THE ENERGETICS OF AGRICULTURAL PRODUCTION IN EASTERN EUROPE AND THE USSR

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The Issue

Although agriculture uses only a small share of the world's total energy consumption, it is generally recognized that its needs are crucial, since the existing technologies for increasing production rely so heavily on energy intensive inputs. It therefore becomes imperative to find ways of economizing in the use of the expensive and rapidly depleting supplies of fossil fuel, to develop alternative sources of energy, and to better utilize existing agricultural energy sources as substitutes for expensive energy produced outside agriculture.

Most studies of energy use in agriculture have described the developed western countries. Less information is available about agricultural energy use in developing and in the centrally planned countries. In the latter two groups of countries, large increases in food and agricultural production are required. Since these countries now possess relatively abundant supplies of agricultural labour, and modest supplies of capital and industrial energy, it is possible that they may have alternatives to the energy intensive path of agricultural development followed in the most technically advanced western agriculture.

Now is a good time to study the energetics of agricultural production in Eastern Europe and the USSR because the agriculture of these countries has been undergoing dynamic change characterized by more intensive use of capital, increased specialization of agricultural enterprises, strengthening of vertical and horizontal integration, and a growing scale of production. Concentration of land, labour, and capital in the big state and cooperative farms under state and social control creates a system of agricultural production which could be quite easily adjusted to changed economic and energy situations.

With current technology, agriculture in these countries would require extremely high direct and indirect energy inputs to bring crop yields and animal productivity to the full potential. Perhaps alternatives exist. In times of energy scarcity, energy analysis of agriculture in different countries can give insights into the viability or competitiveness of different agricultural systems.

This study covers seven socialist countries which are members of the Council for Mutual Economic Aid (Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, Poland, Romania, and the USSR). To gain a perspective on the energy situation, it is necessary to know the actual amounts and productivity of the energy used in the agriculture of the countries under consideration. Therefore, the purpose of this study is: to describe the energy inputs into agriculture in the seven countries and outline changes in these inputs during the period 1960-1977; to measure agricultural output in energy units; and to compare energy inputs with the energy content of agricultural output in order to estimate the efficiency of energy use.

The method used in this study has been adapted from FAO. Energy used in agricultural production was divided into two categories: (1) energy incorporated in agricultural production inputs produced outside agriculture; and (2) energy used directly as fuel and power within agriculture. In the first category are such items as agricultural machinery, tractors, combines, trucks, horse drawn equipment, as well as fertilizer and pesticides. Energy in food was measured on the basis of crops in final form including grains, field beans, potatoes, oilseeds, sugar, vegetables, fruits, and animal products (meat, eggs, and milk). Animal feed was not counted as part of energy output. The energy value of the animal product was multiplied a factor of 7.0 to account for the energy value of the feed. Thus all figures for energy output are converted to crop production equivalents.

Energy Inputs

The years 1960 to 1977 were characterized by a rapid increase in the use of energy in the seven countries, from 849,716 to 2,793,162 million gigajoules (TJ), an increase of 229 percent. The USSR showed a 236 percent increase, with a 1960 use of 597,881, and a 1977 use of 2,006,856 TJ. The six countries of Eastern Europe, taken as a group, exhibited a rise from 251,835 to 786,306 TJ, a 212 percent increase. Material energy (machinery, fertilizers, and pesticides) as a component of farm inputs increased 350 percent. The use of operational energy (energy used directly as fuel, electricity, horse power, and human labour) rose by an average of 143 percent--a 243 percent increase in fuel and electricity and a 42 percent decline in horse power and human labour.

Table 1--Sources of energy inputs into agriculture

	1960	1977	1960	1977	1977/1960
	------TJ-------		-----Percent----		Index
Farm machinery	170,448	406,562	20.0	14.6	239
Fertilizers	169,776	1,120,415	19.9	40.1	660
Pesticides	9,067	44,824	1.0	1.6	492
Subtotal	349,281	1,571,801	40.9	56.3	450
Fuel	271,584	716,851	31.9	25.6	264
Electricity	45,838	373,312	5.4	13.4	814
Subtotal	317,442	1,090,163	37.3	39.0	343
Horses	91,178	52,804	10.8	1.9	57
Labour	93,836	78,394	11.0	2.8	84
Subtotal	186,014	131,198	21.8	4.7	71
Total	849,716	2,793,162	100.0	100.0	329
(of which) USSR	597,881	2,006,856	70.4	71.8	336
Eastern Europe	251,835	786,306	29.6	28.2	312

Changes in energy use occurred from 1960 to 1977. The proportion of material energy obtained from outside agriculture increased. The share of operational energy decreased. In 1960, only in Czechoslovakia and the GDR was more than 55 percent of energy use in the form of machines, fertilizers, and pesticides. In the USSR, the rate was 37 percent; in Romania it was barely 26 percent. The increase in the share of material energy for the seven countries was in the range from 41 to 56 percent. Hungary increased its share by 75 percent. Bulgaria, Czechoslovakia, and the GDR increased their proportion by 66-69 percent. For Romania and Poland, the figure was 58-60 percent and for the USSR about 53 percent.

