að samspili orkuframleiðslu og orkunotkunar við aðra þætti samfélagsins eru stundaðar í hópi sem nefnist Orka og samfélag. Skýrslan er samin á ensku vegna þess að hún er hluti af norrænu rannsóknarverkefni.

Hún er samin af *Ásgeiri Valdimarssyni,* hagfræðingi.

Við viljum koma á framfæri þökkum til allra fyrirtækjanna fyrir gott samstarf og skilning við að leggja til gögn í þessa vinnslu og tökum fulla ábyrgð á því ef eitthvað er rangt farið með töluleg gögn sem notuð eru í skýrslunni. Án þeirra hefði ekki verið unnt að gera líkanið eins nákvæmt hvað varðar raunverulegar tekju- og útgjaldatölur. Einnig þökkum við Helgu Kristjánsdóttur, hagfræðingi, fyrir hjálp við gagnaöflun.

Introduction

This report is funded by a grant from the Energy Committee of the Nordic Council. The Council established five research position in 1991, one in each of the five Nordic countries. The report is written in English because it is a part of the Nordic research co-operation. The author of the report is *Asgeir Valdimarsson.* We would like to thank the companies for good co-operation and for their unselfish interest in the project. We take all responsibility for errors in the presentation of the data from the electricity distributors and producers in Iceland.. A "real world" model would not have been possible without their help. We would also like thank Miss Helga Kristjánsdottir for help in the data collection.

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University of Iceland

Guðmundur Magnússon,
Director

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Research on the Electricity Industry in Iceland

1.1 The Aim of this Study and Report

This report deals with the area of energy economics in Iceland. It is financed by the Nordic Council and belongs to the research work of the Energy and Society Research Group. The research presented below was done under the supervision of Prof. Guðmundur Magnússon director of The Institute of Economic Studies at the University of Iceland.

Energy issues are very important in Iceland. Putting our comparatively great resources in waterpower to the best possible use of our is one of our national goals. The successful harnessing of this natural resource is a big task for a small nation, and a prerequisite for this harnessing is finding a market for the electricity produced. Sales must be assured not only for a year or two but for 20 to 30 years. The income from sale on the spot market is sometimes high enough but should demand decrease for some reason in ten to fifteen years the Icelandic nation will be in dire straits as the owner of the power stations

The economic impact of new aluminium smelter and new power stations will be covered in another report, as well as the prospect of transmitting electricity to Scotland via sea cable. The energy markets in Europe with respect to Iceland are to be covered in a separate report. The plan is to publish four reports on energy use and prospects in Iceland.

This report covers electricity production and retail sales. It analyses the output or sales by sector and relates them to the inputs used by production functions. Similarly it analyses the inputs used, measuring them by value and relates these to the output or sales through linear production functions.

1.2 The Outline Explained

In the main part in chapter two an Input-output model in which all inputs are connected to all outputs is put forth. The Input-output field in economics enjoyed considerable popularity in the period between 1940 and 1970 but seemed to fall from grace in the two decades after 1970. Recently it seems to have regained some interest perhaps due to new computer technology capable of handling big data sets with mumerous differential equations.

My approach in the input-output field is that of partial analysis. I only study one industry at a time and link all output of that industry only to all its inputs in a Leontiefan fashion. I present a model in which output (or demand) for the products of the industry in question is the independent variable. This model I call *The Demand-Driven Input-Output Model*. It is based on the usual reasoning of economic theory that increased demand will call for more production and therefore more inputs and can be used to calculate the increase the use of inputs when a demand shock is applied to the model.

I follow input and output development over a period of four years in order to calculate the coefficients of the input-output model. A sort of "input-output time series" analysis is possible with more data. The relationship thus established between input and output is used to forecast future demand for input. The effects of large, expected increase in one sector´s demand for electricity might be calculated. The impact of doubling the energy intensive industry´s demand for for electricity is calculated as an example.

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An Input-Output Model for the Icelandic Energy Sector

2.1 The Purpose of the Input-Output Model

The model is a simulation model, built to simulate the financial transactions of the electrical industry. It is my aim that this model should become a tool of analysis. A regression is used to fit a line to a scatter of observed points in a diagram with various kinds of statistical maneuvers. The object is often to find which variable is dependent on which other variable and minimize unwanted relationships between variables or time periods or both. I try to avoid manipulating my data in this way. To the extent possible, the data is presented as it appears in the source material, i.e. annual reports of the firms in question. The model should mimic the activity in the industry as closely as possible.

The model could be used to study the effect of major changes in the power industry in Iceland. Then a large increase in sales to a specific sector would be translated into increased demand for inputs into the power industry. Although the use of real data for a whole industry is no simple task, it is my hope that this model will become useful in such calculations

2.2 The Input-Output Model: Some Theoretical Information.

W. W. Leontief at Harvard University was the author of the first clear statement of the input-output method of analysis published in 1936[3]. He published a fuller description in 1941[4]. The analysis is based on the idea that "the economy devotes considerable effort into producing intermediate goods and that the production of intermediate goods is closely linked to the output of final products"[5]. His terminology is this[6]:

$$X_i = \Sigma_j a_{ij} X_j + Y_i$$

X_i = Total product of sector i

a_{ij} = A fixed technical coefficient (or the ratio of input/output, i.e. $a_{ij} = x_{ij}/X_j$)

X_j = Intermediate output of sector i

Y_i = Final consumption of output of sector i

This is the adding across in the input-output table.

If **X** and **Y** are seen, respectively, as the column vector of intermediate outputs and final consumption, then one can write the technical coefficients as the n x n matrix **A** and obtain:

$$X - AX = Y$$

This equation can be solved by using the unit n x n matrix **I** and then we have the Leontief equation:

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

This analysis is useful in order to find the secondary effects of a demand shock. In the analysis I present only the primary effects are involved in the calculations.

2.3 The ADAF Partial Input-Output Model

The general input-output presentation is with inputs (x_{ij} and E_j) in the columns of the input-output table and the output (x_{ij}) in each row. Here the subscript i means row number and the subscript j the column number in the input-output table. Final consumption (Z_i) is put on the right-hand side of the intermediate output. The total consumption (X_i) of each commodity is in the far-right column. Below we see a simplified example of an input-output table for an economy with three sectors and no import.

