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Abstract

Like other non-oil-producing underdeveloped countries, Uruguay was forced to make important efforts at reducing dependence on imported oil after 1973. The implemented measures, together with the high international price of petroleum products, resulted in a substantial increase in consumption of fuelwood and biomass as well as of electricity, especially by industry.

An important fuel substitution process took place in the Uruguayan industrial sector. Although during the period 1976-1988, energy cost share stayed rather constant around 7% of total cost during the whole period, the disaggregation of fuels shows that fuelwood & biomass increased steadily its participation from 15% of energy cost in 1976 to 43% and the share of electricity from 13% to 21%, while the share of petroleum products decreased from 72% to 36% in 1988. These substitution process seems to be explained by the price sensibility of demand for fuels. Fuelwood-petroleum products and electricity-petroleum products showed to be significant substitutes, while fuelwood and electricity were weak complements. The demand for petroleum products turned out to be the most price sensitive followed by the demand for fullwood & biomass.

Wood and other biomass increased their share in total consumption from 22% in 1965 to 29% in 1989. Although wood consumption was not so high, given limited forested areas, the unbalanced growth of supply and demand of fuelwood could lead to important ecological and economic damage. The increasing awareness of these problems motivated implementation of hydropower projects and of an apparently successful forest legislation. The implemented mechanisms promoting forestation (tax reduction, credits, external debt conversion, etc.) have turned out to be quite effective and the country can now look forward to a significant increase in forest area.

I. ENERGY, FUELWOOD AND FORESTRY IN URUGUAY.

Energy consumption in Uruguay has been quite stable during the last decades, but we can still distinguish four periods. During the first, from 1965 to 1972, fuel consumption and GNP grew at a moderate rate (1.6% and 1.4%, respectively). Fuel consumption in tonnes of oil equivalent (TOE) in 1972 was 11% higher than in 1965. During the second period, 1972-1979 (with rising fuel prices), the growth in energy was again moderate (1.8%) in spite of higher GNP growth (4.3%).

The third period from 1980 to 1984 was characterized by economic recession, which explains most of the 15% reduction of fuel consumption (energy use fell at an annual rate of 4% and GNP at 3.8%). The last period, from 1985 to 1989, was one of economic recovery and redemocratization, characterized by significant growth rates (GNP grew at 3.8%, while energy consumption increased 2.2% by year). At the end of the last period, energy consumption was at a level similar to 1973 and only 12% higher than 1965. Energy use per capita actually decreased by 5% during the period (see Figure 1).

Although petroleum products dominated the supply of energy over the entire period (see Table 1), their share decreased by 20% from 1973, while the shares of electricity and fuelwood increased. The share of fuelwood and biomass grew by almost 50% answering for 29% of total energy consumption in 1989 as compared to 22% in 1965. As we will analyze later, changing relative prices could be the reason for this reduction.

TABLE 1. FUEL CONSUMPTION BY SOURCE (1965-1989) AS % OF TOTAL CONSUMPTION OF THE ECONOMY

YEAR	FUELWOOD & CHARCOAL	BIOMASS	PETROL PROD.	MINERAL COAL	ELECTRICITY	TOTAL CONSUMPT KTOE
1965	20.7	0.9	67.9	1.6	6.9	1718
1972	19.5	1.5	67.4	1.0	8.2	1913
1975	20.7	1.5	64.7	1.0	9.2	1882
1980	20.2	1.7	62.6	0.4	11.4	2105
1985	28.1	2.6	51.9	0.1	15.4	1763
1989	25.6	3.0	52.5	0.1	16.3	1919

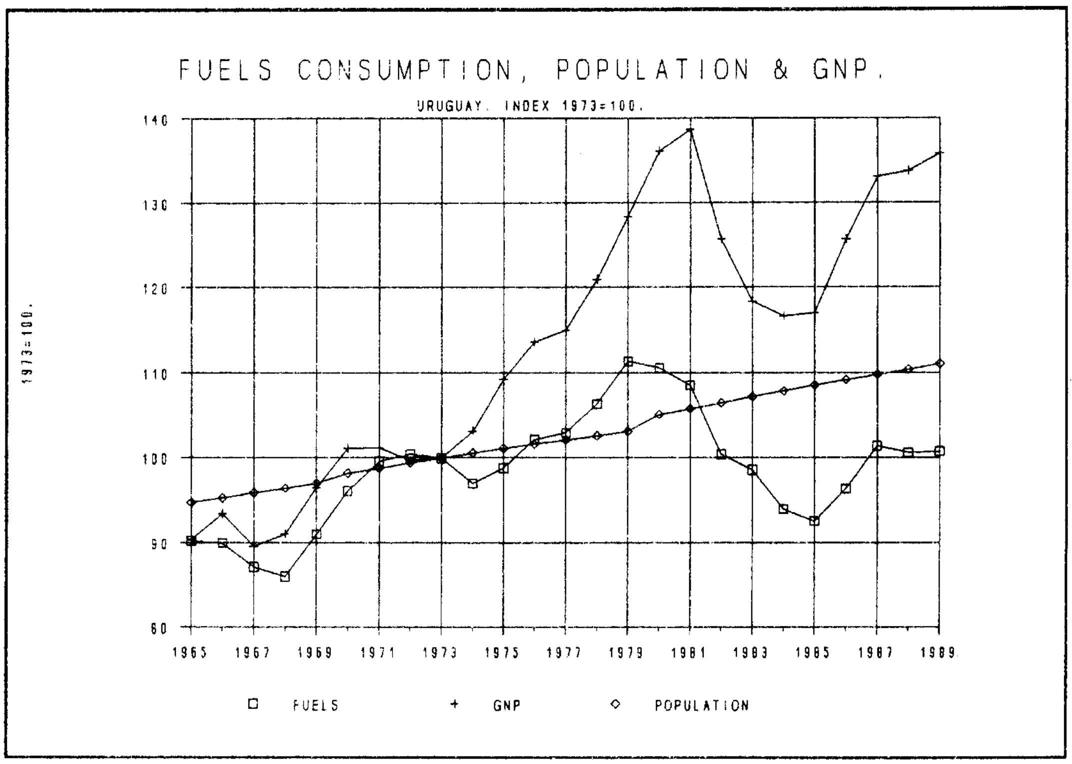
KTOE = Kilo Tons of Oil Equivalent.