In 1960, energy used in the form of farm machinery and fertilizer each accounted for about 20 percent of total energy use. The intensification process caused the share of energy use for fertilizer to rise to 40 percent by 1977 for the seven countries taken together. The fertilizer share rose from 14 to 36 percent in the USSR and from 34 to 51 percent in Eastern Europe.

A rapid increase also occurred in the use of energy in the form of pesticides and herbicides. However, it only amounted to 2 percent of 1977 energy inputs. The use of energy embodied in farm machinery increased gradually, so the proportion of energy inputs thus expended decreased. In the USSR, it fell from 23 percent in 1960 to 16 percent in 1977. In Eastern Europe, the share went from 14 percent in 1960 to 11 percent in 1977. The greatest relative increase in the use of energy embodied in machines was in Poland and Romania. There the 1960-77 period was one of accelerated progress in mechanization.

The use of energy in the form of liquid fuel increased in pace with mechanization. For the seven country group, liquid fuel use increased by a factor of 2.6, while in Eastern Europe there was a fourfold increase. Energy from liquid fuels in the seven countries fell from 32 to 26 percent over the 17 year period. However, for Eastern Europe the share of energy use from liquid fuels increased. For Eastern Europe it was a small increase, from 19 percent in 1960 to 23 percent in 1977. For the USSR, energy use from liquid fuels fell from 38 to 27 percent.

While the portion of energy used directly in agriculture as electricity is modest, rates of increase in use are very high. It increased by a factor of 8 over the 17 year period. Electrical energy, as a share of total energy inputs, increased from 4 percent in 1960 to 7 percent in 1977 in Eastern Europe. In the USSR, it increased from 6 to 16 percent. Although rates of increase in energy use in the form of electricity have been high, agricultural use as a percentage of all electrical energy produced remains low.

For the seven countries taken together, the share of energy from outside agriculture which was used directly rose only slightly and amounted to 39 percent in 1977. Total energy inputs from outside of agriculture rose from 78 percent in 1960 to over 95 percent in 1977.

Energy in the form of work by people and horses declined in relative and absolute terms. Energy from horses went down from 13 percent in 1960 to 2.3 percent in 1977 in Eastern Europe. In the USSR, it went from 10 to just under 1.7 percent in the same period. In Eastern Europe, energy from human labour in 1977 was 64 percent of the 1960 figure. In the USSR, the 1977 human labour input was 75 percent of the 1960 level. In 1960, human work amounted to 15.5 percent of the energy input in agriculture in Eastern Europe and 9.2 percent in the USSR. The comparable figures for 1977 are 3.5 percent for Eastern Europe and 2.5 percent for the USSR.

While the area under cultivation and the number of persons employed in agriculture both declined and the use of energy from outside of agriculture increased, energy inputs per unit of land increased. For the entire region, the use of energy per hectare of agricultural land increased threefold--from 1,478 to 4,558 megajoules (MJ). The increase for Eastern Europe was from 4,143 to 13,046 MJ, and in the USSR from 1,166 to 3,632 MJ. The GDR and Czechoslovakia achieved striking increases in energy intensity.

Energy use per person employed in agriculture increased faster than did energy per unit of land. Energy used per person increased by a factor of four for the entire region, from 17,972 to 70,250 MJ. In Eastern Europe, it increased from 13,844 to 60,921 MJ, and in the USSR from 20,588 to 74,743 MJ.

Energy Outputs

From 1960 to 1977, the energy content of crop production destined for human consumption and for fodder increased in the whole region by 47 percent. In Eastern Europe, it increased by 44 percent and in the USSR by 48 percent. Particularly large increases were registered in Bulgaria, Romania, and Hungary.

Crop production destined for direct consumption grew more slowly than animal production expressed in a crop product form. In Eastern Europe, crop production grew by 25 percent; in the USSR by 35 percent. Comparable figures for animal production are 55 percent for Eastern Europe and 57 percent for the USSR. The crop product share of total energy output for the whole region was, as a result, reduced from 37 percent in 1960 to 32 percent in 1977. The ratio of food crop products energy to total food energy output decreased from 80 to 77 percent in Eastern Europe and from 83 to 81 percent in the USSR.