Table 1 Input-output table with three industries

	1	2	3	Final consump	Total prod
1	x_{11}	x_{12}	x_{13}	Z_1	X_1
2	x_{21}	x_{22}	x_{23}	Z_2	X_2
3	x_{31}	x_{32}	x_{33}	Z_3	X_3
Value added	E_1	E_2	E_3		
Total input	X_1	X_2	X_3		

The production functions can be written this way:

$$X_1 = F^1(x_{11}, x_{12}, x_{13}, z_1) \qquad (1)$$
$$X_2 = F^2(x_{21}, x_{22}, x_{23}, z_2) \qquad (2)$$
$$X_3 = F^3(x_{31}, x_{32}, x_{33}, z_3) \qquad (3)$$

(Dorfman, Samuelson, Solow, 1958)

The function above usually mean adding across the table, i.e. adding in the rows:

$$X_1 = x_{11} + x_{12} + x_{13} + z_1 \qquad (1a)$$
$$X_2 = x_{21} + x_{22} + x_{23} + z_2 \qquad (2a)$$
$$X_3 = x_{31} + x_{32} + x_{33} + z_3 \qquad (3a)$$

The matrix can also be written in terms of total input:

$X_1 = f^1 (x_{11}, x_{21}, x_{31}, E_1)$ (4)

$X_2 = f^2 (x_{12}, x_{22}, x_{32}, E_2)$ (5)

$X_3 = f^3(x_{13}, x_{23}, x_{33}, E_3)$ (6)

or more precisely:

$X_1 = x_{11} + x_{21} + x_{31} + E_1$ (4a)

$X_2 = x_{12} + x_{22} + x_{32} + E_2$ (5a)

$X_3 = x_{13} + x_{23} + x_{33} + E_3$ (6a)

Functions (4a) to (6a) show adding in the columns.

My aim is to create an active connection between one row and one column.

This connection is to include all inputs in relevant column and all outputs (the relevant row) of that particular industry and to calculate the change in inputs following a change in outputs.

Leontief framework has technical constants for the endogeous inputs/outputs or the x_{ij}´s and aims at calculating the change in inputs following change in final consumption of products, Z_i, made by that industry. Although my model only uses a partial input-output table the same formulas as in Leontief framework could be used. My framework is mostly the same. In it change in any output are used as the starting points.

Consider now equation (5a) only. By definition X_2 (in Table 1 above) or the sum of inputs of industry two in column two equals Σ_2 or the sum of output of industry two on the left hand side:

$$X_2 = X_2$$

then $x_{12} + x_{22} + x_{32} + E_2 = x_{21} + x_{22} + x_{23} + z_2$ (7)

The regular Leontief technical coefficients are used:

$$a_{ij} = x_{ij} / X_j \quad i = 1, 3 \text{ and } j = 1, 3 \quad \text{and } i \neq j \qquad (8)$$

The total input is calculated via total output equals total input. Then each input is total input times the technical coefficient:

$$x_{ij} = X_j * a_{ij} \qquad i \neq j \qquad (9)$$

All input is seen as endogenous in the ADAF model, whereas factor input E_j (and imports) are often exogenous in the Leontief framework.

This way we have each input item as a function of all the output items.

The employment of these equations in EXCEL spreadsheet form with twelve sectors or industries is explained in section 2.6. There values for the a_{ij} coefficients are shown.

The X_j equals X_i or total output = total consumption as described above.
The E_j (j=1...n) is the value added in each column or input sector. In this analysis it corresponds to wages, depreciation and profits. The f^i 's stand for the production functions where industrial input is transformed into various outputs.

Above they are drawn for industry or sector number two (row two, column two), but in the sections below I use industry or sector number nine, the electricity industry (i.e. row nine, column nine). There the x_{99} or the output of the electricity industry used by it, cancel out, instead of the x_{22} that cancel out in the example above. The functions employed are objective functions with up to thirteen variables. The functions ($F^{1...j}$) involve constants that are explained above and numerical values are given in sections 2.5 to 2.8.

Suppose we have the model described above. Then what happens when demand increases in one or two of the sectors that use the products of the sector displayed in our model? How much will the demand for inputs increase? And if we had two or more sectors in one model each, could we link them together to find the combined effect?

All of this can be done with regular within Leontief framework.

2.4 Preparing the Model

The main goal of my research in 1991 to 1992 was to put together a partial input-output model of the Icelandic energy industry. It was to contain data from the electric production and distribution companies and from the district heating companies. The data was to be arranged according to sectors by trade. The input-output table would then consist of one column and one row.

The electricity utilities were the first group of firms to be contacted. They have various ways of arranging their production and sales data. Being members of Unipede, Union of Producers and Distributors of Electricity, they have begun to present this information according to the union's standards, which means dividing income and expenses according to sectors of trade. However, this work was begun only recently and focuses on the income side of the books of the companies for the time being.

The input-output tables in this report are made in value or pecuniary terms, the unit of measure is millions of Icelandic kronas (mISK). The exchange rate of the ISK to the US dollar is 68 ISK = 1 USD in October 1994.

The bigger companies have the sales data divided by trade in value terms in their books, so they provide data in the right form directly. The aim is to produce the data in money terms rather than physical or volume so one will have to assign some average price or tariff to each group, in cases where only volume (kWh/year) information is available. Getting information on the sales by volume divided into trade-sectors the way I want to use it from the smaller utilities is rather easy. Having done that it is possible to build the output side (the line or row of output) of the input-output table.

More work is involved in the preparation of the input side of the input-output table. This is due to the fact that the companies do not divide their expense account into categories by trade. Instead a division by kind is used. The information obtainable from that is useful up to a certain degree because in many cases one category by kind can be assigned to input bought from one or two trades.

The Institute of Economic Studies sent a letter of enquiry to the five largest utilities that distribute eletricity in Iceland. The utilities are asked to kindly provide information on sales and expenses and profit in the form seen in appendix 1.

The outcome of this inquiry was fruitful enough to enable me to make an input-output model for the years 1990 and 1991. The biggest of the companies have computerized book-keeping . They are able to produce recent data quickly and had figures for 1990 and 1991 ready in May 1992. It is possible to get the correct recent data from most of the energy companies. However, if we want data that is divided into different categories the computer system may not make things easier at all.

Older data is harder to get, because the books have already been closed and in most cases the book-keeping is done half manually. That means that basic things are computerized, but preparing the financial report and the accounting are done manually.

2.5 The Demand-Driven Partial Input-Output Model The ADAF Model

The main goal of this model is to make it possible to predict changes in input of the electricity industry according to changes in the amount of its output.

The method is to collect data from the electricity utilities. This pertains to the first group of companies included in the study. The next group would consist of the district heating companies in Iceland. Data has been collected from them, but remains to be processed according to the methods used in building the model. The third group consists of large power users. This kind of data has neither been collected for the electric utilities nor other companies before.

The market for electricity distribution in Iceland consists of two large distributors with a 33 per cent marketshare each, three medium sized distributors with 8 per cent marketshare each and 11 small distributors with the remaining 10 per cent market share combined. It was decided to contact the five biggest companies which give information on 90 per cent of the consumer electricity market in Iceland.