Source: NEBU (The National Energy Board of Uruguay)

II. ENERGY CONSUMPTION AND ECONOMIC ACTIVITY.

The energy-GNP ratio decreased from 1973, especially between 1973-1979 when it fell 13%, and between 1985-89 (6%); it was 26% lower in 1989 than in 1973 (see Fig. 1). This seems to indicate a more efficient use of energy, but it must be kept in mind that this measure is merely a preliminary indication of how energy may be related to economic activity, standard of living and stock of energy-using equipment. As Bhatia pointed out, "very important factors are lumped together in the energy-GNP ratio like changes in the mix of goods and services, changes in the energy intensity, changes in the composition of energy sources which provide more useful energy, etc.." (Bathia, 1987).

FIGURE 1.



SOURCE: NEBU & CENTRAL BANK

Another way to present the relationship between energy consumption and the economy is in terms of the energy-GNP growth elasticity, i.e., the ratio of annual energy consumption growth rate and GNP growth rate (see Table 2). This ratio has been lower after 1973 except for the period 1980-1984 when the decreasing rate of GNP was higher than that of fuels. On the whole, energy efficiency appears to have increased quite rapidly both for total and for industrial energy demand. During the entire period from 1965-1989, the energy-GNP elasticity was 0.27% and 0.43 for individual demand. It was only in 1985-1989 that industrial energy demand grew faster than output (see Table 2).

TABLE 2. ELASTICITY OF ENERGY DEMAND TO GNP AND INDUSTRIAL OUTPUT

	ENERGY ANNUAL GROWTH RATE	GNP ANNUAL GROWTH RATE	ENERGY-GNP ELASTI CITY	INDUSTRY ENERGY ANNUAL GROWTH RATE	INDUSTRY OUTPUT ANNUAL GROWTH RATE	ENERGY INDUST. OUTPUT ELASTI-CITY
1965-72	1.55	1.40	1.10	0.99	1.40	0.71
1973-79	1.80	4.25	0.42	3.52	5014	0.68
1980-84	-3.97	-3.80	(1.05)	-5.80	-3.82	(1.52)
1985-89	2.15	3.81	0.56	4.74	4.39	1.08
1965-89	0.46	1.71	0.27	0.54	1.25	0.43

SOURCE: NEBU & CENTRAL BANK.

III. ENERGY CONSUMPTION BY ECONOMIC SECTOR.

Table 3 shows that there has been considerable stability in the distribution of energy consumption by sector. The most important source of fuel supply for residential and service sectors was fuelwood and charcoal which represented about 50% of these sectors' consumption. Electricity shares increased sharply during the period from 11% to 27% while liquid gas increased from 3% in 1965 to 10% in 1989. The decline was concentrated to kerosene which fell from 26% to 7%.

Surprisingly, transport fuel consumption declined slowly at an annual rate of 0.15% between 1965-1989. Gasoline consumption fell by 15% in the same period in spite of the fact that the stock of cars increased on the average of 14000 per year from 1985. In 1988 there were 280.000 cars and 50.000 trucks and buses.

Finally, both transport and agriculture (including fishing) had relatively constant shares. Both areas experienced a good deal of substitution of gasolines and kerosene for diesel. Diesel consumption represented 45% of total fuel consumption in 1965 but 65% in 1973 and 93% in 1989, while gasoline and kerosene decreased from 53% to 5%. The industrial sector's consumption of organic fuels (fuelwood, biomass and charcoal) increased dramatically from 10% in 1965 to over 43% in 1989 (see Table 4).

