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ENERGY BUDGETING: JOULES OR DOLLARS?

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The assumptions which must be made to accept ratios of energy output to energy input as an efficiency measure with normative significance are examined and found to be unrealistic. It is considered better for governments to modify market prices where divergences exist between private and social costs or benefits than to use energy ratios, or prices determined by energy considerations, as a criterion in allocating resources. Moreover, in a trading world, energy considerations are often of little use in positive analysis of the relationship between energy prices and the prices, or profitability of production, of different foods in a particular country.

In western countries, and in many non-western countries also, decisions on resource use in agriculture are determined almost exclusively by individual farmers responding to market forces. Admittedly the prices confronting farmers are often influenced by government actions to protect them or to stabilize prices to farmers and consumers. But, until recently at least, there has been negligible questioning of the position that the interests of society are best served by relying on dollar prices in input and output markets, including futures markets, to guide resource use in agriculture (Harris *et al.* 1974).

In recent years a great deal of attention has been given to the output and use of *energy* by agriculture. Much of the analysis has been *positive*, directed to finding out how much energy is used in and produced by different agricultural systems, the physical possibilities for reducing energy use by substituting some inputs for others, and assessing the implications of energy price rises for the prices of different products. However, some writers, mainly scientists, have seen *normative* significance in ratios of energy output to energy input. They have said or implied that explicit consideration should be given to *energetic efficiency* in determining what foods to produce and the choice of inputs with which to produce them (e.g. Perelman 1972, Slesser 1973, Leach 1976). Discussion of energy efficiency in agriculture sometimes reveals an energy fundamentalism, the acceptance of which requires rejection of basic tenets of production economics as well as consumer sovereignty. Even the *definition* of agriculture is held to depend on the energy ratio (Stanhill 1974).

Economists become wary when they see normative statements about efficiency which disregard prices, especially if they also disregard all but one input. In this paper an attempt is made to spell out in detail, with special reference to food production, the reasons why this wariness is justified in the case of energy efficiency. It is considered that the writings referred to in the paper provide adequate evidence of the job facing economists in ensuring that the 'energy problem' is seen in proper perspective and that the advantages and disadvantages of different ways of tackling the problem are understood.

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The remainder of the paper is divided into five sections. Section I comprises a consideration of the value judgements which must be accepted if energy outputs and inputs are accorded normative significance. It also examines the pricing implications of those value judgements. In section II some additional practical problems important in assessing the usefulness of an energy approach to valuation are raised. In section III some normative uses (actual and proposed) of energy data are critically discussed. Emphasis is focussed on the use of energy ratios in assessing the efficiency of current agriculture. Section IV contains a discussion of some difficulties encountered in using information on energy inputs and outputs for *positive* purposes. The paper is concluded in section V.

I Value Judgements and Pricing Implications Implicit in Using Energy Outputs and Inputs to Guide Resource Use

The purpose of this section is twofold. First, two value judgements implicit in accepting that data on energy output and input have normative significance for resource allocation in food production are stated. Second, the *pricing implications* of accepting that view are examined. In a mixed economy, modification of market prices is the obvious way to achieve the pattern of production/consumption that is consistent with non-conventional value judgements about desirable resource use. This is the *direct* way to achieve any desired change in resource use and therefore commends itself on efficiency grounds. Working via price incentives is also the approach most consistent with the social philosophy of leaving decisions to individual firms and consumers where possible. Other approaches to making producer/consumer behaviour conform with the value judgements would not achieve this objective at lowest possible cost or would involve detailed government planning which would be contrary to prevailing social values (and would probably be judged inferior on efficiency grounds also).

The two value judgements implied by the use or advocacy of energy data *per se* for determining resource allocation in food production are:

(i) that relative *social values* of different foods correspond more closely to relative *energy output* of the foods than present relative prices for food suggest; and

(ii) that the relative *social costs* of producing different foods correspond more closely to relative *energy inputs* than current relative prices indicate.