The five electric utilities in the group were asked to redo their income statement on a sectoral basis. That is, to divide it into twelve trade sectors according to the buyer of electricity.

The trade sectors were:

Agriculture

Fisheries

Fish Processing

Industry

Commerce

Building Industry

Transport

Services

Electricity Industry

District Heating Industry

Public Sector

Banking Sector

The thirteenth sector on the output side is: Final consumption which is the biggest sector in the use of electricity.

The thirteenth sector on the input side is: Factor inputs (E) which is the biggest input in the production of electricity.

This was feasible in all of the utilities for the years 1990 and 1991. Dividing costs in this manner for the period before 1990 required manual sorting of original receipts for the years before 1989, and frankly the companies were not willing to put man-power into such work. However, due to newer computer software which came into use in 1990 it was possible to classify costs for 1990 and 1991, i. e. *costs divided by sectors of recipients of payments* instead of the traditional accounting method used to in preparing the annual report. In the traditional method no account is kept of which sector receives the payment when costs are incurred.

The hints I have got as far as can be seen are that each company seems to be stable in cost divisions year after year. They have a rather different pattern one from another, i. e. the big companies serve two very different markets and the small companies are situated on a scale somewhere between them in terms of the properties of their markets.

The portion of funds used for each expense category seems to be fixed over the years. The question might then be whether this is due to the stable nature of each market region or conservative financial planning.

Collection of data from the district heating companies is under way, as mentioned above. My intention is to combine the data from the biggest companies to make up a picture of the district heating industry and then combine this with the data from the electric distribution industry. Then a model for the sector including large power producers and users can be formed, given that the necessary information will be available.

The input of the five largest electricity distributor companies in Iceland with 90 per cent market share is combined in tables 2.2 to 2.5 . This data is for 1988 to 1991.

2.6 The ADAF Model a_{ij} Technical Coefficients

The basic information is the same for the input-output tables. In this section, where demand is the independent variable, the tables will be labeled "*ADAF*".

$$x_{ij} = X_{ij} * a_{ij} \qquad i \neq j \qquad (9)$$

The equations are embedded in the column.

Each cell in column nine has one formula. The a_{ij} coefficients expresses the share of each input x_{ij} (j = 9) in the total input. The $\Sigma a_{ij} = 1$. The functions show the input as a function of the output i.e. the demand for supplies as a function of demand for the products of the industry involved.

Table 2.2 is the first in the Adaf section. There the summed up total sales and expenses of the electricity industry for 1988-1991 are shown. The National Power Company is included so the figures represent most of the electricity industry in Iceland. Electricity sold wholesale to the retail electricity distributors cancels out because the wholesale and retail is in the same sector.

The figure 247 MISK in row five, column nine (it is the input from commerce into the electricity industry) in table 2.8, or "ADAF1988", is the product of the formula above where: $a_{5,9} = 0{,}034$

The formulas have these a_{ij} constants:

		a_{ij} constant	Input from:
a_{19}	=	0,001	Agriculture
a_{29}	=	0,000	Fisheries and Fish Processing
a_{39}	=	0,026	Industry
a_{49}	=	0,000	Power-intensive Industry
a_{59}	=	0,034	Commerce
a_{69}	=	0,026	Building Industry
a_{79}	=	0,018	Transport
a_{89}	=	0,020	Services
a_{99}	=	0,000	Electricity Industry
a_{109}	=	0,000	District Heating Industry
a_{119}	=	0,011	Public Sector
a_{129}	=	0,005	Banking Sector
a_{149}	=	0,034	Income Taxes
a_{159}	=	0,005	Indirect Taxes
a_{169}	=	0,006	Insurance
a_{169}	=	0,005	Import Duties
a_{179}	=	0,183	Interest Paid
a_{199}	=	0,199	Wages
a_{209}	=	0,367	Depreciation
a_{219}	=	0,061	Profits

In the case of the a_{ij}´s only the row notation (i) changes since the a_{ij}´s are tied with the inputs in column nine.

$$\Sigma a_{ij} = 1$$

2.7 The input-ouput Model: An Overview

In table 2.1 we have the information from the electricity industry. The figures are in millions Icelandic Kroner and in current prices. Column A gives the division of the output to various buying sectors in lines five to seventeen. In lines twenty-two to thirty-two we have the input sectors that sell supplies to the electricity industry. In lines thirty-six to forty nine we have the value-added part in the electricity industry.

The information in this table is a total from all the individual companies. Most of it is fed directly into the input-output tables like table 2.2 which gives an example of these. The row headings in table 2.2 match those in table 2.1, and the information in the upper part of table 2.1, i.e. in lines five to seventeen is copied into row nine in table 2.2.

Then the Adaf constants in the right-most column of table 2.2 are used to give the results displayed in column nine. The Adaf constants are the average ratio of each input to total input for the years 1988 to 1991. Then the inputs are a ratio of total input. Total input is by definition equal to total output each year. The connection between input and output is then only through the totals.

Let´s look at table 2.3 next. It shows the input columns for the years from 1988 to 2012. The Adaf tables for each year are in appendix 2. This base version of the Adaf model is calculated using 3% annual growth for all output and consequently the same growth for all inputs. Graph 2.3 shows this development in inputs over time. The growth constants used are:

1991	1,00
1994	1,09
1996	1,16
1998	1,23
2000	1,30
2002	1,38
2004	1,47
2006	1,56

2008	1,65
2010	1,75
2012	1,86

This is an extrapolation from 1992 according to constant growth of 3% per year. In table 2.4 the predicted input and output of the electricity is shown. Row nine shows the predicted output which is simply the output in 1991 (given in row twenty-six) multiplied by 1,75. The input and output is grown to 18,325 millions ISK. The total input is multiplied by the Adaf constants in column twenty-five and the result displayed in column nine. Appendix 3 holds such input-output tables for the years 1992, 1994, 1996 1998, 2000, 2002, 2004, 2006, 2008, 2010 and 2012.

The estimate becomes more complicated in chapter three when each input has its own growth path. The growth path are determined according to the predicted effects of a new aluminium smelter on demand for each input.

3

Using the ADAF model

3.1 *Using the ADAF Model to Predict Use of Inputs*

The ADAF model is used to calculate the change in inputs when demand for electricity increases. The period estimated is from 1992 to 2000. The model can be used with a general estimate on increase in demand, i. e. that all sectors increase their demand for electricity by the same percentage of present use as in section 2.7 above, or one can put in separate estimates for the growth of demand in each sector. The limited number years of data we have does not allow us to estimate with time series analysis. We have to use simple guesswork to forecast the growth in demand in each sector in the future.

