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The Rhythm of the Rains: Seasonal Effects on Child Health in The Gambia+

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Abstract

We analyze the consequences of seasonal variation in maternal consumption on child health using two nationally representative Gambian household surveys. Seasonal fluctuation in consumption stems from difficulties borrowing when incomes are low during the rainy season and saving when they peak after harvest. The resulting fluctuations in maternal nutritional intake can affect birth outcomes and lactational performance. Using mother fixed effects to isolate the effect of birth season, we find that child health—measured by weight-for-age and height-for-age—varies significantly with birth timing. Children in farm households born during dry seasons (February-June) fare considerably worse than siblings born in other seasons.

JEL: D13, I12, I15, Q12

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I. Introduction

This paper examines the effects of season of birth on the health outcomes of Gambian children. Due primarily to the seasonality of rain-fed agriculture, the incomes of many Gambian households, particularly those in rural areas, fluctuate throughout the year. Though income fluctuations do not necessarily lead to fluctuations in consumption, several conditions present in The Gambia, as well as in many other developing countries, link income and consumption patterns.

Smoothing consumption in the face of volatile income requires the ability to easily borrow and save. Credit markets in The Gambia, however, function poorly, particularly in rural areas (World Bank 2003). In addition, the covariant nature of agricultural shocks and the high degree of regional homogeneity in income sources effectively precludes many informal risk-sharing and credit arrangements. Moreover, the perishability of agricultural produce and the poor storage technology available to many in The Gambia constrain the amount of food that can be stored by poor, rural farmers over long periods.[1]

As a result of these factors, calorie intake among Gambian agricultural households varies by season (Prentice 1980; Lawrence et al 1989). This seasonality in calorie intake, especially among women, can have serious consequences for children, either unborn (at conception or during pregnancy) or during lactation. As a result, the season in which a child is born is likely to be consequential for his or her health. In contrast, in the presence of well-functioning credit markets and risk sharing arrangements, where individual household consumption is unlikely to be dependent on the timing of individual income, we should not expect the seasonal timing of a child's birth to have systematic effects on his or her health.

This paper contributes to the considerable discussion of income and consumption variability by linking two issues of major concern in developing countries: the consequences of the absence of mechanisms that enable consumption smoothing and the health problems caused by steep drops in food consumption.

The impact of seasonal nutritional deficits is particularly important for children in light of a growing recent literature linking early childhood health, including conditions in utero, to later life outcomes. Adverse effects of child health deficits can persist well into adulthood and negatively impact lifetime human capital formation (see, e.g. Case and Paxson (2009), Hoddinott al (2008), Oreopoulos et al (2008), Handa and Peterman (2007), Almond (2006), Case, Fertig and Paxson (2005), Alderman, Behrman, Lavy, and Menon (2001) and Barker (1997)).

Our paper uses two nationally representative household surveys, from 1994 and 2003, to examine the relationship between timing of birth and health outcomes in The Gambia. We measure child health by using the standardized, anthropometric measures weight-for-age (*wfa*) and height-for-age (*hfa)*. We find that variation in season of birth among children explains differences in both measures. We find that the effect of birth season on *wfa* and *hfa* persists even when we control for mother fixed effects and examine differences among children of the same parentage.

Our results are consistent with the explanation that the difference in health outcomes across different seasons of birth is caused by seasonal variation in food intake among women, a variation that stems from the inability of households to smooth consumption in the face of seasonal fluctuations of income among rural, agricultural households. Children in households not dependent on agricultural income show no differences in z-scores across different seasons of birth irrespective of income level.

The use of mother fixed effects (i.e. controlling for possible biological effects by analyzing variations between siblings that share the same mother) enables identification of the causal effect of mother's nutrition on child health as long as other potential confounding variables are time invariant. Time-variant factors could still confound our results, and selection bias due to attrition from mortality and non-random birth timing could make the sample non-random. Nevertheless, robustness checks find little evidence of large, confounding effects.

Close examination of our results points to the likely channels through which mother's nutrition affects child health. Based on the months in which it is relatively unfavorable to be born (the dry season: February-June), it appears that the lower body weight of mothers at conception or the impaired lactation of women during the rainy season (or both) are the main channels through which lower calorie intake of mothers impact the health of children.

