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The dynamics of agricultural production and the calorie–income relationship: Evidence from Pakistan

Jere R. Behrman*, Andrew D. Foster, Mark R. Rosenzweig

Department of Economics, University of Pennsylvania, Philadelphia, PA 19104-6297, USA

Abstract

Panel data on farm households from rural Pakistan are used to estimate the calorie response to different components of income in an analysis that takes into account the sequential nature of agricultural production, labor and capital market imperfections, heterogeneity, and productivity effects of calories. The estimates indicate that the income–calorie relationship depends importantly on production stage, the form of income, the liquidity of assets, and the extent to which income is anticipated. The planting-stage wage–calorie elasticity is 0.61, but income increases in the food-abundant harvest stage have only small effects on calorie consumption confined to households with below-average wealth.

Key words: Calorie consumption; Income; Productivity; Pakistan agriculture
JEL classification: E21; O12; O13; O15

1. Introduction

World Bank (1990) estimates suggest that more than a billion people in developing countries, particularly in rural areas, suffer from calorie deficiencies. Calorie deficiencies are considered unsatisfactory in themselves because they reflect the failure to attain some minimum acceptable living standard. In

*Corresponding author.

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addition, for very poor people, calorie deficiencies are perceived to affect current labor productivity and longer-run labor productivity through limiting schooling and learning.[1] In part as a consequence there has been considerable interest in strategies that might alleviate calorie deficiencies. One major candidate is increasing income for the poor through income redistribution (e.g., food stamps) or through their participation in general economic growth. In the past two decades there have been dozens of studies that have attempted to estimate the calorie–income demand elasticity. The magnitude of these econometric estimates range considerably, from virtually zero to one or more. There have been a number of efforts to understand these differences and to assess which are the best estimates (e.g., Bouis and Haddad, 1992). These efforts have focused on the empirical measure of calories used (e.g., calories available to the household versus calories actually consumed by household members), the aggregation of food groups at the point in the analysis at which food-to-calorie conversion factors are applied, the extent of nonlinearities in the relationship, and estimation issues relating primarily to measurement errors in the income and calorie variables.

Even though most people suffering calorie deficiencies in the developing world are in rural areas, however, the literature on the analysis of the responsiveness of calorie consumption to income change has not been embodied within a systematic dynamic framework that incorporates the stochastic nature of agricultural production, its within-season sequential production processes (e.g., planting, harvesting) and productivity effects of consumption in the context of realistic depictions of labor and capital market imperfections.[2] This is despite the fact that there is a considerable literature exploiting dynamic models for estimating technology or decision rules within the rural sector (e.g., Antle, 1983; Skoufias, 1993). An important implication of the general structure of these types of models for the study of consumption is that differences across production stages in the contemporaneous relationship between income and calorie consumption for the same individual arise even in the absence of credit market constraints that are widely believed to impede the transfer of resources across agricultural production stages in developing countries. Moreover, the dynamic and stochastic nature of agricultural production decisions, in the absence of complete contingent claims markets, means that decision rules differ funda-

[1]Fogel (1994) emphasizes the importance of better nutrition in increasing productivity in the European development experience. Behrman (1993) reviews socioeconomic survey and experimental data based studies for currently developing countries.

[2]The term 'season' often is used to refer to a complete crop cycles (i.e., the Rabi season) but sometimes to refer to stages of production within a crop cycle (i.e., the harvest season). We use season only to refer to complete crop-cycles and refer to two production periods within each crop cycle as 'planting' (the entire pre-harvest period) and 'harvesting' stages.

mentally by stage. For example, if there is not perfect insurance, consumption decisions in the planting stage of production are based on contemporaneous income and expectations about subsequent-stage harvest income. If rural households are risk-averse, higher-order moments of the distribution of harvest-stage production income matter for planting-stage consumption decisions. In contrast, in the harvest stage, consumption decisions depend on the realizations of production income in that period. In addition, if calorie consumption in the planting stage affects subsequent-stage harvest income and calorie consumption in the harvest stage affects only contemporaneous income, the decision rules differ between these two periods. For these reasons, studies that combine data across agricultural stages to estimate calorie–income elasticities not only obtain estimates that are not correct for any point in the agricultural production cycle, but also obscure the possibility that measures directed at certain agricultural stages might be much more effective for reducing calorie deficiencies than those directed at other stages of the production cycle.

Our review of 30 recent studies indicates, in particular, that:[3] (i) 30% use measures of income from time periods that are subsequent to the observations on consumption, so that estimates of income effects on calories will reflect not only smoothing considerations but also farmers' abilities to anticipate or to insure against income variation due to the effects of weather fluctuations and other factors; (ii) 50% pair individual observations on calories from one agricultural production stage with income observations from a different agricultural production stage; and (iii) 87% of the studies that pair calories and income observations within the same time period or stage also, however, combine such pairs from different stages. This latter is appropriate only if calorie–income relationships are the same across stages – a condition that is only likely to be met if calories do not influence productivity and if the calorie–expenditure relationship depends only on the structure of single-period preferences (in which case no

[3]We summarize each of the individual studies that provide unambiguous information on the time periods of observations in Behrman, Foster, and Rosenzweig (1994). This includes 22 of the studies reviewed by Bouis and Haddad (1992, Table 1) (excluding four which did not consider rural areas with micro data or which were superseded by subsequent studies by the same authors on the same data that we include in our additional studies), plus eight studies not covered in their table: Alderman and Garcia (1993), Alderman and Higgins (1992), Behrman, Bouis, and Thomas (1993), Bouis and Haddad (1992), Behrman and Deolalikar (1989, 1990), Pitt and Rosenzweig (1985), and Subramanian and Deaton (1994). The only study among these 30 that examines calorie demand relations for different production stages given initial assets is Behrman and Deolalikar (1989). But this study does not formalize the underlying dynamic model, nor does it include possible cross-stage productivity effects of calories consumed in the planting period that may affect harvest profits, the effect of agricultural production shocks due to the weather, or the endogeneity of the assets with respect to both unobserved preferences and wealth factors as well as to production shocks – all of which features we develop in our analysis below.