The sales of electricity are given in the case of the ADAF model. The growth of electricity sales measured in kWh/year has been very small in the last five year period. The real income has not grown and in nominal terms the increase is the same as the rise in the general price level. For the period of 1992 to 2012 I have used annual increase of 3 per cent, see the base version in tables 2.1 to 2.4 and chart 2.3. The inflation in Iceland is now between zero and 2 per cent per year. The predicted increase in income from electricity sales is just one or two per cent over the price level increases, i.e. the volume grows by one per cent each year assuming that tariffs are unchanged.

The ADAF model is indifferent to whether changes are due to price or volume increases, whereas some other prediction models may need constant volume or constant prices. One only has to decide how much of the increase is due to increases in volume and how much is due to price increases, if one wishes to know each part's contribution to growth.

When we apply separate estimates of growth of demand for electricity in each sector, we can calculate the effect of expected increase in demand. A new aluminium smelter in Iceland using 3 TWh/year increases the total electricity use in Iceland by 75 per cent, or from the present level of 4 TWh/year up to 7 TWh/year. We use the model to simulate what happens with the inputs when the power intensive industry increases its electricity use from 1.8 TWh/year to 4.8 TWh/year. This is shown in tables 3.1 to 3.4. This increase in demand might happen in 1998 to 2000 if the decision to build a new smelter is made soon.

In the case that no power-intensive factories are started in the next ten years we have the base scenario of estimated 3 per cent annual growth in tables 2.1 to 2.4.

In the S-scenario with a new aluminium smelter started in 1998 there is a major increase in the demand of electricity for the power intensive industry. It grows by 200 per cent in two years, i. e. 1998 and 1999. Tables 3.1 to 3.4 show the outcome for demand for inputs in this case. Note the increase in the use of inputs in columns 1998, and 2000 in table 3.1, and upswing at the right side of chart 3.1. The upswing takes into account more electricity use in manufacturing, commerce and services in connection with the new smelter.

A major difference lies in the matrix of growth factors that is shown in table 3.5. Instead of a single value for each year there are twelve values for each year, one for each input. These values have been determined according to expected increase in demand for inputs if a new smelter is started in 1998.

When this is written in 1994 it seems more and more unlikely that this time schedule will hold. That does not make much difference for the model. The growth factor can be manipulated according to a new schedule if necessary.

ADAF TABLE 2.1

	A	B	C	D	E	F	G	H	I
1				*A Total for the Electricity*					
2				*Industry in Iceland*					
3	*Income from*	In millions ISK		Current prices					
4	*electricity sales to:*	1988		1989		1990		1991	
5	1 Agriculture	567	7,6%	647	7,3%	721	7,5%	781	7,5%
6	2 Fish Processing	404	5,4%	462	5,2%	510	5,3%	560	5,3%
7	3 Industry	576	7,7%	672	7,5%	754	7,8%	839	8,0%
8	4 Power Int. Industry	1.423	19,1%	1.920	21,5%	1.764	18,3%	1.659	15,8%
9	5 Commerce	318	4,3%	366	4,1%	416	4,3%	464	4,4%
10	6 Building Industry	101	1,4%	117	1,3%	135	1,4%	151	1,4%
11	7 Transport	19	0,3%	23	0,3%	26	0,3%	30	0,3%
12	8 Services	462	6,2%	534	6,0%	609	6,3%	683	6,5%
13	9 Electricity Industry	0	0,0%	0	0,0%	0	0,0%	0	0,0%
14	10 District Heating	258	3,5%	297	3,3%	338	3,5%	378	3,6%
15	11 Public Sector	989	13,3%	1.153	12,9%	1.306	13,5%	1.465	14,0%
16	12 Banks	59	0,8%	68	0,8%	78	0,8%	85	0,8%
17	13 Final Consumption	2.261	30,4%	2.656	29,8%	3.004	31,1%	3.376	32,2%
18		7.436	100,0%	8.914	100,0%	9.662	100,0%	10.471	100,0%
19									
20	*Expenses*								
21	*on resources from:*								
22	1 Agriculture	1	0,0%	1	0,0%	1	0,0%	2	0,0%
23	2 Fish Processing	0	0,0%	0	0,0%	0	0,0%	0	0,0%
24	3 Industry	191	2,6%	237	2,7%	241	2,5%	349	3,3%
25	4 Power Int. Industry	0	0,0%	0	0,0%	0	0,0%	0	0,0%
26	5 Commerce	255	3,4%	293	3,3%	324	3,4%	386	3,7%
27	6 Building Industry	196	2,5%	246	2,8%	238	2,5%	318	3,0%
28	7 Transport	136	1,8%	175	2,0%	207	2,1%	262	2,5%
29	8 Services	150	2,0%	174	1,9%	201	2,1%	266	2,5%
30	9 Electricity Industry	0	0,0%	0	0,0%	0	0,0%	0	0,0%
31	10 District Heating	2	0,0%	2	0,0%	3	0,0%	4	0,0%
32	11 Public Sector	86	1,2%	100	1,1%	114	1,2%	150	1,4%
33	12 Banks	32	0,4%	35	0,4%	44	0,5%	56	0,5%
34									
35	*Other expenses:*								
36	13 Wages Paid	1.610	21,6%	1.854	20,8%	2.070	21,4%	2.397	22,9%
37	14 Depreciation	2.681	36,0%	3.404	38,2%	4.535	46,9%	4.274	40,8%
38	15 Insurance	42	0,6%	46	0,5%	49	0,5%	61	0,6%
39	16 Import Duties	32	0,4%	99	1,1%	143	1,5%	231	2,2%
40	*Total Regular Costs:*	5.414	72,8%	6.665	74,8%	8.171	84,6%	8.754	83,6%
41									
42	Profits before interest	2.023	27,2%	2.249	25,2%	1.492	15,4%	1.717	16,4%
43	17 Interest paid	1.653	22,2%	1.582	17,7%	239	2,5%	908	8,7%
44									
45	*Taxes:*								
46	18 Income Taxes	252	3,4%	297	3,3%	350	3,6%	437	4,2%
47	19 Indirect Taxes	33	0,4%	-37	-0,4%	-40	-0,4%	-44	-0,4%
48									
49	*Profits/(Losses)*	84	1,1%	407	4,6%	943	9,8%	415	4,0%
50									
51	Total Cost+Profits	7.436	100,0%	8.914	100,0%	9.662	100,0%	10.471	100,0%
52									
53		The National Power Company is included							

