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Education, Income and Nutrition: An Exploration of Pakistani Data *

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Abstract: In this paper, we report results on the determinants of nutritional status as proxied by indecis of height-for-age and weight-for-age. The data is taken from the Pakistan Demographic and Health Survey carried out in 1990/1991 by the *National Institute of Population Studies*. We relate our results to previous work and emphasize the methodological innovations.

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1 Introduction

If we think of *nutrition* as a commodity with its own market price, we can appeal to the standard theory of the consumer and directly deduce the result that the compensated price elasticity of demand for nutrition will not be positive. This is to say, that with a rise in the price of nutrition, the *representative* consumer's demand for nutrition does not rise, and will typically fall, provided the consumer's real purchasing power, suitably measured, is kept constant. If the consumer's commodity space has dimension 2, which is to say that all commodities other than nutrition are lumped into one composite commodity, then the theory will also yield the result that a rise in the price of this composite commodity will not lead to a fall in the consumer's demand for nutrition, and will typically lead to its rise, again with the proviso that real purchasing power is kept constant. However, if we do not force the theory into the straitjacket of a two-commodity world, then with the same conditionalities, the effect on the demand for nutrition of a rise in the price of any other commodity, say education, will be identical, in quantitative terms no less, than the effect on the demand for education of a rise in the price of nutrition! As is well understood, the theory yields no predictions as to the effect of changes in income on the demand for nutrition. We have available to us merely a classification: if demand rises with income, nutrition will be considered a *normal* commodity; if it falls, an *inferior* commodity, also termed a *Giffen good*. The theoretical conception even allows for the fact that changes in income may have no effect on the representative consumer's demand for nutrition. However, by an extension of language that is not totally warranted, it is conventional to assume that nutrition is a *normal* commodity, and if the estimates of the income elasticities, presumably compensated, of the demand for nutrition are negative, there is a puzzle to be explained.

The standard theory of the consumer then gives a coherent framework within which to relate the three conceptual categories to which this paper is addressed: education, income and nutrition. In a nutshell, the theory makes us conceive of nutrition and education as competing for the budgetary resources, and income as defining these resources. However, it is far more productive to use the standard theory in a negative way; namely to bring out why it and its basic categories are inapplicable to the problem under study, rather than as a framework to motivate and interpret the data and the empirical estimates based on it. Put this way, the naiveté of the conception becomes

its strength. It forces us to face up to the issues of the commodity space – what kind of commodities are nutrition and education? Do they have market prices? Is there a representative consumer? and if not, are there aggregation theorems that can be used? How is income defined? and the related question as to the time frame that we have in mind. In this paper, we shall use this standard theory as an introductory backdrop for investigating the interrelationship between education, income and nutrition in precisely this negative way. There have been exciting advances in the last fifteen years in the study of nutrition, both at a conceptual and at an empirical level, and with the case of the less developed countries LDC's in the foreground. What is particularly distinctive, and encouraging, about the work is the interdisciplinary dialogue between economists and experts in nutrition science. This has led to increasing sophistication and redefinitions of the most elementary and basic categories, and it is only natural that this has led to re-evaluation of the existing empirical work. Thus already more than ten years ago, T. N. Srinivasan was writing

> The much publicized estimates of the global extent of hunger and undernutrition by international agencies such as the FAO and the World Bank have very little scientific basis. The methodology underlying such estimates ... is faulty for several reasons.[1]

The rest of this paper proceeds as follows. In Section 2, we present an extension of the standard theory that grapples to an extent with the question of the "commodification" of education – the Chicago-Columbia household production model. Such a model also allows a reinterpretation of the relationship between education and nutrition. In Section 3, we introduce the salient ideas of two nutritionists – Sukhatme and Seckler – and use these ideas in Section 4, to present a reconceptualization of the economic approach to nutrition worked out by Srinivasan and Dasgupta-Ray. With these theoretical antecedents, we present in Section 5 a description of the data source that we explore. Section 6 is devoted to discussion of the statistical methodology, in particular, our use of "factor analysis" to construct variables that serve as formalizations of income. Section 7 is devoted to a presentation of the results, and Section 8 to a summary and conclusions.

[1]Srinivasan (1983; p. 101).

2 The Household Production Model

It is of course a standard observation that nutrition, like health and education, is not a commodity whose characteristics are universally known and transacted in impersonal markets relative to which the actions of any agent, representative or otherwise, are negligible. In short, they are not commodities which satisfy assumptions which ground the results on the desirability of markets – the so-called theorems of welfare economics. They are, at best, commodities in the sense that they can be "manufactured" within the household using both marketed and non-marketed inputs. At this level then, tastes, or more technically preferences, are defined on commodities such as nutrition, for which there are no market prices in the conventional sense, but to which implicit prices or costs can be adduced as a result of inputs purchased in the market, as well as on the basis of "shadow prices" which can be attached to the non-priced inputs such as the value of time.

Thus, analogous to the Heckscher-Ohlin-Samuelson trade model, the consumer solves a grand programming problem in which he has given as parameters, market prices and endowments of non-marketed inputs, and determines the unknown allocations of these inputs, their "shadow prices", the market transactions and the amounts and types of the final commodities produced. The amount of "nutrition" that is consumed by the representative consumer is also produced by him as a consequence of food purchased in the market, along with other marketed commodities; and as a consequence of time, the wife's and/or the husband's, and other non-marketed commodities such as the quality of the house, particularly basic considerations such as refrigeration and sanitation; and finally as a consequence of the abilities and education of the couple. The framework emphasizes simultaneity – the "shadow price" of the wife's time, especially if she is not a participant in the labour force, is determined along with a whole array of human resource variables including those that pertain to health, education, fertility and nutrition.

It goes without saying that the framework can also be criticized on much the same ground as the naive theory exposited in the introduction. The question of appropriate measures of income remain, as does the issue of the correct time frame. Furthermore, the definition of a commodity has simply been pushed one step back – it is not clear, for example, whether it is *nutrition* rather than *food* that enters the domain of a consumer's

preferences? However, inspite of such a straightforward modification, there is already a not so subtle shift of emphasis. For example, education not only competes for the household's resources, it delineates the technology that is available to the household as a whole. More importantly, it is education that may hold the key as to whether households consume nutrition or whether their primary focus is on food, with tastes for this food being formed over time as a consequence of cultural and community variables.[2] Put differently, it is the "educated household" that is sensitive to issues of "roughage" and Vitamin C in the diet, and may be primarily motivated by these characteristics in their food or nutrition shopping and production. In this framework, education now has at least three separate components: an input that is purchased in the market from institutions of learning such as schools and colleges, an output that is manufactured as a consequence of these inputs as well as other non-marketed inputs such as parent's education and community norms, and finally a commodity whose endowment is given and non-marketed and whose "shadow price" is determined in equilibrium.

In addition, the household production model now forces us to confront additional questions: the substitution of the *representative household* for the *representative consumer* begs the question of how these preferences are being determined? Are there aggregation theorems? When we speak of education, whose education do we have in mind? In sum, this juxtaposition of consumption and production clearly yields a richer framework within which to discuss and pose issues, but at the cost of precise restrictions that can be incorporated in empirical estimation.[3] Thus, a change in income, properly measured, yields income effects of the kind emphasized by the standard theory, but also leads to changes in the derived demand for household inputs. This flexibility in interpretation, and in the rationalization of empirical estimates, is evident even in a cursory examination of the literature.

In their influential study, Behrman-Deolalikar (1987) group 120 foods into six food aggregates consisting of nine nutrients. In line with earlier studies, they find the income elasticity of the six food aggregates to be close to one (0.8 or higher), whereas for the nine nutrients, the income elasticities are not significantly different from zero.[4] This discrepancy goes directly to the issue of whether it is food or nutrition that is

[2]On this see Mintz (1994).

[3]See Pollak-Wachter (19??).

[4]Behrman (1991; p. 118) refer to other recent studiesthat "report similar results with food expenditure elasticities about twice the magnitude of calorie elastiocities."

being optimized for by the representative household. Behrman (1991; p. 118) seesm to suggest that it is the former.

> The reason may be that at the margin people are concerned much more with food attributes other than calories and these food attributes may not be associated with high caloric content. Examples include noncalorie nutrients, food texture, status value, appearance, taste, aroma, preparation and composition. Many of these characteristics are not measured in most socioeconomic data sets and therefore their relevance is difficult to assess systematically.

In an insightful piece, Schiff-Valdés (1990) discuss how sensitive the policy recommendations are to the "definition of nutrition used in [the] studies, [and] suggest that the definitions used ... are unsatisfactory." In terms of the household production model, what is being suggested by Schiff-Valdés is that the specification of the household technology in terms of a constant nutrient-to-food conversion factor α is too simplistic, and that it is *nutrition status*, N, that ought to be the relevant dependent variable, where

$$N = N(n, q, p, k, H; S, A, L) \text{ and } H = H(N, p, k, m; S, A, L), \tag{1}$$

N and H are nutrition and health status respectively; n and q are vectors of inputs of nutrients and of non-nutrient food attributes respectively, p and k vectors of privately and publicly provided inputs respectively, m a vector of current and lagged values of additional inputs affecting health, and finally, S, A and L are gender, age and location respectively. The derivatives, and hence the elasticities, of both functions with respect to the first four variables are assumed positive.

Of course, the question remains as to how N and H are measured, but there are at least two points that emerge from the Schiff-Valdés specification. First, the simultaneity between health and nutrition leads to a variety of possibilities concerning elasticities. In particular, "the impact of income on nutrition may be significant, even though nutrient intake remains unchanged or increases only slightly."[5] Second, the inclusion of k and m brings to the fore the relevance of *public inputs* available to the community. Schiff-Valdés explicitly mention in this context "sewerage, potable water,

[5]See Equation 7 in Schiff-Valdés.

electricity, nutritional information, information on hygiene [and] medical and other health-related services." In the work reported in the sequel, we shall be concerned with both of these points. However, it is worth noting that the larger number of variables that a framework connects and includes in its purview, the more diluted will be the emphasis on a particular variable. One can quickly reduce oneself to the situtaion where "everything is more or less relevant and depends on everything else!" The primary emphasis of this study is on the effects of income and education on nutrition and we have to confirm or confront views such as the following.

> Serious and extensive nutritional deficiencies occur in virtually all developing countries, though they are worst in low income countries ... Malnutrition is largely a reflection of poverty: people do not have income for food. The most efficient long-term policies are those that raise the income of the poor.[6]

It is clear that we have to face up to the question of what is nutrition.

3 The Views of Nutritionists

In the several studies on nutrition in LDCs,[7] there is a clear implication, typified by the above quote from a World Bank Report, that nutritional intake of large proportions of the populations of LDCs is less than desired.[8] Thus a 1986 World Bank Report reveals that "34 percent of the population of developing countries, or 730 million people, did not have sufficient energy intakes in their diets to have an active working life, and the diets of nearly half of them were so deficient in energy that they ran the risk of stunted growth and serious health problems." The Food and Agriculture Organization (FAO) "provides two alternative estimates of the proportion of undernourished population in developing market economies for 1979-1981; one of 15 percent (335 million) and one of 23 per cent (494 million)."[9] Thus, under any of the establishment views, this is a problem of major proportions, and leads naturally into the definition of the

[6] World Bank Development Report (1980; p. 59).

[7] See Behrman (1991) and his references.

[8] Thus Behrman-Wolfe (1984) begin their article with the statement that "Widespread nutrition is thought to be a serious problem for much of the developing world."

[9] Both the World Bank and the FAO estimates are also quoted in Srinivasan (1992).

terms *undernourished* and *malnourished,* and thereby to the standards implicit in these definitions.

A poosible working definition is given in an FAO Report.

> Undernutrition is a pathological state arising from the intake of an inadequate amount of food, and hence of calories, over a considerable period of time, with reduced body weight as its principal manifestation.[10]

Srinivasan makes a distinction between *undernutrion* and *malnutrition,* and in his 1992 paper, is "concerned only with the problem of defining adequacy of energy intake and of measuring the extent of undernutrition in the sense of the proportion of the population having inadequate energy intake." He is careful to emphasize that "the broader and more inclusive concept of malnutrition will not be addressed." Osmani (1992; p. 121) also attaches importance to the distinction.

> 'Undernutrition' refers to the phenomenon in energy intake. The broader phenomenon of 'malnutrition' [refers] to the deficiency of some or all of different kinds of nutrients.

There have been two related debates over the last decade as to what constitutes *adequate* nutrition, and they have been associated with P. V. Sukhatme and David Seckler, both of whom have argued that the current standards are too high![11] Needless to say, this has had tremendous implications for both policy and theory – in terms of policy, an alternative standard can cut down the proportion of the undernourished population from half to 15-20 percent; and in terms of theory, the assertion forces one to confront the basic question as to the criteria and standards, both of health and nutrition, as well the processes on the basis of which these standards have been derived. Sukhatme is concerned with intake-based measurements of undernutrition, and with studies that compare observed calorie-intake with a norm of average calorie requirement. Of course the interesting question concerns precisely this requirement – what is it, how is it arrived at, and to whom does it pertain? Seckler, on the other hand, is concerned with anthropometric measures of undernutrition among children, and with studies that compare measures of actual body size with a desirable standard.

