Energy and other inputs as constraints on food production

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The production and subsequent processing, packaging and distribution of food cannot be considered in isolation from the rest of the country's economy. The Input-Output Tables for the United Kingdom (Central Statistical Office, 1968) illustrate the complex interdependencies of all its industries and may indeed be used to quantify the importance of other industrial inputs in determining the output of those concerned in food production. This has been done in Table 1. From the inverse of the commodity×commodity matrix the contributions to the final output of farming and the food industries which derive from value added in these industries themselves and from other sectors of the economy have been calculated. The basic data are those in the most recent Input-Output Tables (Department of Industry, 1976).

Table 1. *The percentage of the final output of the agricultural industry and of the food industries accounted for by inputs from other industries and by imports (computed from UK Input-Output Tables for* 1972 *(Department of Industry* 1976))

Input	Table reference*	Agriculture (1)	Food industries (6, 7, 8, 9, 10)
Agriculture	1	55·6	10·0
Food industries	6, 7, 8, 9, 10	6·5	30·5
Fuel and power	3, 4, 12, 13, 51, 52	1·9	1·8
Chemicals	14, 15, 16, 17	3·3	1·7
Tractors and vehicles	31, 32, 33, 34	0·3	0·2
Machinery	23, 25, 26, 27, 28, 29 35, 36, 37	1·4	2·1
Transport	54, 55, 56	4·1	4·5
Distribution and communication	57, 58	3·5	6·3
Metal and plastics	18, 19, 20, 21, 38, 39, 45, 46, 47, 48	2·4	4·8
Construction	22, 24, 43, 44, 50	2·3	1·6
Services	59	4·8	8·1
Imports	60	16·4	24·4
Residual	(other industries)	0·8	1·9
Tax/subsidy		−3	+2
Total		100	100

*The numbers refer to the industrial classifications in the Input-Output Tables which have been aggregated.

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Table 1 shows that for every £100 of final product produced by the agricultural industry £56 is accounted for by value added in farming itself, £28 accrues from industries and services completely separate from farming and £16 from the importation of goods and services from abroad. Not all the wealth generated in agriculture is thus directly attributable to the efforts of those working in the industry, and the same is true of the food industries. These comprise industries processing cereals, sugar, cocoa, oil, fat and many other products as well as the brewing and distilling industries.

These components of the output of the farming and food production industries which derive from other industries are expressed in terms of money. By making certain assumptions they can be translated into factors of production, that is into quantities of labour and raw materials (Leontief, 1966). The transport item in Table 1, for example, represents that part of the expenditure of labour together with consumption of steel, rubber and other components by the transport services which can be referred to farming. This approach obviously involves estimating that part of a final industrial or service output which is represented by a raw material, by expressing it as an amount of material used per £ of total output. While this can be done a more direct approach is more precise; the actual resources employed to make a particular product can be estimated and the amounts of resources needed summed over the various products to provide a measure of the resource requirement of an industry as a whole (see Foley, 1976). Each approach still preserves the idea of interdependence of the various sectors of the economy, but it will be appreciated that the interrelationships between industries are not then the same as when money is used as the common denominator.

Energy accounting, in which the over-all amounts of primary energy required by an industry are ascertained by summing the energy consumed both directly and indirectly, illustrates this type of resource analysis very well. Energy is indeed a very useful common denominator when dealing with physical resources for almost all tangible items moving in an economy incur an expenditure of energy.