ADAF88.XLS

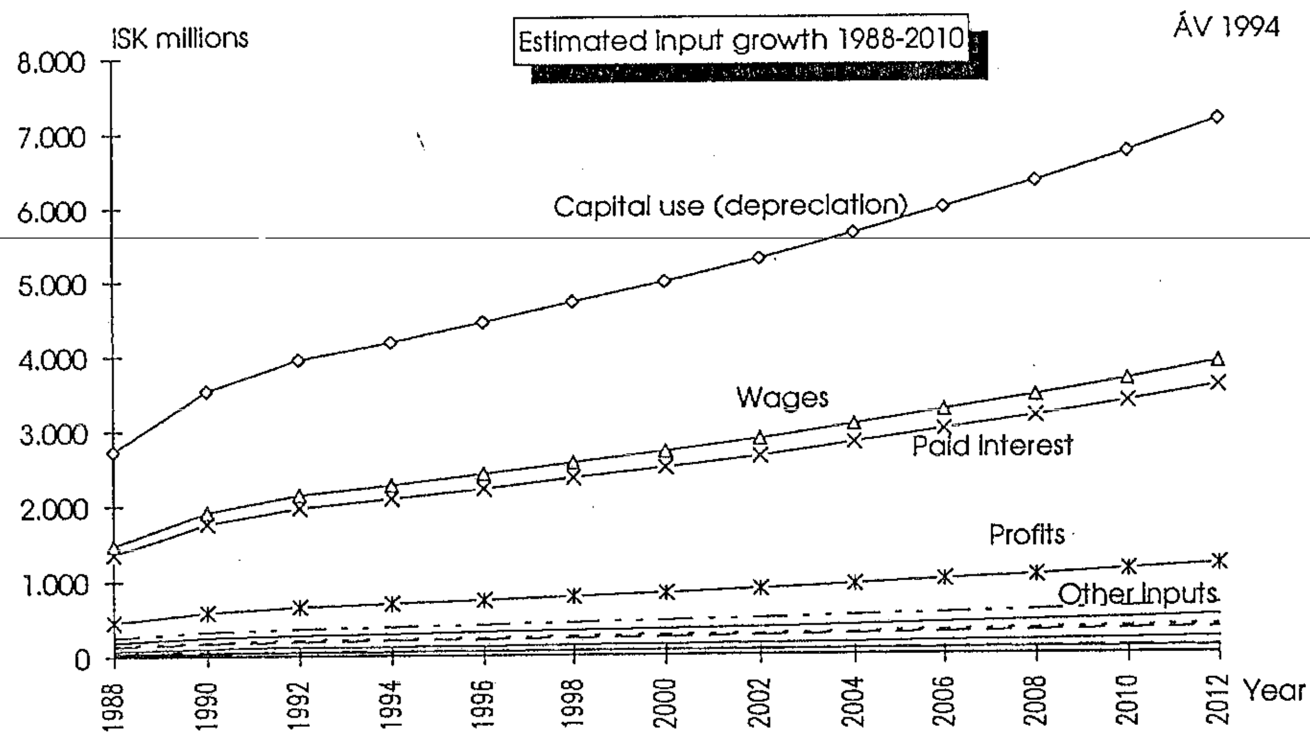
Year 1988 Millions Icel. kr.	1	2	3	4	5	6	7	8	9	10	11	12	18	19	20		!	Input Source Electricity Distribution Retail	Adaf-Constants aij
	Agri-culture	Fish Processing	Industry	Pow.Int. Industry	Commer	Building Industry	Trans-port	Services	Electricity Industry	District Heating	Public Sector	Banks	Subtotal		Final Consump-tion	Output	!		
1 Agriculture									7								!	1	0,001
2 Fish Processing									0								!	0	0
3 Industry									193								!	191	0,026
4 Power Int. Industry									0								!	0	0
5 Commerce									253								!	255	0,034
6 Building Industry									193								!	196	0,026
7 Transport									134								!	136	0,018
8 Sevices									149								!	150	0,02
9 Electricity Industry	567	404	576	1.423	318	101	19	462	0	258	989	59	5.175		2.261	7.436	!	0	
10 District Heating									0								!	2	0
11 Public Sector									82								!	86	0,011
12 Banks									37								!	32	0,005
																	!		
13 Imported input									0								!		
14 Income Taxes									253								!	252	0,034
15 Indirect Taxes									37								!	33	0,005
16 Insurance									45								!	42	0,006
17 Import Duties									37								!	32	0,005
18 Input Subtotal									1.420								!	1.408	
19 Interest paid									1.361								!	1.653	0,183
20 Wages									1.480								!	1.610	0,199
21 Depreciation									2.722								!	2.681	0,366
22 Profits									454								!	84	0,061
23 Value-added									6.016								!	6.028	
																	!		
24 Inputs									7.436								!	7.436	1,000

ADAF TABLE 2.3

AD8812.XLS 6/4/95 11:20 AV

		1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012
		The electricity industry´s inputs 1988-2010							Base version of Adaf model with 3 per cent annual growth					
	Millions Icelandic Kronas													
	Year	1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012
1	Agriculture	7	10	11	11	12	13	14	14	15	16	17	18	19
2	Fish Processing	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Industry	193	251	280	297	316	335	354	376	400	425	449	476	506
4	Power Int. Industr	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Commerce	253	329	367	388	413	438	463	491	523	555	587	623	662
6	Building Industry	193	251	280	297	316	335	354	376	400	425	449	476	506
7	Transport	134	174	194	205	219	232	245	260	277	294	311	330	351
8	Sevices	149	193	216	228	243	258	272	289	308	327	346	366	390
9	Electric Ind.	0	0	0	0	0	0	0	0	0	0	0	0	0
10	District Heating	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Public Sector	82	106	119	126	134	142	150	159	169	180	190	202	214
12	Banks	37	48	54	57	61	64	68	72	77	82	86	92	97
13	Imported Input	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Income Taxes	253	329	367	388	413	438	463	491	523	555	587	623	662
15	Indirect Taxes	37	48	54	57	61	64	68	72	77	82	86	92	97
16	Insurance	45	58	65	68	73	77	82	87	92	98	104	110	117
17	Import Duties	37	48	54	57	61	64	68	72	77	82	86	92	97
19	Interest paid	1.361	1.768	1.974	2.089	2.223	2.357	2.491	2.644	2.817	2.989	3.162	3.353	3.564
20	Wages	1.480	1.923	2.146	2.271	2.417	2.563	2.709	2.876	3.063	3.251	3.438	3.647	3.876
21	Depreciation	2.722	3.536	3.947	4.177	4.446	4.714	4.982	5.289	5.634	5.979	6.324	6.707	7.128
22	Profits	454	589	658	696	741	786	830	881	939	996	1.054	1.118	1.188
24	Inputs Total	7.436	9.662	10.785	11.414	12.147	12.880	13.613	14.450	15.393	16.335	17.278	18.325	19.477