[10] FAO 1982; as quoted in Srinivasan (1983).

[11] See Harper (1985) and his references for a historical sketch of the evolution of nutritional standards.

Again the interesting question pertains to the standard – what is it, how is it arrived at, and to whom does it pertain?

In his overview, Osmani (1992) presents for each debate an establishment (mainstream) view and a heretic view. The former can be characterized in terms of the *fixed requirements model* – for every individual, a single number, whereas the heretic view emphasizes intra-individual variation, and its contention is that the mainstream has "the theory wrong – the theory of how the human body responds to nutritional environment."[12] However, in these two bodies of work, aspects of biological response that are discussed are quite different from each other – Sukhatme focusses on the costless variation in the efficiency of energy utilization whereas Seckler focusses on the variation in the rate of growth of body size.

What is the starting point for both sets of debates is that the the human body has both internal and external functions, and that expenditure of energy is made up of three components – basal metabolic rate, external phsical activity, and thermic effect of food. Thus it stands to reason that expenditure of energy depends on age, sex, body weight, body composition, and the level of physical activity, and we are directly led into the question of the process of energy metabolism:

food $\longrightarrow$ intermediate stores $\longrightarrow$ high-energy bonds $\longrightarrow$ work

Efficiency of energy metabolism – transformations. – work is constant but expenditure of energy varies. In the establishment view, the efficiency of energy utilization is fixed for an individual with given physiological characteristics. Also the work remains fixed. Hence energy expenditure is constant – this is the fixed requirement. Heretics accept that work is fixed[13] but contest that efficiency of energy utilization remains constant.[14]

Osmani asks the question: "How much energy is required to maintain an equilibrium?" and replies, "The answer obviously is the intake associated with the lowest possible equilibrium level." The obvious question now concerns the definition of an equilibrium. The laws of thermodynamics ensure energy balance – intake equals expenditure – but this identity has to be translated into a hypothesis pertining to substantive variables. In aprticular, the definition of equilibrium must confront the

[12]See Osmani (1992; p. 121).

[13]But even here, there may be some dissenting views – both external and internal work can vary; see Footnote 4 in Osmani (1992).

[14]The expert views here seem to be of Hegsted (1974) and Sims (1976).

question of the time frame – at each instant or over an individual's life-cycle? Once defined, does it exist? How many equilibria are there? How does the body choose among these. What are the dynamic processes in terms of which one can inmquire into the stability of these equilibria? The phrase"lowest possible equilibrium level" suggests some criterion and slo constraints relative to which an equilibrium is being chosen. One of these criteria, or constraint, is clearly weight, but is there room for a vectorial conception? Why should the focus be only on weight? Do "susceptibility to desease," or simply "survival" furnish other possible criteria? If the latter, what kind of survival have we in mind?

A FAO/WHO/UNU 1985 document finesses these questions by simply requiring that "Nutrition related functional capabilities can be maintained at desirable levels." More specifically,

> The energy requirement of an individual is that level of energy intake from food which will balance energy expenditure when the individual has a body-size and composition and level of physical activity consistent with long term good health and which allow for the maintenance of economically necessary and socially desirable physical activity.

It is worth contrasting the notion of the "efficiency of energy utilization" with the conventional economic notion of "technological efficiency." A production plan is technologically efficient if thre is no other technological plan that vectorially dominates it. This has as a necessary implication that one cannot obtain more of an output without using more inputs and/or sacrificing other outputs. There is a corresponding implication concerning an input commodity, but what is important is that the definition does not allow for changes in the technological capacity itself. However, it is clear that if this analogy is to be pursued in any depth, we have to consider the underlying ideas in somewhat more detail.

3.1 Sukhatme

To appreciate the underlying reasoning, we have to turn to the theory of *autoregulatory homeostasis*. One can begin with the simple question as to how body weight has remained within such a narrow range in environments when there are no constraints on intake. A variety of answers have been suggested, and they have have ranged

from appetite control, variation in energy expenditure, internal feedback mechanisms to dietary-induced thermogenesis.[15] Sukhatme and his co-workers[16] endorse the latter but go further to assert that energy of efficiency utilization varies over time in an autocorrelated manner, and with a constant level of activity, the intake will also vary over time in an autocorrelated manner. Formally, if I_t denotes the intake on any day consumed by an unconstrained healthy person maintaining body weight and engaged in fixed activity, then the basic hypothesis states that the temporal pattern of intakes can be illustrated by the following equation:

$$I_t = \rho I_{t-1} + \epsilon_t, \tag{2}$$

where ρ is the coefficient of first order correlation and ϵ is the random error. Under this hypothesis, variation in intake arises solely from variation in energy, and therefore, with constant body weight and activity, the mean of the error must stand for the level of intake and expenditure based on average efficiency. This is *stochastic regulation,* and it emphaiszes the idea that body weight is regulated over time through stochastic variation of efficiency.

> The idea of auto regulation consists in the fact that, although efficiency varies from day to day, it does so in an auto regulated manner so as to keep average intake equal to average expenditure.[17]

This hypothesis of autocorrelation in intake has profound consequences for both theory and policy. It should be noted that the hypotheis involves the postulate of the error term ϵ being drawn from a stationary distribution. This implies an equilibrium distribution with a constant mean and variance. Thus, with a large number of observations over time, one can estimate the mean of this distribution. However, the variance of the mean does not decline to zero as the period over which the mean is taken is increased.[18] However, what is of crucial significance is that the emphasis has shifted from inter- to intra-individual variation.

[15]See Osmani (1992; p. 128).

[16]See Sukhatme-Margen as referenced in Osmani (1992).

[17]See Osmani (1992; p. 129).

[18]From the 1970 data of Edholm et al. Sukhatme has estimated that the coefficient of variation of weekly mean is in the order of 12-15 percent; see Osmani (1992; p. 129).

> This is the basis of Sukhatme's contention that intra-individual (or phonotypic) variation overwhelms any truly inter-individual (or genotypic) variation. In physiological terms, it means that, if requirements are found to vary in a population of reference-type individuals, it is not because each has a fixed but mutually different level of metabolic efficiency (as assumed in the establishment view), but because each happens to occupy a different point in the range of intra-individual variation at the time of inquiry.[19]

This alternative viewpoint shifts a static analysis to a dynamic one. "In actual practice, the 'requirement standard' is first postulated for a hypothetical 'reference person' who is defined as an adult male of a given age living in a given environment. The requirement of all the real people (or, more precisely, all *types* of people) are then obtained by applying conversion factors." There are two ways of calculating the requirements: the 'intake-based approach' versus the 'factorial approach,' but under both, we have a group of healthy individuals to iron out genotypic variation. The establishment view simply demands that $m < \mu$ as a criterion for undernourished. With the alternative viewpoint, μ is an estimate of the intra-individual requirement over the long term.

With this emphasis on phenotypic variation as the relevant backdrop, Sukhatme asks the simple but basic question as to what distinguishes healthy people from unhealthy ones? Given that dietary intakes vary. How to distinguish between healthy and unhealthy variation?

> As it happens, 95 per cent of the healthy people [in Edholm's data] can be expected to have intake within the range $\mu \pm 2\sigma$.

Thus Sukhatme reinterprets the average intake over a sample of individuals, and emphasizes not the average value but the lower end of the 'range of homeostasis' which is reduced to $\mu - 2\sigma$.

> By sheer reconceptualization of the requirement norm, the magnitude of poverty was cut down at a stroke from an enormous 46 percent to a morte innocuous looking 15-20 percent.[20]

[19]See Osmani (1992; p. 130).
[20]See Osmani (1992; p. 127).

It goes without saying that Sukhatme's basic hypothesis is intellectually provocative and important, but it is difficult for an economist to judge the extent to which it has been accepted by nutrition scientists. Thus, in his 1990 textbook, Willett emphasis both inter- and intra-individual variation. In his Chapter 3, he presents data on inter-individual variation, and is well aware of issues of correlation in individual diets, as is evident form some of his figures reproduced below.

> A basic assumption underlying the analytic methods described previously is that the within-person component of variation is random, that is, for one person, the deviation from their long-term average intake on one day is independent from their deviation on the previous day. This asumption has been questioned by El Lozy (1983), who pointed out that humans are subject to homeostatic mechanisms (*probably both physiologic and cultural*) such that overeating on 1 day is likely to be followed by undereating the next. Morgan and colleagues (1987) formally explored the assumption of independence for consecutive days of dietatry intake of energy, fat, vitamin A, and iron among 100 women. They found auto-correlations for many subjects. *A simple pattern, however, was not evident as persons with positive auto-correlations were similar in number to those with negative auto-correlations.* [Furthermore,] those with higher mean intakes have greater within person variation.[21]

However, in his Chapter 12 on the correction for the measurement errors, Willett builds on inter-individual varaition; see his Figure 12.1 reproduced below. In their chapter on energy requirements, Devlin-Horton (1990) write,

> Although there are large interindividual differences in energy requirements, much of the variance can be accounted for by FFM [fat-free mass], age, sex and the level of physical activity. Genetic factors also appear to play an important role.[22]

There is also the issue that the theory of autoregulation itself may have to be discredited[23]

[21]See Willett (1990; p. 43), emphasis are mine.
[22]See Brown (1990; p. 5).
[23]Also see Osmani (1992; Footnote 20) and his references.

Osmani (1992; Appendix) has attempted to provide a microfoundation for Sukhatme's hypothesis of auto-correlation. By its very nature, such an exercise must be rooted in physiological processes concerning which economists do not have especial expertise. Accordingly, we shall proceed with the basic law as postulated by Sukhatme but note Osmani's basic criticism. This is simply the observation even though the average intake of "healthy" individuals, their health agreed upon as a result of some exogenous criteria, may lie with the range of $\mu \pm 2\sigma$, this does not imply that all those whose intakes lie with this range are "healthy"! In particular, external socioeconomic constraints may lead individuals in a household to be below μ but above $\mu - 2\sigma$ in the long-run. Such individuals are not taking their average requirements in the long run, and therefore are undernourished! More succinctly, healthy and unhealthy individuals lie within the range of homeostasis! As Osmani states bluntly,

> The mistake lies basically ... in an elementary confusion between 'necessity' and 'sufficiency' ... a logical error in thinking that a necessary condition for being a healthy person caould be used as a sufficient condition for identifying healthy people.[24]

Note that this criticism is logically distinct from those that assume a purely statistical derivation of this criterion. One of these argues that the criterion of a cut-off point of $\mu \pm 2\sigma$ has been decided on a value judgement as to the weight one should give to Type 1 and Type 2 errors, and hence berates a reprehensible value judgement. It is also distinct from the Dandekar-Srinivasan critique based on statistical hypothesis testing – the extent to which $\overline{m}$ falls below μ. "The usual staistical procedure is to assume that the average intake $\overline{m}$ is in fact equal to μ, and to reject the hypothesis only if the probability of its being correct is very low. Now the probability of its being correct will be as low as 5 per cent or less if m happens to be below 'μ minus two standard deviations' (assuming that intake is normaliy distributed." Sukhatme is not concerned with tests of statistical hypotheses, he is simply looking for a distinguishing feature of healthy people.

Our discussion so far has revolved on what Osmani terms the was Mark I rationale for Sukhatme's view. We now turn to Mark II rationale which offers yet another interpretation of the sample mean $\overline{m}$. Under this interpretation, Sukhatme starts with the given that

[24]See Osmani (1992; p. 133-134).

> a point is reached in the intake of food below which BMR [basic metabolic rate] gets depressed and the body is forced to part with its fat in favour of the vital need to maintain body heat. This is the point of minimum physiological requirement or clinical undernutrition.[25]

At this point the body adapts to this changed food intake by changing the efficiency of energy utilization. Again, there is no one requirement for the reference person, but more importantly, these considerations lead one to ask what is *adaptation?* and to distinguish between genotypic and phenotypic adaptation. The latter involving changes in body size or composition, physical activity and efficiency of energy utilization of a single healthy individual over his or her life-cycle. Choice of these mechanisms based on costs and benefits, but the question is the criteria in terms of which these costs and benefits are to be meassured. The objective function is vectorial – *functional capabilities.*

> Sukhatme proposes that variation in efficiency offers an avenue for costless adaptation to low food intake (up to a point).

Now $\mu \overset{+}{-} 2\sigma$ can be described as a *range of adaptation* rather than as a *range of autoregulation.* Thus under either the Mark 1 or the Mark 2 interpretations of Sukhatme's work, one simply replaces a point measure by a range. However, under the former, it is a range within which the intake of a healthy unconstrained person can be expected to lie, whereas under the latter it is a range within which anyone can costlessly adapt. Now the question is whether there is a theorem asserting that these ranges must be equal, or at the very least, does autoregulation imply adaptation?

> It is apparently the autoregressive mechanism in daily expenditure in maintaining bodyweight which enables a man to adapt his requirement to intakes without affecting the net energy needed for maintenance and physical activity.[26]

Both phenomena are characterized by a common mechanism: namely, variation in the efficiency of energy utilization. However the qualitative nature is not the same.