TABLE 3. THE SECTORAL DISTRIBUTION OF TOTAL ENERGY CONSUMPTION

YEAR	RESIDENT & SERVICE	RESIDEN TIAL	TRANS PORT	AGRICULT & FISHING	INDUSTRY
1965	34.4	N.A.	29.1	5.9	28.4
1972	36.0	N.A.	30.9	3.6	27.1
1975	35.1	N.A.	27.9	4.0	29.8
1980	33.3	28.6	25.2	7.5	29.5
1985	39.0	34.2	24.2	8.5	26.2
1989	36.0	30.5	25.1	7.2	29.0

SOURCE: NEBU.

The increase in the country's biomass consumption mainly occurred in the industrial sector: consumption by manufacturing increased 278% between 1965-1989. The biomass share of industrial fuel increased from 3% to 10% in 1989. At the same time the share of fuelwood and charcoal grew significantly from 7% to 33%. Electricity consumption also expanded, from 10% to 22%. The only fuels whose consumption was reduced were fuel oil and mineral coal. Fuel oil consumption was cut in half between 1973 and 1989. Reduction in mineral coal consumption was even more dramatic from several percent of total fuel consumption to practically nothing in 1989.

TABLE 4. STRUCTURE OF FUEL SUPPLY FOR THE INDUSTRIAL SECTOR

YEAR	FUELW. & CHAR-COAL	BIO-MASS	FUEL-OIL	DIESEL GASOIL	BENSIN & NAFTA	ELEC-TRICITY	TOTAL USE 1973=100
1965	7.2	3.1	71.7	1.5	1.0	10.2	93.6
1972	7.8	5.4	68.4	2.5	1.1	10.7	99.3
1975	9.4	4.9	68.4	1.1	0.7	12.3	107.4
1980	12.9	5.7	61.3	2.4	0.7	15.0	119.1
1985	29.7	10.0	35.9	2.0	0.2	21.2	88.5
1989	33.2	10.3	30.7	2.3	0.1	22.1	106.6

SOURCE: NEBU

IV. WOOD CONSUMPTION AND FORESTRY IN URUGUAY.

As a reaction to higher prices, soaring import bills and general uncertainty the Uruguayan economy has turned increasingly to wood for fuel, particularly after 1973. This increasing consumption of fuelwood, added to the use of wood as a raw material, might cause serious environmental problems, if the development of supply and demand for wood are not kept harmonized.

TABLE 5. WOOD CONSUMPTION: DISTRIBUTION BY USE

YEAR	FURNITURE INDUSTRY %	PAPER INDUSTRY %	FUELWOOD CONSUMPT. %	EXTRACT. 1000M' TOTAL	EXTRACT. INDEX 1973=100
1973	12.2	1.8	86.0	1522	100
1975	14.5	2.1	83.4	1750	115
1980	6.8	8.6	84.6	1564	103
1983	3.5	5.6	90.9	2357	155
1986	5.3	4.4	90.3	2668	175

SOURCE: NEBU.

Uruguay is a country particularly well suited to agriculture. This sector has historically represented the main part of the country's GNP and an even greater percent of its exports. Uruguay's territory is mainly covered by natural prairies and only 4% of its area (865.000 ha) was woodland in 1985, 75% of which was natural and 25% was forest plantations. The plantations were mainly small units under 1 hectare (about 40%), originally intended to prevent erosion or as protection for livestock and for crops.

As we can observe in Table 5, an increasing share of the raising extraction was used as fuel. The share of the furniture industry, which is closely related to building activity, decreased significantly from 1981. The increasing consumption of the paper industry prevented a more radical reduction in the share of wood used as raw material.

TABLE 6. FUELWOOD CONSUMPTION BY ECONOMIC SECTOR

YEAR	RESIDENTIAL %	SERVICES %	INDUSTRY %	TOTAL CONSUMPT. KTOE	TOTAL CONSUMPT 1973=100
1965	83.3	6.8	9.9	356	94
1972	82.3	6.9	10.9	373	99
1975	79.9	6.5	13.6	389	103
1980	75.0	6.2	18.9	424	113
1985	71.7	0.8	27.6	494	132
1989	61.7	0.7	37.6	489	130

SOURCE: NEBU.

The consumption of fuelwood has been dominated historically by the residential sector which represented over 80% of total fuelwood consumption in the 1960s (see table 6). For the last five years residential fuelwood consumption decreased by 15% mainly from 1987-1989, when relative prices reversed to favor oil and gas. As can be observed in Tables 7 and 8, fuelwood prices have been fairly stable and increased at a lower rate than most other fuels, including electricity. In 1987 this situation started to change as fuelwood prices grew much faster than other fuels. This is not unusual as the markets for wood are typically far from perfect and it is quite common to find "threshold effects" such that wood is first very cheap when it is perceived to be plentiful and then "suddenly" shortages evolve that send the price soaring (Sterner, 1993).

TABLE 7. ENERGY PRICES IN THE RESIDENTIAL SECTOR
Real price. Index 1979=100.

