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PRODUCTIVITY, WAGES AND NUTRITION

Part II: Some observations

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1. Introduction

The economic theory of the connection between productivity and consumption was discussed in part I of this paper. Our focus of attention was the positive theory of wages. In this second part we discuss ways in which the theory can be tested.

Much of our discussion in part I was based on an explicit relation between productivity and consumption (see fig. 1) postulated by Leibenstein (1957) and used by Mirrlees (1976) and Stiglitz (1976). We shall refer to this as *the relation.* A first task in the examination of the theory is to discover whether the relation, in the form presented by Leibenstein or in the form of the frontier of a consumption set as we have described (see part I of this paper), can be constructed from nutritional evidence.

The theory of wages under study, if it is an appropriate theory, is clearly of substantial importance, for an understanding of the rural labour market in less developed countries to which the theory primarily, but not exclusively, refers is central to an understanding of those economies. However, the empirical literature in economics on the relation and the theory is scanty and, indeed, Mirrlees (1976) states at the close of his article:

> But I suspect that empirical research on the productivity hypothesis may be the right direction for further research rather than theory.

*We have learnt much on the subject of nutrition from Dr. P. Payne of the London School of Hygiene and Tropical Medicine. We are very grateful to him for his kindness and patience and to Drs. D. Bergel and J. Mann of the Faculty of Clinical Medicine, Oxford University for many constructive suggestions. All opinions and errors are ours. For further acknowledgements see part I of this paper.

The interest in the relation is, of course, wider than the theory we have been examining. It is possible that the theory of wages may perform badly under empirical examination yet the relation itself could be very important for policy. If small increases in food would substantially improve productivity then this should surely affect government planning.

Further, an empirical investigation of the consumption set itself, which describes the limits of a consumer's abilities to supply factors given his consumption levels, fills a lacuna in the empirical examination of the concepts of standard economic theory. The demand and production functions of standard economic theory have received close attention from econometricians. The one remaining part of the structure of standard general equilibrium theory, the consumption set [see Debreu (1957)], has been virtually ignored.

We begin our discussion of the nutritional literature with an examination of Calorie recommendations for individuals to be healthy, active and involved in certain occupations. The next step is to ask how work performance is altered by consumption below these levels. And we should go on to ask how many individuals in a given area are consuming below the recommended standards. If many people in an area have low levels of food consumption relative to these standards, if performance can be thereby seriously damaged and if individuals discover this and incorporate the discovery into their economic behaviour then the theories of wages giving a central role to the relation may be of importance.

This approach, through a series of questions, indicates serious gaps in our knowledge of the relation between Calories and work performance and raises substantial doubt as to the relevance of calculations of the numbers in poverty based on calculations of the income required to meet certain nutritional standards.

Our first approach to testing which we have just described is, therefore, to focus directly on the relation itself. This is the content of the next section. We discuss secondly (in section 3), and briefly, the problems associated with a formal econometric test of the hypotheses discussed in part I of the paper. This would involve a formal specification of the nature of the relation as well as the knowledge participants in the economy have of the relation, and the structure of the economy in which they operate.

The third and final method is the less formal comparison of results, and ideas concerning possible markets and behaviour derived from part I of the paper with simple observations on markets and behaviour in practice. This is contained in section 4. The evidence we shall discuss for this section will be influenced by our experience in India in 1974–75 and, in particular in the village of Palanpur in West U.P. where we conducted an intensive study.

We shall conclude by suggesting that the third and least formal method is the best we can do at present to test the positive theory. However we shall be suggesting that the most promising way forward, in particular for policy, is to pursue some of the questions raised in our discussion of the first method and we shall be making particular proposals for further research.

2. Calories, performance and poverty

The relation we wish to examine describes productivity in terms of the number of efficiency hours or tasks performed, in a working day of given clock hours, as a function of consumption. Leibenstein gave it the particular form shown in fig. 1(i). We have chosen to reinterpret the relation as the frontier of the consumption set, in the sense of Debreu (1957). We think of h as the number of tasks carried out per day, and relabel it as n, and c as the minimum consumption required to perform n tasks. The region on and above the frontier [in fig. 1(ii)] is the consumption set itself and is the section of (c, n) space on which individual preferences over (c, n) pairs are defined.

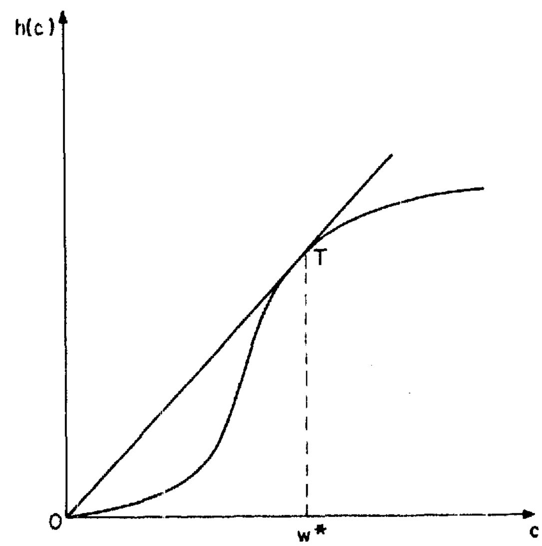

Fig. 1(i). The relation between productivity and consumption as presented by Leibenstein and Mirrlees (c = consumption per day, h = number of efficiency hours per day). In the case where all wages are consumed and wage labour is the only source of consumption, the employer's cost per efficiency hour is minimised at w^*.

The above definition conceals some important questions which concern in particular the distinction between the long run and the short run and some of them are taken up in subsection 2.2.

In subsection 2.1 we report on our investigation of the nutritional evidence as part of our attempt to construct the relation. This is, inevitably, a lengthy and detailed process, but we found it fascinating. We then, in 2.2 look at the consequences of this evidence for the theories discussed in part I of this

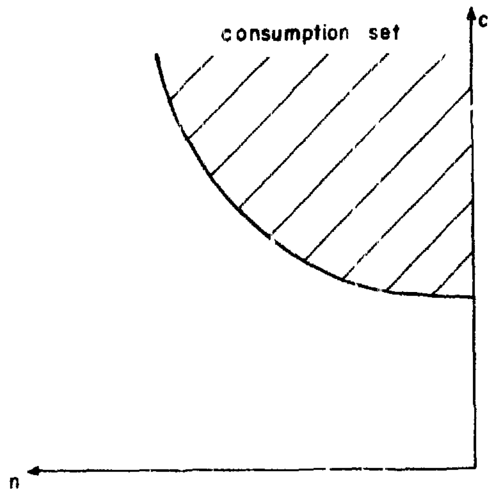

Fig. 1(ii). The frontier of the consumption set as presented in part I of this paper (c = consumption per day, n = number of tasks per day).

paper. In subsection 2.3 we examine, in the light of 2.1, estimates of numbers in poverty in India, and in 2.4 pose some questions and make suggestions for further research.

2.1. The nutritional evidence

The frontier of the consumption set is intended to describe the limit of an individual's possible performance. His maximum feasible number of tasks per day, n, will be determined *inter alia* by his strength, skill, intelligence, psychology, and general health as well as food intake. Further these causes will be interrelated – especially in the long run. In this section, however, we concentrate on the ability to translate food calories into work for an individual of given skill, intelligence, psychology and so on. We shall, therefore, be saying rather little on the long-term effects of some aspects of higher living standards, for example better hygiene, protein and vitamins, on strength, health and general performance. These effects are, we suppose, of substantial importance but we leave them out of our discussion for three reasons. First, they are beyond the limits of our competence; second, we suspect that in the detail required for the relation rather little is known; and third, for the shorter run labour hiring decisions of some employers such considerations may be of minor importance. The qualifications that many of the aspects just mentioned, and others, which are ignored may be of great importance and that requirements vary a great deal across individuals must be borne in mind throughout. Whilst these qualifications should not be forgotten it is tedious to keep repeating the caveats and we shall not always do so.

We shall be discussing the nutritional literature in some detail. This detail is important to our argument. First, incomes in India (see subsection 2.3) and in many other poor countries are such that many people must have food consumption which is very low by nutritional standards. Estimates of the extent and severity of malnutrition and the impact on productivity will be very sensitive to the levels at which standards are set. There is substantial disagreement over these levels and the arguments must therefore be examined carefully. Judgement of the relevance of the theory and the importance of the relation for policy depend critically on our view of the evidence to be examined. Secondly we came to the conclusion that further research is urgently needed. We require detailed discussion to demonstrate this and to identify possible directions.

There are two ways of calculating the energy required, in terms of the number of Calories (1 Calorie = 1000 calories), for given weight and activity levels [see Davidson et al. (1975, p. 28)]. The first involves dietary surveys. Thus the consumption of (apparently) healthy individuals is monitored to see how much food of various kinds individuals with the given weight and activity levels consume without gaining or losing weight. Then food tables are used to divide the food content into proteins, fats and carbohydrates. The heat of combustion of these constituents (which varies a little across foods) is measured using a calorimeter and finally factors are applied to adjust for losses in the urine and faeces. Thus the number of Calories used by the subject is calculated. It is found that the so-called Atwater factors of 4, 9, 4 Cals/gm for protein, fat and carbohydrate give, in general, quite accurate results for heat of combustion multiplied by proportion absorbed when applied to gross food ingested, although of course, the proportion of food absorbed will vary with the individual diet and state of health.