[25] Sukhatme (1982; p. 38. Quoted in Osmani (1992; p. 137).
[26] Sukhatme (1982; p. 38), quoted in Osmani (1992; p. 137).

> In autoregulation, efficiency varies in a spontaneous manner and intake merely follows suit, whereas adaptation is by definition a phenomenon in which variation in efficiency is induced by prior variation in intake.[27]

It is worth emphasizing that the line of causation is completely reversed as bewteen the Mark 1 and 2 variations. Under the former interpretation, it is a spontaneous variations in energy utilization whereas it is induced under the latter.

Sukhatme's work consciously or otherwise draws on the literature on protien requirements. There is a whole history here on how the standard was decided upon, as well as independent evidence for energy efficiency adaptation.[28] Of course, here as elsewhere, the *ceteris paribus* assumption can be criticised – similar activities are not really similar on account of differences in liesure activities. There is also the two questions which have been at the background throughttout our discussion; namely, measurement errors, (ii) low intakes being particulrly erroneous, and how to distinguish genotypic from phenotypic adaptation. The fact is that Sukhatme's findings on Edholm's data are not relevant to these questions, even though we have known since Neumann (1902) that human efficiency of energy utilization can adapt to a wide range of intake.[29] In conclusion, we may note that criticisms based on formalizing adaptation solely in terms of body size, such as those of Gopalan's, may not be entirely on the mark since the precise argument of Sukhatme has been in terms of a given body size (and activity). The misinterpretation may be due to Sukhatme's synthesis of his views with those of Seckler to present a grand vision of what he calls 'the process view of nutrition.' We turn to these.

3.2 Seckler

If Sukhatme's work can be characterized as pertaining to nutritional intake, Seckler's pertains to nutritional outcomes as formalized by anthropocentric measurements such as weight for age, height for age and weight for height.[30] The last is a measure of *wasting* and the second of *stunting* – the first may reflect both. The establishment view goes under the heading of *genetic potential theory,* and in its most simplistic version, it deems

[27]Osmani (1992; p. 138).
[28]See Chapters 5 and 58 in Brown (1990).
[29]As is well known, this is what Neumann termed *luxusconsumption.*
[30]See Waterlow (1972).

anything less than full genetic potential inadequate nutrition. In terms of the practice of determining standards, the measurements of children in developed countries are taken as the relevant norms. The heretic view emphasizes that measures to overcome "undernutrition" are not aspiring to some normative target but to the prevention of functional impairment.

It is this view that Seckler shrapens and focusses. His "small but healthy" SBH hypotheis makes the simple observation that a small body can avoid functional disabilities.

> Though rate of growth remains one of the most useful of all indecis of public health and economic well-being in developing and heterogenously developed countries, it must not be thought that bigger, or faster, is necessarily better. From an ecological point of view, smallness has advantages.[31]

Seckler defines SBH as MMM (mild to moderate malnutrion) and "it is clear from [his] writings that the domain of SBH was meant to be confined to the case of pure 'stunting' unaccompanied by 'wasting.'

> About 90 per cent of all the malnutrition found in these countries involved people with low height for age *but with the proper weight for height ratio'*. [Is] there anything wrong with these small people other than their smallness?[32]

Thus, Seckler's is a much tighter statement than his critics take it to be – in fact the difference bewteen 'stunting' and 'wasting' is a crucial one. The former represents depletion of body tissue whereas the latter refers to slower rate of new tissue adoption – thus two distinct biochemical processes whose functional consequences need not be the same. Seckler simply goes a step further to argue that moderate stunting is not harmful at all. If level of nutrition is not consistent with normal body weight at the genetically permissible height, then equilibrium will have to be achieved by depleting body tissue (wasting) in order to supply additional energy.

> There are no impairments because this range represents an adaptive response of body size to adverse conditions *in order to avoid these impairments*.[33]

[31] Tanner 1978; see Osmani (1992; p. 144).
[32] Seckler (1980), emphasis in the original; as quoted in Osmani (1992; p. 145.
[33] Seckler (1980), emphasis i . the original; as quoted in Osmani (1992; p. 146).

Note that Seckler is nowhere asserting, *pace* Gopalar, that good health translates into a small body size, but that a small body size does not necessarily mean bad health – the operative word is *but*. However, the question does remain as to why 'stunting' is costless in terms of some functional objectives? Indeed, as Payne forcefully argues, the original view that full genetic potential maximizes *all* functions can and ought to be questioned. In particular, there may be a cost in terms of longevity.

> It is reasonable to believe that evolution through natural selection has given rise to some built-in system of priorities, ... it is quite another thing to believe that these priorities are those that we might choose.[34]

What is being questioned is not necessarily the self-optimiizing capacity of the human body, but rather "What the body chooses for itself is not necessarily what we as scientists should accept as best for the body."[35] There is vectorial optimization involved, but one has to avoid the other extreme and hpold the view that full genetic potential is necessarily a concomitant of obesity. Put another way, nobody suggests that we should attain our full genetic potential for accumulating fat.

There are at least possible directions that one can proceed at this stage. The first is primarily methodlogical: we consider elementary but basic questions as to what one means by *genetic potential,* and *long-term good health.* The aords have to be translated into their observational and empirical counterparts, and hypotheses framed keeping in mind questions of of falsifiability. The other direction is to consider the functions themselves. Osmani picks out four: (i) immunocompetence, (ii) reproductive efficiency, (iii) work capacity and productivity, (iv) cognitive development. It is worth taking a brief look at each.

immunocompetence can be studied at two levels: epidemiological studies on mortality and morbidity, and clinical studies of impairments. There is plethora of studies but they suffer from two weaknesses: first, they do not pertain to MMM which is at issue here, and second, the constancy of other variables, particularly those indicating wastage is not assumed. It is natural to ask why regression analysis is not used. Nevertheless, Martorell-Ho (1984) find no evidence that poor nutritional status, as measured by anthropometric indicators, is associated with greater incidence of malnutrition. There does appear to exist an association with severity of infection, but here

[34]Payne-Cutler (1984); as quoted in Osmani (1992; p. 147).
[35]See Osmani (1992: p. 147).

'wasting' is the relevant index. "The findings of Reddy et al.would seem to indicate that no part of the immune system is visibly impaired in the case of pure moderate stunting," and this is also corroborated by Bhaskaram et al. (1980).[36]

As regards reproductive efficiency is concerned, there seems to be current an informal hypothesis that "shorter women produce more vulnerable babies." This is derived as a consequence of two antecedent facts: shorter women have low birthweight babies and latter have higher risk of mortality. The interesting question relates to the the phsiological processes and their theoretical basis, but economists are very much out of water here. In any case, both effects may be caused by socioeconomic factors, and in the absence of theory, this mayn simply be another case of "correlation implies causation."

For physical work capacity (PCW), body size is the most important determinant of the maximal volume of oxygen uptake, $VO_2(\max)$, which is an indicator of the maximal amount of energy that can be liberated by skeletel muscles. The important question here is obviously the following.

> What is wrong if stunting leads to a lowering of the ceiling that is never reached in real life anyway?[37]

One answer is given by Spurr (1983, 1984) whose basic observation is that in heavy physical work, everyone expends energy at the maximal sustainable rate – 40 percent of $VO_2(\max)$ but *energy costs per unit of task* is the same for everyone. Since shorter men have lower $VO_2(\max)$, this leads to the conclusion that they will do less work. Osmani questions the assumption on energy costs by decomposing *energy costs per unit of task* into energy cost of basal metabolism and the energy cost of the work itself. He concedes that both depend on body size, but questions the assumption that smaller men do have less stamina. The question reduces to the empirical evidence, both indirect and direct. As regards the former, there are studies which relate productivity to $VO_2(\max)$, and since smaller men have lower $VO_2(\max)$, we have our result. But the first could be true and the second a consequence of residual factors. In direct studies, as of Spurr and Satyanarayana, it is shown that $VO_2(\max)$, height and body fat are all significantly related to productivity. However, it clear that one has to go beyond simple corrlelation.

[36]As summarized in Osmani (1992; p. 150).
[37]See Osmani (192; p. 153).

Finally, as regards cognitive development, there is a positive correlation between height and mental development. This can be summrized by the slogan "big is smart." The analytical scheme seems to be as follows:

$$\text{nutrition} \longrightarrow \text{activity} \longrightarrow \text{stimulus} \longrightarrow \text{cognitive development.}$$

The ragument reduces to physiological versus environmental influences, but it should be borne in mind that nutrition and external stimulus are not independent factors. There is also the question of making sure that one is screening the sample for acute and severe malnutrition.

In summary, one can quote Osmani:

> While I have concluded that that the current scientific evidence does not support the hypothesis of costless adaptation in the efficiency of energy utilization, I cannot claim that the hypothesis has been refuted either.[38]

4 Towards a Synthesis

We have presented two different professional approaches to the question of the determinants of nutrition – the first emphasized choice and socioeconomic variables like income and education, whereas the second is primarily concerned with physiological processes. However, it bears emphasis that the two are not mutually exclusive but rather complementary which gain from each other. Thus, there is clearly room for a synthetic treatment, and in this section we briefly consider two pioneering efforts – those of Dasgupta-Ray and of T. N. Srinivasan.

Dasgupta-Ray (1986, 1987) begin with a link between food intake and work capacity, and attempt "to provide a rigorous theory that links involuntary unemployment to the incidence of malnutrition." They present a theoretical model in which there are a continuum of agents and both malnutrition and unemployment are endogenously determined. The theorems proved by Dasgupta-Ray are not our concern here – what needs to be emphasized is that their model is a static[39] general equilibrium one, and

[38]See Osmani (1992; p. 158.

[39]Dasgupta-Ray (1986) admit that the "link between nutrition and work capacity is a most complex one and on reading some of the literature one detects that passions among analysts run deep. A simple timrless model in this area will be found otiose even by some who find timeless models of normal production theory readily palatable."

that it takes as one of its basic ingredients the relationship shown in the Figure 2. This relationship goes back to Liebenstein in the late fifties, and has been recently studied by a variety of authors.[40] What is of additional relevance is that the Dasgupta-Ray model assumes a particular standard for malnutrition and goes on from there.

> For our purpose a precise definition of malnutrition is not required, even for the model economy under study. But for concreteness we are going to choose ... the consumption level at which marginal labour power equals average labour power as the cut-off consumption level below which a person will be said to be undernourished. Nothing of analytical consequence depends on this choice – all we need, for our purpose, is the assumption that the reservation wage of a *landless* person is one at which a person is undernourished.[41]

Srinivasan makes a serious effort to grapple with dynamics and with the importance of time as brought out in the debates between nutritionists. Health and well-being relate to the lifetime of the individual and not just at an arbitrary point in time. He is also sensitive to the fact that for progress in our understanding, questions as to the correct "units of observation, duration of observation and objects of observation" will have to be satisfactorily answered. More specifically, he draws the relevance of the "error correction" models of economic time series for describing energy balance regulation. At the same time, he is clear that "if we measure physical activity in units of time spent in performing that activity will depend on how intensively that activity is performed, which may depend *not only on the state of health of the individual but also on incentives.*[42]

> In designing public policy intervention, it is essential to keep in mind the fact that intakes and activities of individuals, in particular children and dependent adults, are largely determined by household decisions regarding consumption, participation in the labour force, choice of occupation, etc.[43]

Accordingly, Srinivasan uses the vocabulary of stochastic dynamics to provide operational definitions of *nutritional stress* and *adaptation*. Familiar concepts of the

[40] A partial listing includes Myrdal, Bliss, Stern, Streufert, Mirrlees and Khan.
[41] See Dasgupta-Ray (1986; 1018).
[42] See Srinivasan (1992; p. 102).
[43] See Srinivasan (1992; p. 117).

existence of a steady state distribution, and the convergence of varaibles of interest to these distributions as well as the response of these distributions to cahnges in the underlying parameters, is used with lucidity to give insight into the various concepts emphasized by Sukhatme, Seckler and others. Thus, the distinction between a lack of equilibrium, as in *nutritional stress*, and an unsatisfactory equilibrium is stressed. Already in 1981, Srinivasan had introduced the distinction between a *regulatory* and an *adaptive* mechanism, the first for "*moderate variations* in intakes with no change in weight or activity," and the second, for adjustments to "*sustained* levels of too low or too high intakes through changes in bodily functions and activity."

As regards errors of measurement, Srinivasan singles out two problems -- satisfactory proxies, and aggregation.[44] What is clear is that "Most of the literature on the measurement and extent of the severity of undernutrition ignores homeostasis (and hence intra-individual variation in intakes),"[45] and that "adequacy [has to be] defined pragmatically rather than in terms of some pseudo-scientific norm for energy intakes."[46]

In summary, the following conclusion seems to emerge as regards the efficacy of income based policies for reducing undernutrition.