CHART 2.3


ISK millions
Estimated input growth 1988-2010
ÁV 1994
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0
Capital use (depreciation)
Wages
Paid interest
Profits
Other inputs
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Year

ADAF TABLE 2.4

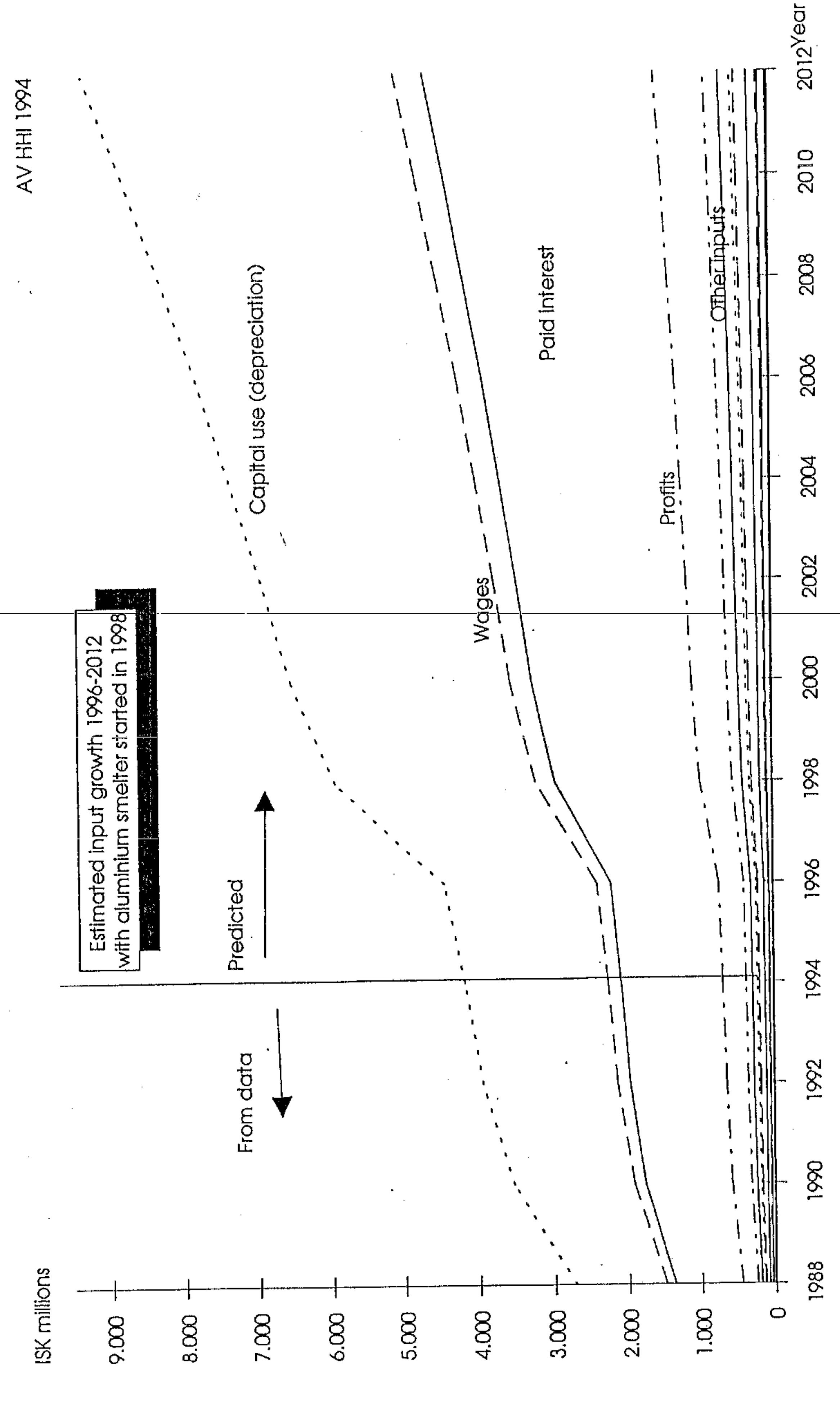
ADAF10.XLS

	Year 2010																		!	Reference	Adaf-
	Millions Icel. kr.	1	2	3	4	5	6	7	8	9	10	11	12	18	19	20			!	1991	Constants
		Agri-	Fish	Industry	Pow.Int.	Comme	Building	Trans-	Service	Electricity	District	Public	Banks	Subtotal		Final		Output	!	Electricity	aij
		culture	Processing		Industry		Industry	port		Industry	Heating	Sector				Consumption		Total	!	Distribution	0
																			!		
1	Agriculture									18									!	2	0,001
2	Fish Processing									0									!	0	0
3	Industry									476									!	349	0,026
4	Power Int. Industry									0									!	0	0
5	Commerce									623									!	386	0,034
6	Building Industry									476									!	318	0,026
7	Transport									330									!	262	0,018
8	Sevices									366									!	266	0,02
9	Electric Ind.	1367	980	1468	2903,3	812	264	52,3	1195	0	661	2564	149	12.416		5909		18.325	!	0	0
10	District Heating									0									!	4	0
11	Public Sector									202									!	150	0,011
12	Banks									92									!	56	0,005
																			!	1.791	0
13	Imported input									0									!		0
14	Income Taxes									623									!	437	0,034
15	Indirect Taxes									92									!	-44	0,005
16	Insurance									110									!	61	0,006
17	Import Duties									92									!	231	0,005
18	Input Subtotal									3.500									!	2.477	
																					0
19	Interest paid									3.353									!	908	0,183
20	Wages									3.647									!	2.397	0,199
21	Depreciation									6.707									!	4.274	0,366
22	Profits									1.118									!	415	0,061
23	Value-added									14.825									!	7.994	
																			!		
24	Inputs Total									18.325									!	10.471	1,00
	Outputs Source	781	560	839	1.659	464	151	30	683		378	1.465	85			3.376					
	Multiplier >>	1,75		(=1,00 in 1991)																	