The second value judgement is frequently made or implied without invoking the first one. However, use or recommended use of *energy ratios* for making decisions on resource use implies the acceptance of *both* value judgements.[1]

[1] The energy ratio (see, for example, Spedding and Walsingham (1975)) for a product is given by

$$E = O/I$$

where E = energy ratio
O = energy (gross, digestible or metabolizable) in the food
I = input of energy, other than current solar energy, used in producing the food.

Both O and I may be measured at various stages in the production/distribution network—e.g. at farm gate, retail store or on the household dinner plate. In look-

The first value judgement

Two versions of this value judgement may be distinguished. According to the *extreme* version values which individuals assign to non-energy food characteristics such as protein, vitamins, smell, taste, and ease of preparation are socially invalid. The *moderate* view implies that non-energy characteristics, while having a social value, should play a smaller role in price determination than they currently do. Both versions of the value judgement involve rejection of consumer sovereignty. The value judgement also implies that services which yield consumers place, form or time utility have a social value only if they add to the energy output of the product.

If, in spite of the need to reject all non-energy characteristics of food as legitimate sources of value, it is decided that the relative social value of foods *does* correspond more closely to relative energy outputs than current food prices indicate, what is the pricing implication? The implication, with the extreme version of the value judgement, is that relative prices of different foods, to consumers and producers, *should be made to correspond to relative energy outputs*. For example, the energy output figures in column (i) of the table indicate that food 1 would have a price per conventional unit (e.g. per kilogram) twice that of food 2. This price relationship, *which cannot be discerned from the energy ratios* in column (iii), is necessary if consumers are to make consumption decisions and producers are to make production decisions with regard to relative social values of different foods. The value judgement in its *moderate* form implies that relative prices should be made *closer* to relative energy outputs.

Example Showing Relevance of Energy Data to Pricing Consistently with First and Second Value Judgements

	(i) Energy output	(ii) Energy input	(iii) Energy ratio (i) ÷ (ii)
Food 1	2	1	2
Food 2	1	0·66	1·5
Producer and consumer price of Food 1 relative to Food 2 implied by first value judgement	2	No price ratio implied	No price ratio implied
Cost of Food 1 relative to Food 2 implied by second value judgement	No cost ratio implied	1·5	No cost ratio implied

ing at energy efficiency of food production at a particular stage, say farm gate, it is usual to include upstream energy used in producing fertilizer, machinery, etc., and transporting these to the farm, as well as on-farm energy use. In the case of labour inputs, energy costs have been variously measured as energy in food consumed (or a proportion of this, allocating some food intake to the non-work activities of labour) or food energy plus energy cost of other goods and services required for maintenance of the workforce (or a proportion of this) or zero (Leach 1976, Gilliland 1975). The terms used to describe energy input include *support energy, ancillary energy, cultural energy* and *energy subsidy*.

If market prices of food were changed to give a set of relative prices corresponding to, or closer to, relative energy outputs, there would be shortages of foods preferred by consumers because of non-energy characteristics and of foods that were relatively expensive to produce per unit of energy. The prices of these items would rise, through the development of black markets if prices in approved markets were inflexible. Extra production and lower consumption would be induced. On the other hand, pricing according to energy output would result in surpluses of foods to which consumers assigned low values for non-energy characteristics and foods which were cheap to produce per unit of energy output. To prevent price falls for these foods governments would need to hold increasing stockpiles or subsidize private stockholdings. As well as adding to the storage resources needed, a policy of holding prices for some foods above market clearing levels would stop consumer substitution towards such foods and away from foods in short supply at energy determined prices.