However, a dietary survey can give no information on how the energy in the diet is expended. The alternative, and more suitable for our purposes, is a survey of energy expenditure. This involves careful recording of how the subject spends his time and then an assessment of the energy cost of each activity. The energy costs of each activity are measured either by observation of oxygen consumed or using published tables. The published tables [see, for example, Durnin and Passmore (1967)] are themselves calculated by measurement of oxygen consumed. The oxygen procedure has been confirmed by direct calorimetry – placing a human in a calorimeter to measure directly the heat emitted.

Both methods of calculating calorific requirements give similar results (and they are, of course, equivalent in principle – see below) but it is clear that, for our purposes, the second carries more information. The economic theory under discussion requires that we formalize this second approach into a functional relationship relating tasks performed to calorific input. This more formal approach seems rare in the nutrition literature. We draw rather heavily on a recent unpublished paper by Payne and Dugdale (1975) [related publications are (1977a, b)]. We shall, however, see that the relationship we require is extremely difficult to identify.

When food is absorbed by the body the available energy may be used in different ways. The individual may be involved in activities of various kinds, he may put on weight and he has to maintain the fabric of his body. Not all food eaten is ingested by the body, some is passed out in the urine and the faeces. References below to Calories retained by an individual will be to the calorific value of the food absorbed into the body, hence net of an allowance for the calorific value of excretions (the Atwater factors described above make such allowances). When food is ingested it may be used to build or maintain body tissue, or it may be oxidized. Most food ingested is oxidized and the energy thus generated is used for bodily functions such as respiration and digestion and for muscular contractions by means of which work is performed. The transition of enegy into work is not completely efficient and a good deal of the calorific content of the food is dissipated as heat, which however serves to maintain body temperature. Assuming constant body temperature the energy retained must be equal (by the first law of thermodynamics) to the sum of the energy involved in various uses. The determinants of the amount of energy involved in the different uses, and the functional forms associated with these determinants[1] are matters for both theory and experiment and will vary across individuals but the accounting equation remains the same in the sense that we add across the different uses to get the total used.

Let the Calories retained by an individual (net of those that are excreted from the system) in some period be c. Suppose the weight of the individual is W (in kg). Then we have[2]

$$c = \frac{1}{e} f(n, W) + \alpha \Delta W + k W^{\beta}. \tag{1}$$

For expository purposes we have offered a particular form of the equation in (1). We shall explain it first and then go on to describe the difficulties of specification and estimation. It is important to realise that eq. (1) is not, as it stands, the relation we are trying to identify. It is a vital first step, however, and we shall discuss the further steps involved in transforming (1) into the

[1]It has been claimed that individual variations are genetically determined and are to be accounted for by variations in the amount of heat generated in the performance of basic bodily functions, respiration etc. For a discussion of these variations and their relation to obesity see James and Trayhurn (1976).

[2]Since this is an accounting equation, a full treatment would include the possibility of a temperature change. For those who maintain a normal body temperature this consideration can be neglected.

relation, or frontier of the consumption set, when we discuss the implications of the nutritional evidence for the theory in subsection 2.2.

The first term on the right-hand-side in eq. (1), $(1/e)f(n, W)$, is the energy used up in the muscular contractions for performing n tasks: the work done is $f(n, W)$ and e is the efficiency of the body in converting energy into work – e is often thought[3] to be around 0.25. The work done by the individual in, say, digging would be the raising of soil, overcoming friction in loosening the soil, moving around the field and so on. The second term represents the energy retained by the body in weight increases over the period (so that for a decrease $\Delta W < 0$). The constant α will depend *inter alia* on the form in which the energy is stored, in particular, the proportion stored as fat – to give orders of magnitude however,[4] one might expect α to be about 5000 (or 5 Calories gives 1 g).

The third term represents the maintenance energy required at minimum activity levels merely to maintain the fabric of a body at given weight. This was taken by the FAO/WHO Ad Hoc Expert Committee [see FAO/WHO (1973, p. 37)] as $1.5 \times \text{BMR}$ where BMR is the basal metabolic rate or the energy expended (that is the heat produced) under resting and fasting conditions. The extra 50% is for the energy expended in the absorption of food, including the work performed by the alimentary canal, plus a 'minimum' level of voluntary muscular activity, such as dressing and washing (we return to this notion of minimum later) and the synthesis of tissue (see below for further discussion). This maintenance energy divided by weight in kg to the power 0.75 shows a striking constancy across different animals,[5] including humans, and seems to give k around $105\,\text{Cals} \cdot \text{kg}^{-0.75}$. The third term is much the most important constituent of daily Calorie recommendations. For example the FAO/WHO (1973, p. 38) report suggests 2600 Calories for maintenance and 400 Calories for moderate activity for an average 65 kg male, at mean ambient external temperature 10°C, aged 20–39, to give a total of 3000 Calories per day. We shall, following the FAO/WHO call him *the reference man.*

We turn now to the problems of specification and estimation. It should be emphasised at the outset that both eq. (1) and the theory in part I of this paper refer to changes in energy retained and expended for an individual. On the other hand much of the evidence to be discussed refers to comparisons across individuals. One must take care, therefore, before incorporating such evidence into eq. (1). We have already stressed that energy requirements vary considerably across otherwise similar individuals. And one cannot suppose in

[3]See Mountcastle (1968, p. 532).

[4]Chapter 3 in Davidson et al. (1975). This value of α would be appropriate for $\Delta W < 0$ – see below especially footnote 6. Davidson et al. (1975) is the standard reference work on nutrition.

[5]FAO/WHO (1973, p. 37). This is the source to which most current specifications of Calorie requirements refer.

comparing individuals of different weights that the capabilities of the lighter individual would be available to the heavier if only the latter lost weight. This last consideration is of particular relevance to an appraisal of evidence concerning the first term in (1). We now examine the terms in (1) in increasing order of difficulty in estimation and specification.

The issues raised by the second term are relatively straightforward although estimates which are both precise and general should not be expected. The value of α will depend on the source of energy extracted from body mass (for $\Delta W<0$), or the way in which energy is deposited (for $\Delta W>0$). When weight is lost it appears that the first source is glycogen in the liver (giving approximately Cals/gm). This source would not be available for more than a few hours and the second source would be body tissue (proteins yield approximately 4 Cals/gm and fats approximately 9 Cals/gm). It is clear that a reduction in lean body mass may have an effect on work performance and thus on the form of the first term in (1). Values of α will be lower for increases in weight than decreases. The variability in α according to source, and the difference for increases and decreases imply that, strictly speaking, our notation $\alpha\Delta W$ is illegitimate.[6]

The problems increase when we turn to the third term. Davidson et al. (1975, p. 31), suggest that, across humans $\beta=1$ seems to do as well as $\beta=0.73$ (the figure they give across species) and indeed the FAO/WHO Committee (1973, p. 79), eventually base their recommendations on $\beta=1$. But for an individual losing weight these values of β do not seem appropriate. Payne and Dugdale (1975, p. 13), show using data from a semi-starvation experiment that $\beta=2$ models the decline for this energy requirement rather well. The experiment [see Keys et al. (1950)], was conducted in the U.S., and involved volunteers on low food intakes for 24 weeks. The number $\beta=2$ would not necessarily be appropriate for maintenance requirements for given W in the long run since adaption takes place (see subsection 2.2). Thus the functional form for the maintenance term is an unsettled issue. It should be recalled that we are concerned with equilibrium and changes over time for an *individual*. However, we are mainly concerned (see subsection 2.2) with Calorific requirements after equilibrium has been established and here variations across individuals would be of some relevance.

There is room for disagreement not only over the functional form but also concerning the overall maintenance levels for a given reference man or woman (of prescribed weight and age). An individual with variable intake will require, on average, more energy to prevent a decline in average body

[6]We are grateful to N. Scrimshaw for information on the ordering of sources when energy is extracted from the body. Apparently there is an energy cost of 50 or 60% in the synthesis of food into tissues but a negligible cost in releasing energy from tissue. These estimates are from experiments on rats and pigs - there seem to be none for humans. For further discussion, see Payne and Dugdale (1975).

weight than an individual with steady intake since there is a cost to deposition of tissue but not to the release of energy from tissue. Payne and Dugdale (1975) suggest that the cost of this variability, in their example, is around 10% of BMR for their reference man or 160 Cals per day. It should be noted, however, that there may be costs in both time and utility attached to maintaining regularity of intake.

There is further disagreement as to whether adjustments to BMR are necessary for differences in external temperature. Davidson et al. (1975, p. 32) suggest a reduction of 5 or 10% of the recommended intakes where the mean annual temperature exceeds 25°C, since the BMR is approximately 10% (p. 26) lower in the tropics than in temperate climates. On the other hand the FAO Ad Hoc Expert Committee (1973, p. 28) in its document does not recommend any such adjustment since they argue a single meteorological characteristic may be misleading and certain adaptions – such as light clothing in the tropics and central heating in the U.S. tend to obscure differences. The average annual temperature in the Indian Gangetic Plain is around 25°C thus the difference between an estimate of total Calorie requirements for the FAO/WHO reference man with and without temperature correction could be as much as 200 Cals per day.

The allowance of 50% above BMR in the calculation of maintenance energy at 'minimum' activity levels may itself be reduced if food is cut back. It is worth quoting here at length from Davidson et al. (1975, pp. 39–40) since it will also be relevant for our discussion of the first term $(1/e)f(n,w)$ the energy expended at work.