YEAR	FUEL-WOOD	ELECTRICITY	KEROSENE	GAS	LIQUID GAS	FUEL OIL
1970	N.A.	131.3	39.3	168.2	64.2	28.2
1976	92.1	120.8	105.3	179.8	113.9	114.3
1980	118.7	98.3	114.9	111.0	114.7	114.9
1985	120.4	116.7	173.9	117.2	145.6	180.0
1988	114.3	112.6	109.9	99.9	93.9	132.8

SOURCE: CENTRAL BANK OF URUGUAY.

The industrial sector increased its fuelwood demand dramatically since 1973 (see Table 6). From 1973 to 1979 fuelwood consumption increased by 70%, and by 149% between 1979 and 1989. Adding up fuelwood consumption and wood as raw material, the share of the industrial sector in 1986 rose to 41% of total wood extraction in the country.

The increasing use of fuelwood by industry appears to have been determined by such factors as price and supply security since this fuel is clearly not the conventional choice. This process of substitution is neatly illustrated by the great number of boiler conversions that took place during the 1980s. In 1979 there were only 4 fuelwood boilers in the industrial sector, but in 1988 there were 119. Forty-five boilers were converted from oil to wood, while 74 new boilers were built for wood use.

TABLE 8. ENERGY PRICES IN THE INDUSTRIAL SECTOR
Real prices. Index 1979=100.

YEAR	FUEL WOOD	ELEC TRICITY	KERO SENE	FUEL OIL	DIESEL	GASOLI NE
1970	N.A.	129.9	39.3	28.2	41.2	82.3
1976	92.1	119.4	105.3	114.3	106.1	130.7
1980	118.7	99.0	114.9	114.9	114.9	115.2
1985	120.4	115.8	173.9	180.0	189.2	148.0
1988	114.3	120.1	109.9	132.8	127.2	102.6

SOURCE: CENTRAL BANK OF URUGUAY.

In the industrial sector three branches (food, cement and paper industries) accounted for 75% of total fuelwood consumption for manufacturing in 1985. If we add textiles, beverages and tobacco industries they accounted for 93% of fuelwood consumption. It is striking to see the consumption of the cement industry (5% of the total), in spite an additional and growing use of other non-traditional fuels such as rice husks which represent up to 25% of fuel consumption in some kilns.

V. DEMAND FOR ENERGY IN THE INDUSTRIAL SECTOR

In this part of the article we evaluate how readily the different fuels may be replaced in the Uruguayan industrial sector. The extent to which interfuel substitution has taken place, and may still be possible, can be evaluated by the examination of the own and cross-price elasticities of demand for individuals fuels. The research reported below estimated those elasticities for the period 1976-1988. The three fuels considerated are: liquid fuels/petroleum products, fuelwood & biomass and electricity (see Tansini, 1990).

Due to the large number of parameters to be estimated when the disaggregation of energy is considered in the cost function, a two level model was adopted (Fuss, 1977). At the aggregate level, the producer is assumed to choose the mix of capital (K), labour (L), and energy (E), which minimizes production cost for producing a given output level (Q). considering input prices. At the second stage, the price of energy is obtained from a unit cost function which, in turn, represents the cost minimizing behavior of the producer who seeks the optimal mix of electricity (El), fuelwood (W), and petroleum products (P) for a given energy level. The price of energy (P_E) is the link between the first and the second level. The demand for the factors of production is in both cases obtained applying Shepard's lemma.

First a static single-stage translog model was estimated based on expenditure shares consistent with the two-stage model. The estimation was based on the well known non-homothetic translog expenditure share energy submodel and estimated by Seemingly Unrelated Regression which is equivalent to Full Information Likelihood (Barten, 1969). The application of Shepard's lemma to the translog cost function yields the cost shares of each production factor:

$$(1) \qquad S_i = \alpha_i + \sum_j \beta_{ij} \ln P_j + \beta_{iQ} \ln Q \qquad i, j = K, L, E$$

The system of demand equations was estimated with the traditional homogeneity and symmetry restrictions imposed. The price of aggregate energy was obtained from a unit cost function which was also approximated by a second-order translog function, using in this case the prices of fuelwood & biomass (P_W), electricity (P_E), and of petroleum products (P_P):

$$(2) \qquad \ln P_E = \lambda_z + \sum_t \lambda_t \ln P_t + 0.5 \sum_t \sum_s \delta_{ts} \ln P_t \ln P_s \qquad t, s = El, W, P$$

Applying Shepard's lemma gives each energy input's share in total energy cost. This system of equations was also estimated with the traditional homogeneity and symmetry restrictions imposed.

(3) $$S_t = \lambda_t + \sum_s \delta_{ts} \ln P_s \qquad t, s = El, W, P$$

The data came from the annual survey of the National Direction of Statistics of Uruguay (NDSU) and from the NEBU. The price series used in the expenditure share model has been converted to series with a common unit, tons of oil equivalent (TOE). The share of capital was defined as the difference between value-added and labour costs. The labour price index used was the wage index for the manufacturing sector from NDSU and the index of imported equipment of the Central Bank of Uruguay was used for capital.

