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Energy demand in Chilean Manufacturing

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The Chilean experience following the 1973 increase in world energy prices is marked by wide inter-industry differences in changes in the energy intensity of production. Some industries, such as wood and furniture, appear to have adjusted quickly to relative price changes by decreasing their consumption of energy per unit of output, whereas others, such as industrial chemicals and non-electrical machinery, were more energy-intensive in 1977 than in 1967. The purpose of this paper is to employ regression analysis to explain this inter-industry variation as a function of four variables: change in industry output, substitution of electricity for other fuels, change in employment of labour, and the survival of establishments. The first section of the paper provides a brief description of the available data on energy consumption and manufacturing production in Chile. The specific variables used and the estimated equations are described in the next two sections. The main empirical findings are summarized in a concluding section.

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I

Data

The manufacturing sector now accounts for more than a quarter of total energy consumption in Chile.[1] Between 1967 and 1977 annual energy consumption in this sector increased by 31%, with the greatest increase occurring in electricity (see table 1). The average price of electricity for industrial use actually fell in real terms over this period of time by more than 20%, while the price of petroleum products increased by more than 50% (see table 2). Relative price changes thus provided Chilean Manufacturers with a strong incentive to increase consumption of locally-produced electricity and economize on imported oil.

Manufacturing output grew much more slowly than energy consumption in the 1967-1977 period. According to official government statistics, manufacturing production fell 25% in the 1975 recession and regained its 1967 level in 1977. The production index compiled by the manufacturers' association (SOFOFA) shows a similar fall in 1975, but indicates recovery in 1977 to a level of output 15% greater than that of 1967. Regardless of the production index one uses, however, there has thus been a clear increase in energy consumption per unit of output in Chilean manufacturing.

In this paper the SOFOFA production index is used because both it and the energy consumption statistics are based on the revised version of the International Standard Industrial Classification (ISIC Rev. 2). These data show that the ratio of energy consumption to gross manufacturing output increased by 13.9% between 1967 and 1977. This estimate of the increase in the energy/output ratio is biased downwards for two reasons. First, it is based on the higher of two available indices of real output. Secondly, energy consumption by small establishments employing fewer than ten persons is included in the 1967 data but excluded from those for 1977. This downward bias, coupled with the increase in the real price of

[1]Total energy comprises commercial fuels and firewood. For data on economy-wide energy consumption, see Comisión Nacional de Energía, *Balance de Energía 1960-1968* (Santiago, Chile, 1980).

petroleum products, is consistent with the fact that energy expenditures as a percentage of gross manufacturing output, both measured in current prices, nearly doubled from 2.2% in 1967 to 4.2% in 1977.

For individual industries, there were mixed changes in the energy intensity of production between 1967 and 1977. Seventeen of the three-digit industries in table 3 show an increase in the energy/output ratio whereas eleven industries show a decrease. At this level of disaggregation, very little of the 14% increase in the overall energy/output ratio can be explained by changes in industry mix, i.e., by an increase in the output of energy-intensive industries relative to other industries rather than a general increase in energy/output ratios within each industry. If energy/output ratios are held constant at their 1967 levels, changes in industry mix account for only about one and a half percentage points of the observed increase in the energy intensity of Chilean manufacturing.

Table 1

CHILE: ENERGY CONSUMPTION IN MANUFACTURING, CLASSIFIED BY TYPE OF FUEL, 1967 AND 1977[a]

	Thousands of tons of coal equivalent		Percentage change
	1967	1977	
Electricity	904	1 549	71.3
Coal	484	386	− 20.2
Petroleum products	1 268	1 552	22.4
Natural gas	24	21	− 11.8
Wood and other	178	227	27.5
Total	2 858	3 735	30.7

Source: Calculated from data in Instituto Nacional de Estadísticas (INE), *IV Censo Nacional de Manufacturas* (1967) and corrected data in INE, *Industrias Manufactureras* (1977).

[a] Data for 1967 refer to establishments employing five or more persons while those for 1977 refer to establishments employing ten or more persons, hence changes in energy consumption are underestimated.