> When European men in prisoner of war camps in the Far East were given a ration providing only 1600 Cals daily, they lost weight at first rapidly but later slowly [Smith and Woodruff, 1951)]. After an interval of many weeks and when the body weight had been reduced by 20 to 25% the losses ceased and many of them survived till liberation three years later with their body weight stable at this low level. In the Minnesota experiment on volunteers subjected to partial starvation, Keys and his colleagues (1950) showed a similar adaption to a low energy intake with stabilisation of body weight at a new lower level. They were able to demonstrate that this adjustment was in part due to a fall in metabolic rates, consequent upon the reduction on cell mass, but the main factor was a marked reduction in voluntary physical activity. Here is an example of the control of body weight by a variation in energy expenditure.

Given that, of the 3000 Cals/day for the FAO/WHO reference man, 400 is for moderate activity over and above 'minimum', 1700 for the BMR and 900 for the 50% above BMR (working in round numbers), the natural interpretation of the remarks of Davidson et al. is that one can cut into this

50% by a reduction in 'minimum' activity. And note that there is a big variability across individuals in the addition to BMR required for the various energy expenditures described above which are part of the 'minimum'. Indeed in a recent paper James and Trayhurn (1976) have argued that whereas individuals with a tendency to obesity have BMRs no higher than otherwise similar subjects, many such individuals require substantially less than an extra 50% to furnish a maintenance level for minimum activity (they give examples where BMR was above 2/3 of *total* energy consumption).

Before examining in detail the energy required for activity above 'minimum' let us summarise the position on total recommended energy levels accepting the FAO/WHO estimate of 400 Cals/day for the energy requirements of moderate activity above the minimum. We begin with the FAO/WHO recommendation of 3000 Cals/day for the reference 65 kg man at 10°C and aged 20–39 and, to give an example of the range of possible disagreement we calculate a low estimate of the requirement for the reference man to maintain constant body weight performing moderate tasks at 25°C. We have suggested that 160 Cals/day could be saved by uniform (non-varying) eating and activity levels. There could be a 200 Cals/day reduction for the higher ambient temperature. Further, and this is rather speculative, it may be possible to cut into the 50% above BMR for minimum activity levels by, say, 200 Cals/day (over and above the 160 reduction for uniformity). Thus a low estimate, accepting 400 Cals/day for moderate activity and the FAO/WHO estimates of BMR would be 2440 Cals/day. However, the FAO/WHO do say that (p.107) 'a variety of values (of the BMR) have been reported in the literature'. We have not surveyed these values but we give an example from the internal evidence of the FAO/WHO report itself. In table 9 (p. 37) they quote from Calloway and Spector (1954) a maintenance energy intake for an adult man as 34 Cals/kg/day. This is to be compared with the 1.5 BMR of the calculation of their recommendations, thus with 2600/65 = 40 Cals/kg/day. Now the use of 34 Cals/kg/day instead of 40 would reduce the 2600 for the reference man to 2210.

Thus a systematic choice of the low figure, whenever possible, could reduce the 3000 by (160+200+200+390) = 950 to 2050 Cals/day. We should emphasise that we are *not* suggesting this as a recommendation and emphasise further the four assumptions different from FAO/WHO which are used in deriving the figure. We merely wish to give an indication of the range of possible disagreement, which seems to us to be very large.[7] And there is disagreement about average levels. We should not forget the considerable variation across individuals.

The above calculations were for a man of 65 kg. Accepting the FAO/WHO

[7]It appears to us that where there has been a choice the FAO/WHO Committee selected estimates on the higher side.

suggestion (p. 29) that for rough calculations total requirements may be taken as proportional to body weight a 55 kg man would require 15% less.

We have concentrated on the maintenance energy since it is such a high proportion of total Calorie requirements. Small differences in estimates of these maintenance requirements will result in large differences in the residual amount of energy left for work, out of a given diet.

We turn now to the first term in eq. (1), $(1/e)f(n, W)$, the energy requirements for work. We begin with an indication of the orders of magnitude involved. The FAO/WHO used 4 classifications: light, moderately, very and exceptionally active. Examples of each would be, respectively, office workers, light industry, mine workers, rickshaw pullers. Farmworkers were either moderately or very active. The daily Calorie recommendations for the reference man were (their table 1, p. 29), 2700, 3000, 35000, 4000, respectively.

One estimate of the function $f(.,.)$ could be obtained from table 1 [Davidson et al. (1975, table 3.9, p. 27)]. The estimates are obtained by measuring the extra oxygen taken in by an experimental subject of the

Table 1
Energy expended (Calories) during 10 min. walking related to speed of walking and gross body weight.[a]

	Body weight (kg)					
Speed (m.p.h.)	45	55	65	75	85	95
2.0	22	26	29	32	36	39
	(4)	(5)	(6)	(7)	(7)	(9)
2.5	26	31	35	39	43	48
	(5)	(5)	(6)	(6)	(8)	(8)
3.0	31	36	41	45	51	56
	(5)	(6)	(6)	(6)	(8)	(9)
3.5	36	42	47	51	59	65
	(5)	(5)	(4)	(9)	(7)	(8)
4.0	41	47	53	60	66	73

[a]Numbers in brackets show differences down the column. Entries are converted to Calories from kilo Joules (4.186 kilo Joules ≡ 1 Calorie).

respective weight while walking at the speed specified. From a knowledge of the extra oxygen used one may infer an estimate of the energy expended. It is suggested (p. 27) that these are accurate within ±15% for any individual. It is clear that a relation expressing increments in energy as a linear function of increments in speed, and in W, would fit very well. Our notion of tasks performed, n, would in some circumstances be captured quite well by speed.

Again note that we have here comparisons across individuals of given weight and not weight changes for a given individual.

Further, the use of tables of energy expended per minute in certain activities involves the implicit assumption of linearity in n of the function $f(.,.)$. For example [Davidson et al. (1975, p. 24)] suggest driving a truck involves 10–20 kJ/min, ballroom dancing 20–30 kJ/min and coal mining 30–40 kJ/min. Now in any given period an individual will spend a fraction (less than one) of the time in performing the tasks associated with the job. This fraction will, one supposes, vary from person to person and job to job and there may be good reasons for setting it well below 1; for example a lorry driver may be more accident prone if his number of hours is increased. However, it would, presumably, require a similar number of Calories to increase from 6 hours to 8 hours of lorry driving a day as from 12 to 14 hours.

The notion that there are limits to human abilities should of course make us suspicious of an indefinite linear relation between calorific input and work output. There would be little point in pouring 4 millions of Calories down the throat of one man in one day and expecting 1 million Calories of output (assuming $e=1/4$). What then might happen if we attempted to increase output and input indefinitely? The human machine would be unable to accept Calories beyond a certain level. Also at a high level the efficiency of transforming absorbed Calories into usable Calories may deteriorate, so that e would drop from 1/4. Finally, work output itself will have an upper limit, on account of muscle fatigue, so that calories above a certain level could only increase weight. We have not investigated the literature on this point. Perhaps more important in our context the transfer of usable Calories into tasks performed, given by the $f(.,.)$ function may deteriorate. Thus the individual would be doing extra mechanical work but would be achieving rather little.

The detailed investigation of work potential at very high Calorie levels is not really our main concern. For our current purposes it seems that, at constant body weight, extra calorific inputs may be linearly related to extra work output over the range of inputs described by the FAO/WHO for the different levels of activity – see fig. 2. The figure accepts the FAO/WHO requirement for the reference man at 'minimum' activity levels of 2600 Cals/day, and assumes constant body weight.

This discussion of linearity must, however, be qualified in an important way. It is based on the assumption of a fixed method of performing tasks. We have already emphasised, in our discussion of the mark-up of 50% over BMR, the importance of adaption by the individual when inputs are cut back. There is an adjustment in weight and an adjustment in the way in which tasks can be performed. And adjustment can be expected in activities other than those connected with productive work. We discuss the connection of this adaption to the theory in the next subsection when we discuss the step from eq. (1) to the relation or frontier of the theory.

We have so far been examining Calorie requirements by looking at the different components of energy usage. These estimates were constructed primarily by examining the energy consumption of individuals involved in certain activities. Thus we go from activities to Calories required. We now examine evidence from studies which look at the question the other way round. Thus *given* the calorific intake they ask about actual or potential performance. This sense of the question is closer to the spirit of the theory. Two of the studies are from the 1940s and are well-known. The frequency with which these two are cited leads us to suspect that few similar studies exist. This is not surprising since conditions where the calorific intakes can be controlled and performance monitored are rare. There is, however, some work in progress by Viteri and his associates in Guatemala. Their experiments are of substantial importance, well-advanced and will be discussed below.

We have already mentioned the example of the Minnesota experiment by Keys et al. (1950). This study is widely quoted, for example Berg (1973, p. 13), Freedom From Hunger Campaign (1962, table 2), Payne and Dugdale (1975, p. 8), Davidson et al. (1975, p. 40), Young and Scrimshaw (1971). Thirty-two volunteers were hired for 24 weeks and given a diet of 1600 Cals/day. Keys et al. found [see FFHC (1962, table 2)] the results given in table 2.

Table 2
Weight loss and performance.

Percentage of body weight loss	Capacity for prolonged physical work percentage change	Actual work performance percentage change
5	–	−10
10	−10	−20
15	−30	−50
20	−50	−80
30	−80	−90
40	−95	−95
50	−100	−100

In Germany during the Second World War there was a survey of energy expenditure in the major industries [Lehmann et al. (1950)]. Reference is made in Leibenstein (1957, pp. 62–76), Davidson et al. (1975, p. 28), FFHC (1962, table 3), Berg (1973, p. 252), and Sukhatme (1965). They found, for example, the results presented in tables 3(a) and 3(b).