> From a long-run perspective, it would appear that rapid economic development that succeeds in lifting the poor out of their poverty, rather than food subsidies or nutritional supplements, is the surest way of eradicating undernutrion.[47]

5 The Data Base

The data on which these analysis are based were collected as part of the Pakistan Demographic and Health Survey (PDHS) of 1990/1991. The survey elicited information on fertility, nuptiality, family size preferences, knowledge and use of family planning, potential demand for contraception, the level of unwanted fertility, infant and child mortality, breast feeding and food supplementation practices, maternal care, child nu-

[44]On this, also see the excellent discussion in Willett (1990; Chapter 12) and Brown (1990; Chapters 48 and 49).

[45]See Srinivasan (1992; p. 105).

[46]See Srinivasan (1983).

[47]See Srinivasan (1992; p. 120).

trition and health, immunization and child morbidity (PDHS 1990/91, p. 9). These data were also meant to provide a basis for comparison with similar data from earlier surveys such as the Pakistan Fertility Survey of 1975 and the Pakistan Contraceptive Prevalence Survey of 1984-85.

The Pakistan Demographic and Health Survey (PDHS) was conducted by the National Institute of Population Studies in collaboration with the Federal Bureau of Statistics on behalf of the Government of Pakistan and the Demographic and Health Surveys IRD/Macro International Inc. of USA (that does similar surveys all over the world) and was funded by the United States Agency for International Aid (USAID) and the Government of Pakistan.

A sample of 8019 households, called secondary sampling units (SSU's) was selected for coverage under this survey from 408 sample areas called primary sampling units (PSU's). These primary sampling units were drawn from the Federal Bureau of Statistics Masters Sample of 7420 primary sampling units in the country. The universe for this sample, consisted of all urban and rural areas of the 4 provinces of Pakistan as defined in the 1981 population census; excluding the federally administered tribal areas, military restricted areas, the districts of Kohistan, Chitral and Malakand, and protected areas of the North West Frontier Province. The population of these excluded areas consists of about 4 percent of the total population. A two stage stratified sample design was adopted for the survey.

For the survey the PSU's were selected from each urban stratum with probability proportional to the number of households and for each rural stratum with probability proportional to the population enumerated in the 1981 census. A fixed number of households (SSU's) were selected systematically with equal probability using a random start and a sampling interval. This interval was 18 SSU's (households) per each PSU in the urban domains in the four provinces and in the rural domain of the Punjab province, and 25 households from each PSU in the rural domain of the remaining provinces. The Pakistan Demographic and Health Survey methodology did not allow for the substitution of households in case of non-response. From the selected households a systematic subsample of 1 in 3 households was chosen for inclusion of the husbands' sample. The husbands of eligible women in these households were considered for interview provided they had slept in the household the night before the interview.

The sample was designed to produce reliable estimates of the population and

health indicators separately for Karachi and for urban and rural areas of Punjab, Sind, NWFP and Baluchistan. The target of 8019 ever married women in the age group 15-49 years was based on the assumption of 1.1 eligible women per household with a non response rate of 10 percent. In general, the sample size was considered adequate and sufficiently representative of the population to provide reliable estimates for the country as a whole, for urban areas, and for rural areas and for the provinces. However, for smaller groups, the sampling errors were generally larger.

In this survey, three types of questionnaires were used: the household questionnaire, the women's questionnaire and husbands' questionnaire. While the household questionnaire was used basically to list all the actual residents of the sample household; it was also used to elicit information on the household itself, such as, on its source of water, type of sanitation facilities, and type of construction and ownership of durable household assets. The husbands' questionnaire on the other hand, was based on a subset of questions from the women's questionnaire with particular emphasis on family planning, marriage and family size preferences.

The field work for the survey was started in 1990 and completed in May 1991. The actual data entry and processing was done at the National Institute of Population Studies in Islamabad. This data entry was started in the first week of January 1991 and completed by July 1991. Of the target sample of 8019 households, 7404 households were actually contacted. Of these, 97 percent were successfully interviewed. This response rate varied from about 92 percent in Baluchistan to 99 percent in the NWFP. However, while the response rate for the households was high, the actual number of eligible women successfully interviewed was only 96 percent. This was due largely to the fact that the number of women per household assumed to be eligible in the identification of the target were higher than those actually found in the household when the contact was made. Additionally, only 77 percent of the eligible husbands could be successfully interviewed. This was due largely to the absence of the eligible husbands from the home despite repeated visits. Such lack of response was most noticeable in Sind.

6 Statistical Methodology

Factor analysis is a statistical technique used to identify a relatively small number of factors that can be used to represent relationships among sets of many inter-related variables.

For our study we have considered following 13 inter-related household level variables: Type of toilet facilities, Whether the dwelling has electricity, Whether the household own's a radio, TV, fridge, room-cooler, washing machine, water pump, bicycle, motorcycle, car-van-tractor, The main material used on outer walls and on the roof of the dwelling.

The mathematical model for factor analysis appears similar to a multiple regression equation. Each variable is expressed as a linear combination of factors that are not actually observed. For example H5(Type of toilet) might be expressed as

$$H5 = a(\text{factor } 1) + b(\text{factor } 2) + c(\text{factor } 3) + .. + U_{H5}$$

where factor 1, 2, 3.. are the common factors i.e. they are not single independent variables but are lables for a group of variables that constitute the factors. U is the unique factor i.e. unique in explaining the variations in H5. Usually, the factors useful for characterizing a set of variables are not known in advance but are determined by factor analysis.

The factors are inferred from the observed variables & can be estimated as linear combination of the variables for e.g

$$\text{Factor } 1 = C_1(H5) + C_2(H6h7\$01) + \ldots\ldots C_{12}H9 + C_{13}H10.$$

where C's are coefficients.

It is possible that all 13 variables contribute to factor 1, but we hope only a subset of variables characterize factor 1, as indicated by their large factor score coefficients.

The total variation explained by each factor is listed in the column labelled eigenvalue. We have selected factors whose eigenvalue are greater than 1, to be used in the model as per usual practise.

Factor	Eigenvalue	% of Var	Cum %
1	4.89134	37.6	37.6
2	1.31153	10.1	47.7

The next column contains the percentage of the total variation attributable to each factor. For e.g linear combination formed by factor 1 has variance of 4.89134 which is 37.6 per cent of the total variance. Almost 50 per cent of the total variation is attributable to the 2 factors. Thus, a model with 2 factors may be adequate to represent the data.

The proportion of variance accounted for by the common factors, or the <u>communality</u> of a variable, is given below ;

Variable	Communality
Type of toilet	.63725
Own electricity	.57107
Own radio	.26332
Own TV	.61194
Own fridge	.64043
Own room-cooler	.53646
Own washing machine	.62173
Own water pump	.36494
Own bicycle	.08297
Own motorcycle	.34691
Own Car-Van-Tractor	.39345
Main material outer walls	.54554
Main material of roof	.58687

This implies 63.725 % of the variation in type of toilet is explained by the two common factors. Communality can take values ranging from 0 to 1. If communality=0 then common factors explain none of the variation in the model and if communality=1 then common factors explain all the variation in the model. Clearly if there were n variables and n factors then communality would equal 1. Uniqueness of variable, measured by U's, equals 1 - communality.

Both factors are correlated with many variables. Since, goal of factor analysis is to identify factors that are substantially meaningful, the rotation factor matrix of factor analysis attempts to transform intial matrix into one that is easier to interpret.

Rotated Factor Matrix:

	FACTOR 1	FACTOR 2
Type of toilet	.76595	.22486
Own electricity	.75531	.02410
Main material outer walls	.72887	.11951
Main material roof	.70800	.29260
Own TV	.66369	.41406
Own radio	.40722	.31223
Own bicycle	.28450	.04503
Own room-cooler	.11515	.72332
Own fridge	.44006	.66841
Own washing machine	.47333	.63063
Own car-van-tractor	-.03277	.62640
Own motorcycle	.14836	.56999
Own water pump	.22917	.55894

One can see that that the first 7 variables weigh heavily on factor 1 and latter 6 on factor 2. Factor 1 may thus be interpreted as variable measuring " Index of housing quality" and factor 2 " Index of asset ownership".

Rotation changes factor matrix. It does not affect communalities and per cent of total variation explained by factor matrix.

This paper is based on the methodology adopted by Alderman, Harold and Garcia, Marito in their paper "Food Security and Health Security: Explaining the levels of nutritional Status in Pakistan" (October 1992). The focus of the paper is to study the response of malnutrition to family resources, assets, community level investments, lagged investment - in the form of no. of vaccination, place of birth, length of breastfeeding etc. - in the children under consideration.

The paper also considers the impact and role of maternal education on child's nutritional outcome. This question has been previously raised and studied by a no. of nutritionists and economists. Strauss, Thomas and Herriques found mother's education and literacy level to play a significant role in determining the height and weight of her children in both rural and urban sectors of Northeast Brazil. This was found to be conditional on household income after controlling for intercommunity heterogeneity. Barrera, Albino also found strong positive correlation between maternal education and child's height-for-age scores. Higher the level of education of the mother higher was the z-scores. Both papers, however, emphasis the need for controlling for physical environment. Infrastructural and sanitation facilities have a large impact on the factors determining nutritional status of the children in the community. Perceiving the importance of infrastructural facilities in governing the z-scores two factors have been created for each household representing the "quality of housing"

and "asset holding" of the household.

The production function approach has been used to address the following question : Role of morbidity in explaining child's height and weight. It evaluates the degree to which the differences in the two factors, mother's education, immunization, vaccination, health and other related factors contribute to the nutritional status of the children.

The Study "Food Security and Health Security: Explaining the levels of Nutritional Status in Pakistan" by Harold Alderman and Marito Garcia uses a production function approach to ask whether the nutritional status of children in rural communities in Pakistan is responsive to changes in household food availability at the margin. It evaluates the role of morbidity in explaining children's weights and heights and degree to which household income accounts for differences in observed nutritional status and the degree to which other factors such as education and public health contribute to the nutritional outcome.

The model is based on standard Beckerian model of household utility where utility is derived both from purchased and home produced goods. Household utility is a function of consumption of n goods (G_n) and the health of its members (H_i).

$$U = U(G_n, H_i)$$

Technology that produces child health is described in terms of j inputs which do not directly influence utility (Y_j) and atleast one input also contributes to the utility of the household (G_1).

$$H_i = \Gamma(Y_i, G_1, \mu_i)$$

where i denotes individual specific health endowments which are exogenous with respect to current inputs. Given exogenous income (I) and prices (P), demand functions for goods and inputs are defined.

$$G, Y = f(I, P, \mu_i)$$

The study model the effects of community factors and role of such outcomes in the production of anthropometric measures of nutrition to circumvent the problem of individual heterogeneity which can result in biased outcomes.

The presumed error structure of the estimating equations for nutrition production and for input demand, using a middle ground between the fixed effects approach and approach which specifies the community characteristics completely, are as follows:

$$H_{vi} = Y_{vi}\alpha + \omega_{Hv} + \mu_{Hvi}$$

$$Y_{vi} = X_{vi}\delta + Z_v T + \omega_{Yv} + \mu_{Yvi}$$

where

v : village or community.

: unobservable community characteristics which influence health production and input demand.

X : observable mean of household characteristics

The analysis suggested that in rural pakistan, where 70% of the population live, child nutrition responds strongly at the margin to health inputs more than to food availability at the household level. Further, morbidity and poor nutritional status were interdependent. Modeled simultaneously, diarrhea reduces child weight-for-height and other illness curtail long run growth. The role of mother's education was found critical in governing nutrition status.

Since incidence of diarrhea and illness are strongly affected by community covariates and parental care, a clear policy remedy is to improve the sanitary environment and encourage female education. Food security alone is not sufficient in improving nutritional status of children.

The production of nutrition status in children as measured by standardized weights and heights is considered to be a process which is influenced by two proximate factors: nutrient availability and (absence of) infection a la Alderman and Garcia. However, since studies by ..... show that their is no nutrient availability deficiency in Pakistan now, this variable has been dropped from our study. The household choices and individual characteristics depend not only on individual amount of exposure but also the susceptibility to infection. Community factors also are of great influence. Exposure to illness and diarrhea are strongly affected by the village sanitation environment. The child feeding practices, vaccination schedule etc also govern its susceptibility. Current age, health at birth,

prxied by probability of birth in hospital also affect susceptibility. This paper, thus, uses the following estimation equations :

Weight-for-Height = f(child's age, age squared, gender, mother's educ, household size, days sick with diarrhea, prob. of diarrhea, prob. other illness, prob. hospital birth, prob. of vaccination, length breastfeed, birth order, one male child, one female child, av. birth spacing, factor 1, factor 2, province)

and

Height-for-Age = g(child's age, age squared, gender, mother's educ, household size, days sick with diarrhea, prob. of diarrhea, prob. other illness, prob. hospital birth, prob. of vaccination, length breastfeed, birth order, one male child, one female child, av. birth spacing, factor 1, factor 2, province)

There are five variables which appear in production model for which community level infrastructure and interactions are presumed important:

- days the child is sick with diarrhea in past 2 weeks
- days the child has other illness in past 2 weeks
- whether the child is vaccinated
- whether the child was breastfed
- whether the child was born in hospital.