insight is gained into the intertemporal resource allocation component of the income–calorie relationship).[4]

In this paper, we use a detailed panel data set from rural Pakistan that enables us to estimate critical dimensions of the calorie response to different components of assets and income distinguished by production stage in the major (Rabi) agricultural season while taking into account heterogeneity in preferences and other time-invariant unobservables. We also estimate how harvest production responds to calories expended in the planting stage. Our estimates indicate that the income–calorie relationship depends importantly on both the period of the year considered and the form of income – in wages, in assets according to their liquidity, and from crop production. In particular, we find that while in the planting stage, the wage income–calorie elasticity is 0.61, increasing food stocks at the beginning of the planting period by 10 percent only increases calorie consumption by 1.3 percent. Increases in income in the harvest stage of production when food is relatively abundant, whether anticipated or not, have on average no effect on calorie consumption and only small effects on calorie consumption among households with below-average wealth. These estimates suggest that wealth differences across households understate differences in levels of well-being and that redistributing incomes to low-wealth households or increasing access to credit among these households would augment, though by a small amount, overall income levels.

2. Theoretical framework

The theoretical framework for this paper is provided by a stochastic dynamic multi-stage agricultural household model, similar to those in Antle (1983) and Skoufias (1993), with particular attention to consumption decisions and their effects on measured profits in contexts in which planting labor effort is incompletely rewarded in the labor market. Households are assumed to maximize expected discounted utility subject to the constraints that labor must be allocated between on-farm production and market work and income may be saved or consumed. There are three key features of the model that are not taken into

[4]When calories influence productivity, decisions about allocations of expenditures cannot be separated from decisions about how much is to be expended. This problem can be corrected if calorie-related productivity differentials are rewarded in the labor market by computing expenditures net of the full-income value of labor given caloric intake. This was not, to our knowledge, done in any of the previous studies. If calories are not completely rewarded in labor markets and especially if they are differentially rewarded in the planting and harvest stages, then the assumption that the expenditure–calorie relationship is the same in different stages becomes even more problematic.

account, at least explicitly, in most prior studies of the relationship between income and calorie consumption in rural households: (i) each crop cycle is divided into two stages corresponding to activity requirements, to income availability, and to the timing of the resolution of uncertainty; (ii) the productivity of labor is assumed to depend on consumption; and (iii) the extent to which nutrient consumption is rewarded in the labor market differs by stage, in accord with many models of rural agricultural contractual arrangements (e.g., Eswaran and Kotwal, 1986).

The first stage of each crop cycle is the planting stage. This stage may be characterized as a stage of shortage because food prices and the cost of borrowing[5] are high. To the extent that calories affect productivity, the low levels of consumption that result may adversely affect worker productivity. Finally, difficulties associated with the monitoring of labor productivity in the context of activities such as planting and weeding limit the extent to which caloric consumption influences wages even if there are important effects of calories on production.[6]

The second stage of the crop cycle is the harvest stage. In this period, labor demand is high, food is plentiful (low cost), and the cost of borrowing is low. Calorie differentials may still affect worker productivity, but the fact that harvest work is easily monitored implies that piece-rate payments may be used and thus that off and on-farm work will equally reward productivity differentials.

We assume that households maximize expected discounted utility with a subjective rate of discount β, and that single-period utility depends on the consumption of nutrients, c_t, and other goods, x_t,

$$\mathrm{E}_t \sum_{s=t}^{\infty} \beta^s U(c_s, x_s), \tag{1}$$

where E_t is the expectations operator evaluated at time t. Each period is assumed to correspond to one stage. Consumption in each period is financed from wage income, savings, and stage-specific farm profits:

$$p_{ct} c_t + p_{xt} x_t + s_t = F_t + \pi_t, \tag{2}$$

[5]Interest data from the study population indicate that the annualized interest rate from money lenders varied from 12% in the harvest period to 40% in the planting period.

[6]Foster and Rosenzweig (1994) present evidence that calories are more rewarded under piece rates than under time wages in the same activity. Although some planting stage activities can be carried out on a piece-rate basis and some harvest activities can be carried out on a time–wage basis, evidence from other Asian agricultural labor markets suggests that time wages tend to be paid for planting-stage activities and piece-rate wages tend to be paid for harvest-stage activities (Walker and Ryan, 1990; Foster and Rosenzweig, 1993).

where p_{ct} and p_{xt} are prices; F_t, is potential labor income and equals $w_t N_t$, where w_t is the relevant stage-specific wage rate and N_t is the maximum time of family members that could be spent working in the period; s_t is net savings; and π_t denotes the stage-specific farm profits which are defined as current-period farm revenues net of expenditures. We also assume that assets have a rate of return r_t that varies over time:

$$A_{t+1} = (1 + r_t)(A_t + s_t). \tag{3}$$

Output in a given harvest stage is assumed to depend on planting and harvest-stage labor and nonlabor inputs and a shock that is observed after the planting-stage decisions are made. In order to allow for the possibility that calories influence productivity we distinguish the total amount of effective work done in each stage from the number of days contributed by workers. In particular, we let $e(c_t)$ denote the efficiency of a worker with caloric intake c_t at time t so that the number of efficiency units of family labor used on the farm may be written $L_t^{\mathrm{ef}} = e(c_t)L_t^{\mathrm{f}}$, where L_t^{f} is the quantity of on-farm family labor used and c_t is the caloric intake of family members at time t. Similarly, the efficiency units of hired or wage worker labor L_t^{w} may be written $L_t^{\mathrm{ew}} = \bar{e}_t L_t^{\mathrm{w}}$, where $\bar{e}_t$ is the average efficiency of labor hired by the household at time t, which depends on the caloric intakes of the workers hired.