TABLE 9. CROSS AND OWN PRICE ELASTICITIES

	ELECTRICITY	WOOD	PETROL
P_E	-0.4	-0.3	0.6
P_W	-0.1	-0.8	1.4
P_P	0.6	1.2	-1.3

During the period 1976-1978, capital accounted for the largest cost share increasing from 59% to 68%. The labour cost share decreased from 34% to 25% in 1988. The energy cost share stayed rather constant around 7% during the whole period. The disaggregation of fuels shows that fuelwood & biomass increased steadily its participation from 15% of energy cost in 1976 to 43% in 1988. The share of electricity also grew, at a lower rate, from 13% to 21%, while the share of petroleum products decreased from 72% to 36% in 1988.

Table 9 presents the estimated average own and cross-price elasticities. Own price elasticities are negative, as expected on theoretical grounds, and they are statistically significant. It can be seen that fuelwood-petroleum products and electricity-petroleum products are significant substitutes, while fuelwood and electricity are weak complements. The demand for petroleum products turned out to be the most price sensitive followed by the demand for fullwood & biomass. The estimated parameters of the energy cost function were used to construct and energy price index for the following level of analysis.

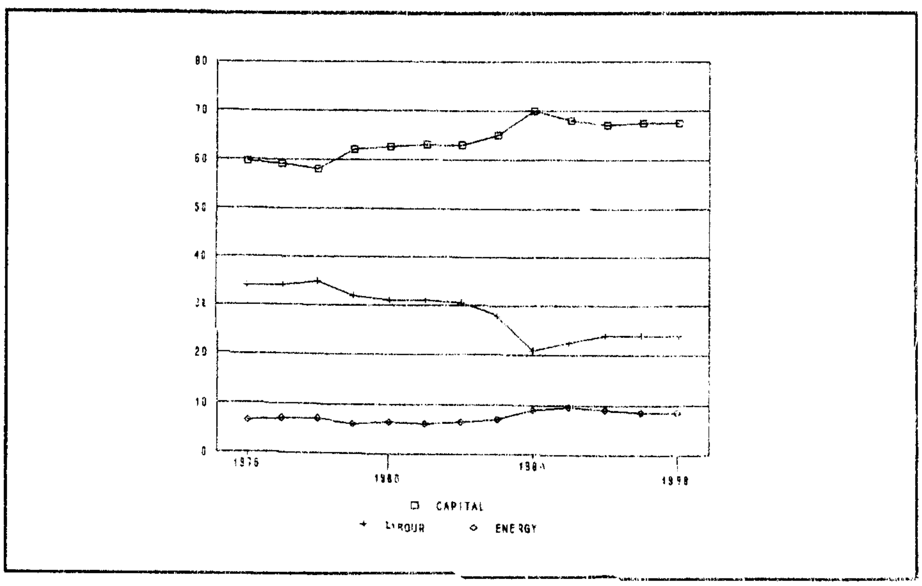
The statistical fit of the system was acceptable and most of the coefficients significantly different from zero, and the hypothesis that the underlying production function was non-homothetic could not be rejected.

Table 10 displays the estimated average price elasticities for a constant output level. Own-price elasticities have negative signs as expected, however not significantly different from zero for labour. Most of the own and cross-price elasticities are less than one in absolute value, indicating limited adjustment to price changes. We note that the demand for energy is very price elastic with an elasticity above unity. With a rising relative price of energy this would explain the reduction in energy intensity. A similar case can be made for capital that the size of the elasticity estimated together with the relative prices does explain at least part of the increase in cost-shares. These effects are further reinforced by the sensitivity of the demand for energy and labour to the variation in capital prices. Looking at the cross-price elasticities we find that energy as a substitute for the other factors in quite sensitive to their price variations.

TABLE 10. CROSS AND OWN PRICE ELASTICITIES

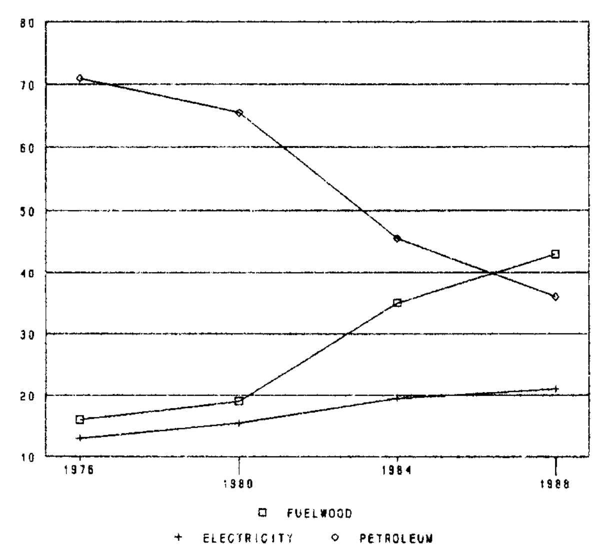
	CAPITAL (K)	LABOUR (L)	ENERGY (E)
P_E	-0.9	1.1	2.5
P_W	0.5	-0.6	0.7
P_P	0.3	0.2	-1.1

FIGURE 2. COST SHARE OF CAPITAL, LABOUR AND ENERGY. 1976-1988.