For each community average are included as instruments exclusive of that child. In addition, factor one (quality of housing) and

factor two (asset holding), based on factor analysis, are used as proxy for permanent wealth and are included as instruments.

The probability of diarrhea, days sick with diarrhea, probability of other illness, probability of hospital birth, probability of vaccination, length of breastfeeding were each independently calculated by regressing child's age, age squared, gender, mother's educ, village prevalence of diarrhea * mother's education, village average excluding self, household size, tapwater, treated for diarrhea in hospital, prop. of children who died before age of five, rural-urban dummy, factor 1, factor 2, prop. of children under five living at home, and province dummy on them.

Some of the variables included do not denote input into nutrition directly but are outcomes of investments in other aspects of health which has then have a direct bearing on productivity of inputs into nutrition. Factor 1 and factor 2 are clearly two such variables. These 2 factors represent quality of housing and asset holding respectively and have been created by use of factor analysis (appendix).

The normal expectation from running this regression would be that larger the days a child is sick with diarrhea lower would be its height-for-age and weight-for-height. However, other illness would effect weight-for-height in the short run but not height-for-age. Probability of birth in hospital, vaccination, length breastfed should be positively related. Factor 1 and factor 2 should be negatively related (since the index runs from better to worse). Similarly, higher levels of mother's education should lead to higher levels of nutritional status.

lead to higher levels of nutritional status.

7 The Results

The model is applied to Demographic and Health Survey data, 1990-91. The survey was conducted in the four provinces in Pakistan. For the selection of the sample, each of the following cities: Faisalabad, Gujranwala, Hyderabad, Karachi, Lahore, Multan, Peshawar and Rawalpindi, constituted a separate stratum. Other cities/towns in each province were grouped to form a stratum. For the rural domain, each district in each province was considered a stratum, except Balochistan where each division constitute sample design was adopted for the survey. The sample PSUs (primary sampling units) from each urban stratum were selected with probability to number of households and from each rural stratum with probability proportional to the population enumerated in the 1981 census. 1420 households in Punjab, 904 in Sindh, 910 in NWFP, and 475 household in Balochistan were thus, selected for coverage from 408 sample areas.

Three types of questionnaire were covered by the survey. Questionnaire one was the household-level questionnaire giving basic information of each member of the household, asset holdings, quality of housing, water and sanitation facilities. Questionnaire two was the woman's questionnaire. This covered variety of topics including vaccinations and health of her children, pregnanc and breastfeeding. Questionnaire three was the husband's questionnaire. Anthropometric measurements of children born after Jan. 1985 within these household were obtained. The present study analyses nutritional status using

heights and weights obtained from 2571 children from questionnaire two. Variables used in the analysis were obtained from questionnaire one and two.

Anthropometric measurements of children born after January'85 within these households were obtained from the DHS data,1990-91. The study is based on the heights and weights obtained from 2,435 children. Factor 1 and factor 2 are based information from questionnaire one and information on all other variables used in the multivariat analysis are from questionnaire two.

The analysis shows that over three quarters of the under six children in the sample areas recorded height-for-age score to be less than -2 i.e. 3/4 of the children were stunted or chronically malnourished as per the definition of the WHO reference standards. Table 1A gives the detailed breakdown across provinces. Punjab, with the least rate recorded a high of 74.32% and NWFP showed over 90%. The table also reports the weight-for-height scores more than one standard deviations below the WHO norm. Approximately 4% of the children in Sindh showed signs of wasting or malnourishment. Wasting was not observed in NWFP and Balochistan. Punjab also showed a very small percentage wasting. Wasting is a short run phenomenon and is subject to high fluctuations in any given population. The result of wasting will differ significantly from period to period within a small time span. Table 1B reports the z-scores across type of residence. 74.71% of the urban children measured showed stunting and over 88% of rural children showed stunted growth. Balochistan

accounted for 8% of the total stunted rural children. Over 30% was accounted for by Sindh and Punjab each. All the cases of child wasting for the rural areas was in Sindh.

The pattern by age groups (Table 2) shows that child stunting is positively correlated with age. Stunting increases with age. Only 36.81% of children below six months were stunted compared to 90% of children above the age of 3 years. The process of stunting is cumulative and is carried over years. If the children are not properly fed and their diet lacks sufficient proteins then not only will they show stunting at the time of measurement but also when they are measured a few years from hence. Thus, older children show higher percentage stunting.

The nutritional outcome was nearly invariant between sexes. Table 3 clearly shows that both male and female children proportion of stunting were same not only for overall survey but also across provinces. Child stunting was more in the males then females though the proportion for both were small. Sindh recorded all the cases of child stunting for females and over 88% for the males.

The correlation matrix of the cluster mean values for various health measures, table 4, indicate that there is a weak relationship among the various measures. This confirms the assumption of the analytical approach were all these factors are considered independent variables in governing the height-for-age and weight-for-height multivariate regressions.

Impact of mother's education can been seen from table 5. 85.75% of the children of females with less than middle school

education showed stunting compared to 47.1% of educated mothers. No educated mother showed child wasting.

The data was collected at the time when the children measured reported to have had diarrhea in the past two weeks and of the children reported to have had other illnesses was low. The morbidity reported was thus low. The mean and standard deviations of the variables used in the analysis are reported in table 6.

5. RESULTS

The main results of the estimation are presented in table 7 & table 8. In most regression the results show expected relations. For e.g. mother's education is negatively related to probability of diarrhea, illness and length of breastfeeding and positively related to probability of birth in hospital and probability of the child having atleast two vaccinations. All the co-efficients were significant, re-emphasizing role of mother's education. Similarly, household size, proportion of children who are under five and proportion of children who died prior to reaching the age of five for any household were directly related to probability of diarrhea. All these factors can be grouped under a variable reading parental care and attention. Higher the parental attention to each member i.e less no. of children below age of five, lesser the household size ; and higher the care i.e lower the proportion of children who died before reaching the age of 5 would decrease the probability of the child having diarrhea. Similarly better sanitation facilities, drinking water, asset

holdings, quality of housing etc. improve the chances of the child as far as probability of acquiring diarrhea is concerned.

One unexpected result in table 7 is that of treatment for diarrhea in hospital is positively related to probability of diarrhea. This would indicate either bad hospital management and unhygienic environment or statistical errors.

Table 8 (second stage regression results) again show expected signs. Mother's education is positively affecting both height-for-age and weight-for-height scores. Household size is negatively related to the z-scores. Some of the interesting results were seen as far as household with only one daughter and household with only one son were concerned. Former was negatively related and latter positively related to height-for-age scores.....This to an extent can be explained by the son preference of most household's in Pakistan. Thus a sole son is more cared for and nourished than households with more than one son and household with one daughters. The average birth spacing was also negatively related to z-scores. This is to an extent related to breastfeeding practses of the females in Pakistan. Length of breastfeeding usually depends on the next birth. larger the difference in the births larger is the length of breastfeeding. Breastfeeding though has its advantages in the formative years but if not supplemented by appropriate diet with higher protein level food leads to slow under nourishment and stunting over the years.

Table 9 shows that stunting in fact increases if breastfeeding is increased to 6 or 12 months. It also shows that

stunting decreases with decrease in the household size and increases if each child recieved atleast two vaccinations. If all mothers have education level above middle school then both stunting and wasting declines. Conversely if mothers'education level is below middle school then both scores increase. Interestingly, if days of diarrhea are reduced by one day then child stuntingimproves but wasting worsens.....why?

Additional Diagrams and Tables to go with the text.

1. Nutritionists Views of how tastes are formed
2. Intra-versus Inter-individual variation — from Willett
3. 5 tables illustrating intra-individual variation. Different periods of duration.
4. Intra-individual variation in one year in Bangladesh
5. The nutrition function studied by Dasgupta-Ray.
6. Different methods of data collection.

Table 1A: Nutritional Status by Province

Province	Child Wasting % Children below -1 WHZ	Child Stunting % Children below -2 HAZ
Punjab	0.45	74.32
Sindh	4.06	77.74
NWFP	0.00	90.37
Balochistan	0.00	89.47

Table 1A: Nutritional Status by Type of residence

	Child Wasting % Children below -1 WHZ	Child Stunting % Children below -2 HAZ
Urban	2.21	74.17
Rural	0.56	88.22

Table 1C: Nutritional Status breakdown by Province of rural sector alone

Province	Child Wasting % Children below -1 WHZ	Child Stunting % Children below -2 HAZ
Punjab	0.00	36.97
Sindh	100.00	22.52
NWFP	0.00	32.43
Balochistan	0.00	8.08

Table 2: Nutritional Status by Age

Age(months)	Child Wasting % Children below -1 WHZ	Child Stunting % Children below -2 HAZ
Below 6	0.00	36.81
7-11	0.00	73.24
12-24	1.06	83.01
25-36	3.21	87.36
37-48	2.58	92.25
49-60	0.00	90.91

Table 3: Nutritional Status by sex

Sex	Child Wasting % Children below -1 WHZ	Child Stunting % Children below -2 HAZ
Male	2.66	80.44
Female	0.15	81.36

Table 3A: Nutritional Status by province of male children

Province	Child Wasting	Child Stunting
Punjab	11.43	31.60
Sindh	88.57	29.14
NWFP	0.00	28.57
Balochistan	0.00	10.69
	100.00	100.00

Table 3B: Nutritional Status by province of female children

Province	Child Wasting	Child Stunting
Punjab	0.00	30.70
Sindh	100.00	30.80
NWFP	0.00	26.62
Balochistan	0.00	11.88
	100.00	100.00

Table 4A: Simple correlation matrix :

Variables	Probability of diarrhea	Diarrhea days	illness	birth in hospital	Vaccination	Breast-feeding
Diarrhea	1.00					
Diardays	.81	1.00				
Illness	.21	.21	1.00			
Born Hosp	-.03	-.03	-.02	1.00		
Vaccination	-.04	-.07	-.06	.13	1.00	
Breastfed	-.02	-.04	-.04	-.14	.12	1.00

Table 4B: Simple correlation matrix :
Village averages of health and calories measures

	Village Avearges excluding self				
	Diarrhea	Illness	Born in Hospital	Vaccination	Breastfeeding
Diarrhea	1.00				
Illness	.29	1.00			
Born in Hospital	-.07	.03	1.00		
Vaccination	-.04	.01	.25	1.00	
Breastfeeding	-.08	-.10	-.33	.02	1.00

Table 5: Nutritional Status governed by mother's education

Female educ. above middle sch.	Child Wasting % Children below -1 WHZ	Child Stunting % Children below -2 HAZ
No	1.62	85.75
Yes	0.00	47.10

Table 6: Variables used in the analysis: mean and standard deviations.

Variables	Mean	Std Dev
Child age/months	29.28	17.38
Child age squared/months	1158.81	1070.41
Sex of child	1.50	.50
Mother education till primary school	.22	.42
Mother education till middle school	.13	.33
Days sick with diarrhea	.69	2.19
Diarrhea in last 2 weeks	.13	.34
Cluster mean for Diarrhea in past 2 weeks	.69	.94
Illness in last 2 weeks	.29	.46
Cluster mean for illness in past 2 weeks	.29	.21
Probability born in hospital	.16	.36
Cluster mean for born in hospital	.16	.24
Vaccination dummy	.41	.49
Length breastfed	15.26	9.15
Birth order: first child	.70	.46
Birth order: second child	.27	.44
Birth order: third child	.03	.17
Total members in household	7.78	3.30
Dummy for only one daughter	.25	.43
Dummy for only one son	.24	.43
Tapwater	3.16	1.79
Average birth spacing	2.69	1.35
Index of housing quality	.00	1.00
Index of asset ownership	.07	.95
Percentage of total children born who died	7.86	13.45
Proportion of children under 5	.47	.28
Type of place of residence	1.48	.50
Height for age	-2.29	2.16
Weight for age	-1.60	1.58
Weight for height	-.20	1.90
Rural-Urban dummy	1.48	0.50