The second value judgement

This value judgement also comes in extreme and moderate versions. The extreme version says that the relative costs of two products depend *solely* on the relative amounts of energy used, directly and indirectly, in producing them.[2] The moderate version says relative costs are closer to relative energy inputs than current relative prices indicate. Measurement of the relative cost of producing different products by the relative amounts of energy (measured in joules or BTUs, for example) used directly and indirectly in producing them implies that inputs are valued, in the case of fuels, only for the energy which they provide and energy used in making them available or, in the case of other inputs, only for the energy which has been used in making them available. Even in the case of fuel resources valued primarily for their energy properties (for example gas and oil) there are generally differences in relative scarcities, pollution associated with their use and convenience to users. These are not regarded as inter-fuel differences in social costs when costs are measured in terms of energy. When one turns to non-fuel inputs (for example machinery, buildings, labour, management) the limitations of measuring costs by embodied energy is even more evident. Relative values of such inputs in the world as it is just do not correspond to relative amounts of embodied energy. Energy is not the only scarce resource, nor is it clear that 'energy must be the fundamental basis of the cost structure of industry and agriculture and so of the cost of production of a product' (McClymont 1973).

Disregarding the conceptual objections (and the huge practical difficulties) to determining costs by energy inputs, what are the pricing implications of the second value judgement? The correct interpretation of the pricing implication is as a guide to pricing *inputs* (see, for example, Huettner 1976). Pricing inputs according to embodied energy is the only way to provide incentives to economize that are consistent with the second value judgement. Again, *energy ratios* are not what is needed to determine prices (see table). A policy of pricing inputs according to their energy content, if it were feasible, would mean a rise in the relative

[2] If the pricing implications of both value judgements are accepted the need for a *third* value decision arises. It is then necessary to decide on the relationship between price for energy output and energy inputs.

price of inputs that are now relatively cheap per unit of embodied energy and a fall in the relative price of inputs now relatively dear per unit of energy. There would be an imbalance in the supply and demand for *inputs* if these were priced in accordance with, or closer to, relative energy content. Black market prices would rise above approved prices for resources in excess demand at the energy content prices. Resources for which supply exceeded demand at these prices would be sold below approved prices.

If pricing policies reflected the implications of the *second value judgement but not the first one*,[3] relative food prices would depend on the interaction of freely expressed consumer preferences and on production forthcoming with energy pricing of inputs. The pattern of food production would be different from that occurring if foods were priced by energy outputs. Higher prices for foods valued highly because of characteristics other than energy would induce extra production while lower prices for items valued predominantly for their energy output would reduce production. Quantities of each food supplied and demanded would balance, though there would still be excess demand for some inputs and excess supply of others at energy determined prices. As in the case where food prices reflected energy outputs, the maximizing behaviour of producers under competitive conditions would ensure a tendency for marginal cost to be equated with food price. However, unexpected shifts in supply and demand (due for example to climatic factors and income changes) would mean that the output price which equated supply and demand would not necessarily be equal to energy cost.[4]

Final comment

To conclude this section it is worth emphasizing that those who advocate use of energy ratios for resource allocation purposes imply the existence of *two* reasons for dissatisfaction with the outcome of market forces. On the one hand, present relative prices for foods are an unsatisfactory guide to real relative values—the first value judgement. On the other hand, present relative prices for inputs do not adequately reflect real relative costs—the second value judgement. Information on *energy ratios* does not help in removing misallocation due to either of these reasons. *If* the first value judgement is accepted data on the *numerator* of the energy ratio for different foods helps to achieve a better set of relative prices for foods. And *if* the second value judgement is accepted information on the energy embodied in different inputs is necessary to obtain a satisfactory set of relative prices for inputs. In the language of economists, if there are two sources of economic inefficiency it is necessary to have information on each and a policy for each to achieve an efficient allocation of resources.

[3] Either value judgement on its own, or the two together, merit the description 'energy theory of value', though the second on its own parallels most closely the labour theory of value.

[4] Some writers appear to think product prices should be determined by *adding up the energy costs incurred in production.* In fact, however, the tendency for price to equal energy cost when inputs are priced on energy content is the result of the *maximizing behaviour of producers.*

II Additional Considerations in Using Energy Data to Determine Resource Use

This section examines three extra matters that are important in considering the use of energy as a criterion for resource allocation in agriculture. The three issues are: the scope for using energy data to reduce the misallocation and distributional inequities that occur when market prices guide resource use; bringing food outputs and inputs in food production into relationship with production and inputs elsewhere in the economy; and the prospects for using energy data to determine resource allocation in a multi-country trading world.