BD8888S.XLS 25/4/95 18:38 AV TABLE 3.11

		The electricity industry´s inputs 1988-2012						Version S of Adaf model with						
		Estimated with ADAF model						planned aluminium smelter started in 1998						
Millions Icelandic Kronas														
		1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012
1	Agriculture	7	10	11	11	12	16	18	19	20	21	23	24	25
2	Fish Processing	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Industry	193	251	280	297	316	420	464	492	521	553	587	623	661
4	Power Int. Industr	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Commerce	253	329	367	388	413	550	606	643	682	723	768	814	864
6	Building Industry	193	251	280	297	316	420	464	492	521	553	587	623	661
7	Transport	134	174	194	205	219	291	321	340	361	383	406	431	457
8	Sevices	149	193	216	228	243	323	357	378	401	425	451	479	508
9	Electric Ind.	0	0	0	0	0	0	0	0	0	0	0	0	0
10	District Heating	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Public Sector	82	106	119	126	134	178	196	208	221	234	248	263	279
12	Banks	37	48	54	57	61	81	89	95	100	106	113	120	127
13	Imported input	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Income Taxes	253	329	367	388	413	550	606	643	682	723	768	814	864
15	Indirect Taxes	37	48	54	57	61	81	89	95	100	106	113	120	127
16	Insurance	45	58	65	68	73	97	107	113	120	128	135	144	152
17	Import Duties	37	48	54	57	61	81	89	95	100	106	113	120	127
19	Interest paid	1.361	1.768	1.974	2.089	2.223	2.958	3.263	3.461	3.670	3.890	4.131	4.382	4.649
20	Wages	1.480	1.923	2.146	2.271	2.417	3.216	3.548	3.763	3.991	4.231	4.492	4.765	5.055
21	Depreciation	2.722	3.536	3.947	4.177	4.446	5.931	6.526	6.921	7.340	7.781	8.262	8.763	9.298
22	Profits	454	589	658	696	741	986	1.088	1.154	1.223	1.297	1.377	1.461	1.550
24	Inputs Total	7.436	9.662	10.785	11.414	12.147	16.178	17.829	18.911	20.055	21.259	22.574	23.943	25.404

CHART 3.1


AV HHI 1994
Estimated input growth 1996-2012 with aluminium smelter started in 1998
Capital use (depreciation)
Wages
Paid Interest
Profits
Other inputs
Predicted
From data
ISK millions
9.000
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Year

ADAF96.XLS

	Year 1996																		!	Input	Adaf-
	Millions Icel. kr.	1	2	3	4	5	6	7	8	9	10	11	12	18	19	20			!	Source	Constants
		Agri-	Fish	Industry	Pow.Int.	Comme	Building	Trans-	Service	Electricity	District	Public	Banks	Subtotal		Final		Output	!	Electricity	aij
		culture	Processing		Industry		Industry	port		Industry	Heating	Sector				Consumption		Total	!	Distribution	
																			!	Retail	
1	Agriculture									12									!	2	0,001
2	Fish Processing									0									!	0	0
3	Industry									316									!	349	0,026
4	Power Int. Industry									0									!	0	0
5	Commerce									413									!	386	0,034
6	Building Industry									316									!	318	0,026
7	Transport									219									!	262	0,018
8	Sevices									243									!	266	0,02
9	Electric Ind.	906	650	973	1924,4	538	175	34,6	792	0	438,2	1700	99	8.230		3917		12.147	!	0	0
10	District Heating									0									!	4	0
11	Public Sector									134									!	150	0,011
12	Banks									61									!	56	0,005
																			!	1.791	0
13	Imported input									0									!		0
14	Income Taxes									413									!	437	0,034
15	Indirect Taxes									61									!	-44	0,005
16	Insurance									73									!	61	0,006
17	Import Duties									61									!	231	0,005
18	Input Subtotal									2.320									!	2.477	
																					0
19	Interest paid									2.223									!	908	0,183
20	Wages									2.417									!	2.397	0,199
21	Depreciation									4.446									!	4.274	0,366
22	Profits									741									!	415	0,061
23	Value-added									9.827									!	7.994	
																			!		
24	Inputs Total									12.147									!	10.471	1,00
	Outputs Source	781	560	839	1.659	464	151	30	683		378	1.465	85			3.376					
	Multiplier >>	1,16																			

ADAS98.XLS 27/4/95 11:00 AV BDAF TABLE 3.12

		1	2	3	4	5	6	7	8	9	10	11	12	18	19	20			!	Input Source	Bdaf-Constants	Industry Coefficient
		Agri-culture	Fish Processing	Industry	Pow.Int. Industry	Comme	Building Industry	Trans-port	Service	Electricity Industry	District Heating	Public Sector	Banks	Subtotal		Final Consumption		Output Total	!			
																			!			
1	Agriculture									16				16					!	2	0,001	
2	Fish Processing									0				0					!	0	0	
3	Industry									420				420					!	349	0,026	
4	Power Int. Industry									0				0					!	0	0	
5	Commerce									550				550					!	386	0,034	
6	Building Industry									420				420					!	318	0,026	
7	Transport									291				291					!	262	0,018	
8	Sevices									323				323					!	266	0,02	
9	Electric Ind.	859	728	1175	4645,2	928	196	38,8	888	0	453,3	1861	102	11.874		4288		16.162	!	0	0	
10	District Heating									0				0					!	4	0	
11	Public Sector									178				178					!	150	0,011	
12	Banks									81				81					!	56	0,005	
										0									!	1.791		
13	Imported input									0				0					!		0	
14	Income Taxes									550				550					!	437	0,034	
15	Indirect Taxes									81				81					!	-44	0,005	
16	Insurance									97				97					!	61	0,006	
17	Import Duties									81				81					!	231	0,005	
18	Input Subtotal									3.087									!	2.477		
19	Interest paid									2.958									!	908	0,183	
20	Wages									3.216									!	2.397	0,199	
21	Depreciation									5.931									!	4.274	0,367	
22	Profits									986									!	415	0,061	
23	Value-added									13.091									!	7.994		
																			!			
24	Inputs Total									16.178									!	10.471	1,00	
	Outputs Source	781	560	839	1.659	464	151	30	683		378	1.465	85			3.376						
	Multiplier >>	1,10	1,30	1,40	2,80	2,00	1,30	1,30	1,30		1,2	1,3	1,2			1,3						
	(=1,00 in 1991)																					