Because output arrives in the harvest stage, planting-stage 'profits' are negative, consisting of the costs of the planting-stage agricultural inputs such as fertilizer and labor. Denoting the tth period as a harvesting period, $t = h$, and thus period $t - 1$ as its corresponding planting period, $t - 1 = p$, harvest-stage profits are

$$\pi_h = p_{fh} f(I_h, L_h^{\mathrm{e}}, I_p, L_p^{\mathrm{e}}, \varepsilon_h) - p_{Ih} I_h - w_h^{\mathrm{e}} L_h^{\mathrm{ef}} - w_h^{\mathrm{e}} L_h^{\mathrm{ew}}, \tag{4}$$

where p_{fh} is the price of the output good, $f(.)$ is the production function, ε_h is the production shock, I_h denotes nonlabor harvest-stage inputs and p_{Ih} its price, and w_h^{e} is the harvest-stage wage per efficiency unit of labor or, equivalently, the piece-rate price. Note that output depends on the total efficiency units of labor used in each of the planting and harvesting stages but that harvest-stage profits are gross of planting-stage input costs and net of harvest-stage input costs.

The farm household chooses inputs and calorie consumption in the harvest stage to maximize (4), taking as given asset stocks, planting-stage inputs chosen in the prior planting period, contemporaneous prices and wages, and the information on the now-realized production shock. Substitution of the optimal decisions into (4) would thus yield a harvest-stage profit *function* with planting-stage inputs, planting-stage consumption, the production shock, assets, and prices as arguments, including the harvest-stage prices of all consumption goods and the stock of financial savings (which influence harvest-stage calorie consumption).

The profit function can also be solved conditional on harvest-stage consumption, thereby eliminating all consumption prices and financial assets. It is easily seen that the effect of planting-stage inputs on profits in such a function is equal to the marginal revenue product of these inputs, $\partial\pi_h/\partial I_p = p_{fh}(\partial f/\partial I_p)$. The interpretation of the effects of stage-specific caloric intakes on profits depends on whether calories affect productivity and whether the resulting productivity differentials are rewarded in the labor market. For the harvest stage, when productivity differentials are fully compensated with wage payments, there is no effect on profits of calories consumed by family workers in that stage:

$$\frac{\partial\pi_h}{\partial c_h} = \left[\frac{\partial f}{\partial L_h^{\mathrm{e}}} - w_h^{\mathrm{e}}\right] e'(c_h)L_h^{\mathrm{f}} = 0. \tag{5}$$

The term in brackets is zero because of the assumption that the efficiency units of family and hired labor are perfect substitutes and efficiency units are rewarded appropriately: workers will be hired up until the point that the marginal product of an efficiency unit of labor is equal to the wage per efficiency unit of labor.

By contrast, the effect of planting-stage calories on harvest-stage profits is

$$\frac{\partial\pi_h}{\partial c_p} = \frac{\partial f}{\partial L_p^{\mathrm{e}}} e'(c_p)L_p^{\mathrm{f}}, \tag{6}$$

which will be positive if family labor is used on farm, there is a positive effect of calories on productivity, and the marginal product of planting-stage labor is positive. The fact that expressions (5) and (6) are different may appear to be a result of the fact that planting-stage costs are not a component of harvest-stage profits. However, if planting-stage input costs are subtracted from harvest-stage profits planting-stage consumption will still positively affect profits as long as calories are not rewarded in the labor market in the planting stage. Thus in the presence of labor-market imperfections that are a marked feature of many rural labor markets and of models of the agricultural sector concerned with contractual arrangements in these markets, calories have the same effect on a more conventional measure of profits, aggregating stage-specific profits, as they do on harvest-stage profits alone.[7]

[7] In the absence of planting-stage labor-market imperfections and assuming that the shock does not affect the marginal harvest-stage product of planting-stage labor, a zero effect of family planting-stage calories on aggregated profits will obtain. While this result suggests that a test for labor-market imperfections might be constructed using estimates of an aggregated profit equation, it should be noted that a positive effect of calories on profits may nonetheless be observed if family labor is not properly valued. It is also true that if labor productivity is appropriately rewarded in the harvest stage, the consumption of calories by hired workers does not affect profits, net of wages, because the marginal product of efficiency units of labor is equated to the labor price in that stage. The same will be true for family-worker calorie consumption; however, only if profits correctly incorporate the opportunity cost of family labor, which requires that all members work for wages in the relevant period.