The energy output of agriculture per unit of land and labour rose. From 1960 to 1977, energy output rose from 23.5 to 34.5 gigajoules (GJ) per hectare. Energy

produced per person employed increased from 78.6 to 161.1 GJ. The largest energy output per hectare (55 GJ) and per person (484 GJ) in 1977 was in the GDR. Czechoslovakia followed with 40 GJ per hectare and 312 GJ per person.

Energy Efficiency of Agricultural Production

The energy efficiency ratio is computed by dividing the energy output by total energy input. This calculation allows a comparison of seven quite diverse agricultural systems. A sizable drop in the energy efficiency occurred between 1960 and 1977. For the whole region, the following indices prevail (1960=100): energy inputs, 329; energy produced in agriculture, 147; and energy produced as food products, 136.

The energy efficiency ratio decreased from 5.01 to 2.27 in the entire region. It fell from 5.68 to 2.64 in Eastern Europe and from 4.83 to 2.13 in the USSR. In the entire region, energy produced in the form of food products divided by energy inputs declined from 2.47 to 1.03. In Eastern Europe, the ratio fell from 2.61 to 1.10, and in the USSR from 2.41 to 1.00. A ratio of less than 1.00 indicates that for each unit of energy contained in foodstuffs more than one unit of energy input is needed. In the years 1975-77, such a situation prevailed in the GDR, Czechoslovakia, and the USSR. In the remaining countries, the ratio of energy output to energy input is approaching 1.00. It is noteworthy that two of the countries with the lowest value of energy efficiency are those with the highest energy inputs per unit of land and labour.

Table 2--Ratio of energy output to energy input

	Ratio of energy produced in agriculture to energy inputs			Ratio of energy produced in the form of food products to energy inputs		
Countries	1960	1970	1977	1960	1970	1977
Bulgaria	3.68	2.13	2.31	2.12	1.19	1.17
Czechoslovakia	5.14	2.80	2.51	2.15	1.09	0.98
GDR	4.77	2.93	2.66	1.84	1.04	0.93
Hungary	6.11	2.59	2.72	2.97	1.17	1.27
Poland	7.39	3.53	2.65	3.31	1.30	1.03
Romania	5.01	2.37	2.85	2.77	1.16	1.42
USSR	4.83	2.85	2.13	2.41	1.41	1.00

Conclusions

As a result of an increase in the input intensity of agriculture during the years 1960-77 in all of the countries of the region, there was a great increase in energy use. More energy of industrial origin was employed, especially energy in the form of fertilizer and electricity. At the same time, the amount of energy delivered by people and horses declined.

The energy content of agricultural output increased but more slowly than did the energy content of agricultural inputs. As a result, the ratio of energy output to energy input declined. The decline was accelerated by the increase in animal production.

One of the main goals of agricultural policy in Eastern Europe and the USSR will be to continue to increase agricultural production. At the same time,

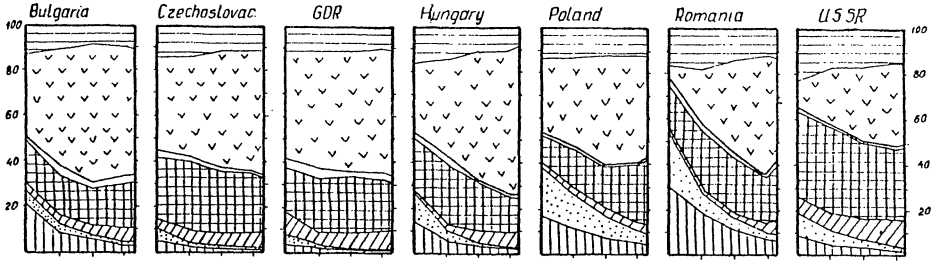

Fig 1. Structure of energy inputs: labor, horses, electricity, fuel, pesticides, fertilizers, farm machinery

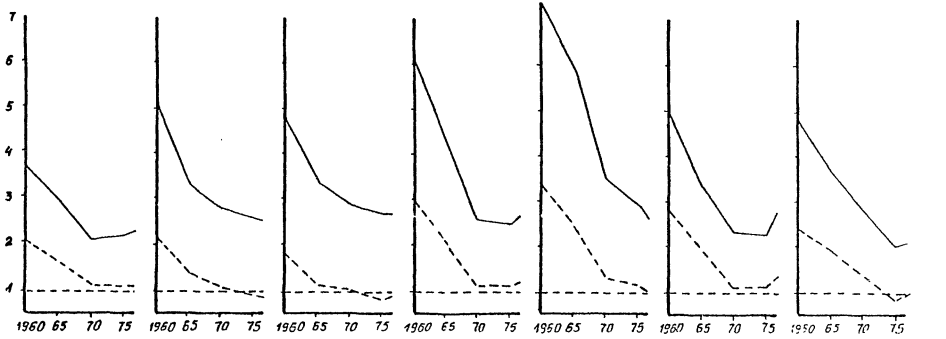

Fig. 2 Energetical efficiency ratio —— gross output: total inputs --- net output: total inputs

increases in the cost of energy and possible further declines in the energy efficiency ratios will spur the search for more economical energy management systems and for more effective methods of energy use. Problems of energy efficiency in agriculture will be a matter of concern both at the level of the production unit and the national level of policymaking. Solutions to energy problems will involve those who produce energy and agricultural inputs. As new information becomes available, what is taught by agricultural information and extension services will need to be changed.