Table 2

CHILE: AVERAGE FUEL PRICES PAID BY MANUFACTURING FIRMS IN 1967 AND 1977

(Escudos per thousand tons of coal equivalent)

	Current escudos per thousand TCE		1965 escudos per thousand TCE[a]		
	1967	*1977*	*1967*	*1977*	*Percentage change*
Electricity	222	1 545 000	141	111	− 21.4
Coal	136	1 307 000	86	93	8.9
Fuel oil	121	1 691 000	77	121	57.6
Diesel oil	166	2 237 000	105	160	52.1
Gasoline	262	3 471 000	166	248	49.6
Kerosene	146	2 218 000	92	159	72.1
Natural gas	449	3 501 000	284	250	−11.8
Firewood	146	1 478 000	92	106	14.6

Source: Calculated from data in INE, *IV Censo Nacional de Manufacturas* (1967) and corrected data in INE, *Industrias Manufactureras* (1977).

[a] Nominal prices deflated by the implicit deflator corresponding to the index of gross value of manufacturing output, which is 158 for 1967 and 13 982 for 1977 (1965 = 100).

II

Variables used in the regression analysis

Change in energy intensity (E)

The dependent variable is the energy/output ratio in 1977 divided by the ratio for the same industry in 1967. This is denoted as E and is listed in the last column of table 3. With the exception of electricity, different fuels have been aggregated on the basis of their inherent thermal content in the calculation of these ratios. Electricity has a value far beyond that of its thermal energy alone, so the amount of fossil fuel required to produce electricity in thermal plants of average efficiency (600 kg of coal equivalent per thousand KWH) was used as a conversion factor in lieu of the thermal energy available from electricity (123 kg of coal equivalent per thousand KWH).[2]

Change in output (Q)

Production growth in each industry is measured by the ratio of gross output in 1977 to gross output in 1967, both measured in 1967 prices. Only eleven of the 28 three-digit industries registered a larger output in 1977 than 1967. Since an expanding industry is more apt to adjust to higher energy prices by investing in energy-efficient plant and equipment than is a stagnant or declining industry, one can expect a negative coefficient for this variable.

There is another important reason to expect a negative coefficient. The implicit deflator for domestically-produced manufactured goods in 1977 was nearly 9 000 times that of 1967. Price inflation of this magnitude introduces unusually large errors into estimates of real output. These measurement errors enter the denominator of the dependent variable, giving rise to a negative but spurious correlation between production growth and changes in energy intensity. In other words, overestimation of the growth in real output of an industry leads to underestimation of the increase in its energy/output ratio and vice versa.

Substitution of electricity for other fuels (S)

This variable is measured as the ratio of the 1977 proportion of electricity in total energy consumption to the 1967 proportion. Eighteen of the 28 three-digit industries increased their consumption of electricity relative to other fuels. For the sector as whole, electricity as a percentage of total energy consumption increased from 32% in 1967 to 41% in 1977.

Assuming that electricity will by its nature be used more efficiently in a physical sense than other fuels, increased consumption of electricity relative to other fuels should be associated with a decrease in the energy/output ratio. Four types of substitution of electricity for other fuels are possible. First, in broadly defined industries there is ample scope for changes in product-mix, i.e., for shifts into electricity-intensive products and away from products relatively intensive in other forms of energy. Secondly, there may be direct substitution, such as the change from a diesel engine to an electric motor. Thirdly, there may be a shift away from self-generation to the outside purchase of electric power which will produce recorded gains in energy efficiency as small, inefficient thermal generators are replaced by power from large thermal and hydro plants. Fourthly, and most importantly, electricity consumption is a proxy for mechanization. Although there is a well-known *positive* correlation between mechanization and energy intensity,[3] in a period of rising energy prices in-

[2]See United Nations, *World Energy Supplies 1973-1978* (New York, 1979), p. xvi.

[3]See, for example, J.S. Wabe, "Energy Expenditure in Sectors of Manufacturing", *Energy Economics* 3:3 (July 1981), pp. 178-81 for evidence that capital-intensive industries tend to be energy-intensive. For 28 Chilean industries in 1967, the rank correlation (Kendall's tau) between energy output ratios and capital intensity is .593 when capital intensity is measured as installed horsepower per employee and .598 when it is measured as electricity consumption per employee. Both coefficients are highly significant.

