Staff Paper

Identifying Policy Relevant Variables for Reducing Childhood Malnutrition in Rural Mali

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Abstract

The paper uses OLS and Logit analyses of household survey data to identify and compare determinants of the health and nutritional status of Malian children living in three distinct agricultural production zones (cotton, millet/sorghum, and irrigated rice). These preliminary results suggest that improvements in health center coverage (e.g., reducing the average distance to a health center from 20 to 10 kilometers) and more diversity in complementary foods after six months of age (two or more different foods during a 24 hour period) have the potential to significantly improve standardized height for age scores. Other factors of importance are mothers' incomes, prenatal visits, and parents' standardized heights (reflecting either genetic traits or generations of poor nutrition). Recommendations for reducing Mali's high prevalence of malnutrition include the need to raise awareness of the problem among rural populations. Because rural health workers, local administrators, and parents do not recognize malnutrition as a problem, newly empowered decentralized governments will need some external assistance to get the issue on local agendas and identify potential solutions.

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Identifying Policy Relevant Variables for Reducing Childhood Malnutrition in Rural Mali

Problem Statement: Child malnutrition is a serious problem in Mali. By 18 months, 25% of children are wasted and 40% are stunted.[1] Given the conventional wisdom that high rates of malnutrition are associated with low incomes, it was surprising to many that sustained increases in Malian agricultural productivity and rural incomes during the 1990s were not accompanied by a reduction in the prevalence of malnutrition (Penders, 1999). This apparent paradox is symptomatic of a broader problem: the need to better identify and understand the relationships among the variety of factors that affect children's health and nutritional status in Mali. A recent study of the linkages between child nutrition and agricultural productivity growth in Mali (LICNAG) addressed this challenge. This paper reviews the key LICNAG findings on the determinants of children's nutritional status and the policy implications of the findings.

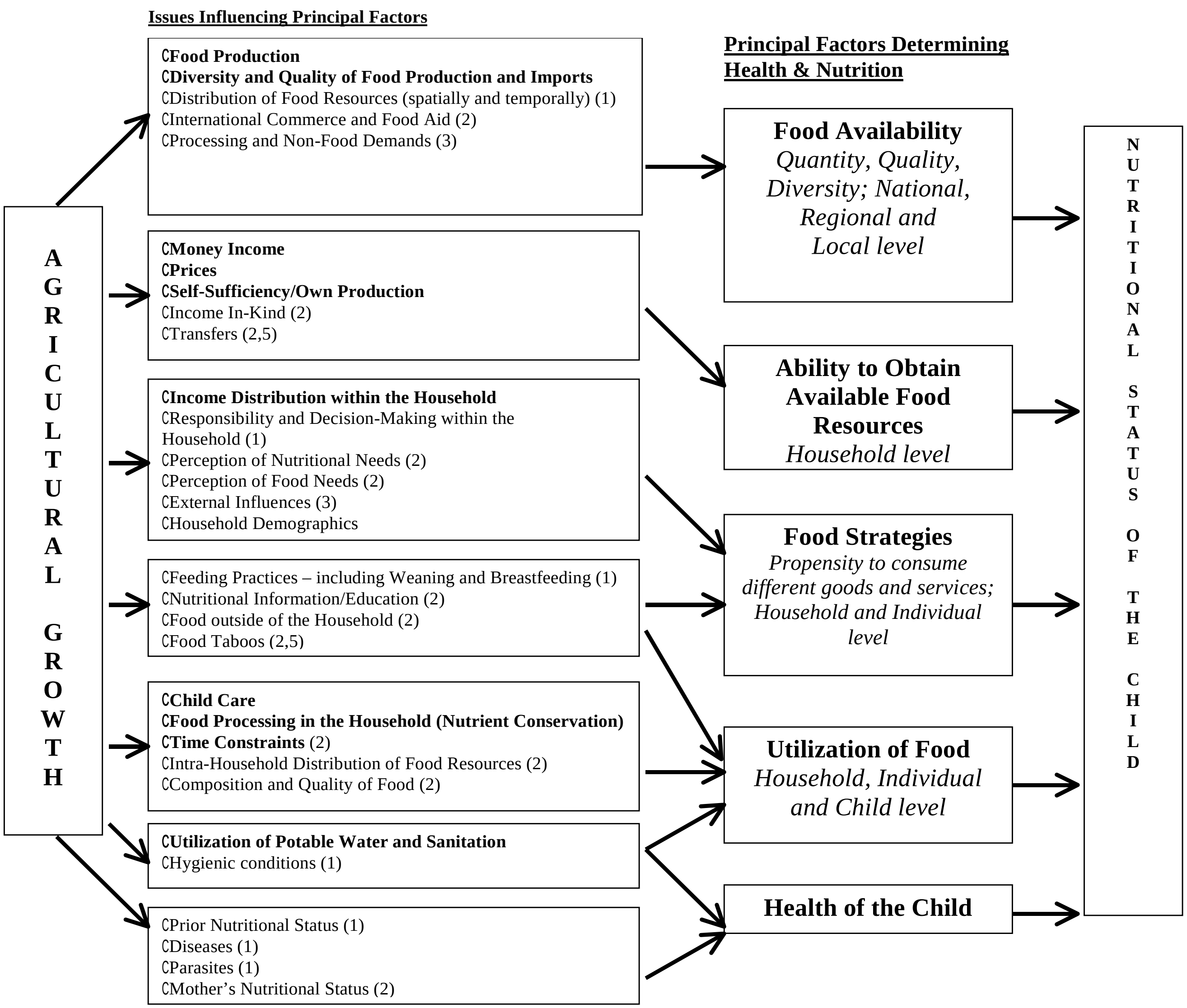
Research hypotheses Children's health and nutritional status can be influenced by a broad range of factors, as illustrated in Figure 1. Nutrition research elsewhere has shown that the relative importance of these determinants and whether the impact is positive or negative is not consistent across different studies (see Penders, 1999, for a review). These results underscore the need to examine the Malian situation directly rather than drawing conclusions from other studies. The LICNAG study took the framework shown in Figure 1 as a point of departure in developing testable hypotheses and designing data collection methods. The study focused on testing hypothesizes about factors thought to be positively correlated with better nutritional status for rural children in Mali. These factors include:

1. Higher agricultural incomes and/or household wealth
2. More educated parents
3. Mothers who use recommended feeding and childcare practices
4. Availability and use of well staffed health facilities
5. Parents who are knowledgeable about prevalent childhood diseases
6. Use of recommended hygiene and sanitation practices
7. Parents' age, health and genetic attributes
8. Location (type of agricultural production system, level of infrastructure, etc.)

Although we have firm hypotheses about the positive direction of these relationships, we have no firm hypotheses concerning the relative importance of each factor in the overall picture.

[1] Prevalence determined by wasting (weight-for-height) and stunting (height-for-age) Z-scores (standard deviation units) < -2.00.

Figure 1: Conceptual Framework



Data: The LICNAG survey data represent three agricultural production systems in Mali: the irrigated rice growing area of the *Office du Niger* in the Segou region, which has experienced important increases in productivity during the 1990s; the cotton-growing area of the Sikasso region, which substantially increased production in the late 1990s through increased area cultivated; and the millet/sorghum zone in the Mopti region, which has had stagnant production and productivity during the past decade. Each of the three production systems is represented by two administrative *cercles* which we call zones. The two zones within each production system differ in terms of infrastructure and, in some cases, in terms of agricultural opportunities. The key characteristics of these six zones are summarized in Table 1.

Table 1: Characteristics of Survey Zones

Production Systems	***Cercles*/Zones**	**Characteristics**
Cotton System	Kolondieba	New cotton zone; producers tend to be less experienced and have less animal traction equipment
	Koutiala	Old cotton zone; producers well established and infrastructure better developed than in the newer zone
Irrigated Rice System	Niono	Located in part of irrigation scheme with full water control and upgraded irrigation infrastructure; primary occupation of households is rice production; dry season horticultural production common; better access to transport than Macina
	Macina	Water control less well developed than in Niono; for some households production of rainfed millet and sorghum crops is more important than irrigated rice; sample includes important share of households whose primary occupation is fishing.
Millet/Sorghum System	Bandiagara	Some households have access to water retention structures that permit onion cultivation during the dry season; road and market access easier than in Koro; migration to provide harvest labor in Office du Niger irrigated perimeters common.
	Koro	Few dry season agricultural opportunities as wells tend to dry up; difficult access to/from major urban centers

The data include a full set of monthly anthropometric measurements for approximately 2000 children <5 years of age plus household level data for the 750 households to which the children belonged. The household data include information on assets, expenditures, and agricultural production activities for the period May 2001 through April 2002. These data were collected using bi-weekly interviews with a variety of household members.

In addition, a Knowledge, Attitudes and Practices (KAP) survey was administered to the parents of 457 sample children who were 2.5 years of age or younger at the end of the survey period

(April/May 2002). It is this survey that provided information for testing hypotheses about childcare and feeding practices, household health and sanitation practices, prenatal care, parents' knowledge of the causes and treatments of common diseases, and parents' health status (represented by standardized height measurements).