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OPENER'S REMARKS--John S. Nix

The derived energy efficiency ratios are very different from those calculated by Renborg, but no doubt an explanation could be found if one had time to study both papers in detail. Both are invaluable in instructing farm management economists to stop thinking entirely of resource use and optimal resource allocation simply in terms of land, labour, and capital (measured in both physical and financial terms), and to consider factors other than the profitability of the individual farm. We have been quite properly forced to think much more broadly--in terms of the whole world and of the future--about the increasing use of energy and its finite supply. We now need to concentrate on the problems posed in the second paragraph of the paper--economizing in the use of energy, developing alternative sources, and making better use of existing resources.

In the 1920s, when UK farms were first mechanized, 10 to 20 MJ of energy were required to substitute for one hour of labour. Today the figure is estimated to be 230. Furthermore, energy in the 1920s (and even the 1950s) was very cheap and in apparently inexhaustible supply. Thus the marginal revenue is now very much lower and the marginal cost very much higher.

We know the main possibilities for increasing the energy efficiency ratio: using more legumes in place of nitrogenous fertilizer; reducing machinery inputs (for example, by nonploughing, minimal cultivation, and direct tilling); reducing waste; making greater use of animal faeces and straw for manuring, fuel, and feed; and, most destestable and difficult of all to contemplate when improved nutrition standards are needed by so many of the world's population (but especially vital), reducing the dependence on animal products and increasing the emphasis on crop products for direct human consumption.

Above all, there is the problem of the developing countries whose needs for agricultural development mean that they are bound to increase their demands for energy substantially. Developed countries are clearly in no position to preach about energy conservation, especially that just to feed each person in the UK and USA takes about three times the average per capita energy used for all purposes in the developing countries. But perhaps we can at least help develop techniques that use additional energy more economically than we have done in our own agricultural development. Obviously, the rapidly increasing price of energy will to a large extent dictate that this is done, through sheer economic necessity; that is, the price mechanism will operate as it should.

Of course, we can argue that agriculture is responsible for a comparatively small part of total energy use--estimated to be one or two percent in the UK and about three percent in the USA--although in the developed countries the total percentage is considerable if the amount used to make farm products available for final consumption is included (transport, processing, packaging, and so forth).

The proportion is then estimated to be 12 to 16 percent in the UK and USA—or even 25 percent by the time the food is prepared and ready to eat. Thus a small redirection in the proportion of energy used beyond the farm gate would save far more than even a large reduction in its use in agricultural production itself.

Still, this does not save those of us working in agriculture from having to face up to this large problem and doing our best to tackle it—even if we agree with Renborg that the situation is far from desperate. Certainly I very much support Renborg when he argues that the blunderbuss "make cuts" approach is too gross and simplistic, and that here surely is an area which cries out for economic analysis.

Reference

Renborg, U. (1981) Energy analysis of agriculture: Biology or economics—A survey of approaches, problems, and traps, in Rural Change: The Challenge for Agricultural Economists (edited by G. L. Johnson and A. H. Maunder). Farnborough; Gower Publishing Co.

RAPPORTEUR'S REPORT—John P. McInerney

The main points raised in the discussion were concerned with the focus on energy efficiency ratios as a single factor approach to efficiency measurement. In the context of a complex production system such as agriculture, with its dependence on both natural and processed energy sources, and a role in the economy that could not be adequately reflected simply in terms of energy processes, the nonenergy aspects of inputs and food output cannot be ignored.

It was insisted that the approach presented in the paper was of little diagnostic use and would not provide a basis for improving efficiency, as it was necessary to look at all possible combinations of factors at each stage in the production system. The need for any specific emphasis on energy aspects was questioned anyway, since there is little evidence of a consistent rise in the real price of energy in the long term.

The issue of energy input associated with labour was raised and related to the earlier paper by Renborg. It was suggested that if the total energy required for the life support of labour is employed in calculating energy inputs, then the computed efficiency of energy use in agriculture remained unchanged between 1956 and 1972, even allowing for the highest energy requirement needed to support the increased living standards employed by labour over the same period.

Contributing to the discussion were John S. Nix, Geoff W. Edwards, George T. Jones, Martin Popescu, and Ulf Renborg.