As a consequence of the dependence of harvest-stage profits on lagged (planting-stage) consumption and of the stochastic nature of harvest-period income, the structure of consumption decision rules differ across stages. In particular, decision rules in the planting stage incorporate complex relationships because they importantly influence subsequent harvesting decisions. The planting-stage consumption decision rule may be written

$$C_p = C_p(A_p, w_p, F_p, \boldsymbol{p}_p, G), \tag{7}$$

where G is the joint distribution of the stochastic variables that become known to the farmer at the beginning of the harvest stage, including harvest-stage wages and prices, the production shocks, and the efficiency of planting-stage hired workers. It is assumed that G is the same in each planting stage.[8] The harvest-stage consumption decision rule can be expressed in terms of the planting-stage state variables, as in

$$C_h = C_h(A_p, \boldsymbol{p}_p, \boldsymbol{p}_h, w_p, w_h^e, F_p, F_h, \bar{e}_h, G, \varepsilon_h). \tag{8}$$

As can be seen, Eq. (8), the harvest-stage consumption relation, differs from Eq. (7), the planting-stage consumption function, in that in the latter neither the harvest-stage wages (and prices) nor the unanticipated component of profits appears as an argument. Estimates of the relationship between income aggregated over the two stages of production and consumption in the *planting* stage thus correspond to neither the harvest nor the planting-stage decision rule. In particular, the unanticipated component of 'income' (the shock ε_h) could not possibly influence consumption in the planting stage, and the other, anticipated, component of harvest-stage profits is the consequence of planting-stage decisions, inclusive of calorie consumption. Thus it is critical in obtaining meaningful estimates of how income affects consumption in the context of rural households not only to differentiate the consumption decisions by production stage but to distinguish between stage-specific known, anticipated, and unanticipated components of income.

3. Specification and estimation procedure

In our theoretical framework, there are four distinct contemporaneous 'income effects' on calorie consumption in the two stage-specific decision rules (7) and (8): the effect of wage income in the planting stage on planting-stage consumption, the effect of planting-stage assets (or asset income) on planting-stage consumption, the effect of harvest-stage wage income on harvest-stage

[8] Over long time periods G may change as a consequence of advances in cropping technology that alter the riskiness of agricultural production.

consumption, and the effect of the unanticipated component of harvest profits (the shock) on harvest-stage consumption. Our estimation strategy is to measure these effects by estimating approximations to the two stage-specific decision rules. To estimate the harvest-stage decision rule we need an estimate of the unanticipated part of harvest profits ε_h. To obtain this, and to estimate the effect, if any, of planting-stage consumption on harvest profits, we first need to estimate the harvest-stage conditional profit function. The assumption that hired and family labor are perfectly substitutable in the harvest stage, when piece rates are pervasively used, means that the model is quasi-separable, or separable conditional on the planting-period production inputs inclusive of the consumption of family members if such consumption is not rewarded in the labor market. Thus we need information on harvest-stage profits, planting-stage inputs, and consumption and harvest-stage prices to estimate this function.

We obtain estimates of the conditional harvest-stage profit function by first normalizing using total cultivated area, and then estimating a generalized-Leontief profit function with an additive fixed-effect. In particular if K is the vector of normalized arguments in the profit function other than the stochastic terms then we may write the estimated per acre profit function for farmer j in the period-t harvest as

$$\frac{\pi_{ijt}}{H_{ijt}} = \sum_{k_1=1}^{k} \left[\gamma_{k_1} K_{k_1 t} + \sum_{k_2=k_1}^{k} \gamma_{k_1 k_2} K_{k_1 t} K_{k_2 t} \right] + v_{ij} + \varepsilon_{ijt}, \tag{9}$$

where H_{ijt} is total cultivated area[9] and v_{ij} represents time-invariant characteristics of the household, such as its land quality, farming ability, and preferences, that are not measured in the data.

The principal problem in estimating the conditional harvest-stage profit function (9) is that all of the planting-stage production inputs are likely to be correlated with the permanent component of the error term and thus are endogenous, although they cannot be, given the information assumptions, correlated with the post-planting harvest shock. Differencing (9) across adjacent harvest stages eliminates the (linear) influence of the unmeasured time-invariant land and farmer quality inputs. However, differencing also potentially introduces a new estimation problem because the harvest production shock in the first crop-cycle affects harvest-stage consumption in that first crop-cycle (Eq. (8)) and thus the next-cycle planting-stage stocks that may influence the input and consumption decisions in the second-cycle planting stage (Eq. (7)). We use instrumental variables to correct this problem, employing as instruments lagged

[9] Because, as discussed below, profits includes revenues from shared out and shared in land, which may be importantly affected by weather and other shocks, the measure of cultivated area used for normalization is the sum of own, shared-in, and shared-out cultivated area.

values of assets (including inherited assets), prices, and wages. Note that because the fixed effect is eliminated by differencing, any variables not appearing in the crop-cycle normalized conditional profit function and occurring prior to the realization of the *first* crop-cycle-specific shock ε_{ijt-1} are valid instruments, and effective if they are correlated with the difference in input values across crop cycles.

The estimates of the profit--function parameters enable, by subtracting the predicted harvest-stage profits from actual harvest-stage profits, the computation of two compound residual terms for each household containing the household profit fixed effect v_{ij} and the stage- and crop-cycle-specific post-planting shock ε_{ijt}.[10] These are used to estimate a linearized approximation to the consumption decision rules for the planting and harvest stages, the latter containing in addition to the harvest output shock the planting-stage stocks and unobservable time-invariant preference and wealth factors (e.g., land quality, distributional characteristics of area-specific weather) as determinants. We employ a similar estimation strategy as for the estimation of the conditional harvest-stage profit function, except that to take into account possible nonlinearities we estimate the linear approximations to the consumption functions separately for different land-wealth groups. Instruments are needed not only because crop-cycle-specific consumption shocks influence future stocks, so that the difference in planting-stage stocks across crop-cycles is correlated with differences in planting and harvest-stage consumption shocks, but also because the computed harvest-stage production shock ε_{ijt} contains measurement error. We discuss below the additional assumptions and variables we employ as instruments to eliminate the problem due to measurement error.