Earlier studies on The Gambia that examine the effects of seasonal variation in consumption have focused on specific regions or villages (Moore et al 2001; Ceesay 1997; Moore et al 1997; Cole 1993; Prentice 1980). Our paper is the first to use a nationally representative survey. Furthermore, the data set covers more than one time period, which makes it unlikely that the results we find are temporally isolated. Previous studies (Moore et al 1997; Moore et al 2001) on birth timing in the Gambia have also failed to control for both genetic and environmental effects specific to each child, a deficit we correct for by using mother fixed effects. More crucially, our data on source of income allow us to better identify the role of agricultural dependence.

While earlier work has highlighted the link between poor nutrition and child growth (e.g. Hoddinott and Kinsey 2001), our results bring to light new information concerning the consequences of large, seasonal dips in consumption. Specifically, we show that negative effects of drops in consumption can saddle children from the moment of birth, and likely before. Further, seasonal variation in health persists among relatively wealthy agriculturalists, indicating that the problem is not one of total resource deprivation, but rather of inability to smooth lumpy flows of income. Additionally, we find that preconception exposure to the rainy season significantly increases the probability that farm dependent mothers will give birth to a girl, which echoes results from other studies linking periods of starvation with increases in the female to male sex ratio.

Finally, despite receiving little attention from development economists in recent years, seasonal hunger remains an important development challenge. Our results show that Gambian children born in three separate decades have endured this annual obstacle.

II. Seasonality in Consumption and the Intergenerational Transmission of Nutrition

In the case of perfect credit markets, transitory income changes should not influence household consumption patterns. However, in developing countries, income tends to be a significant explanatory variable of changes in consumption (Morduch 1995), which suggests that credit market are typically incomplete. The microeconomic development literature documents many instances of poor households struggling to smooth their consumptions (not always successfully) in the event of bad shocks (Behrman, Foster and Rosenzweig 1997).

Previous work has documented the health consequences of seasonal variations in food consumption, including studies focused on Gambian households. Muller and Paul (1980), Prentice (1980), Lawrence et al (1989), Cole (1993) and others have found that the nutritional intake of rural Gambian women falls significantly during the rainy season and recovers to higher levels after harvests. Such dips affect the quality and quantity of milk produced by lactating women (Prentice 1980) and birth outcomes (Ceesay 1997). In other, more recent papers, Bengtsson (2007) found that transitory changes in income have an adverse effect on body weight among rural Tanzanians. Specifically, these drops in income induce malnutrition among women and children but not in men. Hoddinott (2006) observes a similar gender pattern in response to drought shocks in Zimbabwe. These studies suggest that intrahousehold imbalances influence the degree of consumption variability across members of the same household, and that women face a disproportionally larger risk of facing acute consumption shortfalls.

Less than adequate nutritional intake has other health consequences. In particular, insufficient nutrition can compromise the immune system. For example, Caulfield et al. (2004) find that under-nutrition can be a major determinant of susceptibility to malaria and other diseases among children.

The medical and health literature provide strong evidence for a link between maternal nutrition, fetal growth and neonatal outcomes. The potential direct effect of maternal nutritional status on child health can take place in three broad phases: before pregnancy (preconception), during pregnancy and during lactation.

Mother's nutritional status before conception can influence her child's health. In a study of 575 women in Anhui, China, Ronnenberg et. al. (2003) finds that while low conception maternal body mass index (BMI) has no effect on gestational age and preterm birth, it has significant adverse effects on fetal growth and also contributes to low birth weight. The results from this trial support earlier findings from the World Health Organization (1995) and Kramer (1987).

The effect of the nutritional status of the mother is thought to continue through gestation. While noting significant ambiguity regarding the timing of these effects, Eidelman (2001) cites evidence that fetal growth and maternal nutrition may be most closely linked during the second and third trimester. In a randomized study over a five-year period involving the distribution of balanced dietary supplements to rural women in The Gambia, Ceesay et. al. (1997) found that the increased weight gain from the supplements had a positive and significant effect on birth weight. However, the size and specification of the link between poor maternal nutrition during pregnancy and infant and fetal outcomes has not been clearly delineated in other studies (Kramer 1993; Kramer and Kakuma 2003; Ramakrishnan 2004).