Methods: The analyses reported here are based on the subsample of 457 children whose parents participated in the KAP survey.[2] We use standardized height for age (HAZ) scores–an indicator of "stunting" or "chronic" malnutrition–as the principle variable reflecting children's health and nutritional status.[3] A HAZ score of zero means the child's height for age is equivalent to that of the reference population mean. A score of -2 means that the child's height for age is two standard deviations below the reference mean. Children are generally considered malnourished when their Z-scores are lower than -2 and severely malnourished if their Z-scores are below -3. Multivariate analyses consist of OLS and Logit models that permit us to identify statistically significant determinants and to evaluate the relative impact that small changes in these determinants would have on HAZ outcomes. In the discussion which follows, we focus on presenting the multivariate results. Bivariate analyses (e.g., t-tests comparing mean values and correlation coefficients) supplement the discussion, particularly the discussion of hypothesized determinants that were not significant in the multivariate models.

Results: We find that child feeding practices, proximity to and use of health centers, and household income all represent statistically significant determinants of HAZ scores. These variables represent the types of determinants that can be acted on through policy reforms or development programs. We find that a mother's age and her child's age also play a role; these variables represent information that can be used for targeting nutrition interventions. Two additional variables–mother's and father's height–are also significant, suggesting that part of a child's HAZ score may be determined by either the genetic traits of their parents or socio-economic and environmental factors such as persistent poverty that contributed to parental stunting. Finally, we note that there are some poorly understood determinants associated with being located in different agricultural production systems; living in the cotton zone, for example, results in lower HAZ scores than living in other production zones. Table 2 summarizes these modeling results for a simple linear regression and a Logistic model.

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2 The KAP variables are particularly important for avoiding problems of missing variable bias in the multivariate analyses used to identify the determinants of malnutrition**.**

3Reference population numbers were taken from the National Centers for Health Statistics/World Health Organization (NCHS/WHO) random survey of infants and children in the United States. Though this reference population consists solely of U.S. children, studies have shown that the growth patterns of children from varied ethnic backgrounds will be similar for "well-fed healthy preschool children" (Bhandari et al, 2002).

Table 2. Summary of linear and logistic model results

	Linear Model		Logistic Model		
	Coef.	Sig.	Odds Ratio	Coef.	Sig.
Male child	-0.13		0.86	-0.16	
Child 0-6 mos.	0.57	*	1.52	0.42	
Child 7-12 mos.	0.32	**	2.08	0.73	***
Child's diet diverse	0.51	***	2.42	0.88	***
Mother's schooling (yrs)	-0.04		1.00	0.00	
Mother's age (yrs)	0.08	**	1.24	0.22	**
Mother's age squared	0.00	***	1.00	0.00	***
Mother's height (standardized)	0.22	***	1.23	0.21	*
One or more prenatal visit=1	0.29	**	1.53	0.42	*
Father's age (yrs)	0.01	*	1.02	0.02	
Father's height (standardized)	0.21	***	1.51	0.41	***
Schooling PCU head (yrs)	-0.07	*	0.91	-0.10	
Literacy training PCU head (yrs)	-0.05		0.79	-0.23	**
Ln kcal cereal consumption/ae	-0.13		1.00	0.00	
Ln expenditure/ae	0.19	*	1.96	0.67	***
Clinic fully staffed = 1	0.30	**	0.92	-0.08	
Distance to clinic (km)	-0.01	**	0.98	-0.02	*
New cotton zone (Kolondieba) = 1	-0.75	***	0.30	-1.20	**
Old cotton (Koutiala =1	-0.59	**	0.51	-0.68	
Rice/millet zone (Macina) = 1	-0.15		0.70	-0.35	
Rice zone (Niono) = 1	0.14		1.54	0.43	
Mil/sor/onion zone (Bandiagara) =1	0.53	**	2.01	0.70	
Constant	-4.65	***		-10.03	***
Observations	457		457	457	
Prob F	0.00				
Adj. R sq	0.21				
Prob Wald chi sq			0.00		
Pseudo R2			0.15		
Correctly classified predictions			71%		
Distribution of residuals	normal		n.a.		

Note: Models run using Huber/White/sandwich estimator of variance/ Similar models were run using a two-stage instrumental variables procedure to address the issue of income endogeneity; Hausman tests did not reveal any significant difference between the OLS and the IV approach.

* 0.10 level; ** 0.05 level; *** 0.01 level or better

The linear regression identifies variables that explain the actual HAZ score (which ranges from -4.98 to +2.58). The logistic model classifies children into two groups--stunted and others–and estimates the probability that a child will fall into the “other” group, comprised of children with acceptable nutritional status (HAZ<2 standard deviations *below* the mean of the reference group). Although there are some differences in the statistical significance of individual variables for the two models, the results for 15 of the 22 variables are consistent across both models using a .10 probability cutoff. We focus the discussion on these variables.