Table 3(a)
Output in coal mine against rations in Ruhr coalfield in Second World War.[a]

Daily calories 'available for work' (over and above 2200)	Output tons	Calories per ton	Body weight
1200	6.7	177	Constant
1600	9.4	169	Loss of 1.2 kg in six weeks
2000	10.8	192	Slow rise

[a]*Source*: FFHC (1962, table 3) from Lehmann et al. (1950).

Table 3(b)
Output in steel works against rations during Second World War.[a]

Year	Daily calories 'available for work' (over and above 2200)	Production of steel, per man per month
1939	1900	122
1940	1600	112
1941	1450	95
1942	1200	83
1943	1120	85
1944	1150	78

[a]*Source*: Sukhatme (1965, table 2.7) from Lehmann et al. (1950).

In both table 3(a) and 3(b) it is clear that the hypothesis of a linear relation between Calories 'available for work' and output per man receives quite strong support. In the examples involved in both tables 2 and 3 we have studies which examine changes in consumption, work and weight for given individuals over time. The examples are, therefore, of particular relevance for eq. (1) – see also the example from prisoner-of-war camps above.

Both the Minnesota and German World War Two studies examined contractions in Calorie intake coupled with reductions in performance. There is, however, a recent study of great importance and relevance to our discussion, by Viteri et al. which examines increments in intake and increases in weight and activities. We are fortunate to have seen a preliminary report on that study and be granted permission to quote [see Viteri (1975)]. We are grateful for their permission and should emphasise that results are still provisional. Published reports are expected shortly.

Two cane-cutting communities in Guatemala 2 km apart were selected. Workers in community 2 received an energy supplement and those in community 1 acted as a control. The head of the family received the supplement in the form of sucrose in a sweetened drink (taken twice daily) which also contained certain vitamins. Workers in community 1 also received drinks which contained the vitamins but a low calorie sweetener was used instead. The additional intake from the drinks in community 2 was 650 Cals/day. It was found that the high-energy supplemented workers cut their intake from home sources from around 2800 Cals/day to 2500 Cals/day.

Viteri (1975, p. 23) concludes:

> The available measurements of total productivity, work intensity and performance in the field indicate that the energy supplemented workers show a consistent tendency towards greater work intensity, energy expenditure and productivity than the control workers belonging to community 1.

Further results are to be reported on changes in family consumption and off-the-job activity. The study provides a good and rare example of the kind of work we believe should be encouraged and we shall return to it briefly when we make some suggestions for further research.

We conclude this subsection by summarizing the conclusions of our examinations of the nutritional literature. One can divide energy usage at constant weight into energy for maintenance and energy for work. The first of these is quantitatively more significant – for the FAO/WHO reference man the two requirements were 2600 and 400 Cals/day at moderate activity levels. It is possible however to arrive at estimates substantially lower than 3000 Cals/day by adjusting the maintenance requirement for a temperature difference between 10°C (FAO/WHO reference) and 25°C (roughly a mean for N. India), lower notions of 'minimum' activity levels, steady diet and lower estimates of BMR. An *extreme* low figure may be around 2000 Cals/day instead of 3000. It is unanimously agreed that *ceteris paribus* lower body weights mean lower requirements. Differences over the maintenance requirement will lead to much larger proportional differences in the residual available for work out of a given diet.

At constant body weight the ability to do work seems to be linearly related to Calories above maintenance over quite a large range if techniques of work stay the same. It seems plausible that at some level of intake significant non-linearities must be present.

When food intake is cut adaption can occur in several ways, a reduction in 'minimum' activity levels and a change in the way in which tasks are performed. 'Unfortunately, experience has shown that human beings can adapt themselves, at a low level of vitality and with their powers impaired to an insufficient ration, without realising that they are underfed' [Gopalan, Rama Sastri, Balsabramanian (1974, p. 9)].

So far, in discussing the interpretation of the relation between productivity and consumption as being due to nutritional factors we have considered only the calorific value of food intake as compared to energy expenditure in doing work. An obvious reason for focussing on this aspect of food consumption is that the relation to work is direct and allows of precise quantification, at least in principle. However, there are other influences at work, one of which deserves mention although we will not be able to say anything precise about it. Everyone knows that there are some people who feel faint and find it hard to concentrate if they miss a regular meal. A possible cause is depletion of the level of blood sugar. Blood sugar level is not necessarily linked to recent food ingestion but in the case of some individuals it seems that the level falls markedly when they fast.

When blood sugar level falls the result is not dissimilar to that which follows a decline in blood oxygen level: the subject feels drowsy and cannot concentrate, reactions are slowed and lethargy results. In the case of a person in this condition the marginal productivity in terms of effective work output of a small quantity of food intake could be very high. Even if blood sugar is an important factor for only one in ten of workers, but supposing that the employer cannot identify who these workers are, it could still be worthwhile to pay higher wages to ensure an adequate level of current food intake. Note that the employer would want to ensure if possible that the extra wages were consumed by his worker during the course of the working day, including ideally breakfast.

All this is very speculative. Very little is known in quantitative terms about blood sugar and food intake and until more is known it will not be possible to make the link to the theory of wages more precise.

We turn now (subsection 2.2) to the consequences of our discussion for the theory described in part I of this paper and (subsection 2.3) to the consequences for estimates of numbers in poverty and for further research.

2.2. *The consequences for the theory*

We must now discuss the connection between eq. (1) and the relation, or frontier, we are trying to identify. This involves a definition of the meaning of that frontier (see section 1 and fig. 1). This is not as simple as might appear at first sight. Leibenstein (1957), Mirrlees (1976) and Stiglitz (1976) merely state in some form or other that the number of efficiency hours produced in a day is an increasing function of the wage. Indeed, this was our procedure in part I of the paper.

It is clear from the Calorie approach of subsection 2.1 that we must consider the relation as a fairly long-run phenomenon. In the short run one can perform work without any food intake by reducing body weight although of course, for stable body weights, on average over time, the energy stored in the body must be replaced. Whether one would wish to reduce body weight rather than do less work is a separate question.

The energy from ingested food is available quite quickly. A graph of available energy from food against time from ingestion of food would show a peak after an hour or so with the majority of energy available within three or four hours [see Garrow (1974, pp. 146–147)]. However, unless energy usage is synchronised with energy availability there will be storage in, or extraction from, the body. It is this role of the body as a store which implies that the relation is not a short-run phenomenon.

A body weight which is on average stable may fluctuate over quite long periods. Davidson et al. (1975, pp. 38–39) quote a careful study (1962) of a woman who had a weekly cycle of losing on average one pound per day on week-days and replacing at weekends. And she was unaware of this until the results were analysed. Haswell (1975) (see section 4) shows in the village she studied in Gambia that there was a yearly cycle in body weight given the agricultural work calendar and availability of food. Given the behaviour of the body as an energy store we must consider the theory, in so far as it is based on energy, as referring to a period longer than a few days and frequently much longer.

Mirrlees (1976), for example, is perfectly clear that he has a long-run relation in mind although this is not always so clear in Rodgers (1975) (see, for example, p. 74 where he claims 'wages on one day effect capacity on the next').

Accepting the relation as a long-run phenomenon we must enquire as to the long-run adjustment hypothesis. An initial candidate might appear to be a given weight. However, this does not appear to be the notion that previous authors had in mind. For example, Mirrlees (1976, p. 20) refers to the 'fairly healthy and well-fed' (and hence more productive) workers. We take it that in this context he also means heavier workers. Leibenstein (195[illegible], pp. 62–75) and Myrdal (1968, p. 1603) do not seem to have been talking about workers of given weight either.

But what should we assume about the long-run weight adjustment? Let us now turn to eq. (1) and examine alternative approaches. Since we are taking the long run we assume that (on average over a few days) ΔW is zero, and thus that weight has settled down to a steady level for given (c, n). Thus we have

$$c = \frac{1}{e} f(n, W) + kW^{\beta}. \tag{2}$$

The assumption of $W = \bar{W}$ independent of (c, n), together with $f(\cdot, \cdot)$ linear in

n, would give the relation shown in fig. 2. Employers would show unambiguous preference for lighter workers since both the fixed cost kW^{β} and the marginal cost would be lower. Further the employer would select a very high number of tasks per worker since his optimum, the minimum cost per task, is given by the tangent from the origin to the relation or frontier (see part I and fig. 1), and thus cannot occur on the linear portion XB. Certainly the former conclusion sounds implausible (see return to this in section 4).

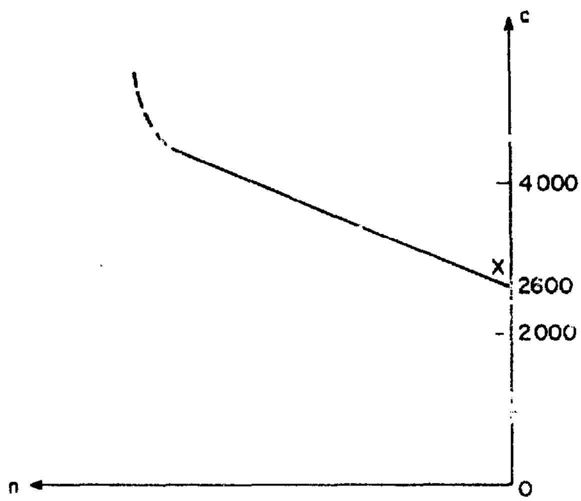

Fig. 2. Calories required as a function of tasks performed for the reference man at constant body weight and with fixed method of performing tasks [c=consumption per day (in Calories), n=number of tasks per day].