The units in which energy accounting is carried out have to be explained. The unit is the heat of combustion of the primary fuel used. Electrical energy is not a primary energy resource. Electricity generation is only 28% efficient (National Economic Development Office, 1974) in terms of coal energy. Coal, however, has to be mined and transported and for every 100 J of coal at the power station some 5–10 J has to be expended to produce it and get it there. In addition, the transmission of electrical power involves a small loss, and the replacement of generating plant equally involves an energy cost to make cement, steel, ceramics and other components. In terms of primary cost, electrical energy is more than three times more expensive than coal energy or oil energy. Primary energy cost is thus by convention the cost expressed in terms of the resource of energy in the ground (Leach & Slesser, 1973). Using this convention a number of studies have been made of food production systems throughout the world, the most thorough one for the United Kingdom being that of Leach (1976). Even in this study, however, a number of approximations had to be made. Table 2 summarizes the estimates of energy input into United Kingdom agriculture made by Blaxter (1975) and by Leach (1976). The estimates apply to different years and slightly different conventions have been used by the authors. In particular, Leach charged to farming the energy cost incurred in growing imports and shipping them to the United Kingdom, while Blaxter charged all farm electricity consumption to the industry, thus including domestic consumption in farm households. Correcting for these differences the two estimates are not wildly disparate; indeed, Leach's corrected estimate for 1972, which involved extrapolating values for some components, gave a value of 326×10^9 compared with Blaxter's 317×10^9 MJ/annum.

Table 2. *Comparison of two estimates of the support energy input into UK agriculture (MJ × 10^9/annum)*

	Blaxter's (1975) estimate for 1972	Leach's (1976) estimate for 1968
Direct power, including coal, petroleum and electricity	144·5	108·4
Fertilizers, lime and agrochemicals	129·3	90·4
Machinery, repairs, feed processing	50·9	58·8
Transport to and from the farm	15·7	16·3
Imported feeding stuffs	—	104·5
Total	340	378
Corrected [reduction of Blaxter's estimate of electricity consumption to equate for home use by farmers and removal of import charge from Leach's estimate]	317	274

The support energy in the food industry and in distribution can similarly be estimated and Table 3 summarizes the components of the total food system. Some of the estimates of individual items which make up the totals in Table 3 may be criticized and no doubt some items are over- and others under-estimated. Error arises from paucity of statistical information and from uncertainty about the energy required in individual production processes.

Whatever the uncertainties, the fact emerges that to produce 1 J of energy as edible food on the consumer's plate entails the consumption of about 10 J of support energy mostly derived from fossil fuels. Studies in other western societies show a similar high consumption of energy in the whole process of food provision (de Wit, 1975; Pimentel, Hurd, Bellotti, Forster, Oka, Sholes & Whitman, 1973; Steinhart & Steinhart, 1974) and retrospective studies show that growth in support energy consumption per unit food produced has been continuous. Certainly, in the farming sector spectacular growth in consumption has been continuous from the 1940s until 1973, the year in which the massive increase in oil prices took place.

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Table 3. *The support energy required for the total food system of the UK ($MJ \times 10^9$/annum)*

Component	Annual cost	Reference and comment
UK agriculture	317	See Table 1
Import of animal feed	60	Blaxter (1975)
Food industry	527	Leach (1976)
Food distribution to retail outlet	451	Leach (1976)
Import of human food	208	Assumed 2 J/J food produced and transported
Sub-total to retail outlet	1563	
Home expenditure, including cooking, preservation and transport from retail outlet	728	Estimated from UK energy statistics on domestic fuel use and from estimates of the energy cost of moving 1 ton of food and drink and its associated packaging from retail outlet to the home
Garbage and sewage disposal	26	Estimated from energy costs of Greater London disposal scaled to UK population
Sub-total from retail outlet to the consumed food	754	
Grand total	2317	
Energy required by the population	241	Blaxter (1975)
Ratio, energy input:energy consumed by man	9·6	