Testing Hypotheses: Modeling results confirmed that five of the eight factors hypothesized to affect children's nutritional status have a statistically significant relationship to HAZ scores and exhibit the anticipated signs. To fully understand the implications of the modeling results it is important to look more closely at the precise nature of the variables used to represent the different determinants.

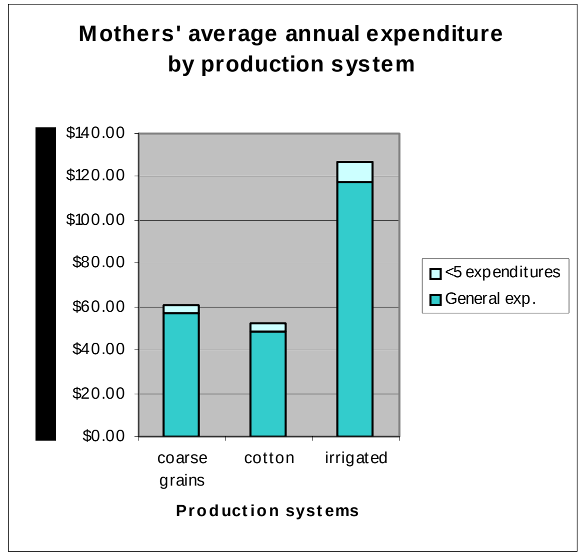
Feeding and childcare practices: The KAP survey collected information from mothers and fathers about a wide range of feeding and childcare practices. Among the questions used to examine the quality of care given to the child were:

> Was the child exclusively breast-fed during first 72 hours after birth?
> Was the child exclusively breast-fed during first 6 months?
> At what age did the child start receiving complementary foods on a regular basis?
> How many complementary foods did the child receive during the previous 24 hours?
> Who was the primary care-giver (mother, older sibling, grandparent, etc.)
> Did household duties, agricultural work, or personal income generating activities compete with time needed for childcare?

Only one variable created from these questions was significant in the models; it was a dummy variable created to represent dietary diversity. A value of one for this variable indicates that a child had received two or more complementary foods during the previous 24 hours. For the overall sample, 85% of children had diversified diets consisting of two or more complementary foods. Percents varied by zone with the highest prevalence of diversified diets found in the Niono zone of the irrigated rice system (94%) and the lowest prevalence in the millet/sorghum zones (74%). We believe more diversified diets in the Niono zone are encouraged by higher incomes for women in the irrigated rice system (Figure 2) and women's involvement in horticultural production, which provides easy access to appropriate complementary foods.

A child who receives these complementary foods is 2.42 times more likely than others to have a HAZ score >-2 (based on the odds-ratio results). This is the largest odds ratio obtained in the model, underscoring the strong potential that promotion of dietary diversity among children less than 2.5 years of age has for improving their nutritional status. The probability that a child receiving a diverse diet will not be stunted is 71% (odds ratio/(1+odds ratio)).

Figure 2



Note: <5 expenditures are those made for children <5 years of age.

Availability and use of health services: Three variables were used to examine these factors: distance to nearest health center in kilometers, a dummy variable equal to one if this health center was fully staffed with a doctor or nurse, and a dummy variable equal to one if the child's mother had one or more prenatal consultations. The average distance to the health center was 11.3 kms (minimum=0, maximum=80). Fully staffed health centers were available to the mothers of 69% of the children, while the mothers of 67% of the children had at least one pre-natal visit.

Living closer to a health center has a positive effect on the level of HAZ scores in both models. Full clinic staffing and prenatal consultations were statistically significant in the linear regression but not in the logit model.

Simulations of average HAZ scores under different assumptions about distance to the nearest health center showed a clear trend of improved HAZ scores as distance declined (Table 3).

Table 3. Relationship between HAZ scores and distance to the nearest health center

	Actual situation	Simulated average HAZ scores assuming all children are at the following distances from the nearest health center			
	avg. of 11.3 kms	<2 kms	<5 kms	<10 kms	<20 kms
Average HAZ	-1.60	-1.49	-1.53	-1.59	-1.70

Source: Estimated using linear model coefficients and indicated assumptions.

The results on distance provide support for the Ministry of Health strategy of expanding the number of health centers until all rural households are within 5 kilometers of a health center. The largest reduction in HAZ scores is, however, attained by providing health centers within 10 rather than 20 kilometers. This finding suggests a strategy of beginning with the cases where families must travel more than 10 kilometers before reducing the distance for those who are already in the 6 to 10 kilometer range.