Suppose now that we abandon the assumption of given weight $\bar{W}$ and go to a different extreme, namely that given (c, n) the weight adjusts to a long-run equilibrium value determined by (2). But this would seem to imply no relation at all between (c, n). We could pick any (c, n) pair we wished and there would be a long-run equilibrium W. This again is most implausible – very low c for given n would merely imply a low long-run W, even if it happens to be 5 kg.

The point is that a Calorie accounting equation of the form of (1) can be used in two distinct ways. Although the particular functional form might need to be adapted to the particular use, it is after all an identity. We have for the most part, used the equation to estimate Calorie requirements given work output and then, setting $\Delta W = 0$, the right-hand side determines the left-hand side. But one may with equal logic use the equation to determine the change in weight given work output and Calorie input, so that the left-hand side will determine the right-hand side.

The implausibility of the two specifications we have tried so far must lie in their ignoring the notion of strength or physical ability. We think of a person as being too weak to perform a certain task or more than a certain number of tasks. This idea is best captured in terms of a relation between $W(n)$ which would describe the ***minimum*** weight required to achieve a number of tasks n. Indeed many nutritional standards are now related [see, for example, Gopalan and Raghavan (1969)] to weight, height, and other anthropometric measures.[8] This idea of minimum weight $W(n)$ is important to our suggestions for further research and is discussed further in subsections 2.3 and 2.4.

Let us suppose, then that a $W(n)$ function can be defined. Eq. (2) becomes

$$c = \frac{1}{e} f(n, W(n)) + kW(n)^{\beta}. \tag{3}$$

This is now a relation between c and n and we take it to be the definition of ***the*** relation or the frontier of the consumption set. We have discussed β and the $f(.,.)$ function so to determine the shape of the frontier it remains to discuss $W(n)$. It is clear that the function $W(n)$ will vary across individuals and will not be easy to define for any one individual, but it does seem indispensable to the relation we seek. We suppose that W increases with n and $W(0)$ is positive. Empirical information on the function $W(n)$ is provided by table 2 and is shown on the graphs of fig. 3. There are two important points we should note about these data. They depict the con-

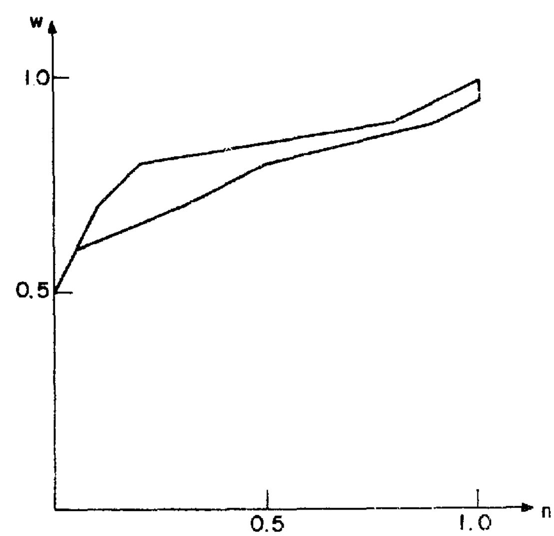

Fig. 3. The relation between weight and performance in the Keys et al. (1950) semi-starvation experiment (w = weight as a proportion of initial weight, n = performance as a proportion of initial performance). The lower line uses the second column of table 2 (capacity for prolonged physical work) and the upper line the third column (actual work performance).

[8]It is obvious in this context that we are not concerned with the problems of obesity, and that one should discuss proteins in the building of muscle.

sequences for work performance of weight *reduction* for heavier individuals, whereas we are primarily concerned with the effect of extra food on the undernourished. Secondly [FFHC (1962, p. 16)] 'the effects of malnutrition in these experiments are much more severe and occur earlier than in chronically undernourished populations. Obviously, the sudden change from a relatively rich North American diet to starvation rations allowed only a partial adaption to the new situation'. Moreover our $W(n)$ function is, in principle, an equilibrium notion in the sense of steady weight. The Minnesota results refer to observations taken while weight was falling. We return to both these qualifications with our suggestions for further research in subsection 2.4. Viteri (1975) does not give sufficient detail to provide a $W(n)$ function but it is recorded that those receiving high-energy supplements put on extra weight as well as achieving higher productivity.

The $W(n)$ curves shown in fig. 3 are at first concave then convex. Over a substantial part of their length they are linear and we should, given the remarks above, expect the linear approximation to improve if the period of adaption is longer.

We can now use (3) to sketch the relation. On the assumption that $\beta=1$, $f(.,.)$ is linear, and $W(n)$ is linear we have a linear relation which would be as in fig. 2 but with a steeper gradient since we have, along the relation, increases in W as a result of the change in n. Given that β may be less than one and that diminishing returns in $f(.,.)$ as function of n may set in, we should be inclined to regard the relation as more likely to be convex although there may be a small concave portion near the vertical axis in accordance with the $W(n)$ relation of fig. 3. Thus we sketch the relation in fig. 4. Further (minor) evidence in favour of a convex curve can be obtained by examining the relation between weight lifting records and weight division. For example the world records for the different weight brackets for the jerk are as presented in table 4. Note, however, that the capacity to lift a heavy weight is not identical to the capacity to engage in prolonged physical effort.

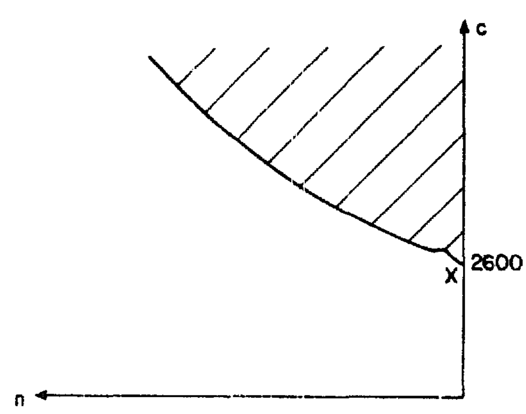

Fig. 4. The relation [c=consumption per day (in Calories), n=number of tasks per day].

Table 4
Weight lifted for competitor against weight limit for competitor (jerk).[a]

Weight limit (kg)	Weight lifted (kg)
52	140
56	151
60	159
67.5	178
75	190
82.5	203
90	214
110	228
110+	241

[a]*Source*: Guinness Book of Records (1974).

Diminishing marginal returns to body weight seem to set in strongly for comparisons across individuals and would, we suppose, be yet more marked for any one individual. The shape drawn in fig. 4 for the $W(n)$ curve must, however, be speculative and we return to this point in subsection 2.4 when we discuss further research.

It should be recalled that $W(n)$ was the *minimum* W for given n. It would not necessarily be the W which the individual would regard as preferable or be 'optimum' in any medical sense. There may also be a maximum W for given n. The consumption set is the area above XD but presumably has an upper boundary. The individual would order (c, n) pairs in the consumption set taking into account the consequent $W(\ )$.

We should emphasise that at higher income levels the assumption that one can confine attention to a two-dimensional consumption set (tasks and food) becomes impossible to sustain since expenditure on food would become less important in the budget. The employer would be justified in assuming that increases in consumption consequent on increases in work would be met by a relatively minor budget adjustment by the employee and would not take 'the relation' into account in setting the wage (see part I).

We note briefly the theoretical consequences of the relation or frontier sketched in fig. 4. The first is that if the consumption set is convex there is no scope for the differential treatment of identical individuals as suggested by Mirrlees (1976). We saw in part I that this result depends crucially on the consumption set being non-convex. Our consumption set (see fig. 4) is the area bounded by the frontier XD and the vertical axis above X. The line OX is *not* included and hence it is a convex set (ignoring the small region close to X). Mirrlees suggested that a family which could not produce enough to survive whilst feeding identical members equally may nevertheless survive by treating identical people unequally. If our specification of the frontier is correct this is not possible. The only solutions are migration, activity in an area or occupation not covered by the model, or death of some members.

The second consequence arises from the possible proximity to linearity. It will be recalled from part I that the employer minimizes cost per task by selecting the point of tangency from 0 to the consumption set (see fig. 1). If the 'close-to-linearity' proposition is correct the employer would select a very high number of tasks per worker, if he were indeed able to choose along the frontier, since his optimum cannot occur on the 'close-to-linear' portion of the frontier. We shall return to this point in section 4 when we discuss simple tests of the theory and in particular (briefly) slavery.

2.3. *Estimates of numbers in poverty*

Our initial purpose in examining estimates of numbers in poverty based on nutritional criteria was to show that there are sufficiently many people with incomes which must imply a low nutritional status to justify the examination of theories of wage determination which focus on the relation between productivity and consumption. We took India as our example and it is not surprising that the number who can be assumed to be at this low level is large. The relation of this finding to the theory is discussed in section 4. We showed in subsection 2.2 that major differences exist over Calorie requirements and we wished to examine the consequences of these differences for estimates of the numbers in poverty. We shall see that the estimates of these numbers are highly sensitive to the specification of Calorie requirements. In subsection 2.4 we go on to ask about the meaning of the statement that a substantial number of people are below minimum levels and to make suggestions for further research.