Table 7: Nutritional status determinants: first stage instrument equations

Independent Variables	Probability of diarrhea	Diarrhea days	Probability of illness	Probability of Birth in hospital	Probability of Vaccination	Length of breast-feedin
Intercept	-0.9935	-22.4390	-0.5015	-1.5587	-1.9571	1.8934
	(3.923)	(0.206)	(2.372)	(5.19)	(8.771)	(1.612)
Age in months	0.0125	0.0799	-0.0032	-0.0143	0.0628	0.9378
	(1.692)	(0.104)	(0.518)	(1.713)	(9.638)	(31.899)
Age, squared	-0.0004	-0.0052	-0.0001	0.0002	-0.0007	-0.0116
	(3.282)	(0.214)	(1.426)	(1.317)	(6.506)	(21.757)
Sex of child	-0.0235	-0.3337	-0.0561	0.0260	-0.0309	-0.1946
	(0.365)	(0.179)	(1.044)	(0.346)	(0.577)	(0.689)
Mother's education	-0.1668	-2.5148	-0.1038	0.6812	0.2851	-1.5936
	(1.341)	(0.252)	(1.061)	(6.554)	(3.025)	(2.952)
Village prevalence of diarrhea x mother's education		-0.3607				
		(0.696)				
Village average excluding self		0.6003	0.8634	1.2247	1.1803	0.0671
		(0.324)	(6.758)	(7.213)	(10.789)	(1.800)
Household Size	0.0027	-0.0038	-0.0002	-0.0208	0.0088	-0.0356
	(0.241)	(0.013)	(0.019)	(1.654)	(0.976)	(0.736)
Tapwater	-0.0269	-0.4465	0.0069	0.0152	-0.0086	
	(1.212)	(0.275)	(0.375)	(0.602)	(0.473)	
Treated for diarrhea in hospital		1.1524			-0.0037	
		(1.172)			(1.823)	
Proportion of children who died before age five	0.0046	0.0672	0.0039	-0.0001	-0.0187	
	(1.982)	(0.255)	(1.981)	(0.047)	(0.254)	
Rural-Urban dummy	-0.1884	-2.0394	-0.1034	-0.1173	-0.0652	0.8529
	(2.114)	(0.187)	(1.404)	(1.065)	(1.711)	(2.271)
Index of housing quality	0.1541	3.0752	0.0278	-0.4336	-0.0507	0.9666
	(3.311)	(0.345)	(0.728)	(6.993)	(1.58)	(4.803)
Index of asset ownership	0.1256	2.2600	0.0731	-0.2068	-0.0155	0.5691
	(2.883)	(0.308)	(2.149)	(5.587)	(0.146)	(3.143)
Proportion of children living at home who are under five	0.0199	0.1010	-0.1475	0.3799	0.2789	-3.1827
	(0.158)	(0.035)	(1.396)	(2.691)	(2.733)	(5.954)
Dummy for Punjab	0.3129	3.8173	0.2760	-0.0339	0.1745	-1.2638
	(2.415)	(0.208)	(2.588)	(0.205)	(1.708)	(-2.270)
Dummy for Sind	0.5204	6.2388	0.2588	0.5433	0.0740	-0.7087
	(4.045)	(0.208)	(2.415)	(3.334)	(0.712)	(-1.232)
Dummy for NWFP	0.0131	-1.8414	0.1118	0.0306		-0.1314
	(0.095)	(0.603)	(1.022)	(0.178)		(-0.232)
Inverse Hills Ratio		19.6160				
		(0.276)				

Note: Figures in the parentheses are t-values.

Annexure 2 : Nutritional status determinants (N=2435)

	Ordinary least squares	
	HEIGHT FOR AGE	WEIGHT FOR HEIGHT
Intercept	-2.39	0.62
	(2.06)	(0.55)
Age in months	-0.04	-0.12
	(0.89)	(2.69)
Age in months, squared	0.00	0.00
	(0.46)	(2.53)
Sex of child	-0.05	0.22
	(0.63)	(2.89)
Mother's education	0.41	0.30
	(2.25)	(1.73)
Household size	-0.02	-0.02
	(1.29)	(1.74)
Days sick with diarrhea	-0.01	-0.01
	(3.49)	(3.24)
Probability of being ill with fever	0.32	-0.38
	(1.50)	(1.81)
Probability of birth in hospital	0.25	-0.07
	(1.34)	(0.39)
Probability of being vaccinated	0.18	0.17
	(1.70)	(1.67)
Length breastfed	-0.09	0.08
	(1.85)	(1.66)
Birth-order: first born	1.60	-0.17
	(1.42)	(0.15)
Birth-order: second child	1.29	-0.38
	(1.14)	(0.35)
Birth-order: third child	1.17	-0.19
	(1.02)	(0.18)
Dummy for only one son in family	0.02	0.11
	(0.19)	[illegible]
Dummy for only one daughter in family	0.21	[illegible]
	[illegible]	[illegible]
Average birth spacing	0.01	0.00
	(0.15)	(0.10)
Index of housing quality	-0.15	-0.09
	(1.94)	(1.24)
Index of asset ownership	-0.06	-0.07
	(1.12)	(1.32)
Dummy for Punjab	0.94	-0.53
	(5.96)	(3.51)
Dummy for Sind	0.40	-0.64
	(2.59)	(4.29)
Dummy for NWFP	0.67	-0.33
	(4.45)	(2.32)

Note : Figures in the parentheses are t-values

Table 9 : Simulation of key variables affecting malnutrition.

Intervention	Child Wasting Percent Children below -1 WHZ Current Level	with	Impact	Child Stunting Percent Children below -2 HAZ Current Level	with	Impact
Days with diarrhea, past week	1.52			86.61		
Reduced by one day		2.14	-0.62 (40.50)		80.51	0.06 (0.07)
Reduced by two days		3.29	-1.77 (116.15)		74.78	11.83 (13.65)
Vaccination	1.52			86.61		
Atleast two vaccinations		0.33	1.19 (78.38)		84.44	2.17 (2.51)
Breastfeeding	1.52			86.61		
Atleast 6 months		0.70	0.82 (54.05)		88.50	-1.89 (-2.18)
Atleast one year		0.62	0.90 (59.46)		88.54	-1.93 (-2.23)
Household size	1.52			86.61		
Reduced by one		1.19	0.33 (21.62)		86.28	0.33 (0.38)
Reduced by two		0.86	0.66 (43.24)		85.87	0.74 (0.85)
Educational level of female	1.52			86.61		
All below middle level		1.93	-0.41 (26.99)		90.85	-4.24 (4.90)
All above middle level		0.12	1.40 (92.11)		73.55	1.69 (1.95)

* Impact = Current Level of child wasting and stunting minus with intervention.
Figures in the parantheses represent percent reduction from currnt levels of wasting and st

NUTRITIONAL STATUS DETERMINANTS: FIRST STAGE INSTRUMENT EQUATIONS

Independent Variables	Probability of diarrhea	Diarrhea days	Probability of illness	Probability of Birth in hospital	Probability of Vaccination	Length of breast-feeding
Intercept	-0.9935	-22.4390	-0.5015	-1.5587	-1.9571	1.8934
	(-3.923)	(-0.206)	(-2.372)	(-5.19)	(-8.771)	(1.612)
Age in months	0.0125	0.0799	-0.0032	-0.0143	0.0628	0.9378
	(1.692)	(0.104)	(-0.518)	(-1.713)	(9.638)	(31.899)
Age, squared	-0.0004	-0.0052	-0.0001	0.0002	-0.0007	-0.0116
	(-3.282)	(-0.214)	(-1.426)	(1.317)	(-6.506)	(-21.757)
Sex of child	-0.0235	-0.3337	-0.0561	0.0260	-0.0309	-0.1946
	(-0.365)	(-0.179)	(-1.044)	(0.346)	(-0.577)	(-0.689)
Mother's education	-0.1668	-2.5148	-0.1038	0.6812	0.2851	-1.5936
	(-1.341)	(-0.252)	(-1.061)	(6.554)	(3.025)	(-2.952)
Village prevalence of diarrhea x mother's education		-0.3607				
		(-0.696)				
Village average excluding self		0.6003	0.8634	1.2247	1.1803	0.0671
		(0.324)	(6.758)	(7.213)	(10.789)	(1.8)
Household Size	0.0027	-0.0038	-0.0002	-0.0208	0.0088	-0.0356
	(0.241)	(-0.013)	(-0.019)	(-1.654)	(0.976)	(-0.736)
Tapwater	-0.0269	-0.4465	0.0069	0.0152	-0.0086	
	(-1.212)	(-0.275)	(0.375)	(0.602)	(-0.473)	
Treated for diarrhea in hospital		1.1524			-0.0037	
		(1.172)			(-1.823)	
Proportion of children who died before age five	0.0046	0.0672	0.0039	-0.0001	-0.0187	
	(1.982)	(0.255)	(1.981)	(-0.047)	(-0.254)	
Rural-Urban dummy	-0.1884	-2.0394	-0.1034	-0.1173	-0.0652	0.8529
	(-2.114)	(-0.187)	(-1.404)	(-1.965)	(-1.711)	(2.271)
Index of housing quality	0.1541	3.0752	0.0278	-0.4336	-0.0507	0.9666
	(3.311)	(0.345)	(0.728)	(-6.993)	(-1.58)	(4.803)
Index of asset ownership	0.1256	2.2600	0.0731	-0.2068	-0.0155	0.5691
	(2.883)	(0.308)	(2.149)	(-5.587)	(-0.146)	(3.143)
Proportion of children living at home who are under five	0.0199	0.1010	-0.1475	0.3799	0.2789	-3.1827
	(0.158)	(0.035)	(-1.396)	(2.691)	(2.733)	(-5.954)
Dummy for Punjab	0.3129	3.8173	0.2760	-0.0339	0.1745	-1.2638
	(2.415)	(0.208)	(2.588)	(-0.205)	(1.708)	(-2.27)
Dummy for Sind	0.5204	6.2388	0.2588	0.5433	0.0740	-0.7037
	(4.045)	(0.208)	(2.415)	(3.334)	(0.712)	(-1.232)
Dummy for NWFP	0.0131	-1.8414	0.1118	0.0306		-0.1314
	(0.095)	(-0.603)	(1.022)	(0.178)		(-0.232)
Inverse Mills Ratio		19.6160				
		(0.276)				

NUTRITIONAL STATUS DETERMINANTS: SECOND-STAGE REGRESSION

Independent Variables	Height-for-Age	Weight-for-height
Intercept	-2.3939	0.6145
	(-1.976)	(1.345)
Age in months	-0.0401	-0.1164
	(-0.828)	(-2.401)
Age in months, squared	0.0003	0.0014
	(0.421)	(2.263)
Sex of child	-0.0506	0.2244
	(-0.632)	(2.944)
Mother's education	0.4054	0.2999
	(2.398)	(1.863)
Household size	-0.0175	-0.0227
	(-1.368)	(-1.763)
Days sick with diarrhea	-0.0113	-0.0100
	(-3.754)	(-3.614)
Probability of being ill with fever	0.3235	-0.3748
	(1.655)	(-1.796)
Probability of birth in hospital	0.2465	-0.0692
	(1.486)	(-0.435)
Probability of being vaccinated	0.1810	0.1712
	(1.727)	(1.846)
Length breastfed	-0.0868	0.0751
	(-1.749)	(1.54)
Birth-order: first born	1.6020	-0.1653
	(1.351)	(-0.446)
Birth-order: second child	1.2880	-0.3826
	(1.087)	(-1.046)
Birth-order: third child	1.1718	-0.1938
	(0.968)	(-0.406)
Dummy for only one son in family	0.0187	0.1120
	(0.187)	(1.143)
Dummy for only one daughter in family	-0.2117	0.0260
	(-2.236)	(0.26)
Average birth spacing	-0.0047	-0.0029
	(-0.16)	(-0.134)
Index of housing quality	-0.1514	-0.0926
	(-1.941)	(-1.25)
Index of asset ownership	-0.0638	-0.0722
	(-1.126)	(-1.276)
Dummy for Punjab	0.9425	-0.5330
	(5.201)	(-3.001)
Dummy for Sind	0.4033	-0.6408
	(2.273)	(-3.733)
Dummy for NWFP	0.6676	-0.3339
	(3.921)	(-2.001)

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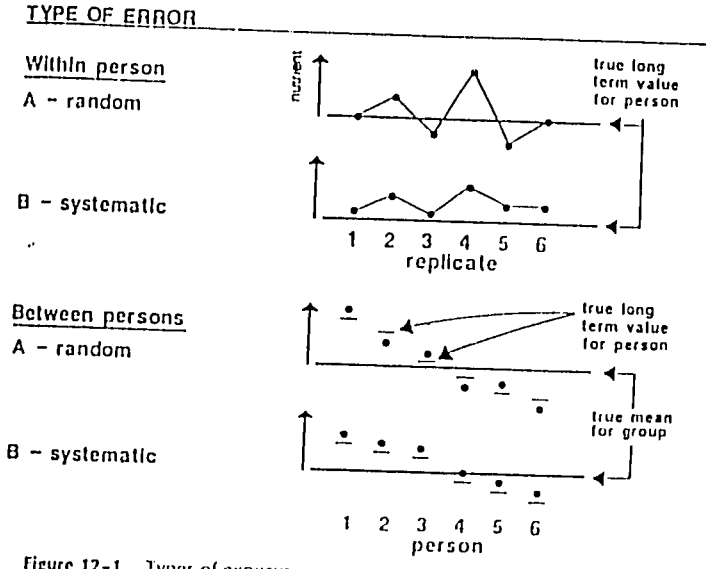

Figure 12-1. Types of exposure measurement error in epidemiologic studies.

Figure 1. Intra- versus Inter individual variation. (From Willett (1990; Chapter 12).)