A simulation using actual distances to the health center in combination with different assumptions about staffing (see Table 4) produces an average HAZ of -1.51 if all health centers are fully staffed versus -1.81 if none of them are fully staffed. A simulation assuming that all children are within 2 kilometers of a fully staffed health center produces an average HAZ score of -1.40; this represents a 12.5% (0.20/1.60) decrease in the gap between the reference group average HAZ (zero) and the sample group average HAZ (-1.60).

Table 4. Simulation results for assumptions about health center distance and staffing

	Actual situation	No center fully staffed (actual distances)	All centers fully staffed (actual distances)	All centers fully staffed and <2 kms away
Average HAZ	-1.60	-1.81	-1.51	-1.40

Source: Estimated using linear model coefficients and indicated assumptions.

The results on staffing are mixed due to the lack of significance on the variable in the logistic model. The simulation results suggest that a policy of fully staffing all clinics (all else unchanged) has the potential of reducing the gap between the reference group and sample group average HAZ scores by 0.30 standard deviations; this is a much larger effect than the 0.17 improvement associated with reducing health center distance from 10 to 5 kilometers. In other words, if the average HAZ for the sample is -1.60 and we are able to improve staffing to a point where all clinics are fully staffed, the estimated average score will be -1.30; reducing distance from 10 to 5 km will result in average HAZ scores of -1.43 (i.e., not as much change in the desired direction).

Two-thirds of mothers in the KAP survey had one or more prenatal consultations. Simulation results suggest that if all mothers had at least one prenatal consultation, average estimated HAZ scores would improve from -1.59 to -1.50. This is a relatively small improvement because such a large share of women are already availing themselves of prenatal consultations. Although this variable is only significant at the 0.11 level in the logistic model (just beyond our cutoff point), the odds ratio suggests that children of mothers who have prenatal visits are 1.53 times more likely to have acceptable nutritional status (HAZ >-2). Analyses reveal a statistically significant difference in the average distance to the nearest health center for mothers availing themselves of prenatal visits (9 km) versus mothers who did not (16 km), suggesting that by reducing the distance to health centers one could also increase the use of prenatal services.

Household income and assets: A key hypothesis is that increased rural incomes will be associated with improvements in children's nutritional status. Both models confirm this hypothesis, using household expenditure during the survey year as the indicator for income.[4] The logistic model results are stronger both in terms of significance and impact than the linear regression results. The odds ratio in the logistic model suggests that a one unit change in the natural log of income

[4] The income variable is the total of all household expenditures per adult equivalent except those related to purchased or home-produced quantities of cereal consumed. We omitted cereals from the income variable because cereal consumption is shown as kilocalories of cereal consumed per adult equivalent in a separate variable.

(which ranges from 7.3 to 12.0 for the sample, with an average value of 10) makes a child 1.98 times more likely to have an acceptable HAZ score (>-2). The results of simulations assuming a 10% increase and a 10% decrease in incomes are summarized in Table 5.

Table 5. Estimated changes in average HAZ scores from simulated income changes

Income assumptions	Estimated sample average HAZ score
Actual income in data file	-1.60
10% decrease	-1.79
10% increase	-1.41

A 10% increase in income represents a 1.19% reduction in the gap between Malian children and the referenced population–a small but statistically significant effect.

In addition to the direct effect of household income on HAZ scores, there is evidence that income may be acting indirectly through the mobilization of household income to provide community services. For example, t-tests show that mean levels of household income are significantly higher for households living less than 10 kilometers from health centers and for households having access to fully staffed health centers. This suggests that wealthier communities may be doing a better job of providing health care services. Higher average incomes are also found in communities with schools located in the village. Furthermore, a positive (0.19) and highly significant (.000) correlation between household income and percent of taxes collected by communes further supports the hypothesis that increases in rural incomes are indirectly affecting HAZ scores through community investments. These indirect effects are not captured by the household income variable used in the models.

Most studies of the determinants of nutritional status use assets to evaluate the contribution of economic well being to a child's nutritional status. Assets fluctuate less over time and are thought to better reflect lifetime incomes whereas income based on expenditures can be extremely variable across time, particularly in agricultural economies. LICNAG collected information on both assets and income/expenditures. We found that ownership of more assets (e.g., land per adult equivalent, agricultural equipment, and vehicles such as animal drawn carts, bicycles, and motorcycles) explain higher levels of income, but the only asset variable that was positive and significant when we modeled HAZ scores as a function of assets rather than income was land owned per adult equivalent (significant at the 0.06 level in the linear model).