4. Data

To estimate the relationships between assets, income, and calorie consumption within the context of the dynamic-stochastic model, while taking into account heterogeneity among households, poses considerable demands on data: information is needed on stage- and season-specific prices and wages, and on household-specific variables such as consumption, assets, production inputs and outputs for at least two complete and comparable crop-cycles. The longitudinal data set that we use meets these requirements more closely than any other among those of which we are aware. The data are from a recent survey carried out by the International Food Policy Research Institute (IFPRI), the Pakistan

[10]It is possible that the shock contains both an anticipated and an unanticipated component. For example, an early intraseasonal drought period may influence planting-stage decisions. We test below whether the shock is purely unanticipated.

Food Security Survey. It is not only comprehensive in production, earnings, and consumption information but was collected in many rounds sufficiently closely-spaced to identify specific crop-stages within each of the two annual crop-cycles (Rabi and Kharif). The data were collected in twelve rounds at approximately three-month intervals and cover a sample of 926 households residing in 52 villages in three major wheat-growing provinces of Pakistan – Punjab, Sind, and the Northwest Frontier Province – followed over the period July 1986 through September 1989.

Because information in the survey refers to the interval between rounds, with the exception of consumption information and some other variables, only four of the twelve rounds permit a reasonably precise identification of variables in planting stages and their corresponding harvest stages for the same crop cycle, the Rabi, which is the major crop cycle.[11] In the three provinces, Rabi planting takes place in the months of November and December, while Rabi harvesting occurs in March and April. Information from rounds 7 and 10, which recorded information in the interval between the months of July and January for 1987–88 and 1988–89, thus are used for Rabi planting-stage variables and rounds 8 and 11, which recorded information in the interval between January and March/April for the corresponding years provide the variables for the Rabi harvest stages. Because, for the most part, inputs and assets are identified as belonging to a stage *cum* season by the interval in which they appeared and/or by the type of input (e.g., fertilizer versus thresher) and crop outputs are identified in the data as belonging specifically to either the Rabi season or Kharif season, information for computing profits and estimating profit functions could be obtained for each of the three Rabi seasons.

Rabi harvest profits were computed by subtracting from the value of harvested Rabi crops grown on the household's self-cultivated land the value of family and hired labor used in harvesting and thresher costs. Harvest labor costs were computed by dividing up both hired and family labor into adult males and females and children, summing within categories across hired and family labor, and multiplying each category of labor by the year/season and stage-specific

[11] Because the Rabi period immediately follows the Kharif season in rural Pakistan the degree of scarcity in the Rabi planting stage is likely to be less severe than that in the Kharif planting stage. To the extent that consumption-smoothing problems are evident in the Rabi planting period, they are likely to be more dramatic in the Kharif planting period. It should also be noted that to the extent that Rabi planting overlaps in time significantly with Kharif harvesting, the approach suggested above would not be appropriate for the analysis of the Kharif season even if the data permitted appropriate allocation of inputs in that season. The reason is that our approach assumes that labor markets are operating efficiently during harvest stages, an assumption that would be of questionable validity if Kharif harvest and Rabi planting occurred at the same time and labor markets inefficiencies arise during planting stages.

daily wages for that category of labor. The aggregation of harvest labor across family and hired labor conforms to the assumption of the model and to information from other data that harvest labor is paid by piece rates so that the usual advantages of family over hired labor associated with incentives problems are minimized.

A small fraction of households leased in or out land on a share basis. As a consequence, because households sharing out their land share in the (risky) output of that land and thus contribute to risky harvest income, we added to household profits from self-cultivated land the landlord's (household's) share (provided in the data) of the value of output harvested on the shared-out land. Any (planting-stage) inputs provided by the household to the share tenant were then included, as a separate input, among the planting-stage inputs, which also included fertilizer value (Rs), bullock days, and male and female labor days in planting activities, along with owned land, by irrigated or dry, under cultivation. The household's inputs provided to its tenants included the amount (acres) of shared out irrigated and nonirrigated land and the value of all other inputs provided to the tenant. Similarly, the landlord's share of the value of the output harvested on land shared in by the sample household was subtracted from the harvest profits on shared-in land, and shared-in land, by irrigation type, and landlord provided nonland inputs are included among the planting-stage inputs.[12]

Daily per-capita calorie consumption was computed by IFPRI staff from the information collected in each round on foods consumed by the household in the week preceding the round-specific survey date. Per-capita daily calorie consumption in the Rabi planting stages (rounds 7 and 10) is included among the set of inputs in the conditional profit function.

Using our first-differencing method we are able, using information on asset flows that are provided in the data, to estimate the effects of planting-stage food stocks, debt, financial savings, and inventory on daily per-capita calorie consumption in the planting and harvest stages. In addition, we use data on the flows of monies and food stocks provided to friends and relatives and received from friends and relatives to obtain an estimate of the effect on calorie consumption of variations in net informal indebtedness ('transfer debt') – the difference between the cumulative stock of all transfers out and transfers in.

Finally, we computed the value of family potential (full) labor income in the planting and harvesting stages by multiplying the number of adult family males,

[12] We exclude fixed-rent land from the profit function because these payments (in or out) do not influence the unanticipated component of profits, assuming that there is no default; in any case, the data do not provide sufficient information on the timing of the payment of rents to assign with precision this component of revenues to the planting and harvesting stages. Note that this exclusion does not present a problem from the perspective of the estimation of consumption decision rules because land payments reflect decisions that are made in the planting stage.