The calculation of numbers in poverty based on nutritional status proceeds as follows. A nutritional standard is prescribed and a diet, based on local materials, which meets it defined. That diet is then costed and we suppose this yields X Rupees. The proportion θ spent on food by those with low incomes is estimated and the poverty line is then defined as X/θ Rupees. This calculation has been carried out by Bardhan for rural India for 1960–61 and 1968–69 [Bardhan (1973a)] using data from the National Sample Survey. He considers the cost of a 5 item basket – 15 oz cereals, 3 oz pulses, 4 oz milk, 1.5 oz sugar and gur, 1.25 oz of edible oils per day. This is his minimum diet for an average 'Indian adult in moderate activity'. He calculates the cost of this basket at rural prices as Rps. 24.43 per month in 1968–69 (Rps. 11.87 in 1960–61). Assuming the average person to be 0.81 adults he calculates a requirement of Rps. 19.79 per person per month for food (Rps. 9.61 in 1960–61). The figures for food are then translated into figures for total income using the ratio of expenditure on food to total expenditure for the poorest

50% of the rural population. In this way (using data on income distribution) one obtains an estimate of the proportion of the rural population living on incomes inadequate to meet minimum nutritional needs. Bardhan finds this proportion to have risen from somewhat less than 38% in 1960–61 to about 54% in 1968–69.

The calorific value of the basket in Bardhan's budget can be calculated[9] using tables on the nutritive values of Indian foods [Gopalan, Rama Sastri, and Balasubramanian (1974)] as 2386 Calories.

Now suppose that we dropped the Calorie requirement for the reference male (see footnote 8) by about 20% from Bardhan's implicit figure of around 2400 Cals/day to around 2000 Cals/day. It is not our purpose to defend such a figure since we are concerned with demonstrating sensitivity but we note that 2000 Cals/day *could* be defended, for example as follows. Take the FAO/WHO standard figure of 46 Cals/day per kg body weight (FAO/WHO p. 79). Reduce by 10% to allow for the ambient temperature of 25°C [Davidson et al. (1975, p. 32)] thus obtaining 41.4 Cals/day per kg body weight. Specify a standard body weight of 48 kg and we have 2000 Cals/day. 48 seems close to average Indian weights for 20 year old males[10] (our reference man is aged 20–29). Alternatively drop the Calorie requirement by 10% and Bardhan's estimate of prices by 10% to achieve a 20% reduction in required income. Alternatively one could suppose that θ (proportion of income spent on food) was underestimated by 10% so that required income was overestimated by 10%, together with an error in price of 10%. Alternatively one could suppose that the incomes of the rural poor were underestimated by some percentage (and this seems quite possible).

It should be clear from the above that it is possible that either Bardhan's required minimum income was 20% too high or the estimated incomes of the rural poor were 20% too low or a combination of the two giving the same result. Using a 20% reduction in minimum requirements[11] we find that we should have 20% of the population in poverty in 1960–61 rather than

[9]For details of the calculation, see Bliss and Stern (1976). Bardhan omitted (for lack of price figures) 1 oz of ground nut and 6 oz of vegetables from the basket. These would add another 200–300 Calories and bring the total close to the current ICMR recommendations of 2800 for a 55 kg man. Bardhan (1973) refers (p. 249) in the paper to 2700 (although this may be a misprint) Calories and 55 gm of protein and says they are the recommendation of the ICMR. Since 1958 the ICMR has recommended 2800 Cals and 55 gm of protein for a 55 kg man in moderate activity. We take it that Bardhan must be referring to a 55 kg man since it has been standard ICMR practice since 1958 to recommend 1 gm of protein per kg body weight for the reference male [see Gopalan and Narasinga Rao (1974, p. 2)]. However our main point here is not to argue in favour of a particular level but to show sensitivity of numbers in poverty to variations in the level chosen.

[10]Gopalan and Vijaya Raghavan (1969) give the average weight of 19 year old males as 48.1 kg.

[11]We multiplied Bardhan's estimated minimum income for 1960–61 of Rps. 14 per month by 0.8 to obtain an annual income of Rps. 134. By interpolating B.S. Minhas' (1974, p. 68, table 2) we arrive at the 20% quoted.

Bardhan's calculated 38%. Thus a 20% reduction in the 'line' *halves* the number of people below it. With this kind of sensitivity and the uncertainty in all the figures involved in calculating the number in poverty we should suggest that such calculations have rather little value. And we should emphasise that the approach is a common one. We have selected Bardhan's example because it concerns India and rural areas both of which are of particular interest to us. For a series of similar calculation for a large number of poor countries and regions, see Reutlinger and Selowsky (1976). Even though the notion of requirements plays a central role in their analyses the authors subject neither the level nor the meaning of requirements to serious question. We turn to the issues of the measurement of poverty in the next section.

These questions having been raised let it not be forgotten that our calculations do confirm that a large proportion of the population of rural India and, presumably, an even larger proportion of landless labourers (see section 4), must be consuming at rather low Calorie intakes by the standards of only moderate work. The implication is that these labourers must be lighter, or doing less productive work or using less energy outside their productive work than the hypothetical individuals being used to define the standard (and we shall go on to discuss the questions raised by such conclusions in subsection 2.4). It should be emphasised that the figure we used in the example of 2000 Calories is a low one based as it is on an average weight of Indian males of 48 kg. The average includes a large number of the 'undernourished' and this may be inappropriate as a 'target'. Equally, as an average it must be *above* the weight of the least nourished.

Further Bardhan's main purpose was to show that the numbers in poverty increased between 1960–61 and 1968–69 (from 38% to 54% he suggests) and nothing we have said contradicts the assertion that a large increase has taken place.

2.4. *Some questions*

The preceding subsections have raised questions and encountered difficulties which are important for economists and nutritionists. We can summarize the conclusions of this part of our discussion by posing the questions directly.

We set out on an attempt to use the nutritional literature to construct a relation between consumption and productivity and we concentrated on quantity of food, measured through Calories. We saw in subsections 2.1 and 2.2 that one could not really construct the relation at issue without first constructing a relation between weight and ability to work. Thus our question is: 'What are the consequences for an individual, in terms of ability to perform tasks of being a certain weight?' Or: 'What is the minimum weight (if it exists) an individual would require to be to perform a given number of tasks and how does this weight vary with the number of tasks?'

We shall see that a similar question emerges from our discussions in subsection 2.3 of the numbers in poverty according to nutritional standards. We saw that Calorie recommendations depend on weight. The Indian Council of Medical Research, through their National Institute of Nutrition in Hyderabad, issue Calorie recommendations and these numbers form the basis of most of the discussion of nutrition in India. They currently recommend 2800 Calories and 55 gm of protein for a man of 55 kg in moderate work [see Gopalan and Narasinga Rao (1974, p. 2)]. Suppose we carried out an exercise such as that described in subsection 2.3 and deduced that many such males were consuming less than 2800 Cals/day. What then follows? It must be (assuming that our calculations are correct) that these males weigh less than 55 kg, or that their basal metabolic rates are lower, or that there is less activity performed or at a slower rate, than is implicitly assumed. Presumably it is some combination of these effects.

But now we must ask why 55 kg was chosen as the standard weight for recommendations. The average weight of the reference Indian male would appear to be around 48 kg.[12] The ICMR documents recognise this point but say rather little. In the latest recommendations Gopalan and Narasinga Rao (1974, p. 5), when discussing recommendations for children state:

> The low body weights of majority of Indian children are attributable to poor nutritional status. It has also been shown [Taneja (1967)] that the growth potential of Indian children is not different from that of European or American children. Therefore the earlier recommendations of Calorie allowances for normal Indian children based on expected body weights, appear to be reasonable.

But this leaves open the question of the ultimate body weight one supposes. The standard reference man for developed countries weighs 65 kg, but for India weighs 55 kg. These numbers are based on an average healthy weight, a level, which is, we suppose, difficult to define.

We do not wish, and have not the competence, to suggest particular weights for the reference man. Our aim is to emphasize the following point. The calculation of numbers in poverty by nutritional standards involves the assertion that individuals are underweight by certain standards. A policy judgement should be informed as to the *consequences* of being underweight. We are therefore back at the question which arose from subsections 2.1 and 2.2. What are the performance consequences of being 'underweight'?

[12] We have been unable to find an average figure for the reference male (aged 20–39). However the average for 19 year old males is given in Gopalan and Vijaya Raghaven (1969) as 48.1 kg.

The above question raises suggestions for further research and for indices of poverty and welfare. We suggest that there should be studies of the relations between Calories, weight and performance which are different in two important respects from the main experiment hitherto [Keys et al. (1950)] which put North America volunteers on a low level diet for 24 weeks. The studies should be *longer* term and look at the consequences for performance of higher level diets which lead to *increases* in weight.[13] Thus in a less developed country batches of volunteers of various weights could be recruited and their performance on different diets could be examined, both as equilibrium weight is approached and after that equilibrium (for given diet and activity level) has been established. Presumably it is less hard to find volunteers, in a less developed country, for experiments which increase weight than those which reduce it. The work of Viteri (1975) described in subsection 2.1 provides a good example of the kind of research which is needed. The problems of research design would be substantial. Apparatus for measurement can be disconcerting, the incentives faced by participants must be analysed, energy expended across the whole range of daily activities should be measured and so on. Viteri has shown that such problems need not nullify these experiments.