Given these income and asset results, we conclude that accumulation of assets–particularly productive assets such as land and agricultural equipment–is associated with higher incomes, which contribute to improved HAZ scores both directly (through household expenditures on better nutrition and health care) and indirectly (through mobilization of incomes across households to provide community services).

Parents and children's ages: Parents' and children's ages were incorporated into the model. As anticipated, there is a quadratic relationship between HAZ scores and mother's age with relatively younger and relatively older mothers being more likely to have children with lower HAZ scores. Simulations (Table 6) show that sample average HAZ scores would be approximately 0.20 standard deviations lower (i.e., further below the reference group mean) if all mothers of children in the sample were either very young (14 years old) or relatively older (40 years old).

Table 6. Estimated sample average HAZ scores based on simulations for mothers' age

Assumptions about mothers' age	Estimated sample average HAZ
Actual data used (avg. 28 yrs.)	-1.60
If all mothers = 14 yrs	-1.79
If all mothers = 40 yrs	-1.75

One explanation for this result might be that older and younger mothers are more likely to have had problems during pregnancy and delivered low birth weight babies (data are not available to confirm this). Programs to educate parents about the potentially negative consequences of mothers having children at very young or relatively advanced ages could contribute to a reduction in malnutrition. Because increases in age have a positive impact on HAZ scores through the age of 40, a complementary explanation might be that very young mothers have less experience with childcare and proper feeding practices. The logistic model shows that all else equal, a one year increase in mother's age improves the odds of a child having an acceptable HAZ score by 1.24.

Father's age is positively correlated with HAZ scores, but the overall effect is small. This variable is more likely to represent maturity and improved capacity to care for children than biological factors.

The children's age variables are significant and confirm that the prevalence of stunting increases as children move from younger to older ages. The odds ratio in the Logit model shows that children aged 7 to12 months are 2.08 times more likely than children aged 13-30 months to have acceptable HAZ scores >-2; the comparable ratio for the youngest children (0 to 6 months) is a bit smaller (1.52).

These age variables provide some guidance for targeting programs to improve children's nutritional status. Given the cumulative effect of stunting, the results suggest programs should target the very youngest children and their mothers. It also suggests that a program to reduce the number of mothers giving birth at young ages could reduce the prevalence of malnutrition.

Parents health and genetics: The standardized height of parents in the sample was used as an indicator of parents health status as well as possible genetic influences on children's HAZ scores.[5] The parents' height variables were both highly significant. The odds of a child having a HAZ score >-2 increases by a factor of 1.23 if the mother's standardized height increases by one unit (e.g., from -2 to -1); the comparable odds for an increase in father's height is 1.51. A variety of descriptive statistics looking at the relationship of these height variables to income and ethnic group lead us to conclude that the variable is picking up something other than genetic factors.

The sample included parents representing 10 ethnic groups. The average mother and father heights for members of the Dogon ethnic group (the predominant group in the Mopti region) is significantly lower than that for all other ethnic groups (-0.34 for Dogon mothers vs. 0.19 for others; -0.33 for Dogon fathers v.s 0.12 for others). This result can be interpreted as either a genetic trait or the result of generations of poor nutrition in this zone of relatively low incomes and economic development. Providing support for the hypothesis that income might be involved in the height differences is the highly significant correlation between income and both mothers' (.20 correlation coefficient) and fathers' (.19 correlation) heights. Average heights are also significantly lower for the lowest income quartile than for parents in other income quartiles (Table 7).

Table 7. Mothers' and Fathers' standardized heights by income quartile

	Average Standardized Height	
Income quartile	Mothers	Fathers
Lowest quartile	-0.21	-0.17
All others	+0.14	+0.06

T-tests of average incomes for Dogon versus all others also confirm that Dogon household incomes are significantly lower than those of other ethnic groups.

These results bring to light the intergenerational nature of the determinants of children's health and nutritional status, but suggest that it may be a socio-economic determinant rather than a genetic one. In the absence of special targeting efforts to rapidly improve children's nutritional status in zones or socio-cultural environments characterized by persistent, intergenerational poverty and poor nutrition, rates of malnutrition are likely to remain high for several generations.

Education: Education, particularly mother's education, is frequently reported as a statistically significant variable in the nutrition literature (Behrman and Wolfe, 1984; Penders 1999); better educated mothers have healthier, better nourished children. The lack of significance on the education variable for Malian mother's (years of formal schooling) is not surprising given that

[5]Much of the literature on nutrition suggests that genetic factors associated with height do not become apparent until children are more than 3 years old. Kebede (2003), however, considers the link between parents heights and indicators of childrens' nutritional status to represent genetic factors in his analysis of Ethiopian data.

only 8% mothers in the sample had any formal schooling and less than 1% completed primary school. Further compounding estimation problems was the fact that all of the mothers who went beyond primary school were located in the irrigated rice zones, making it difficult to separate education from zone and income influences.