SOURCE: CENTRAL BANK OF URUGUAY.

FIGURE 3. COST SHARE OF FUELWOOD, ELECTRICITY AND PETROLEUM PRODUCTS IN ENERGY EXPENDITURES. 1976-1988.



SOURCE: CENTRAL BANK OF URUGUAY.

VI. FORESTS: PRESENT SITUATION AND PERSPECTIVES.

Based on information from the National Energy Board of Uruguay (NEBU) and on Migues et al (1990), it is possible to analyze the supply and demand of wood in 1988. Migues et al (1990) was mainly intended for the evaluation of eucalyptus fuelwood demand of the industrial sector, but included other sectors and identified the contribution of the different types of trees to the supply of fuelwood in 1988.

The NEBU (1989) estimated that total fuelwood consumption in 1988 was about 1.735.000 tonnes equivalent of dry fuelwood estimated at 2700 kcal/kg which, in turn, represented about 468 KTOE. The difference with the total consumption of KTOE 487 reported by the NEBU is explained by the utilization of branches and by-products of trees that did not imply any direct damage to the forests.

Eucalyptus accounted for the highest share of consumption: 74% of total fuelwood consumption, while pine trees only accounted for 1%. Fuelwood from natural woods represented about 25% (see table 11). Most of the "natural" forests fuelwood (93%) was consumed by the residential sector (56% in urban residential and 37% in rural areas).

TABLE 11. FUELWOOD CONSUMPTION IN 1988. BY SECTOR AND ORIGIN: TONNES OF FUELWOOD (AT 2700 KCAL./KG.)

FOREST TYPE	URBAN RESIDEN-TIAL	RURAL RESIDEN-TIAL	INDUSTRY	COMERCIAL	TOTAL
NATURAL %	246000 (46.8%)	159200 (33.8%)	0.0 (0.0%)	31000 (20.8%)	436200 (25.2%)
PINE TREE %	17600 (3.3%)	2900 (0.6%)	0.0 (0.0%)	0.0 (0.0%)	20500 (1.2%)
EUCALYPTUS %	262300 (49.9%)	308900 (65.6%)	588250 (100%)	118000 (79.2%)	1277450 (73.6%)
TOTAL %	525900 (100%)	471000 (100%)	588250 (100%)	149000 (100%)	1734150 (100%)
TOTAL IN TOE	142000	127000	159000	40200	468200

SOURCE: NEBU.

Of the total consumption of eucalyptus fuelwood, the industrial sector took 46%, and commercial activities 9% (bakeries, restaurants, brick factories, etc.), 20.5% went to urban residential use and 24% to rural residential consumption. Of fuelwood consumption, 72% was concentrated around the capital, Montevideo, with 45% of population. Natural forests accounted for 27% of this consumption and eucalyptus for 71%.

According to the estimate of the NEBU, the eucalyptus forest area increased by 4% or 4.300 hectares between 1985 and 1987, totaling roughly 25 millions m^3 of wood equivalent in 1987. The region which traditionally provides fuelwood to the southern region of the country, surrounding the capital, accounted for half of the new forested area.

The NEBU also estimated the potential fuelwood supply from eucalyptus forests for 1988, based on the Average Annual Growth (AAG) of the country's forests with a reasonable exploitation of the woodland. They assumed that AAG would be 20 m^3/ha. by year, that the forests under 10 ha. are not exploited, to prevent environmental damage as a result of over-exploitation and that 33% of the area cut was replanted. The estimated production for 1988 was TEDF 1.010.000 contrasting with the utilization of TEDF 1.277.000 that year, which implies a deficit of TEDF 267.000, i.e. 26% of the potential supply. This deficit was equivalent to about 9.140 ha. of woodland or 30% of the eucalyptus forests over 10 ha.. If the exploitation of half the forests under 10 ha. was allowed the potential supply would increase to TEDF 1.277.000, eliminating the deficit estimated in the previous case. But it must be kept in mind that these forests under 10 ha. are generally either natural forests or plantations intended to prevent soil erosion.

Besides the use of wood as fuel, it is also in demand as a raw material. It was estimated by the Forestry Department of the Agronomic Faculty that the consumption of eucalyptus alone as raw material in 1988 was about 230.000 m^3. They estimated that about 90.000m^3 were intended for the paper industry, 150.000m^3 was exported and 80.000m^3 in demand by the furniture industry (Migues et al., 1990).

If the use of eucalyptus wood as raw material is added to the consumption of fuelwood in 1988, it is clear that it is not possible to avoid significant supply shortages in the near future, even if forests under 10 ha. are exploited. The amount intended for raw material would be equivalent to 16% of the wood cut in 1988, on the assumption that their growing-time is similar to that of trees intended to be used as fuelwood, which probably is an optimistic assumption. If forests under 10 ha. are not exploited, the total deficit rises to 42% of total supply, but if 50% of the forests under 10 ha. are exploited the deficit is reduced to 39%. This deficit has been covered by import of wood from Paraguay and Brazil, mostly as raw material. NEBU was also aware of the damage caused by exploitation of natural woodlands and recommended that it be avoided.