Such studies would have consequences for welfare measures. We have suggested that calculations of numbers in poverty based on nutritional requirements are of dubious value. Presumably at incomes so low that physical capabilities can suffer a main policy concern is the state of those physical capabilities. Thus it would follow that, where possible, one should measure these directly. Nutritionists do carry out related measures (for instance height to weight ratios). The kind of research we have proposed would inform the use of these measures in discussing poverty and suggest further indices. Such measures should then be used as alternatives to the types of calculations of the incidence of poverty which were described and criticized in subsection 2.3.

There is a risk that much of what we have said may be misunderstood so we should conclude this section by emphasizing the following. We have been concerned with one aspect of nutritional status only, Calorie intake. It is clear that there are many others of substantial importance. Secondly, our statement that estimates of numbers in poverty based on nutritional standards are of little is *not* rooted in a lack of concern for the poor. The distribution of incomes and the extent of poverty are important issues which demand a serious response. The calculation of the numbers below some arbitrary level is inadequate. We want to know about the numbers with various dietary intakes and the consequences for individual welfare of

[13] We suppose that some important nutritional effects are very long term, in particular those operating across generations. At this point we have in mind something between 24 weeks and a generation.

consuming at different levels. Similarly, the assertion that we are insufficiently informed as to the performance consequence of being underweight does not imply that the consequences are unimportant. We should expect the research we recommend to show the opposite.

3. The problems of formal econometric testing

We concluded section 2 with suggestions for an experimental approach to the relation. Now economists are used to encountering the inability to experiment, and indeed, econometrics has been developed primarily to cope with the problem of statistical inference in economic models where experiment is not possible. It is therefore natural to ask whether an econometric exercise, based on the kinds of data that are available, or could be easily available, would be able to identify the relation that we seek.

Let us now see how such an exercise might proceed. We take it that the question is posed for agriculture and that time series would be more complicated than cross-section because of the long periods required for the former. One would need then a cross-section of farms with data on output, labour, input, other inputs (land, capital and so on), and the consumption of workers. We consider two cases. The first where all labour is hired and the second where all labour comes from the family. With more than one type of labour matters are, of course, more difficult.

Where all labour, l, is hired we require to estimate

$$y = F(l, c, x), \tag{4}$$

where c is consumption of workers, y is output and x a vector of other factors influencing production. One must specify the functional form of $F(\ )$. If one supposed that one could work in terms of efficiency units, as postulated in the relation (see fig. 1 and also part I of this paper) one could rewrite (4) as

$$y = F^0(lh(c), x), \qquad (4\ )$$

and the problem becomes one of functional form for $F^0(\ )$ and $h(\ )$. Presumably crude specifications could be tried such as $h(c)$ a cubic in c (to allow the shape shown in fig. 1) and F^0 of some standard form.

One would need to suppose that farmers are unaware of the relation since otherwise one would observe only points round T on the curve (see fig. 1). Further one would need a reasonable spread of wage rates since a major interest in the exercise is to try to identify *changes in curvature*. Thus there is the frequent econometric problem that the wider the spread of wages the less reasonable is it to suppose that the underlying structure is similar across the sample, and in particular that we are dealing with similar individuals. In any case one would not be able to observe wages around zero.

The best Indian data available would appear to be from the Farm Management Studies. However the data are, inevitably, crude, and even a simple production function analysis puts credulity under some strain,[14] and the more delicate attempt involved in (4') would, we suggest, be like rearranging the deck chairs on the Titanic.

The problems become worse when one turns to the case of the family farm with no hired labour. For then one has a second equation representing the consumption function:

$$c=H(y, l, z), \tag{5}$$

where z is a vector of factors influencing consumption. Thus we have a simultaneous equations problem and one would have to suppose x, z, and the functional forms were such as to allow identification. In specifying the consumption function $H(\ )$ we include l since hours of work would, no doubt, affect consumption. But there is the difficult complication that the family may have some partial knowledge of eq. (4). Thus the functional form or parameters of (4) would affect (5). We have not attempted to carry out the estimation in either of the cases presented here or in the more complicated, and more natural, mixed case of part hired and part family workers. We should not therefore be dogmatic. We suggest, however, that an attempt to tease something out of the data, which is much more delicate than the crude production function, with all the problems attendant to that simple exercise, would not be justified.

4. Simple tests of the predictions of the theory

We examine, in this section, how some simple predictions of the theory fare when confronted with evidence on agricultural wages together with some suggestive evidence on the relation itself. We concentrate on evidence from India and we are particularly influenced by our stay in the village of Palanpur in West U.P. in the winter season of 1974–75.

We saw in our discussion of subsection 2.3 that a substantial proportion of the rural population in India can be assumed to be malnourished and the proportion of landless labourers who are malnourished will far exceed the proportion for the rural population as a whole. Dandekar and Rath (1971, pp. 14–15) calculate (using a 'minimum' Calorie level of 2250 Cals/day per capita) that for 1956–57 57% of agricultural labour households were below the minimum.

[14]See Bharadwaj (1975) or Junankar (1976). Further they do not contain data on consumption of workers. One would presumably need to use wages instead.

Evidence that malnutrition is commonplace in India is only weak supporting evidence for the Mirrlees–Stiglitz model. It shows that conditions are such that the effect of consumption on productivity might be playing an important role in influencing wages; it does not show that wages are in fact being importantly influenced.

We saw in subsection 2.2 that the theory could only be sensibly considered as applying to longer-term contracts, certainly more than a few days Thus one way of testing the theory would be to compare the wages of those to whom the theory could be thought to apply, permanent labourers, and to those where it is unlikely to apply, that is casual labourers. The theory would lead one to expect that permanent labourers would consume at a higher level since permanency allows employers to capture the long-term benefits of giving extra food. Further we suggested in subsection 2.2 that since the relation may be linear over a substantial part of its range we should expect an employer, with a permanent contract who is setting his wage in accordance with the theory, to pay high wages and demand heavy work. Further in a situation where malnutrition is prevalent we should expect a high incidence of long-term labour contracts.

For 1956–57 we are able to make such a comparison. Bardhan[15] has provided us with the following calculation from the evidence collected by the Second Agricultural Labour Enquiry in India 1956–57: he calculates that the annual per capita consumer expenditure for a casual agricultural labour household was Rps. 136.5 and for permanent (or 'attached' in the Report) it was Rps. 149.9. The difference therefore has the direction predicted and seems roughly the 'right' magnitude for the theory.[16]

Less favourable to the theory is that permanent labour contracts seem relatively unusual. In Palanpur in 1974–75 out of a village population of 750 there was only one such case. For further evidence see for example the Indian Government (Ministry of Agriculture) annual publication *Agricultural Wages in India*. There are, of course, less formal long-term arrangements [see, for example, Bell (1975)] which may be overlooked by those who gather official statistics. Rodgers (1975, p. 69) discussing the Kosi region of Bihar found that tying was a common practice. Nevertheless the incidence does seem very much less than would be predicted by the theory, for many parts of India and, certainly in the part of West U.P. where we were working.

[15]We are very grateful to P.K. Bardhan for supplying these figures, in addition to many other helpful comments.

[16]The ICMR [Gopalan and Narasinga Rao (1974, p. 2)] suggest 3900 Cals/day for heavy work as opposed to 2800 Cals/day for moderate activity for a reference Indian male weight 55 kg. The increase is 39%. A permanent labourer would be unlikely to do heavy work throughout the year. Further someone doing heavier work could consume a higher proportion of his income and could command a higher proportion of food inside the family. Thus one would expect to find a percentage difference in income between permanent and casual workers of very much less than 39%.

Perhaps the most striking implication of the theory is that wages will tend to be constant for workers with similar consumption backgrounds notwithstanding variations in demand for labour and various factors affecting productivity such as cooperating inputs and season. We saw in part I of the paper that the efficiency wage theory when applied to workers of different consumption backgrounds concludes in both the competitive and non-competitive cases that wages are such that the marginal worker receives his efficiency wage. If the marginal worker in different regions is typically a *landless labourer* we would expect similar wages. In the light of this implication it is worth asking how and according to what patterns wages do vary in India across different districts and across different seasons.

The available data are mostly contained in the official publication *Agricultural Wages in India*. The data are voluminous. Wage rates are given for each month, for several districts within each state and often for two or three villages from one district. Moreover in many cases wage rates are provided for many different types of agricultural field labour, for example, ploughing is distinguished from sowing, and so on. Hence a summary of what the data show would be formidably difficult and probably pointless. What concerns us here is that the picture that emerges is one of great, even bewildering, diversity. Not only do wages vary across states, as everyone would expect, they also vary spectacularly, often by a factor of 2, between neighbouring districts, even between neighbouring villages. There is also variation with season but this is less marked. If there is any stability it is for one observation point over the year although even in this case there is some variation.[17]

It may well be that the official wage data are highly inaccurate – the manner in which they are collected does not lead one to have great confidence in them – but it is hard on the other hand to believe that they show diversity where in fact there is uniformity. If anything the opposite would be expected. Of course all our inferences here are very uncertain. We do not know the consumption background of the agricultural workers. We do not know where scarcities of labour that are highly local may be negating a model solidly based on the efficiency wage. We do not know when a factor such as the unionization of agricultural labour – which would have to be taken into account in considering e.g. Kerala – is operating. Nevertheless in the winter season of 1974–75 when we were in West U.P. the daily wage in our village was 4–5 Rps. per day whereas in the Punjab the daily rate for agricultural labour was 8–9 Rps. and in Bihar 2–3 Rps.[18] It is hard to believe that the efficiency wage theory could account for these differences.