Energy analysis and misallocation with the market system

Even the most pro-market economist would not suggest that free operation of markets will ensure an efficient allocation of resources. Externalities, departures from perfect competition in product and factor markets, subsidies and taxes are some of the sources of resource misallocation much discussed by economists. Economists' concern with resource allocation problems caused by factors such as these is shown in two directions which economic analysis has taken. First, much attention has been directed to identifying divergences between private and social cost or benefit and to devising efficient policies to remove them (for example Johnson 1965, Corden 1974). Second, a great deal of effort has been given to *making allowances* for immovable divergences when formulating policies and evaluating projects. Webb and Pearce (1975) comment that 'the EA (energy analysis) literature contains numerous comments on the biases imparted by using market prices but we have nowhere noticed even an awareness of the idea of shadow pricing, perhaps because energy analysts mistakenly identify economics with the free enterprise ethic'.

In spite of the fact that external diseconomies, subsidies and other causes of market misallocation have been used to justify use of energy analysis, these pose problems for the energy analyst just as they do for the economist (Huettner 1976). In a world in which relative prices for outputs and for inputs were determined basically by energy considerations, price adjustments could be made to deal with such causes of resource misuse. But the energy pricing approach would not allow divergences between private and national benefit or cost to be dealt with *more easily* than with a market pricing approach. In the *actual* world where relative prices are determined primarily by market forces rather than by energy data, it seems impossible to deny that the economist's approach to handling divergences is superior to anything (is there anything?) which energy analysis suggests.

Interest in energy analysis is due largely to concern about the future availability of energy, especially of petroleum and natural gas. Energy is sometimes called the 'ultimately limiting resource' (for example Slesser 1973). The valuation of exhaustible resources would therefore appear to be central to achieving a pattern of resource use which energy analysts regard as satisfactory. However, the approach implicit in energy analysis, of valuing energy from different sources on the basis of joule equivalents, makes *no allowance for differences in scarcity*. Many economists have argued that market determined prices for exhaustible resources give too little weight to long term availability of energy and the interests of people living in the future. They see validity in the criticism that price 'reflects present day values and not real, long term costs' (Leach 1976) and see merit in policies to raise prices above the market generated prices. Some economists, including Boulding (1974) have suggested that the price rises for oil brought about by the OPEC cartel will make users of oil pay prices closer to the real social costs.[5] Although economists recognize that economics does not provide all the answers concerning the pricing of exhaustible resources it has what seems to be a fundamental advantage over energy content pricing of assigning a major role to scarcity relative to demand.

Market determined prices reflect the prevailing distribution of income and wealth. The prices for different food items produced by a particular country will be influenced by the way income and assets are distributed within the country and, for a trading country, by distribution in other countries. Economists recognize that the configuration of relative prices, production and consumption corresponding to a Pareto-efficient allocation of resources will in general be different for each of the infinitely large number of distributional possibilities. There is very widespread acceptance among economists that an unsatisfactory distribution of dollar votes is best dealt with by redistribution of income rather than by changing prices in a way considered favourable to those deserving more.[6] However, regardless of one's view on this, there appears to be no reason for thinking that a policy of energy pricing would be a sound way to achieve desired changes in the distribution of income or wealth.[7]

Relating the value of outputs and inputs in food production and elsewhere

The value of food production at the farm gate is a small share of national output in high income countries. Similarly, farm production accounts for only about 3 per cent of fossil fuel energy used in countries such as the United States and the United Kingdom (Stansfield 1974, U.S. Senate 1975). This figure is increased to around 10 per cent if energy used in marketing and food preparation are included. How are production of non-food items and inputs into non-food activities to be valued if the energy approach is adopted? Relative prices in the non-farm economy would also need to depend on energy considerations. In fact, it would not be sensible or feasible to restrict energy pricing of inputs to one sector, though pricing of food in accordance with energy outputs need not necessitate a similar approach in other industries. Some writers have indicated that they have in mind the use of energy pricing on an economy-wide basis. For example, Hannon (1975) has said that 'in the long run we must adopt energy as a standard of value and perhaps even afford it legal rights'.