Table 1
Means and standard deviations by owned land

	Total	Land $\leqslant$ 1.5 acres	Land > 1.5 acres
Rabi planting-stage daily calories per person	2180 (657)	2076 (652)	2277 (647)
Rabi harvest-stage daily calories per person	2602 (1039)	2488 (1819)	2711 (1048)
Rabi planting-stage potential labor income per day (Rs)	87.8 (42.1)	84.4 (42.1)	91.2 (41.8)
Rabi harvest-stage potential labor income per day (Rs)	158.6 (72.6)	151.3 (70.08)	165.4 (74.4)
Rabi harvest-stage profits (Rs)	7164 (25031)	4452 (10509)	8361 (30001)
Rabi planting-stage food stocks (Rs)	723.7 (1509)	331 (711.7)	1126 (1944)
Household size			
Total	8.207 (4.186)	7.949 (3.859)	8.450 (4.464)
Men $\geqslant$ 15	2.691 (1.599)	2.573 (1.573)	2.811 (1.618)
Women $\geqslant$ 15	2.431 (1.396)	2.255 (1.344)	2.610 (1.427)

adult females, and children (ages 6 through 15) by the relevant stage- and season-specific median of daily wages for the relevant sex/age groups.[13] Table 1 provides means and standard deviations for a number of the computed stage-specific Rabi-season variables for the sample of 685 wheat-growing households for whom we could compute all of the relevant variables and for the subsamples of households differentiated by owned landholdings (the harvest-stage profit variables refer to the 586 cultivating households in this sample). As can be seen from that table, per-capita calorie consumption is significantly higher (by 19% overall) in the harvest stage compared to the planting stage, and this is true for both the small landholding and larger landholding households, indicating the likelihood of substantial variance in the cost of consumption within the year. While the absolute differential in calorie consumption between the larger and smaller landholding households remains constant across the two stages, it is

[13]Changes in family composition across the two Rabi seasons used for estimation were negligible. Thus household variations over time in potential income only reflect wage-variation and family-composition variables do not appear as separate regressors in the differenced specifications.

interesting that the variability in consumption rises considerably from the planting stage to the harvest stage, by 58% overall, and particularly so for the smaller landholding households, for which the standard deviation rises by 179%. This rise in consumption variability may reflect the fact that at the planting stage calorie consumption is close to subsistence, while at the more food-abundant harvest stage heterogeneity in individual preferences for food consumption may be playing a more important role.

5. Estimates

Table 2 reports the computed sample-mean derivatives, and their associated standard errors, based on IV differenced estimates of the parameters of the conditional normalized generalized Leontief harvest-stage profit function obtained from the sample of 586 cultivating households. The computed standard errors are robust to heteroskedasticity and are corrected for the nonindependence of observations from households contributing more than two observations. Because the four variables describing the proportion of land area shared out or in, classified by irrigation status, did not change very much over the two years, these variables were included only as linear terms and their coefficients and standard errors are reported directly. The first column is distinguished from the second in that planting-stage household calorie consumption is excluded from the former. Both specifications also include interactions between village dummy variables and the crop-year to capture area-specific differences over time in all input and output prices.[14] Hausman tests indicate that, as expected, the error terms in the differenced specification are significantly correlated with the set of included regressors for both specifications. In addition, the set of 46 squared and interaction terms associated with the generalized Leontief form are statistically significant ($F(46, 446) = 4.24$), thus rejecting a linear profit-function specification.

The estimates of conventional inputs effects are, for the most part, reasonable although not precisely estimated. The latter may be due in part to the use of an estimation method that is not fully efficient. The point estimates indicate that self-cultivated and own irrigated acres are substantially more profitable than self-cultivated and owned nonirrigated acres – transforming an owned acre from dry to irrigated increases its profitability at the sample means by a statistically significant 4300 rupees – and the share return from an irrigated acre that is shared out is substantially higher than that of a shared out dry acre by a similar

[14] The estimates of the full set of 60 input parameters and 79 time–village dummy coefficients are available from the authors upon request.

Table 2
IV differenced estimates: Normalized generalized Leontief harvest-stage profit function for rabi crops

	I	II
Derivatives at sample means		
Own irrigated cultivated area	4304 (1469)	4434 (1529)
Bullocks (days)	114 (74.0)	92.8 (76.7)
Fertilizer (Rs)	– 2.79 (2.97)	– 2.96 (3.02)
Inputs provided to tenant (Rs)	12.8 (9.85)	11.8 (10.3)
Inputs from landlord (Rs)	14.7 (5.72)	15.5 (5.89)
Total male labor (days)	1939 (1701)	2095 (1717)
Family male labor (days)	74.5 (38.8)	87.9 (41.5)
Total female labor (days)	– 312 (223)	– 357 (227)
Family female labor (days)	– 149 (125)	– 131 (132)
Coefficients		
Irrigated land shared out	3891 (1569)	4018 (1607)
Dry land shared out	293 (814)	172 (819)
Irrigated land shared in	– 2245 (3401)	– 3146 (3420)
Dry land shared in	– 2130 (1690)	– 2929 (1775)
Per-capita calories per day	—	0.884 (0.549)
Per-capita calories squared ($\times 10^{-3}$)	—	– 0.132 (0.066)
χ^2 test of exogeneity (df)	144.8 (58)	112.2 (60)

Estimates based on 586 households contributing 1172 observations.

All specifications include village × time dummies (not shown). These control for contemporaneous variation in wages and prices.

All right-side variables other than village × time dummies are treated as endogenous. Instruments include planting-stage variables from initial crop-cycle, inherited assets, household composition, land ownership, and village-land inheritance interactions.

Robust standard errors in parentheses.

amount. The estimates also indicate that male family labor in the planting stage is significantly more profitable than male hired labor, by 75 rupees per day per acre. The estimates also suggest, however, that fertilizer and female labor on average contribute insignificantly to profits.