After testing a variety of education variables for adult males in the household, we used two variables: years of formal schooling and years of literacy training in local languages for the household head. Education and literacy variables for fathers were tried but were never significant. In the linear model years of formal schooling is significant and negative; in the logistic model years of literacy training is significant and negative. The negative sign of both of these variables is unexpected. We suspect that it has something to do with the low level and unequal distribution of education in the sample. Only 10% of the household heads had any formal schooling and half of them did not get beyond third grade. Literacy training involved only 7% of household heads (none of whom had formal schooling) and it was concentrated in the Koutiala and Macina zones. We suspect that these variables are picking up other socio-economic characteristics of the households that are correlated with decisions about sending male children to school or decisions of adults to participate in literacy training programs.

Given the weight of the evidence on education/nutrition linkages from other countries (including many African countries), we do not interpret our results to mean than investment in education, particularly for Malian girls, is not an important component of a long-run strategy for improving children's nutritional status. Our results suggest, however, that investments in general education are unlikely to provide any short-run improvements in children's nutritional status given the extremely low levels of schooling for girls in rural Mali.

Knowledge of disease and treatment: Diarrhea and malaria were the most commonly reported childhood illnesses for children in the LICNAG study. Consequently, KAP interviewers asked fathers if they knew the causes of these diseases. Surprisingly, only 19% of fathers knew that mosquitoes transmitted malaria; 47% properly identified one or more of the potential causes of diarrhea. Mother's were queried on how they cared for their sick children (e.g., more, less, the same frequency and volume of breast milk and/or other liquids). We used dummy variables and indices combining information from several variables to incorporate this information in the models but none of the variables was significant. Simple descriptive statistics also failed to reveal any significant relationship between HAZ scores and parents knowledge of disease.

Our survey does show a strong correlation between frequency of illness and low HAZ scores, suggesting that what parents do to protect children from illness or to treat sick children could have an impact on the HAZ scores. The lack of significance for this set of knowledge variables may be due to problems with the data (a poor understanding of the questions on the part of the parents). It may also mean that correct knowledge of disease causes and treatments has little impact because other factors prevent parents from using this knowledge (e.g., lack of resources to purchase mosquito nets, lack of time to feed child properly, social pressure to follow customary practices). If it is more than a knowledge problem, campaigns to educate parents on these points will not reduce malnutrition without accompanying measures addressing the resource or social problems.

Household health and sanitation practices: The KAP survey included questions about where animals spent the night (inside or outside of the compound), where mothers disposed of their children's feces, source of drinking water, mother's hand-washing practices, type of latrine, and use of mosquito nets. Individual variables representing these different factors were not statistically significant. An index variable created using the hand-washing variables, number of mosquito nets per adult equivalent, type of latrine and animal stabling location was also not significant. Lack of significance may be due to some multicollinearity in the data. The index variable has a highly significant correlation with income (.40 correlation coefficient). Distance to health center and prenatal visits were also significantly correlated with the index, but with smaller coefficients (-0.21 and 0.16, respectively). In the absence of a statistically significant coefficient on this group of variables, we conclude that reductions in HAZ scores are more likely to be achieved by working directly on the income variable, which is positively correlated with many of the desirable health and sanitation practices.

Undefined zone effects: The zone variables capture zone-level determinants not accounted for by the other variables in the model. The statistically significant and negative coefficient on the dummy for the new cotton zone (Kolondieba) means that there is something in this zone causing HAZ scores to be lower than those of the millet/sorghum zone (Koro) which is included in the constant term of the model. This is the only dummy which is statistically significant in both models. The probability (odds ratio/1+odds ratio) of a child in this zone having a HAZ score >-2 is only 0.23 (compared, for example, to a child in the irrigated rice zone of Niono who has an estimated probability of .61).

The linear model suggests that a child living in the new cotton zone (Koutiala) will have a lower HAZ score than a child living in Koro (all else equal). The lower scores for both cotton zones, where incomes tend to be higher, are surprising. We believe that these results may be due to issues of income distribution within the very large extended families that characterize the cotton zones. As noted in Figure 2, women in these zones have extremely low incomes, making it more difficult to purchase complementary foods for their children and pay for health care. Concentration of cotton income (the largest component of cash income for most households) in the hands of the often elderly heads of the production/consumption units (large extended families comprising up to 100 individuals) may also make it difficult for the mothers and fathers of young children to access cash for childcare needs. Although our survey work suggests these income distribution and family structure issues may be relevant, quantifying the effects requires the development of more complex household models capable of incorporating intra-household decisions making.