An analysis of the concomitant changes which have been associated with the increase in the use of support energy in agriculture illustrates the problems which may have to be faced if energy supply becomes a constraint on food production. The increase in support energy in agriculture has been associated with a marked fall in manpower in the industry, a disappearance of the horse as a mobile power unit and an increase in the yield of crops and livestock per unit area. Table 4 summarizes the changes that had taken place in a period of 20 years ending in 1972, that is to the year before October 1973 when the OPEC countries increased the world price of oil. The displacement of a man from the industry was associated with an increased consumption of energy of 358×10^9 J/year equivalent to 9 tons of oil per year and an increase in output of crops and livestock which are roughly equivalent to the addition of 12 hectares of land. Not all the increase can be attributed to increased industrialization of the industry; technical efficiency has also markedly increased, but the release of land through the change in structure is clearly much greater than can be accounted for simply by disappearance of the horse as a source of power. Maximally this might have accounted for 2 ha/man. The increase in support energy during the 20 year period ending in 1972 of 70% was associated with a reduction of the labour force of 40% and an increase in production equivalent to a 45% expansion of our acreage. These associations in themselves show that resources of land, labour and input items are closely inter-related.

Table 4. *Statistical information about the output of the farming industry in 1952 and 1972 and the labour and fossil fuel inputs*

Component	1952	1972	Crude annual rate of change	Crude rate of change per man leaving farming
Number of farmers and workers $\times 10^3$	1180	709	−23·6	—
Support energy input (J $\times 10^{15}$)	241	410	+8·45	$358 + 10^9$ J
Cereal production, dry weight (tonnes $\times 10^3$)	6997	13 346	+317	
Potato production, dry weight (tonnes $\times 10^3$)	1475	1031	−22	
Crude sugar from beet (tonnes $\times 10^3$)	795	933	+7	
Dry weight of main crops (tonnes $\times 10^6$)	9·27	15·31	0·30	12·8 tonnes
Carcase meat (tonnes $\times 10^3$)	1341	2070	+36	1·5 tonnes
Milk (l $\times 10^9$)	9·74	13·38	3·64	15 381 litres
Eggs (no. $\times 10^9$)	9·17	14·71	0·28	11 737
Land equivalent (ha) of yield changes/man leaving farming:				
12·8 tonnes main crop dry matter at 4 tonnes/ha				3·2
15·4 $\times 10^3$ l milk at 2·5 $\times 10^3$ l and 0·125 tonnes meat/ha				6·2
1·5–0·8 tonnes meat at 0·3 tonnes/ha				2·3
11·8 $\times 10^3$ eggs at 17·3 $\times 10^3$/ha				0·7
Minimal land equivalent				12·4

With the complexity of events taking place up to 1972 established, one can consider what has taken place in British agriculture since the massive increase in the price of fossil fuel. The net output of British agriculture at constant prices continued to rise until a peak in 1974–75 and thereafter fell to 90% of that value in 1975–76 and is expected to be 81% of the 1974–75 peak for the period 1976–77 (NEDO, 1977). Some of the reasons for these falls are undoubtedly due to seasonal vagaries, but undoubtedly the cost of major inputs such as labour and the goods and services provided by other industries, and which have been aggregated in terms of energy, have in part been responsible. From 1972 to 1975, the direct consumption of primary fuels by agriculture fell by 14% and phosphatic fertilizer consumption by 32% while consumption of potassic and nitrogenous fertilizer remained virtually unchanged. At the same time machinery purchase appears to have increased in terms of the new horsepower deployed. This is shown in Fig. 1. In the last 3 years tractor power has increased by 7%. This is similar to the situation in other countries (Manby, 1973) where the trend is for the horsepower of tractors to increase at a linear rate. Taking two major manufacturers of tractors in the UK the range of the horsepower of models available to farmers in 1965 was from 30 to 66, now, in 1977 the range is from 47 to 180, with the main concentration in a 60–100 bracket.