In the second column, the estimates of the per-capita planting-stage calorie consumption variables are jointly statistically significant at the 0.03 level.[15] The point estimates indicate that the relationship is nonlinear in the expected way – there are positive (up to almost two standard deviations above sample mean per-capita calorie consumption in the planting period) but diminishing harvest-stage profit effects of changes in per-capita daily calorie consumption in the planting stage. This result thus suggests that the notion that the consumption and income decisions are separable, as is assumed in studies that estimate the relationship between total expenditures and calorie intake, is incorrect due to the existence of a calorie–productivity relationship. Moreover, studies that assume that farm income is exogenous to calorie consumption are also likely to yield biased results, particularly if a component of income is measured from the harvest stage and consumption is measured at the planting stage. At the sample mean in the planting stage for those cultivating households owning less than 1.5 acres of land, the point estimates indicate that for each increase in household per-capita consumption of 100 calories in the planting stage, harvest income would be increased by 34 rupees per acre cultivated (3%). The same increase in per-capita calories for cultivating households owning at least 1.5 acres of land yields only a 22 rupee-per-acre increase in profits.

The estimates of per-capita calorie effects on profits do not suggest that increasing calorie consumption is profitable. Assuming that the effect of calorie consumption on profits is through the work effort of adult family members and that the planting stage lasts 100 days, to increase each family worker's per-capita daily calorie consumption by 100 calories for the whole stage requires an increase of 50,000 calories (assuming five adult equivalents per household).[16] The cost of increasing calories by this much (approximately 67 rupees) just exceeds the additional profits of 51 Rs for the best-off poor (1.5 acres owned) household for a reasonable estimate of the cost of calories in Pakistan (750 calories per Rs).

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[15]In contrast, as predicted if labor markets are operating efficiently in the harvest stage, harvest-stage calorie consumption and its square do not have a statistically significant effect on harvest-stage profits conditional on planting-stage calorie consumption ($F(2,153) = 1.25$).

[16]Our use of per-capita (adult-equivalent) calorie consumption in the profit function assumes the household allocates calories proportionately among family members. Because the data do not provide individual-specific food consumption, it is not possible to identify the effects of alternative intrahousehold allocation rules or to assess the profit consequences of providing the increased calories only to workers.

Estimates of the planting-stage consumption decision rule for the entire sample of 685 households are presented in the first column of Table 3, where again village–year interaction coefficients included to control for prices are not presented. The estimates indicate that the set of planting-stage state variables are statistically significantly related to planting-stage consumption.[17] The estimate of the effect of an increase in labor income is positive and statistically significant, with the point estimate indicating that the labor income elasticity is 0.61 in the planting stage. This estimate is at the higher end of those studies using income, but is only marginally higher than the 'lean season' elasticity in Behrman and Deolalikar (1989). The estimated effect of an increase in own food stocks on calorie consumption in the planting stage is also statistically significant, indicating a food-stock elasticity of 0.13. Households with greater debt at the beginning of the planting period exhibit lower consumption during that period, but the effect is small – a 1000 rupee increase in indebtedness at the beginning of the planting stage is associated with only a 4.2 calorie decrease per person. The signs on the coefficients on inventory are positive and significant as might be expected while the signs on savings and equipment are (surprisingly) negative. Interestingly, an increase in the level of transfer debt (i.e., the stock of remittances received in previous periods) also results in a significant decrease in caloric intake, with the magnitude being about twice the size of that observed for other debt.

In columns two and three the estimates of the planting-stage/consumption relationships are presented for households differentiated by land holdings. These results indicate that the labor-income/calorie elasticity is considerably higher in the poorer (by land wealth) half of households – for those households with landholdings with 1.5 or less acres of land, the calorie/income elasticity is 1.0, while the corresponding elasticity for the households with more than 1.5 acres of land is 0.54.[18] Similarly, a 100 rupee increase in the value of food stocks of poor households results in a 2.9% increase in calories for the poorer households and only a 1.3% increase for the better-off households.[19] The magnitude of the effect

[17] It is not suprising that the individual coefficient estimates are not precise. It is likely that our instruments are not able to predict well the specific asset compositions of farmers even though they evidently predict overall asset accumulation by stage and year.

[18] Behrman and Deolalikar (1989) also find a similar pattern when they divide the sample that they use between large and small cultivator households. For the lean season, for example, they report calorie elasticities with respect to full labor income of 0.61 for small cultivators and 0.34 (and very precisely estimated) for large cultivators.

[19] Given the approximate price of calories in Pakistan, this estimate appears reasonable. At 750 calories per rupee the 100 rupee increase could support 75,000 calories over the entire planting stage for all household members, while the measured effect indicates caloric intake increases by 30,000 calories. Thus it is clear that some stocks are held as hedge and/or are used support other forms of consumption.

Table 3
IV differenced estimates of per-capita daily calorie decision rules in rabi planting and harvesting stages