The model results also show that some characteristic of the millet/sorghum/onion (Bandiagara) zone results in higher HAZ scores for children in this zone than for children in Koro. Our hypothesis is that the better infrastructure for dry season cropping and easier access to urban centers helps mothers earn more income and better care for their children.

Implications and recommendations: The following four recommendations on broad areas to address draw on the results of the analyses reported above. A number of the more specific actions suggested under each of the main recommendations are drawn from complementary analyses, interviews with health service personnel, and discussions with local leaders involved in Mali's new government decentralization program (see
http://www.aec.msu.edu/agecon/fs2/mali_nut/index.htm
for a variety of synthesis papers drawing on these interviews).

1) Programs that improve the diversity of complementary foods for children, such as
   a) Educating parents on the importance of complementary foods
   b) Gardening projects that provide easy access to such foods
   c) Income generating activities for women that permit them to purchase foods
2) Investments to provide better health center coverage, such as
   a) Making sure all children are within 10 km of a health center
   b) Making sure that the health centers are fully staffed
   c) Programs that increase the number of women using prenatal consultations and discourage pregnancy among very young women
3) Promotion of economic development that increases rural incomes
   a) In the cotton zones, attention to intra-household income distribution is needed so that both mothers and fathers of young children have personal sources of income that can be used for childcare (food, medicines, etc.)
   b) In the millet/sorghum zones major technology breakthroughs, crop diversification, and/or income diversification will be needed for income growth; without improvement in income in these zones the inter-generational problems of stunting noted in the analysis will continue
   c) Poverty in the irrigated rice zones appears to be limited in breadth, but severe for those households that are affected (particularly households with small land holdings); improving economic opportunities for these households through non-farm work or access to more irrigated land should help
   d) Across all zones, it is clear that an increase in women's incomes is associated with improved health and nutritional status of children. A major change in agricultural development strategies, with particular attention to crop diversification and women's access to crop land and inputs, will be needed if women in the cotton and millet/sorghum zones are to increase their incomes
4) Promotion of programs that mobilize rural incomes for community investments
   a) Better tax collection
   b) Non-governmental community efforts to fund schools and health services
   c) Training programs to improve local skills for collection and management of community funds

Results also suggest that targeting of programs toward very young children (or the mothers of very young children) has the potential to reduce the increase in the prevalence of stunting as children reach 3 to 5 years of age. Programs targeted to these mothers should provide information on the importance of introducing complementary foods at six months of age.

Two of these recommendations stand out as being relatively novel in the Malian context: the large impact that diversity in complementary foods can have on HAZ scores and the large impact on average HAZ scores of reducing the distance to health centers from 20 to 10 kilometers. Attention to these findings should help the Government of Mali improve the cost-effectiveness of their program and investment decisions.

Returning now to the income/malnutrition paradox mentioned at the beginning of this report, we can confirm that increased rural incomes in Mali do contribute to lower rates of childhood malnutrition. The impact on HAZ scores of increased income acting directly through household expenditures is, however, relatively small. The modeling results combined with descriptive information about zone differences, intra-household income distribution, and inter-generational income/health status correlations suggest that as income increases, some household income must be mobilized to improve the provision of community services. These services should aim to (1) improve the access to and the quality of health care (including health education about child feeding practices) and (2) stimulate further economic growth through investments in services such as transportation and market infrastructure, education, agricultural extension and research).

An important bottleneck that must be overcome if the above recommendations are to be implemented is the level of awareness of malnutrition among rural health workers, local administrators, and the general population. Interviews with community health professionals and local government officials in the survey zone revealed that no one was aware of the extent and gravity of wasting and stunting in their zone. The lack of awareness of the problem and a poor understanding of its causes represents a major hurdle facing any attempt to improve child nutrition. This is particularly true given the process of administrative decentralization now underway in Mali, which gives rural communities the responsibility for allocating local tax revenues. It is likely that some centrally funded efforts will be needed to raise communities' awareness of the nutrition problem and involve them in a process of assessment, analysis and action to identify investments that would most likely have immediate positive impacts on nutritional outcomes. For example, villages in the Mopti region consistently cited bore wells as their top priority, an investment that could reduce the incidence of water-borne disease and decrease the high prevalence of wasting. Other options might be improved roads and bridges or markets that directly stimulate economic development, contribute to higher household incomes and an expanded tax base.

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