[5] If this view is accepted fundamental questions arise concerning the desirability of selling oil to poor countries at prices well below world prices (as advocated by Freeman *et al.* (1974) for example). International income transfers which do not hide the real costs of using oil would seem to be a preferable form of assistance.

[6] If one is unhappy with the *international* distribution of incomes the direct approach would seem to be to work for international redistribution. We are all free as individuals to redistribute our own incomes and accumulated wealth to the poor overseas and to pressure governments to make international transfer payments.

[7] For evidence on this see Freeman *et al.* (1974).

Use of energy data to determine resource allocation in a trading world

It would generally, probably always, be infeasible for an individual trading country to unilaterally adopt an energy pricing approach to resource allocation in food (or other) production. Even if a government considered that energy units *were* a better measure than dollars, or should supplement dollars, as a measure of the cost of producing food (or of the value of food consumed by its citizens) the relative gains from exporting different foods (and inputs into food production) and the relative costs of importing different foods (and inputs) would continue to be given by relative prices in world trade. A country can ignore these price realities, determined entirely or predominantly beyond its borders, only at a cost. The size of the cost would probably always be significant and the *maximum possible* cost would be very high, though, being dependent largely on future world prices, it could not be known at the time a country decided to adopt energy pricing.

The likelihood of achieving *international* agreement on an energy pricing approach, or even on movement to a pattern of relative prices *closer* to relative energy outputs/inputs is negligible—largely, no doubt, because it would be unworkable. If the pricing implications of both value judgements were effected world-wide it would be necessary to allocate the resulting production between consumers. For each country production would have to be distributed between users within its own borders and overseas: the national and international product-mix, determined by energy considerations, would not coincide with what consumers wanted. If, in spite of the enormous difficulties and restrictions on individual freedom an international system of food rationing was used, black market premiums for some foods and ever-increasing stockpiles of others would lead to breakdown of the system. The input pricing consequences of the second value judgement would also be unworkable internationally. The forces underlying supply and demand are too strong to allow maintenance of a set of relative input prices which involved shortages of some resources and surpluses of others.

III Some Normative Uses of Energy Data

There are difficulties in determining the significance which many writers on energy attach to energy input-output information in evaluating current agriculture. Some convey the impression that the present reliance on support energy inputs is undesirable and indicative of bad use of resources, though when attempting a tight summing up more caution is exercised: the emphasis then is often on implications for the future 'if' or 'when' energy becomes scarce or expensive (for example Pimental *et al.* 1973). However, some writers appear to accept that energy considerations themselves show that resources are being used inefficiently at present (for example Perelman 1972, Heichel 1973, Slesser 1973, Tribe *et al.* 1975, Leach 1976).

A factor which has been emphasized is the downward trend in the ratio of food energy produced to support energy utilized in modern farming. Pimental *et al.* (1973) found the ratio in U.S. corn production was 2·8 in 1970 compared with 3·7 in 1945. Steinhart and Steinhart (1974) and others have pointed to the fact that the energy ratio falls, and the counterpart *energy subsidy* rises, for agriculture as a whole with general economic growth. Tribe *et al.* (1975), in summing up the nature of modern farming, commented:

> 'The crux of modern farming is that high yields are now possible by the use of large fossil fuel inputs. As yields increase the net energetic efficiency of the process decreases until a point is reached where, in many cases, the yield of productive energy from the system is little more, or even considerably less, than the non-solar energy inputs. The modern farmer is no longer harvesting solar energy for the good of mankind. The situation has been summarized by Odum (1971) in his remark that industrial man "no longer eats potatoes made from solar energy; now he eats potatoes partly made of oil"—a remark that has been updated in the light of Leach's calculations to read "now he eats potatoes wholly made of oil"!'