Miguez et al. (1990) also evaluated substitution possibilities of fuel oil in the manufacturing sector. Their analysis is based on a survey conducted in 1989 of the technical characteristics of boilers which could be converted to fuelwood. During 1988 fuel oil consumption of the industrial sector was 185.500 TOE, a third of industry's energy consumption and 80% of the country's consumption of fuel oil. They evaluated the substitution possibilities in three scenarios determined by different assumptions on price and technical restrictions for boiler conversions. The basic scenario assumed a fuelwood price of U$ 18 per ton (the average 1988 price, transport cost included). The pessimistic scenario was based on price rise of 40% and the optimistic one a decrease of 40%. In the basic scenario the substitution of fuel oil would be 12-15%, in the pessimistic scenario 5-10%, and finally in the optimistic scenario 17-18%. In the basic scenario this corresponds to roughly 10% of total fuelwood cut in 1988 (excluding forests under 10 ha.).

The state-owned electricity company is evaluating a wood-fired 100 MW. power plant to be operational before the year 2000, when hydropower capacity will reach its ceiling. This project was also analyzed by the Swedish consulting firm, Swedforest Consulting AB and three alternative fuel sources were evaluated: oil, coal and wood. Antman & Cian (1990) concluded that with certain prices fuelwood could be an adequate fuel and that eucalyptus would be more profitable than fuel oil, if capacity utilization was between 27% and 60%. The evaluation of wood vs. coal, on the contrary, is very sensitive to price relations. Estimated wood consumption would be about one million m^3, with a capacity utilization of 80%, which is equivalent to 50.000 hectares of forest (assuming a growth of 20 m^3/ha. by year). This new demand alone represents about half of the eucalyptus forests above 10 ha. in 1988. Thus to avoid future supply shortages, the only way to meet these requirements will be through new forest plantations.

Obviously the combination of raw material demand, industrial fuel conversion and new wood-fired power plants would pose a considerable threat to the sustainability of supplies. This has already caused some concern although little attention, if any, has been paid to the substantial environmental damage which could result from over-exploitation. The increasing consciousness has stimulated legislation and state intervention which clearly encourages afforestation, prevention of soil erosion and protection of indigenous forests, as well as increasing the supply of wood in the near future.

VII. THE NEW FORESTAL LAW

In 1987, after two years of discussion, a new forest law was approved by Parliament (replacing the previous one from 1968). Its approval gained broad support from the various political parties. The most important aspects of the new legislation were that it anticipates tax reductions and financial facilities for afforestation to be provided by the government.

The present Law is aimed at promoting so-called "artificial afforestation", in those areas not well-suited for agriculture, the conservation of soils, water, animals and indigenous vegetation. The legislation concerns three categories: 1) protective forests 2) production forests and 3) common forests. According to the law, the state should support protective and production forests as long as they are planted on "forest land". "Forest land" was defined as "that land which has no other permanent productive use or land declared of forest priority by the Forest Authority, for soil erosion considerations" (the priority area covers about 2.000.000 ha. of the country, i.e. twice the total woodland area in 1988). Thus, the state restricts incentives to forestation to these priority areas, but allows forestation all over the country. The designation of land as forest priority should be based on soil conservation considerations. The legislation also mandates the afforestation of land seriously damaged by soil erosion and it forbids the exploitation of natural forests without authorization of the Forest Authority. Although soil degradation is not as serious as in other countries, it must be prevented before it becomes a serious or irreversible problem. FAO evaluation of soil degradation in Uruguay in 1983 reported that 7% of the territory was severely deteriorated, 28% was moderately deteriorated and 65% of the territory was lightly or not deteriorated by soil erosion.

The instruments included in the Forestal Law are mainly tax exemptions, which in some cases can extend to 12 years. Another instrument is the so-called "Tax Reinvestment Mechanism" which is intended to encourage farmers to invest in afforestation of unproductive land. This mechanism allows a part of the investment in forest plantation to be tax deductible. Other important mechanisms are the implementation of special subsidies and credits for different stages of forest growth. The legislation also made legally possible the afforestation of a third person's land.

The National Forestry Plan aims for the afforestation of 420.000 ha. in 30 years, starting in 1990. The first five-year goal is 100.000 ha. at an estimated cost of U$ 4 million. Of this, 47.000 ha. were intended to meet the annual deficit, 30.000 ha. to face new demand as a consequence of boiler conversion, 6.500 ha. for export and 15.000 ha. for soil erosion prevention.