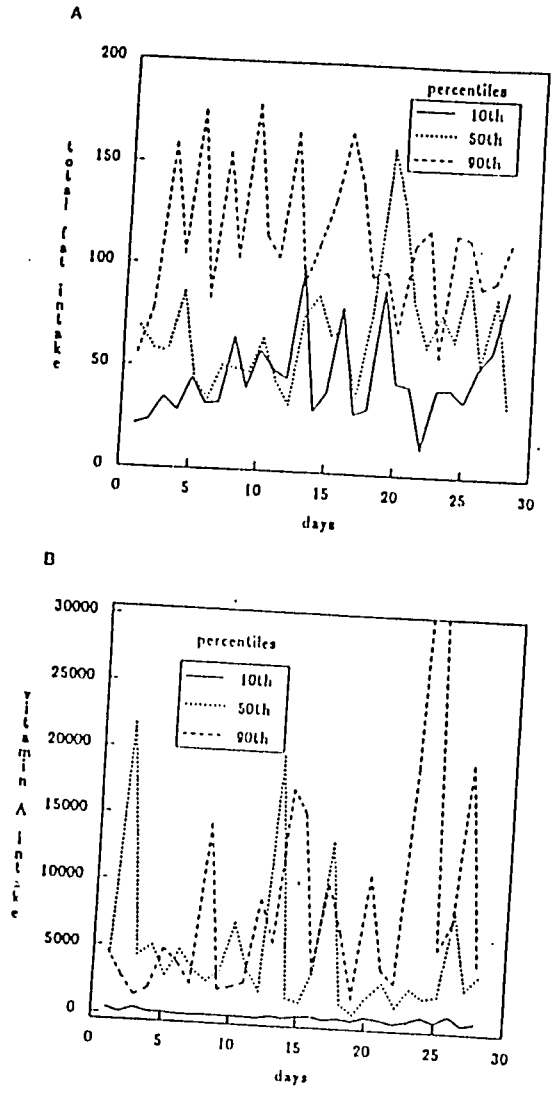

Figure 3-1. Daily intakes for three women at the 10th, 50th, and 90th percentile of distributions for total fat intake in grams (A), and vitamin A intake in international units (B). See text for details.

Figure 2. Illustration of Intra-individual variation. From Willett (1990; Chapter 3).

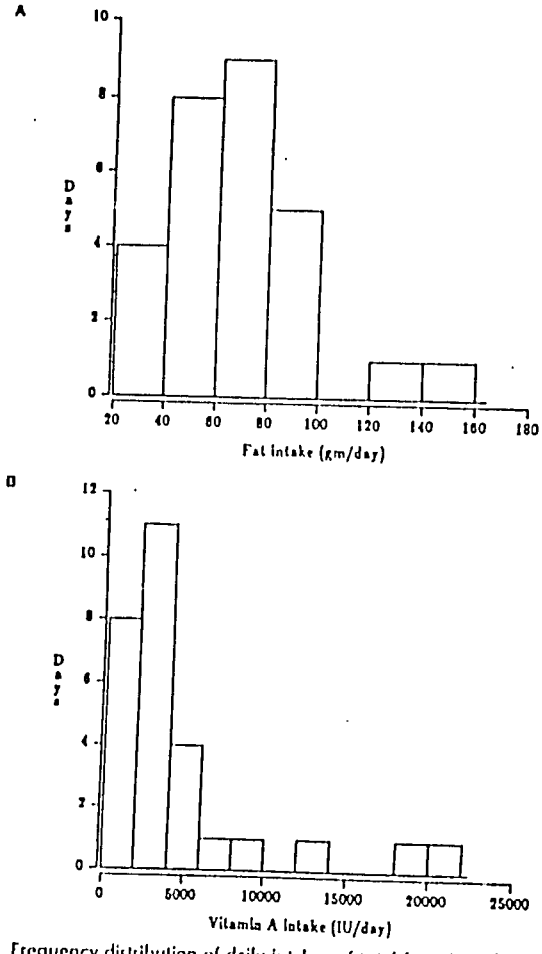

Figure 3-2. Frequency distribution of daily intakes of total fat (A), and vitamin A (B) for one woman (the women at the 50th percentile in Fig. 3-1). For this person, 28 days of intake are displayed; the mean of these days can be considered as the true intake for that person.

Figure 3a. Another illustration of intra-individual variation. From Willett (1990, Chapter 3).

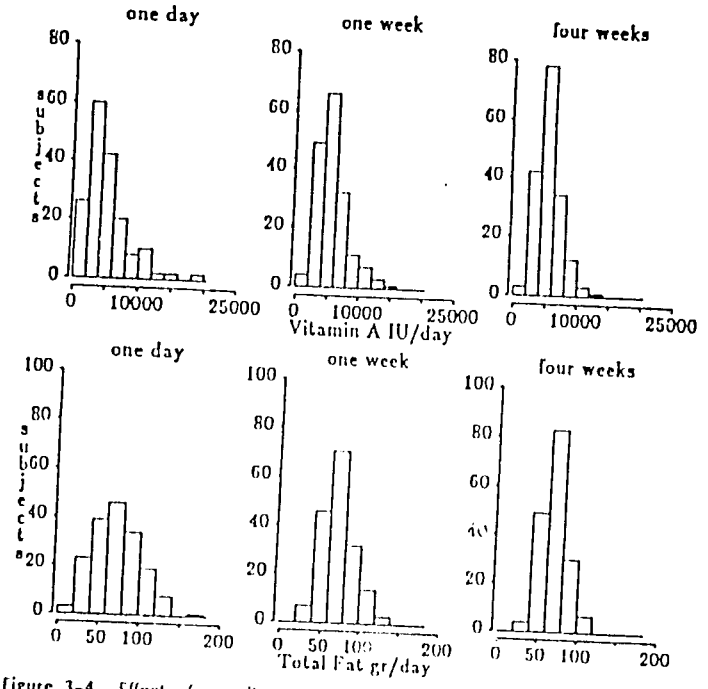

Figure 3-4. Effect of sampling 1 day, 7 days, or 28 days per subject on the observed distribution of fat and vitamin A intake. Data are based on diet records provided by 194 women.

Figure 3b.

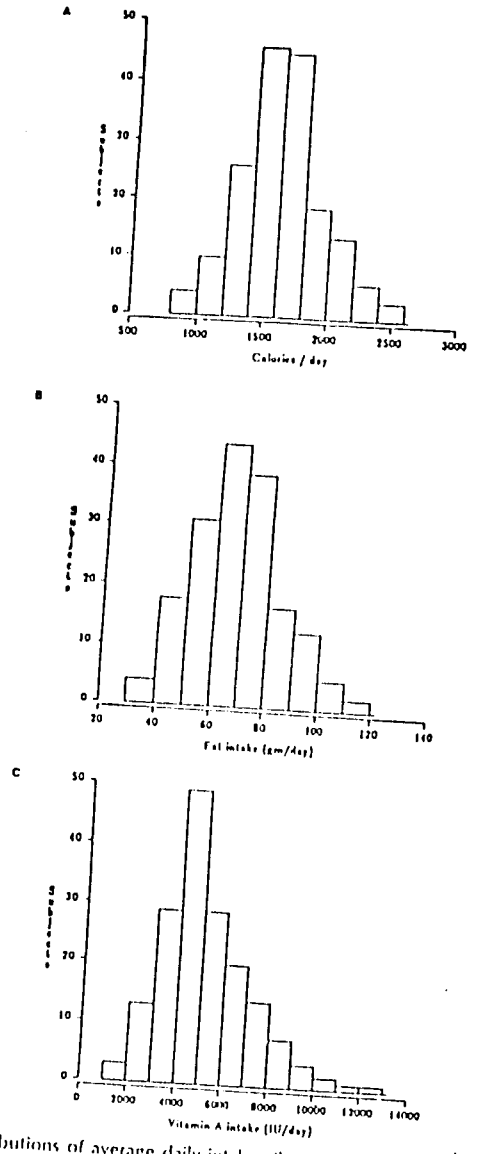

Figure 3-3. Distributions of average daily intakes (based on 28 days per person) for calories (A), total fat (B), and vitamin A (C) for 194 women. Because the average of a large number of days is used for each woman, these distributions closely approximate the true between-person variation for this group of women.

Figure 3c.

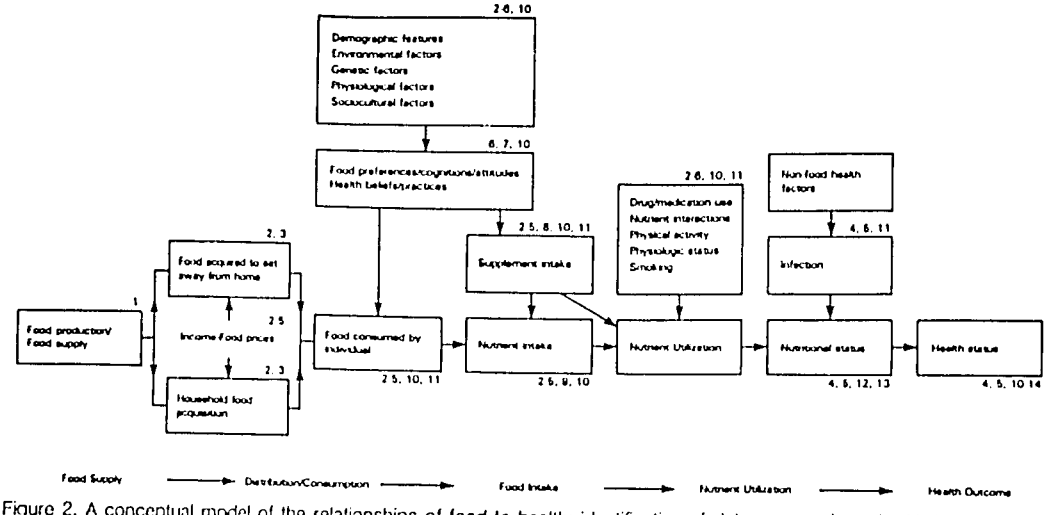

Figure 2. A conceptual model of the relationships of food to health: identification of data sources from the National Nutrition Monitoring System. Data source: 1 = U.S. Food Supply; 2 = NFCS; 3 = CSFII; 4 = NHANES; 5 = HHANES; 6 = BRFSS; 7 = HDS; 8 = VMSIS; 9 = TDS; 10 = NHIS; 11 = NEFS; 12 = PedNSS; 13 = PregNSS; 14 = Vital Statistics. Adapted from the Second National Nutritional Monitoring Report of the Expert Panel (July 1989).

Figure 4. Nutritionists' views of food consumption. From Brown (1990; p. 416).

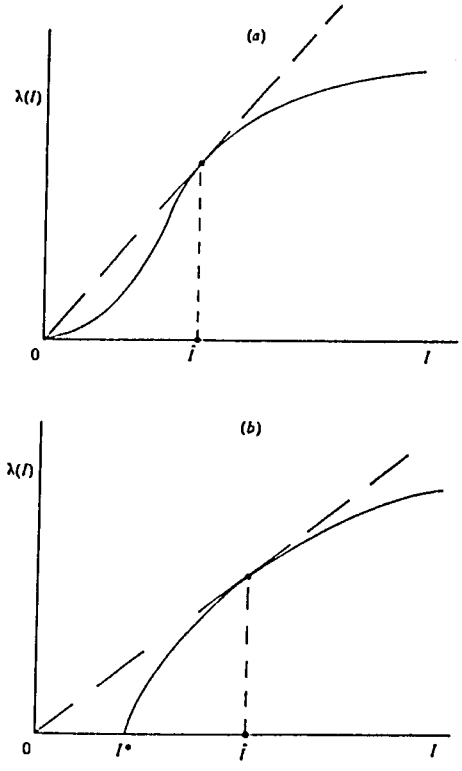

Fig. 1

Fig. 5. The "effort function" of Liebenstein-Myrdal and used in the analyses of Dasgupta-Ray (1986, 87).

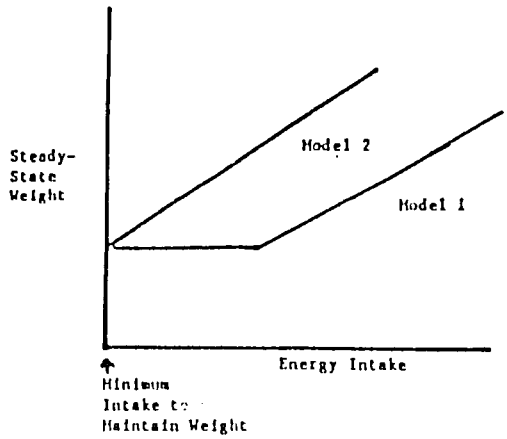

Figure 11-4. Alternate models of response to an increase in long-term energy intake. In model 1, increased thermogenesis prevents weight gain until up to a certain increment in energy intake. In model 2, any compensatory increase in energy expenditure occurs only in conjunction with weight gain.