The quotation illustrates the way in which, by concentrating on a single input, one can reach conclusions that are inconsistent with commonsense and with production economics theory. Conceptually it seems impossible to regard all the inputs used in producing potatoes as satisfactorily represented in terms of energy content (let alone as *reducible to oil*). However, even if this is disregarded, the conclusion that potatoes are made wholly of oil implies that inputs of sunlight make no contribution to production.[8] It is surprising to see agricultural scientists adopt this position: their definitions of agriculture often go something like 'a process of converting solar light energy to chemical energy in protein, carbohydrates and fats in economic crop and animal products' (McClymont 1973). It is surprising also to see it claimed that the *definition* of agriculture swings on the proportion in which fossil fuel is combined with other inputs such as land and labour. Thus Stanhill (1974) says that when the energy balance is negative (the energy ratio less than one) 'modern agriculture can be described as the process of converting *concentrated fossil fuel* into an edible form' (emphasis added). Tribe *et al.* (1975) say 'the modern farmer is no longer harvesting solar energy for the good of mankind'. The implication seems to be that, although agriculture is often seen as concerned with producing 'economic crop and animal products', use of a combination of *inputs* that is economic under current relative prices is undesirable if this involves an energy ratio lower than one. A rationale for this is hard to see. No fundamental change occurs in the prospects for continued availability of oil or other fossil fuels with a rise from 0·9 to 1·1 in the energy ratio.

The use of energy ratios in judging the current soundness of modern agriculture seems to require either rejection of market prices as the key mechanism for allocating resources, or use of energy ratios *together with* market information to obtain a pattern of resource use that is in some sense better than that possible using only economic data as a guide. Few people have stated which, if either, of these views they hold. An exception is Leach (1976). He calls for a new 'ecology of the technosphere' which he describes as 'a new science that will supplement economics by thorough study of the inputs, outputs, flows and con-

[8] Even if the marginal product of solar energy was zero, which would be an efficient situation if inputs of solar energy could be varied independently of other inputs, the marginal product of intramarginal units of sunlight would be positive.

versions of physical resources in our techno-industrial world'. Energy analysis is seen as a central component of the new science. While Leach expresses dissatisfaction with market valuations of resources, he does not explain, either from the view of principles or operation, *how* physical information on 'inputs, outputs, flows and conversions' could assist in making decisions on resource allocation. Rather than introduce an extra criterion (and with it the inevitable trade-off problem) it would appear more promising to use the framework provided by economists and concentrate on identifying divergences between actual and socially relevant prices and on changing such prices where possible and making allowance for them (through use of second-best pricing policies and shadow prices in project appraisal) when they cannot be changed.

IV Energy Data and Positive Analysis

An objective which is emphasized by many writers on energy is increased understanding of the consequences of changes in energy prices on costs, production, input combinations, and the economics of new energy sources. The importance of positive analysis of questions of this type seems beyond dispute. However, the complexity of such studies has not always been recognized. Because of their training in general equilibrium analysis economists are much more aware of the pitfalls in predicting the consequences of an initial price change than are many non-economists who engage in such prediction. But it may not be amiss to refer briefly to some of the main difficulties that arise in assessing the consequences of higher energy prices for agriculture.

First, even if one assumes unrealistically that an increase in world energy prices applies *only to farmers*, the analysis is far from simple. In a world of positive supply responses the initial response of the world *as a whole* to higher prices for energy inputs is contraction of output. But the resulting rise in *product* prices works to increase production.

Second, even under the limiting assumption made above, higher food and energy prices would in many countries have important general equilibrium effects through their influence on the balance of payments. In countries, such as Australia, which for energy and food considered together are net exporters, the balance of payments would probably be made stronger compared with the unchanged energy price situation. Restoration of equilibrium through currency appreciation would tend to hold down food and energy prices. Countries whose balance of payments deteriorated because they are net importers of food plus energy would tend to devalue in relation to other countries. This would cause additional rises in the prices of energy and food in those countries.