Mother's nutrition continues to have an effect on child health after birth via lactation. Breastfeeding in some form is a nearly universal practice in the Gambia, with breastfeeding rates estimated between 95.4 and 99.8 percent throughout the first year of life, so impacts on the quality and quantity of mother's milk due to her nutritional intake should affect her child's health (UNICEF 2000). In a study involving rural Gambian women, Prentice (1980) found significant reductions in calorie intake, body weight, and fat among pregnant and lactating women during the rainy season, a time period also referred to as the "hungry season" due to the widespread drop in food stocks and consumption in rural, farming areas. More importantly, the lactational performance of breastfeeding women, which was tracked throughout the year, responded to these changes in calorie intake. While the study showed no adverse effects on breast milk production during the first two months of lactation, between the second and the sixth month of lactation, there was a marked reduction in milk output during the rainy season when calorie intake among women fell. This reduction in milk output was not caused by reduction in milk demand by children or significant changes in the frequency of feeding. In a study from Guatemala, Delgado et al (1982) report similar findings, with maternal dietary intake of lactating mothers significantly and positively correlated to infant weight gain during the interval of three to six months after birth.

III. The Data Set

The data set is derived from two nationally representative surveys (1994 and 2003) carried out by the Gambia Bureau of Statistics. The surveys cover all the administrative regions in the country and are organized as repeated cross-sections. The coverage of the survey carried out in 2003 was larger than the one in 1994, which is why approximately 53% of our sample comes from that year. Both survey years include anthropometric information on children younger than six years old as well as detailed information on individual adults, including the mothers of the children in our sample, and household characteristics.[2] Income data were collected for the full sample in 1994 and for a subsample of respondents in 2003. From these data, we matched each child with his or her mother. Finally, we constructed a sibling dataset consisting of all children under six years of age who share a mother with another child under the age of six. Of a total of 5,412 children under six with 3,987 mothers, the sibling dataset we use here contains 2,755 children matched with 1,330 mothers.

Summary statistics on relevant child, mother and household variables are presented in Table 1. The children in our sample range from 1 month to 72 months old with the average child being 31 months old (the median is 32). The children's weights and heights were recorded to the nearest tenth of a kilogram and centimeter, respectively. Using the weight variable, we constructed the *wfa* and *hfa* z-scores for all children using 2000 Center for Disease Control (CDC) growth charts. The average *wfa* in the sample is -1.11 (median is -1.13).[3] Height measurements were not available for nearly one third of the children in both survey years, and the average *hfa* in the sample is -1.00 (median is -.99). These anthropometric measures are lower in rural areas, with the differences statistically significant at the five percent level. Figures 1A, 1B and 1C compare the distribution of *wfa* z-scores across different characteristics.

As expected, those living in the Greater Banjul area, the only strictly urban area in the Gambia, have higher incomes and smaller household sizes than those in more rural households. The latter tend to rely mainly on agriculture, while urban households depend mainly on wage and enterprise incomes. Specifically, the average rural household derives 48 percent of its income from agriculture compared to only 3 percent for the average urban household. In between these extremes, those living in areas classified as periurban rely on a more balanced mixture of wage and agricultural income (24 and 16 percent, respectively). Overall, non-rural households tend to have a more diversified income source.

IV. Empirical Strategy and Econometric Specification

The Gambian climate can be categorized into two seasons: rainy and dry. The rainy season typically extends from July to October of each calendar year while the dry season covers the rest. Figure 2 shows the typical distribution of rainfall in the country in a calendar year alongside the typical consumption pattern of women. As the figure shows, calorie intake of women tends to be lowest during rainy season.[4]

The large dip in consumption during the rainy season is a widely known and recorded phenomenon in areas that depend on rain-fed agriculture (Paxson 1993; Sahn 1989). Food stocks and consumption reach their peaks just after harvest, at the end of the rainy season. During this time, farmers start receiving the receipts from their farm produce sale in December and January when produce is sold to marketing boards (mainly groundnuts) and agricultural sellers (mainly corn, sorghum and millet). Over the course of the subsequent months, both unsold food stock and income received from the sale of produce are slowly depleted. At the start of the next rainy season, in June or July, agricultural households have severely depleted their food supply.