Table 3

CHILE: ENERGY/OUTPUT RATIOS FOR 28 MANUFACTURING INDUSTRIES, 1967 AND 1977

ISIC	Major products	Energy/output ratios[a] 1967	Energy/output ratios[a] 1977	1977/1967
311-312	Food	110.6	114.1	1.032
313	Beverages	76.0	59.6	0.784
314	Tobacco	8.0	7.7	0.953
321	Textiles	124.1	127.0	1.023
322	Clothing	22.4	37.7	1.683
323	Leather	111.6	97.7	0.875
324	Footwear	19.5	41.4	2.129
331	Wood	153.2	63.9	0.417
332	Furniture	33.1	18.7	0.564
341	Pulp and paper	425.2	782.5	1.840
342	Printing	37.5	68.3	1.821
351	Industrial chemicals	299.5	960.2	3.206
352	Other chemicals	61.2	38.0	0.620
353	Petroleum refineries	82.8	36.1	0.436
354	Petroleum and coal products	71.3	121.7	1.708
355	Rubber products	101.4	115.5	1.139
356	Plastic products	75.8	89.0	1.174
361	Pottery	384.0	560.1	1.459
362	Glass	558.5	435.5	0.780
369	Cement	577.0	1 016.0	1.761
371	Basic iron and steel	497.2	590.9	1.188
372	Copper	153.3	144.0	0.940
381	Metal products	69.4	79.6	1.146
382	Non-electrical machinery	79.1	234.0	2.957
383	Electrical machinery	38.9	69.6	1.791
384	Transport equipment	46.9	66.9	1.425
385	Professional and scientific equipment	74.7	71.9	0.962
390	Other manufactures	37.4	21.9	0.585
	Total manufacturing	*134.8*	*153.5*	*1.139*

Source: Calculated from the index of industrial production prepared by the Sociedad de Fomento Fabril; INE, *IV Censo Nacional de Manufacturas* (1967) and, with corrections, INE, *Industrias Manufactureras* (1977).
[a]Direct energy consumption in tons of coal equivalent per million 1967 escudos of gross production.

creased mechanization could well result in increased energy efficiency, and a *negative* correlation could emerge between *changes* in mechanization and *changes* in energy output ratios.

Change in employment (L)

The employment variable used is the average number of employees in 1977 divided by the average number in 1967 excluding, in both cases, establishments with less than ten employees. Only five industries recorded an increase in employment between 1967 and 1977; for the manufacturing sector as a whole, employment in establishments with ten or more employees declined from 327 000 to 247 000 persons.

In view of the drastic reduction in both labour union power and import tariffs in Chile after 1974, a fall in employment is likely to reflect, at least in part, efficiency gains and the removal of redundant labour. The data suggest, in fact, that change in the level of employment is not a good predictor of change in the level of production: the simple correlation between employment changes (L) and output changes (Q) is only .27, which is not significantly different from zero at the 5% level in a one-tailed test, and the rank correlation (Kendall's tau) is 15, which is even less significant. For this period in Chilean history, employment changes are thus likely to be a good proxy for efficiency changes. Increased efficiency implies decreased energy intensity in a period of increasing energy prices, so a positive coefficient is expected for this variable.

Survival of establishments (N)

Establishment survival is measured as the ratio of the number of establishments with ten or more employees in 1977 to the number with ten or more in 1967. The number of establishments fell sharply in all industries, with a reduction from 6 350 to 2 150 for the sector as a whole. It is possible that these figures exaggerate the mortality rate of manufacturing establishments, for 1967 was a complete census whereas 1977 was a survey which may understate the number of smaller plants. An additional 5 118 establishments employing between five and nine persons were registered by the 1967 census but there are no data on the number of establishments of this size category in 1977. The expected sign of the coefficient of the establishment survival variable is positive, on the assumption that a reduction in the number of firms in an industry is likely to reflect industry rationalization and efficiency gains, including gains from the improved use of energy inputs.

III

Empirical results

The simple correlation coefficients between changes in energy intensity and each explanatory variable are presented in table 4. All of the coefficients have the expected sign and all are statistically significant at customary levels of confidence.