To move closer to reality we recall that the fossil fuel used in food production is a small part of total fossil energy used—about 3 per cent to farm gate stage in the U.S. and the U.K. (U.S. Senate 1974, Stansfield 1975). This suggests that in a realistic consideration of the consequences of higher energy prices the effects on food prices at farm level will be a relatively small factor. The effects on the various transport, processing, cooking and other services added to food between farm and dinner plate are likely to be more important. For the U.S. these account for 3 times as much energy as is used to the farm level (Steinhart and Steinhart 1974). Gifford and Millington (1975) have estimated that 89 per cent of the energy used in getting food to the dinner table in

Australia is utilized beyond the farm gate. However, approximately 90 per cent of energy used in a modern economy is used *outside the food production/marketing/preparation system.* Carter and Youde (1974) have argued 'that major long-term adjustment problems for (U.S.) agriculture will result indirectly from the impact of energy prices on general price levels and economic growth rates, rather than from direct price increases of energy-based farm inputs (electricity, fuel, fertilizers and chemicals)'. Energy pricing policies which slow the movement of world price rises through to energy users are in many countries (including the U.S. and Australia) tending to delay the direct effects and to add to the current relative impact of indirect effects exerted through the balance of payments and economic growth.

The pattern of relative food prices and production costs in the future will depend in a complex way on a large number of factors. On the demand side growth in income, changes in tastes, and price and income elasticities of demand will be important. On the supply side, the key factors include the pattern of technological progress and changes in the relative prices of inputs. It is changes in supply and demand factors *throughout the trading world* that are relevant in considering the future profitability of different lines of production in a particular country. Overall price/cost trends will not necessarily work to the detriment of products which now or in the future make relatively heavy use of fossil energy at the farm level. Even for a food item which, throughout the trading world, has a low energy ratio, producers in countries having the 'least unfavourable' ratio may find it profitable to increase production, perhaps substantially, when prices for energy and for the product rise. Australia, which relies more on rotations including legumes and less on nitrogenous fertilizers than many other countries, could find it economically rational to expand production of certain agricultural products under energy/product price conditions which reduce production in the trading world as a whole.

This consideration of energy/food price relationships in a price responsive, trading world indicates a need for great care in assessing the effects of higher energy prices and in drawing policy implications, for example for future production patterns or for research priorities, from energy ratios. They indicate, for example, that McClymont's (1975) suggestion that special emphasis should be given to research aimed at maximizing energy ratios in crop and animal production is naïve.

V Conclusions

A ratio of joules made available in food to joules of non-solar energy used in producing food can be regarded as a normatively useful measure of efficiency in food production only if implausible assumptions are accepted. The main assumptions are: energy available from food is an adequate measure of its value to local and overseas consumers; inputs other than energy used in food production can be treated as though they are costless; and inputs of x joules from each of two energy sources can be treated as identical regardless of differences between them in scarcity, convenience and pollution generated. In the absence of general validity of the above assumptions, use of market prices for food and for inputs of natural resources, labour, capital and energy seems to be the only satisfactory way of deciding what food products to produce and what combination of inputs to use in producing them.

Where product or input prices do not reflect social values or costs accurately it may be desirable to introduce policies which change prices to consumers and/or producers. This is far removed from abandoning market determined prices and substituting an alternative criterion of benefit and cost.

Conservation of scarce energy resources can be increased if prices to *users* are increased through market forces or government action. Higher *producer* prices increase the available quantity of economically attractive resources.

In the unlikely event that international agreement was reached on allocating resources as though input costs depended only on embodied energy (or depended more on this than current relative prices for inputs suggest) there would be imbalance between quantities of inputs supplied and demanded at energy determined prices. If foods were priced according to energy outputs there would be surpluses of some foods and shortages of others. Either of these situations, let alone the two simultaneously, would lead to the breakdown of international energy pricing.

In a trading world an *individual country* can depart from the dollar criterion for determining the pattern of its food production and consumption only if it accepts the losses involved in isolation from world prices. It cannot escape the fact that for both products and inputs the relative value of different exports and the relative costs of different imports depends on money prices in world markets. Moreover, when allowance is made for all the direct and indirect effects of a rise in energy prices throughout the trading world, it is not clear that, for a particular country, there will be a relationship between the energy ratio for various products and the impact of a rise in energy prices on profitability.

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