It may be thought that the seasonal stability of wages provides support for

[17]Rao (1972) has suggested that the seasonal stability may be spurious.

[18]These are rough figures collected as responses to our own questions. We are not referring to payments for harvesting which is usually on the basis of a 5% share.

the theory. Indeed Rodgers (1975) gives evidence of stability in the villages he studied in the Kosi region of Bihar. However the theory would predict stability of the *real* wage. Thus seasonal stability of money wages is evidence against the assertion that wages are, throughout the year, as determined in the theory if prices have big seasonal movements. We saw in subsection 2.1 that small changes in the level of work activity do not produce large proportional variations in the Calorie requirements, thus one cannot use the theory together with changes in the type of task over the season to account for fluctuations in the real wage. It is quite possible of course that the theory could be relevant for some periods in the year, when say work was on a steady basis, but not for others where it was more casual.

In the village of Palanpur in the winter season of 1974–75 the price of wheat (the staple cereal) increased by 20% from October 1974 to January 1975 while the wage moved downward slightly, from around 5 Rps. to 4 Rps.[19] The slack labour time (February or March) in our village coincided, and this is presumably a general pattern, with a time when the wheat price was high being roughly nine months from the last harvest. This produced a low real wage. Such a pattern is common elsewhere in North India, is easily explicable by simple supply and demand and is inconsistent with the theory.

The theory would predict the payment of kind wages, particularly meals, where possible in an attempt to raise the proportion spent on food. Rodgers (1975) and Bell (1975), for example, found kind wages to be important in Bihar. Rodgers (1975) shows that the wages provided in the form of meals on the job constitute around half the wage. We consulted 30 farmers[20] in Palanpur in 1974–75 as to why they usually paid 4 Rupees plus meal per day rather than 5 Rupees, (the meal was valued at approximately 1 Rupee). The large majority of those who offered a reason said that it was to save working time since the worker would go home for his meal if it were not provided by the employer, whereas if it were provided the meal would be eaten in the field. Only one farmer mentioned in addition to the reason given that it might make the worker perform better.

P.K. Bardhan has discussed a notable observation which might seem at first dramatically in accord with the non-competitive version theory.[21] He notes from the 25th round of the NSS Survey that for 11 states out of 14 the average daily wage received by pure landless labourers is in excess of that received by small-holders. This is exactly what the non-competitive version of the Mirrlees–Stiglitz model would lead one to expect if labourers with some land are interpreted as workers with a positive consumption background. Unfortunately it is not clear, as usual, that the cause is the factors isolated by the theory. For example it may be that employers will pay higher wages to

[19]We are adding the value of a meal (around 1 Rp.) into the wage.
[20]These were the farmers of our sample wheat plots [see Bliss and Stern (1979)].
[21]Bardhan (1973b).

workers whom they can get just when they want them and these will be the landless labourers.[22] Note too that the differences in wages, if they are to support the model, should occur in the same village and that the competitive version of the model predicts the opposite ranking (see part I of this paper).

Our last pieces of evidence are from outside India[23] and first we give two examples of the applicability of the theory where there is permanency and close control of labour. They come from South Africa and from slavery. Feeding of workers in South Africa has been a matter of some attention. After surveying studies showing its advantages in industry, Keyter (1962, p. 15) concludes 'from these measurements it appears that the most immediately obvious benefit of feeding to the employer is a reduction in sickness, absenteeism and accidents'.

The most permanent form of labour of all is a slave. Hence it is interesting to note the observation of Fogel and Engerman[24] that slaves on the plantations of the ante-bellum South had an average daily Calorie intake 10% higher than that for the rest of the population (4185 per day in 1860 as opposed to 3741 in 1879). They go on to argue that slave farms were much more efficient than free farms:

> In other words even after one adjusts for the fact that on large plantations slaves generally worked on better land than free southern farmers and had more equipment, large plantations were still some 34% more efficient than free farms.[25]

The authors remark further that 'the higher rate of utilization of labour capacity was partly due to what was, by the usual standards of farmers, an extraordinary intensity of labour'.

Berg (1973, pp. 13–14) provides a further example. He quotes from Freyre (1946) that 'in north-east Brazil sugar plantation owners soon learned that the energy of the African in their service, when abused or subjected to strain paid less dividends than when it was well conserved ... . The Negro slave in Brazil appears ... to have been, with all his alimentary deficiencies the best-nourished element in society'.

Obviously evidence from slave system in the ante-bellum South and 19th century Brazil is not evidence for India in the twentieth century (and it should be recorded that the empirical findings of both studies are controversial). It does, however, provide rather striking support for the twin assertions that the relation must be considered as a long-term notion and

[22]See Bardhan (1973b) for further discussion. He does not discuss efficiency wages as a possible explanation of the phenomenon but does offer a list of other possible reasons.

[23]Turnham (1971, pp. 80–88) provides a valuable discussion of nutrition and poverty and some useful references.

[24]Fogel and Engerman (1974, pp. 112–113).

[25]Fogel and Engerman (1974, p. 210).

that it is of form that would lead one to suppose that, if it were relevant, work levels would be high.

Finally Haswell (1975) has presented some evidence from peasant farming in the village of Genieri in Gambia in 1947–48. She draws attention (pp. 38–39) in the decline in body weight during the 'pre-harvest hunger' in November–December. The harvest was over in March and the supply of food together with relative inactivity caused a recovery in body weights. The season of heaviest work was July through October and this coincided with relatively low intake.

She goes on to say (p. 45): 'Persistently poor feeding and lowered resistance to disease adversely affected the performance of some farmers', and (p. 102): 'Calorie expenditure during the agricultural season on actual farm work was dependant upon the extent to which villages were prevented by shortage of food from adjusting intake to requirements'. Thus we have an example of the body acting as a store of energy in the short term and on apparent effect of low food intake on performance.

Let us now summarize the conclusions of the results of our tests of the simple predictions of the theory. Many of the local labour markets in India are conducted on a day to day basis and the wages paid in different markets vary a great deal. For such markets we conclude that the efficiency wage theory has no strong relevance. The large variations in the level of real wages for similar types of labour across quite small regions and over the year which we found in India also undermine the applicability of the theory which, we saw in part I, gave a presumption in favour of uniformity.

Comparisons of relative wages for different kinds of labour do however, lend some support to the theory. We found a difference in incomes in favour of permanent labourers relative to casual labourers and landless relative to landed labourers.

It is, however, unreasonable to suppose that one theory could apply across all the labour markets in a country as large and diverse as India. We would suggest that in the area of West U.P. in which we were working the standard supply and demand explanation of traditional economic theory seems to operate quite well. However, Rodgers (1975) does give some arguments (not all of them convincing as we have seen) for supposing that in the poorer Kosi region of Bihar the efficiency wage theory has more relevance. And no discussion of agricultural wages in Kerala or Tamil Nadu could ignore the influence of the agricultural trade unions.

5. Concluding remarks

We have examined the nutritional evidence on the connection between productivity and consumption. Our main conclusions were as follows. The relation or frontier discussed in the theory does seem to be a real phenomenon with some of the features used by previous writers. The quantity of energy required for 'minimum' daily requirements is large relative to that required for work so that small changes in estimates of the former lead to large changes in estimates of the residual left for work out of a given diet.

There is a big range of possible estimates for Calorie requirements. This leads to very large variations of estimates of numbers on poverty in India if these are based on nutritional standards. Concern with the physical well-being of the population should lead us to measures of welfare which focus directly on physical attributes such as weight and longevity. The Calorie approach is not particularly reliable.

The relation as based on energy is long term since over periods of at least a few days the body acts as a store. Over a substantial range of tasks the energy requirements seem to be linearly related to the number of tasks. This implies that an employer choosing his wage according to the theory would specify a high work load.

Further experimental research is urgently needed since the relation may be of substantial importance for policy purposes. We suggest in particular a long-term closely monitored study of the effect of higher feeding and different work loads on previously malnourished groups.

Formal econometric modelling and testing of the theory is possible but given our present state of knowledge of possible functional relations and the absence of a large body of published data of the detail and reliability required we concluded that the exercise is not at present worth the effort.

We suggested that less formal analysis of the Indian data could provide some tentative conclusions. With many labour markets on a day to day basis and with wide differences in wages for apparently similar work the theory does not have general applicability. We found examples, however, where the relative wages for different kinds of work were in the direction suggested by the theory. For example landless labourers who are paid more than landed and permanent labourers more than casual. We emphasized that it is where labour contracts are more permanent, that the theory is more convincing. The high food intake and intensive work amongst slaves in 19th century USA and Brazil provide extreme examples.

We should like to conclude by emphasizing our suggestions for further empirical research. The problem of identifying the relation is tractable, if difficult of great potential importance for policy and has been largely ignored by applied economists. We quoted the example of the work of Viteri to show that studies of the relation between food intake and performance can be fruitful. A second and related suggestion is for a series of careful studies to provide anthropometric indicators of work potential. We should not expect one single measure to be reliable and research studies should be of a broad selection of both indicators and communities. Some such indicators (for example weight to height ratios) are already used but we need additional ones and guidance on their interpretation. Measures of these kinds should replace the comparatively useless calculations of numbers in poverty which involve calorific standards and deficits.

These are not questions for idle intellectual curiosity but are of pressing practical importance. Given this importance and the possibilities for research the comparative absence of knowledge and lack of current active research is both regrettable and worrying.

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