An ordinary least squares regression with all variables measured in natural logarithms produced the following result (t-statistics are in parentheses):

$$\ln E = .529 - .854 \ln Q - .469 \ln S + .693 \ln L + .158 \ln N \qquad R^2 = .81$$
$$\qquad\qquad (-4.97) \qquad (-3.94) \qquad (3.41) \qquad (.87)$$

Table 4

SIMPLE CORRELATION COEFFICIENTS: CHANGES IN ENERGY INTENSITY AND VARIOUS INDUSTRY CHARACTERISTICS, 1967-1977

Industry characteristics	Correlation with changes in energy/output ratios	
	Coefficient	t-statistic
Change in output (Q)	−.644[a]	−4.29
Substitution of electricity for other fuels (S)	−.648[a]	−4.33
Change in employment (L)	.319[b]	1.72
Survival of establishments (N)	.397[b]	2.21

Note: All variables are logarithms; the units of measurement are described earlier in the text.
[a]Statistically significant at the .01 level.
[b]Statistically significant at the .05 level.

All coefficients in this equation are significant at the .01 level with the exception of ln N. The insignificance of ln N is a product of collinearity between that variable and ln L (r = .62).

The significant correlation between the employment variable (L) and the establishment survival variable (N) is not surprising, for the removal of redundant labour in an industry often occurs via the removal or merger of inefficient firms. When ln L is dropped from the regression, the coefficient for ln N increases and becomes highly significant:

$$\ln E = .761 - .653 \ln Q - .494 \ln S + .563 \ln N$$
$$\qquad (-3.37) \qquad (-3.46) \qquad (3.42)$$

$R^2 = .71$

Similarly, the size and significance of the coefficient of ln L increases when ln N is deleted from the equation:

$$\ln E = .396 - .889 \ln Q - .465 \ln S + .808 \ln L$$
$$\qquad (-5.35) \qquad (-3.93) \qquad (5.29)$$

$R^2 = .80$

In all of the calculations up to this point, the conversion factor for electricity has been based on the amount of coal required to produce electricity in thermal plants of average efficiency. If we follow the alternative procedure of converting electricity on the basis of its inherent thermal content, all energy/output ratios are lower and the coefficient of ln S will increase, for substitution of electricity for other fuels will have, for strictly arithmetic reasons, a stronger negative effect on measured energy/output ratios. The regression equation becomes:

$$\ln E^* = .548 - .757 \ln Q - .714 \ln S^* + .698 \ln L$$
$$\qquad (-4.19) \qquad (-9.04) \qquad (3.15)$$

$$+ .153 \ln N \qquad R^2 = .88$$
$$(.77)$$

where the asterisk (*) refers to the system of lower weights for electricity relative to other fuels. The absolute value of the coefficient of ln S* is fifty per cent greater than that of ln S, but the size and significance of the other regression coefficients are affected very little by this substantial change in the conversion factor for electricity.

IV

Conclusion

Estimates of real output changes in Chile are subject to wide margins of error as a result of the rapid price inflation experienced in that country, but it would appear that 14% would be a conservative estimate of the increase in the energy/output ratio for Chilean manufacturing between 1967 and 1977. This increase in the energy/output ratio for the sector as a whole is due almost entirely to changes in energy intensity within each of the 28 three-digit industries rather than to changes in industry mix. Regression of variations in energy/output ratios on four independent variables shows clearly that decreased energy intensity of production is associated with increased output, a shift away from other fuels to electricity, a decrease in the amount of labour employed, and a reduction in the number of establishments in an industry. The significance of the last two variables is undoubtedly due to the industry rationalization that took place in Chile after 1974 as a result of a drastic reduction in both import tariffs and trade union power.

Appendix

COEFFICIENTS USED TO CONVERT FUELS INTO TONS OF COAL EQUIVALENT

Fuel	Coefficient
Electricity (1 000 KWH)	0.6
Coal and coke	1.0
Fuel oil (tons)	1.5
Fuel oil (cubic metres)	1.4175
Diesel oil (tons)	1.557
Diesel oil (cubic metres)	1.308
Gasoline (cubic metres)	1.168
Kerosene (cubic metres)	1.28
Liquefied petroleum gas (tons)	1.729
Liquefied petroleum gas (cubic metres)	0.951
Natural gas (1 000 cubic metres)	0.571
Wood (tons)	0.5

Source: Calculated from data in Comisión Nacional de Energía, *Balance de Energía 1960-1978* (Santiago, Chile, 1980), Annex A.