The forest legislation has shown encouraging results in its four years of application. The most important result is the forestry plan, which reasonably predicts the future wood consumption and plans the growth of wood supply in accordance to it. During the 1970s and 1980s, the average new forest area was about 2.000 ha. per year and from 1989 has doubled every year until the present. In 1989 the afforested area was over 5.000 ha., in 1990 over 8.000 ha. and it is estimated to 20.000 ha. for 1991. There are other indications that show the growing interest in forestation such as the increase in projects submitted to the Forest Authority (114 projects in 1991 compared to 26 and 41, respectively, in 1989 and 1990). Furthermore some projects are financed through "Debt for Nature Swaps". In 1991, 23 projects were submitted of which 5 were for afforestation. The projected investment is U$ 70.000.000 allowing for the afforestation of 70.000 ha.

These projects, together with the fact that 35.000 ha. were afforested in the first two years of plan implementation, show that it should be possible to reach the goal of 100.000 ha. in five years. The forestry law, together with these special mechanisms to reduce external debt and to promote direct investment thus appear relatively successful. The increasing interest in afforestation may be reinforced by the fact that the opportunity cost of the land in Uruguay is lower than in the neighboring countries (the Forestal Authority estimated that the cost of forestation per m^3 of eucalyptus tree was U$ 6.6, under the assumption that land opportunity cost is 12%, rent of land included, while it was U$ 7.0 in Argentina and U$7.7 in Brazil).

VIII. CONCLUDING REMARKS.

Like other oil-importing LDCs, Uruguay was badly hit by rising oil prices in the 1970s. The economy has responded by a combination of greater energy efficiency and substitution of oil by fuelwood. The energy-GNP ratio fell 26% from 1973 to 1989 and fuel consumption per capita decreased 9% in the same period. This trend is confirmed by the energy-output growth elasticity which was 0.27 for the economy as a whole for 1965-1989, and 0.43 for the industrial sector.

In this paper we have seen how energy policy initially resulted in substantial increase in consumption of renewable fuels such as fuelwood, biomass and electricity. While the consumption share of petroleum products decreased from 68% in 1973 to 52.5% in 1989, the consumption of renewable fuels and electricity dramatically increased from 28% to 45%. Although the residential sector is the largest fuel-user, the substitution of fuels took place mainly in manufacturing, where the wood share increased from 12% in 1973 to 44% in 1989 and electricity from 11% to 22%.

The interfuel substitution has been important in the industrial sector. The results of the two level modelization showed that the demand for individual fuels were quite price sensitive for the period 1976-1988. The three fuels considerated were: liquid fuels/petroleum products, fuelwood & biomass and electricity.

During the period 1976-1978, capital accounted for the largest cost share in the industrial sector, increasing from 59% to 68% and the labour cost share decreased from 34%

to 25% in 1988. Although the energy cost share stayed rather constant around 7% during the whole period the disaggregation of fuels showed that fuelwood & biomass increased steadily its participation from 15% of energy cost in 1976 to 43% in 1988. The share of electricity also grew, at a lower rate, from 13% to 21%, while the share of petroleum products decreased from 72% to 36% in 1988.

Fuelwood-petroleum products and electricity-petroleum products showed to be significant substitutes, while fuelwood and electricity were weak complements. The demand for petroleum products turned out to be the most price sensitive followed by the demand for fullwood & biomass.

On the other hand, the results showed that the demand for energy was very price elastic with an elasticity above unity. With a rising relative price of energy this could explain the reduction in energy intensity. A similar case can be made for capital that the size of the elasticity estimated together with the relative prices does explain at least part of the increase in cost-shares. These effects were further reinforced by the sensitivity of the demand for energy and labour to the variation in capital prices. Looking at the cross-price elasticities we found that energy as a substitute for the other factors is quite sensitive to their price variations.

The main reason for the increasing fuelwood consumption in the industrial sector was the conversion of boilers. On the basis of a survey of the technical requirements for fuelwood prices in 1988, it was estimated that the potential substitution in manufacturing could be in the range of 12% and 15% of 1988 fuel oil consumption. This would represent about 10% of wood extraction from forests over 10 ha. which would further add to the existing deficit.

The evaluation of the potential wood extraction from eucalyptus forests, under the assumption of sustainable forest management (avoiding deforestation and keeping regeneration capabilities unchanged) showed that the deficit in 1988 was 42% of total supply, if the exploitation of forests under 10 ha. was not allowed or even worse if the exploitation of natural forests is avoided. This shows that the increasing consumption of wood, could lead to serious problem if there is not an equivalent growth in forest areas in order to expand supply.

Current legislation enacted to remedy this deficit is however showing encouraging results in the four years of implementation. 35.000 ha. have been afforested in the first two years and an additional 70.000 ha. will be afforested through a debt-for-nature conversion. These results show that the planned 100.000 ha. new forest in the first five years of the plan was a realistic goal. However, increasing wood consumption can still lead to bottle-necks in the future if the announced, and necessary protection of natural forest areas is implemented.

Future energy requirements must be met by a combination of increased efficiency and improved forestry. Forest plantations should be the prime tool since they have the additional advantage of stopping soil erosion while the natural forests need to be protected for recreation and biodiversity.

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