To exacerbate this problem, the beginning of the rainy season is also the most demanding period of the year, as households need to both ensure that their fields are cleared and tend to young crops so that weeds do not overwhelm them. As such, food consumption tends to be at its lowest when energy requirements are relatively high, and Gambian women suffer severe net energy deficits (Lawrence et al 1989). Using eleven years of longitudinal data on rural Gambian women, Cole (1993) finds typical rainy season weight loss ranging from 4.5 to 9 pounds. Lawrence et al (1989) find weight loss of a similar magnitude among rural Gambian women, and estimate an average reduction in body fat of approximately forty percent between its March peak and November nadir.

The rainy season is also the peak malaria season in The Gambia. During this season, open bodies of water create ideal breeding grounds for mosquitoes, the vectors of the malaria parasite. Due to the severe health consequences of malaria, the confluence of low nutrition and high prevalence of malaria in the country during the rainy season creates an additional complication in isolating the effect of nutritional intake on child health (Deen et. al. 2002; Okoko et. al. 2002).

A pooled OLS estimation that ignores between household variations is inadequate to identify the impact of seasonal consumption variation on child health. Consequently, we use a mother fixed effects estimation strategy driven solely by variation between siblings of the same mother (i.e. within family estimate). This approach allows us to control for biological factors that might increase the likelihood for some women to give birth to shorter or lower weight children, and socio-economic factors that influence child health. Similarly, this estimation also somewhat alleviates, though not completely, the problem posed by malaria because the susceptibility to malaria infection should be related for children of the same household.[5,6]

Equation (1) represents our basic estimating equation:

$$wfa_{ij} = \beta_0 + \beta_1 RS_{ij} + \beta_2 HS_{ij} + X_{ij}^{'}\Gamma + \upsilon_j + \varepsilon_{ij} \quad (1)$$

Where wfa_{ij} represents the z-score of weight-for-age of child *i* of woman *j*, *X* is a vector of child characteristics, υ_j is the mother fixed effect and ε_{ij} is the error term. The variables we include in *X* are child age, gender, birth order and rainfall shocks immediately preceding and following a child's birth. These shocks are measured as millimeter of rainfall deviations between the rainfall in child *i's* district and that district's ten year average. The season of birth of the child—with *RS* denoting a rainy season birth, and *HS* denoting a harvest season birth—is the key variable of interest in the right hand side of equation(1).[7]

Since the fixed effect estimator only allows variation at the level of the child, any other variables included on the right hand side of equation (1) that are constant for children of the same mother would be dropped due to collinearity. However, our main interest is isolating the effect of season of birth from other confounding variables, not the estimation of the health production technology of the household. Thus, while it may be useful to know the effect of, for example, the mother's education or household wealth on child health, their presence in equation (1) is not necessary in allowing us to obtain consistent estimates of the effect of the season of birth on child health.

Our basic hypothesis test focuses on whether the coefficients on the seasons of birth are jointly significant (i.e. non-zero). The basic test is

$$\beta_1 = \beta_2 = 0 \quad (2)$$

Rejecting the above null hypothesis implies that season of birth among children in our sample is a significant determinant of child health.

V. Results

The main results are presented in Table 2. The two variables, *RS* and *HS*, indicate birth in the rainy season and harvest season, respectively. The reference season of birth is the dry season. Using the whole sample, being born in the rainy season or the harvest season is associated with nearly a one third standard deviation increase in *wfa* relative to birth in the dry season. Additionally, the two seasonal dummies in column 1 (*RS* and *HS*) are jointly and individually statistically significant at the 1 percent level, indicating that different seasons of birth explain variations in z-scores of *wfa*.