These indicators do not suggest there has been a great decrease in energy consumption by the industry other than that which no doubt reflects sensible

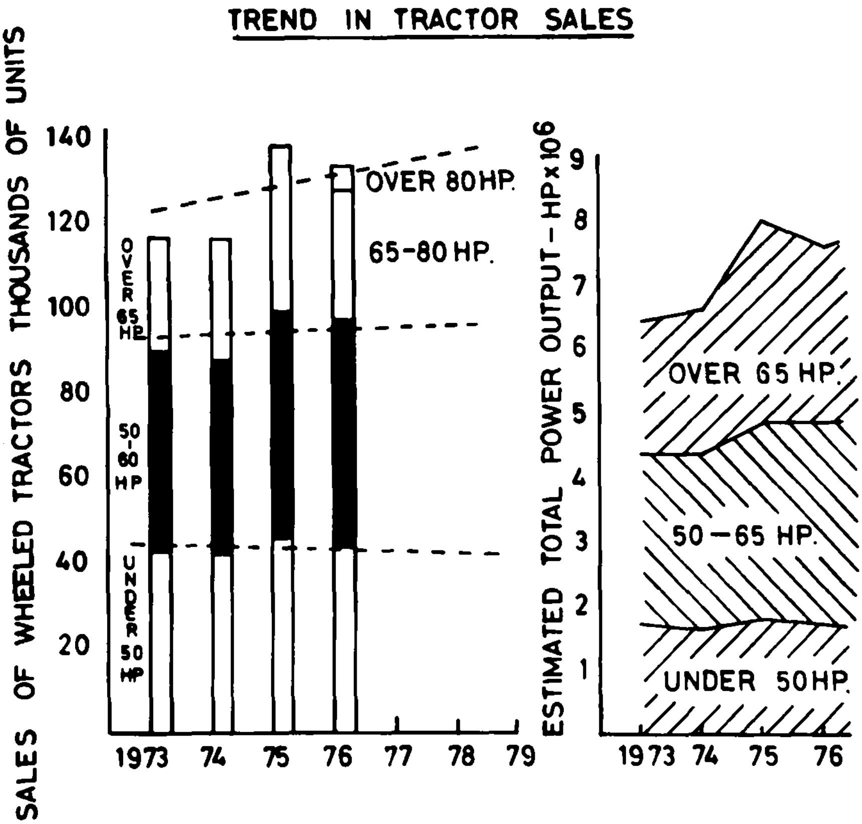

Fig. 1. The trend in tractor sales showing increase in horsepower (HP) deployed.

economy. It might have been thought that an economy in N fertilizer application would have occurred since this is very expensive in terms of primary energy. Table 5 gives prices of tractor diesel fuel and fertilizer N together with those of farm products in 1965 and 1977. The price of fuel has increased almost sixfold, that of agricultural products about threefold, but the over-all price of fertilizer N, including the subsidy paid in 1965, has hardly doubled. This reflects the fact that the feed-stock of natural gas used for the manufacturer of ammonia is bought at a contract price negotiated by government and this is about 20% of current world energy prices (R.K., 1977). As such it represents as much a subsidy for the farming and food industry as did the direct one of 1965. It is indeed more economic now for farmers to apply nitrogenous fertilizers than it was before the so-called 'energy crisis'.

This illustrates a crucial point. By a variety of actions elsewhere in the economy government can affect the way in which resources are deployed in the farming and in the food industry.

There is no doubt that fossil sources of energy are finite and that we cannot continue to accelerate consumption of them for ever. Food production now

Table 5. *The prices of tractor fuel and of fertilizer N and of certain primary products of farming in* 1964 *and in* 1977

Commodity and unit	Price 1964	Price 1967	Ratio 1977:1964
Diesel tractor, fuel (p/l)	1·46	8·36	5·72
Fertilizer N (£/ton N) (production cost)	106	204	1·92
Fertilizer N (£/ton N) (less subsidy)	72	204	2·85
Barley (£/ton)	26·7	80	3·00
Beef (£/kg live weight)	0·179	0·65	3·63
Milk (p/l) (June price)	2·7	8·9	3·29

depends heavily on these sources both directly and indirectly; indirectly through the considerable dependence of food production and processing on goods and services provided by other industries. Alternative energy sources are necessary in the long-term if present output is to be maintained. In the shorter term, however, energy supplies are not a constraint on production provided that it is recognized that the safeguarding of the food supply is a matter of priority and fiscal and other steps are taken to avoid such economy on farms that food production is impaired.

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