	Planting stage			Harvest stage		
	All	⩽ 1.5 acres	> 1.5 acres	All	⩽ 1.5 acres	> 1.5 acres
Planting-stage state variables						
Labor potential income (Rs/day)	15.2	24.9	13.4	− 9.26	− 12.6	− 7.56
	(5.28)	(6.75)	(2.04)	(9.55)	(15.2)	(12.0)
Food stocks (Rs)	0.381	0.599	0.306	− 0.116	− 1.92	0.0866
	(0.083)	(0.148)	(0.086)	(0.073)	(1.59)	(0.082)
Debt ($\times 10^{-2}$ Rs)	− 0.419	− 0.000	− 1.41	0.0367	− 0.0918	− 0.904
	(0.279)	(0.001)	(0.382)	(0.153)	(0.068)	(0.378)
Savings ($\times 10^{-2}$ Rs)	− 1.74	− 1.01	− 1.29	− 0.223	− 1.36	− 0.547
	(0.719)	(1.77)	(0.729)	(0.001)	(0.809)	(0.456)
Equipment ($\times 10^{-2}$ Rs)	− 0.629	14.4	− 0.427	− 0.100	59.8	0.335
	(0.403)	(9.73)	(0.411)	(2.5)	(42.4)	(0.353)
Inventory ($\times 10^{-2}$ Rs)	1.65	0.563	− 0.074	0.0662	0.467	− 0.665
	(0.727)	(0.662)	(0.389)	(0.118)	(0.556)	(0.723)
Transfer debt ($\times 10^{-2}$ Rs)	− 0.874	− 4.74	− 0.309	− 0.406	− 0.160	− 0.0318
	(0.444)	(2.07)	(0.332)	(0.327)	(0.410)	(0.318)
Harvesting-stage realizations						
Potential labor income (Rs/day)	—	—	—	4.47	6.26	− 0.265
				(15.4)	(23.2)	(26.5)
Production shock ($\times 10^{-2}$ Rs)	—	—	—	0.188	2.24	0.0567
				(0.289)	(0.679)	(0.315)
F-statistic for joint significance of state variables:	3.61	5.97	4.44	0.642	2.65	1.59
df1,df2	7,679	7,309	7,322	9,675	9,307	9,318

Analysis based on 730 households, with two observations per household. 358 of these households have land < 1.5 acres and 372 have land > 1.5 acres.

All specifications include village × time dummies (not shown). These control for contemporaneous variation in wages and prices.

All right-side variables other than village × time dummies are treated as endogenous. Instruments include initial crop-cycle state variables (other than the production shock and food stocks), inherited assets, household composition, land ownership, and village × land inheritance interactions.

Robust standard errors in parentheses.

for transfer debt is much higher for the poorer households. Thus the general picture that emerges is that caloric intake is sensitive to resource availability primarily for the lower half of the land distribution in the sample area studied.

The evident high income and food-stock elasticities for the poorer households during the planting stage appear to be mainly the result of the low levels of consumption during the planting stage that, in turn, reflect the high prices for food and/or credit in that stage. The estimates of the calorie consumption relations in the harvesting stage for the entire sample, reported in column four, suggest that on average none of the stocks or harvest-stage labor income or the harvest-stage profit shock affect calorie consumption. However, this is not true for the less-wealthy households. The estimates of the consumption relations for the two land-wealth classes are reported in the last two columns of Table 3. Not only are the set of asset variables statistically significant for the poorer households, the effect of the income shock is positive and significant (column five). However, the precisely estimated shock coefficient implies a calorie transitory income elasticity of only 0.05, and neither the asset stocks nor the income shock affect consumption among the wealthier households. Thus, income or food appear to be sufficiently abundant in the harvest stage that income or wealth increases in that period have little effect on calories consumed by the sample households, even among the poorer households. It is interesting to note that averaging our estimated harvest-stage and planting-stage elasticities of calories with respect to income for the poorer households using equal weights gives an 'overall' elasticity (0.52) that is comparable to the estimated elasticities for the lowest income deciles found for a number of countries (Strauss and Thomas, 1995).

There are two possible reasons that a favorable harvest, indicated by the production shock variable, does not affect calorie consumption for the wealthy and has a small effect on the consumption of poorer households compared to the effect of potential labor income in the planting stage. First, the shock variable that we have constructed, because it is based on estimated parameters and because it will contain any measurement error in profits, imperfectly measures the stochastic component of harvest income. Second, even if measured without error, the harvest shock may partially reflect anticipated harvest profits. To eliminate measurement error in this variable we included among the instruments interactions between inherited land and village dummies. These variables reflect the differential effects of village-level weather and price shocks on households with different holdings of (inherited) land wealth, and thus with different probabilities of cultivating land in the study period. To test the hypothesis that the shock was partially known in the planting stage, we jointly estimated using three-stage least squares planting-stage input decision rules for bullocks, fertilizer, male and female labor, and calorie consumption including the harvest-stage shock as a state variable. We could not reject the hypothesis that the set of coefficients associated with the harvest-stage shock was zero

($F(5,1130) = 0.815$). Thus there is no evidence that the shock contains an anticipated component.

6. Conclusion

In this paper we have examined the relationships between income and calorie consumption, bringing to bear more realistic characterizations of the constraints facing households in rural areas of low-income countries. In particular, we have incorporated credit and labor market imperfections, productivity effects of calorie consumption, and the seasonal nature of production. Our estimates, based on data from rural Pakistan, suggest that distinguishing between the stages of agricultural production is critical for understanding the impact of income on caloric consumption. This is both because of the differential costs of consumption in the two stages of production and because of harvest productivity effects of calories consumed in the planting stage. As a result, we find considerable variation in calorie–income elasticities not only by wealth class as noted by others, but also by stage of production within class. Studies that are not attentive to this heterogeneity that reflects the underlying realities of rural populations, can potentially lead to misleading inferences with regard to the productivity effects of increased nutritional intake, the welfare costs of market imperfections, and disparities in welfare across wealth classes. Our estimates imply, for example, that there are small productivity effects of caloric consumption in the planting stage that are realized only in the harvest stage, and the calorie elasticity with respect to labor income in the planting stage is relatively high, particularly for households with relatively small landholdings. But there is no evidence of productivity effects of calories and little responsiveness of calories to fluctuations in income in the harvest stage in which food is generally relatively plentiful. Our finding that for low-wealth farmers the cost of an increase in calories in the planting stage approximately equals the resulting increase in profits combined with our finding that their calorie consumption increases substantially in the harvest period suggests that these farmers face a high cost of transferring resources across stages. This implies that improving the operation of credit markets would increase both the welfare and productivity of poor relative to wealthy farmers.

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