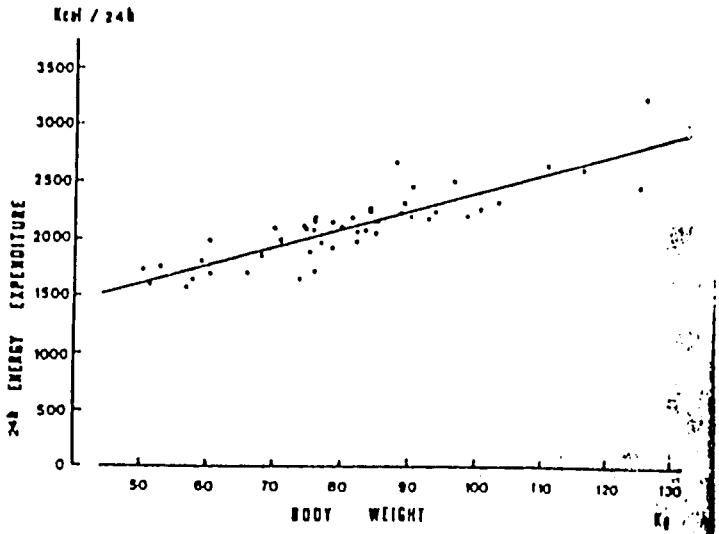

Figure 11-3. Relation between body weight and 24-hour energy expenditure, based on respiration-chamber measurements. (From Jequier and Schultz, 1983; reproduced with permission.)

Fig. 6.

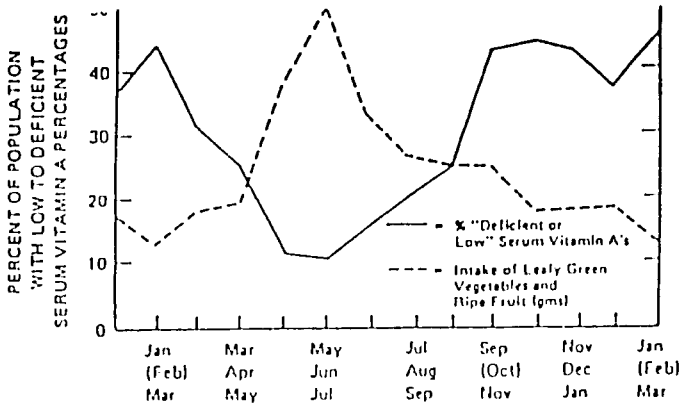

Figure 3-5. Seasonal variation of intake of leafy green vegetables and ripe fruit and of serum vitamin A in Bangladesh. (From Schaefer, 1981.)

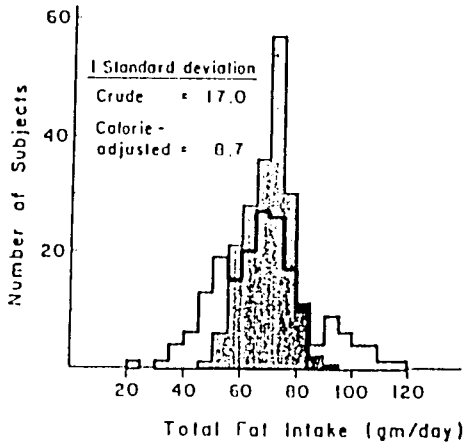

Figure 11-6. Distribution of total fat intake with *(shaded area)* and without *(dark line)* adjustment for total caloric intake. Data are based on four 1-week diet records completed by 194 Boston-area women aged 34 to 59 years. Calorie-adjusted values were calculated as described in the text, with residuals computed in the $\log_e$ scale to improve normality. (From Willett and Stampfer, 1986, reproduced with permission.)

Fig. 7. Inter- and Intra-individual variation in Intake.

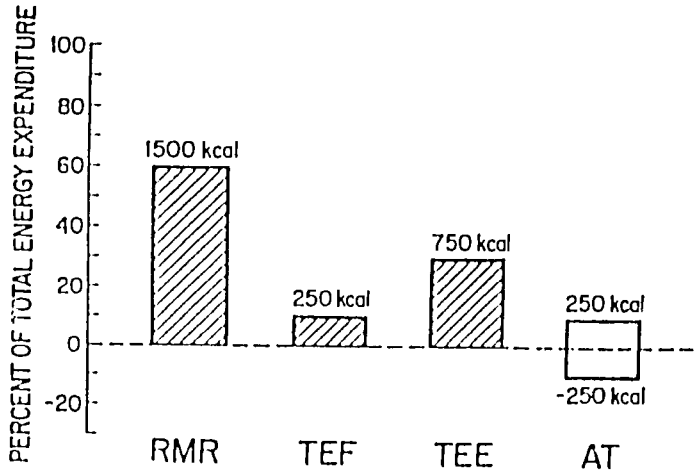

Figure 11-1. Components of energy expenditure. (From Horton, 1983, reproduced with permission.)

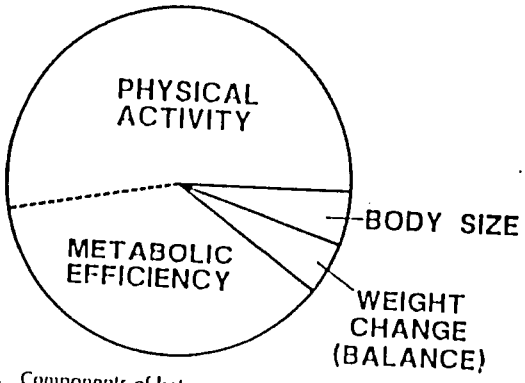

Figure 11-2. Components of between-person variation in energy intake. The relative size of these components varies depending on the population being studied.

Fig. 8.

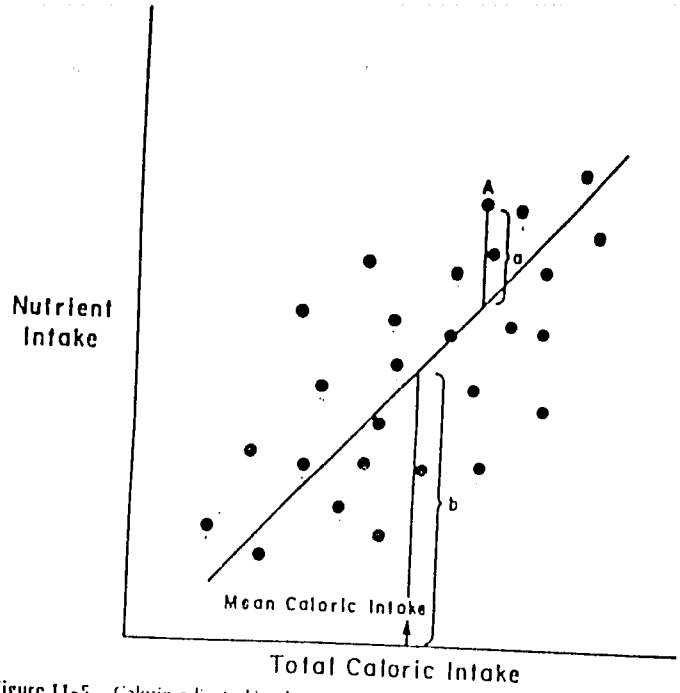

Figure 11-5. Calorie-adjusted intake = a + b, where a = residual for subject from regression model with nutrient intake as the dependent variable and total caloric intake as the independent variable and b = the expected nutrient intake for a person with mean caloric intake. (From Willett and Stampfer, 1986; reproduced with permission.)

Fig. 9.

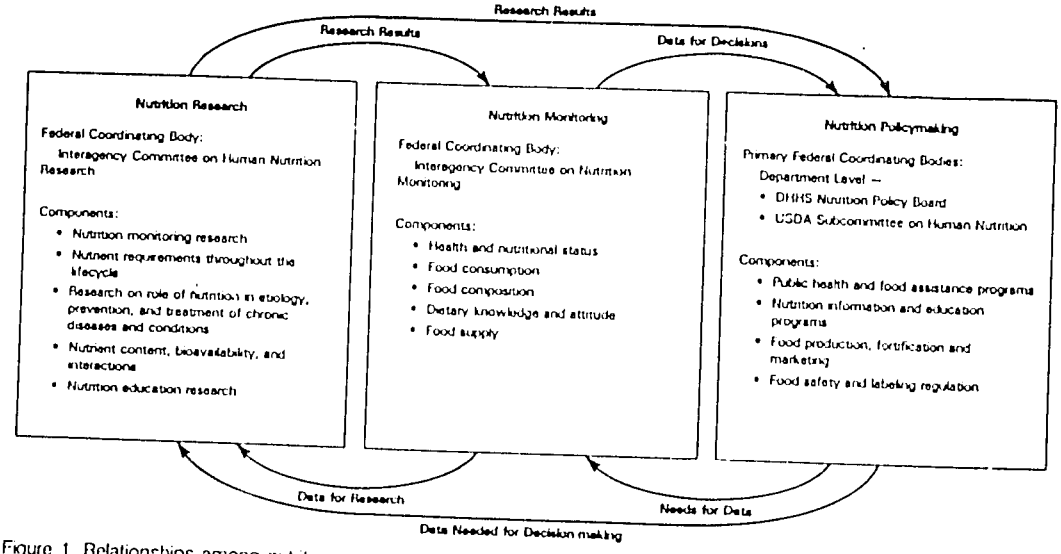

Figure 1. Relationships among nutrition research, monitoring, and policy making. Adapted from the Operational Plan for the National Nutrition Monitoring System (August 1987).

Fig. 10.

Appendix: Methods of Estimation of Dietary Intake. From Pao + Cypel in Brown (1990)

Table 1. Strengths and weaknesses of food record methods

Strengths	Weaknesses
1. Respondent does not rely on memory.	1. Respondents must be literate.
2. Time period is defined.	2. Respondents must be highly cooperative.
3. Portions can be measured to increase accuracy.	3. Food consumed away from home may be less accurately reported.
4. Omission of foods is minimal.	4. Habitual eating pattern may be influenced or changed by the recording process.
5. For elderly people, records may be more accurate than recalls.	5. Requirement for literate respondents may introduce bias as a result of overrepresentation of more highly educated individuals.
6. Food intakes are quantified so nutrient contents can be calculated.	6. Record keeping increases respondent burden.
7. Multiple days may yield a measure of usual intake for a group.	7. Increased respondent burden may adversely affect response rates.
8. Multiple days provide reliable information about less frequently eaten foods.	8. Self-administered records require more callbacks and editing than interviewer-administered reports.
9. Two or more days provide data on intra- and interindividual variation in dietary intakes.	9. One-day records provide an inadequate indication of usual intake for groups or individuals.
10. One day records kept intermittently over the year may provide an estimate of usual intake by an individual.	10. Validity of records may decrease as number of days increases.

Table 2. Strengths and weaknesses of 24-h food recall methods

Strengths	Weaknesses
1. Respondent burden is small.	1. Repondent recall depends on memory.
2. Administration time is short.	2. Portion size is difficult to estimate accurately.
3. Reliance on memory is minimal.	3. Intakes tend to be underreported compared with other methods.
4. Time period is defined.	4. Dietary adequacy of an individual's intake cannot be assessed from one day's intake.
5. Food intake can be quantified.	5. Trained interviewers are required.
6. Procedure does not alter individual's habitual dietary patterns.	6. One-day intakes do not represent usual intake for groups or individuals.
7. Interviewer administration allows probing for omitted foods on incomplete information and fewer callbacks.	
8. Response rates are relatively high.	
9. A single contact is required.	
10. Procedure is often used to evaluate dietary intakes of large groups.	
11. Two or more days provide data on intra- and interindividual variation in dietary intakes.	
12. Multiple days are necessary to provide reliable data on less frequently eaten foods.	
13. Multiple days may yield a measure of usual intake.	
14. Repeated recalls over a year may provide an estimate of usual intake by an individual.	

Table 3. Strengths and weaknesses of food frequency methods

Strengths	Weaknesses
1. An indication of usual dietary intake may be obtained.	1. Memory of food patterns in the past is required.
2. Highly trained interviewers are not required.	2. Recall period may be imprecise.
3. Method can be interviewer administered or self-administered.	3. Quantification of food intake may be imprecise because of poor estimation of recall of portions or use of standard sizes.
4. Administration may be simple.	4. Respondent burden is governed by number and complexity of foods listed and quantification procedure.
5. Customary eating patterns are not affected.	5. Recall of past diets may be biased by current diets.
6. Individuals may be ranked or classified by food intake.	6. Heterogeneity of populations influences the reliability of the method.
7. Response rates are high.	7. Suitability is questionable for certain segments of the population, such as individuals consuming atypical diets or foods not on the list.
8. Respondent burden is usually light.	8. Intakes tend to be overestimated compared with some other methods.
9. Relationship between diet and disease may be examined in epidemiological studies.	9. Validation of the method is difficult.

Table 4. Strengths and weaknesses of diet history methods

Strengths	Weaknesses
1. Method yields a more representative pattern of intakes in the distant past than other methods.	1. Highly trained interviewers are usually required.
2. Measurement of past diet is useful in epidemiological studies of disease states that develop slowly over time.	2. Recall period is difficult to visualize accurately.
3. Respondent literacy is not required if interviewer administered.	3. Respondents must be highly cooperative.
4. Method may be designed to assess total diet or only selected food items.	4. Respondent and interviewer burden may be heavy.
	5. Method may require considerable time.
	6. The method tends to overestimate intakes compared with other methods.
	7. Recall of diets in the past may be biased by current diets.
	8. A commonly accepted method is not yet available.