ADAS00.XLS 27/4/95 11:04 AV BDAF TABLE 3.14

Year 2000																		!	Input	Adaf-
Estimated	1	2	3	4	5	6	7	8	9	10	11	12	18	19	20			!	Source	Constants
with smelter	Agri-	Fish	Industry	Pow.Int.	Comme	Building	Trans-	Service	Electricity	District	Public	Banks	Subtotal		Final		Output	!	Electricity	
	culture	Processing		Industry		Industry	port		Industry	Heating	Sector				Consumption		Total	!	Distribution,	
																		!	Retail	
1 Agriculture									18				18					!	2	0,001
2 Fish Processing									0				0					!	0	0
3 Industry									464				464					!	349	0,026
4 Power Int. Industry									0				0					!	0	0
5 Commerce									606				606					!	386	0,034
6 Building Industry									464				464					!	318	0,026
7 Transport									321				321					!	262	0,018
8 Sevices									357				357					!	266	0,02
9 Electric Ind.	937	728	1259	4645,2	1021	196,1	44,8	1161	0	566,6	1758	111	12.427		5402		17.829	!	0	0
10 District Heating									0				0					!	4	0
11 Public Sector									196				196					!	150	0,011
12 Banks									89				89					!	56	0,005
									0									!	1.791	0
13 Imported input									0				0					!		0
14 Income Taxes									606				606					!	437	0,034
15 Indirect Taxes									89				89					!	-44	0,005
16 Insurance									107				107					!	61	0,006
17 Import Duties									89				89					!	231	0,005
18 Input Subtotal									3.405									!	2.477	
																				0
19 Interest paid									3.263									!	908	0,183
20 Wages									3.548									!	2.397	0,199
21 Depreciation									6.526									!	4.274	0,366
22 Profits									1.088									!	415	0,061
23 Value added									14.424									!	7.994	
																		!		
24 Inputs Total									17.829									!	10.471	1,00
Outputs Source	781	560	839	1.659	464	151	30	683		378	1.465	85			3.376					
Multiplier >>	1,20	1,30	1,50	2,80	2,20	1,30	1,50	1,70		1,50	1,20	1,30			1,60					
(=1,00 in 1991)																				

ADAF TABLE 3.4

Growth constants for ADAF S version with aluminium smelter started in 1998

	1	2	3	4	5	6	7	8	9	10	11	12	18	19	20
	Agri-culture	Fish Processing	Industry	Pow.Int. Industry	Commerce	Building Industry	Trans-port	Services	Electricity Industry	District Heating	Public Sector	Banks	Subtotal		Final Consumption
1991 = 1,00															
1996	1,16	1,16	1,16	1,16	1,16	1,16	1,16	1,16	1,16	1,16	1,16	1,16	1,16	1,16	1,16
1998	1,10	1,30	1,40	2,80	2,00	1,30	1,30	1,30		1,20	1,30	1,20			1,30
2000	1,20	1,30	1,50	2,80	2,20	1,30	1,50	1,70		1,50	1,20	1,30			1,60
2002	1,27	1,38	1,59	2,97	2,33	1,38	1,59	1,80		1,59	1,27	1,38			1,70
2004	1,35	1,46	1,69	3,15	2,47	1,46	1,69	1,91		1,69	1,35	1,46			1,80
2006	1,43	1,55	1,79	3,33	2,62	1,55	1,79	2,03		1,79	1,43	1,55			1,91
2008	1,52	1,64	1,90	3,54	2,78	1,64	1,90	2,15		1,90	1,52	1,64			2,03
2010	1,61	1,74	2,02	3,76	2,95	1,74	2,02	2,28		2,02	1,61	1,74			2,15
2012	1,71	1,85	2,14	3,99	3,13	1,85	2,14	2,42		2,14	1,71	1,85			2,28

References.

Dorfman, R., Samuelson, P., A., Solow, R., M., *Linear Programming and Economic Analysis*, The Rand Series, McGraw-Hill Book Company, Inc. New York, 1958.

Bardarson, H., *Torskefiskerienes Regionalökonomiske virkninger*, Fiskerikandidatsoppgave, Noreges Fiskerihögskole, Tromso University, Norway, 1994.

Breuil, J., M., "Input-Output Analysis and Pollutant Emissions in France", *The Energy Journal,* Vol. 13, no. 3, 1992.

Annual accounts 1988-1991 of five largest electricity distributors in Iceland:
Reykjavik Municipal Electric Works
State Electric Power Works
Orkubu Vestfjarda
Rafveita Akureyrar
Hitaveita Sudurnesja.

Danmarks Statisitic: Input-Output tables and analyses 1987.

Chiang, A. C., *Fundamental Methods of Mathematical Economics*, McGraw-Hill Book Company, Inc. New York, 1984

Appendix A

A copy of the letter mailed to the electricity utilities in Iceland:

Hagfræðistofnun Háskóla Íslands
Institute of Economic Studies
Odda/Sturlugötu Tel: 694554 og 694531
101 Reykjavík Fax: 26806

Reykjavík, 11. February, 1992

Dear Mr. Aðalsteinn Guðjohnsen, Director

At the Institute of Economic Studies at the University of Iceland we are building an input-output model of the Icelandic energy sector. To be able to produce meaningful results with the model we would like to collect certain financial information from the electricity utilities in Iceland. With this letter we are asking for help from your company to find these figures in the financial records of your company. Furthermore we ask for permission to use this imformation publicly as an industry total so that figures from each company are not disclosed. The Association of Icelandic Electricity Utilities could act as a mediator in this matter.

The data we ask for is all expenses divided by origin of industry and a division of all income by the trade or industry of the paying customer. Enclosed is a list of the trade sectors into which we divide the whole economy.

The model is built around an input-output table where the input or resources of all the companies combined, for one year, is listed in value-terms and divided by trade of origin. The output or sales of same period is defined in the same manner and listed as well. The only way to build up such a table for an industry in Iceland is with information provided by the companies involved. The model could be used for input-output analysis of most industries, and the experience gained in producing the I-O table for the energy industry is valuable for future development in this field. The results from the model could show the product value of of the power industry in Iceland. It may also be used to forecast future development in demand for inputs and outputs. And it might be used when similar models are made for other industries.

In the hope of a positive response

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Professor	Economist

The form used in the inquiry:

Information from financial accounts for the year of 1988

Division of Income:

Millions of krónur

Electricity Sales to:

1.	Agriculture	______________
2.	Shipping	______________
3.	Fish processing plants	______________
4.	Manufacturing industry	______________
5.	Commerce	______________
6.	Building industry	______________
7.	Transport	______________
8.	Services	______________
9.	Electric companies	______________
10.	District heating companies	______________
11.	Public sector	______________
12.	Banks	______________

Division of Expenses or Input bought from:

1.	Agriculture	______________
2.	Shipping	______________
3.	Fish processing plants	______________
4.	Manufacturing industry	______________
5.	Commerce	______________
6.	Building industry	______________
7.	Transport	______________
8.	Services	______________
9.	Electric companies	______________
10.	District Heating Companies	______________

11. Public sector .... ________________

12. Banks .... ________________

Other Expenses:

13. Salary (gross) .... ________________

14. Depreciation .... ________________

15. Profits .... ________________

16. Taxes .... ________________

17. Value-added tax .... ________________

18. Insurance .... ________________

19. Import duties .... ________________