The estimation results in columns two and three indicate that the impact of the season of birth on child anthropometry is not confined to one survey year, as the rainy season and harvest season dummies are jointly significant when estimating equation (1) for the 1994 and 2003 samples in isolation. The magnitude and significance of the effects of the individual seasonal dummies do differ slightly, however. In the 1994 sample, birth during the rainy season is associated with a .372 higher *wfa*, which is both statistically significant and double the coefficient on the insignificant harvest season dummy. The opposite is true in 2003, where the coefficient on the harvest season dummy is significant and nearly double that of the rainy season. Most tellingly, the final two columns of Table 2 illustrate a clear difference between the urban and rural sample. Point estimates for the season of birth coefficients are approximately 25 percent larger in the rural sample than in the urban, and are significant in the former but not the latter. The F-tests for the joint significance on the season of birth coefficients for urban and rural children also demonstrate a significant relationship in the former but not the latter, which supports the assertion that only rural children exhibit variation in health due to season of birth.

Table 2 also includes two variables which capture the rainfall shocks in districts just before and right after each child's birth. The rationale for including these variables is that they serve as proxies for temporal, within-sibling variations in household income that might affect health investments and overall consumption levels before and after birth[8]. The results in table 2 indicate that the deviation in rainfall before and after a child's birth positively impact *wfa* in the 1994 sample, but had no significant effect in the 2003 sample. We also re-estimate a slightly different version of equation (1) where we replace the seasonal birth dummies with months of birth. Those estimation results are presented in the appendix and indicate that children born in September and November fare best, while those born during the dry season months do relatively worse.

Table 3 displays the results of estimation using *hfa* as the dependent variable. The patterns of results largely track those obtained from *wfa* in table 2. The main difference between the estimates using these measures is that for *hfa*, only harvest season births are significantly different from the dry season in the rural sample. Due to the small sample size, other seasonal coefficients are not significant at traditional levels.[9]

Sources of Income

The ability of season of birth to explain variation in *wfa* and *hfa* is consistent with the inability of a large number of households to smooth their consumption over the course of a year, as within sibling seasonal variation in child health likely reflects the seasonal consumption pattern of the mother. Because agricultural households are most likely to experience seasonal income changes, children in these households should exhibit the most pronounced birth season variation in anthropometric measures if the inability to smooth consumption is indeed driving the results in tables 2 and 3. So to further examine if seasonal fluctuations in maternal consumption are responsible for our results, we split our sample into two categories: households that depend significantly on farming and those that do not. We define “depending significantly on farming” by the share of total household income derived from agriculture.

Tables 4 and 5 display the results of estimating equation 1 according to subsamples based on the agricultural share of household income, denoted by the variable *aginc*. Cutoff levels of 10, 25 and 50 percent of household income derived from agriculture are used to indicate the level of dependence on agriculture, and the pattern of results is not sensitive to the precise cutoff levels employed. Results from farm dependent households, shown in the first three columns, demonstrate a clear pattern of increasing seasonality in health outcomes as farm dependence increases. For *wfa* (table 4), columns 1, 2 and 3 show that the coefficients on the impact of a rainy season birthday are all positive and significant, and increase from .576 to .624 to .662 as the farm-dependent cutoff increases from 10 to 25 to 50 percent. The harvest season coefficients demonstrate similar pattern, though they are marginally insignificant. Further, the coefficients on birth during the rainy and harvest season are jointly significant at the one percent levels for all three categories.

In contrast to the strong variation in *wfa* according to birth season found among agriculturally dependent households, children in non-farm dependent households (columns 4-6) exhibit no such variation. Indeed, the coefficients on the seasonal variables are insignificant individually and jointly. The p-values for the joint test of significance are all greater than .6, and decrease as the sample includes more households with some degree of agricultural income.

The statistical significance of the birth season variables in the farm dependent sample but not the non-farm dependent sample cannot be explained away as an artifact of discrepancies in sample size. The non-farm dependent regressions have a slightly larger number of degrees of freedom in two of the three regressions.

For *hfa* (table 5), the harvest season coefficient demonstrates a similar pattern to the *wfa* results in table 4. As agricultural dependence increases, so does the magnitude and precision of the estimated harvest season coefficients. While the p-values for the test of joint significance of the harvest and rainy season birth coefficients approach the 10 percent level in the farm-dependent regressions, in the non-farm dependent regressions the p-values are close to one. However, because the *hfa* measurement is missing for a large number of households, dividing up the sample severely limits the available degrees of freedom. As such, the results for *hfa* should be treated with caution.

Disentangling Dependence on Agricultural Income from Low Wealth

The previous section's results demonstrate that seasonality in anthropometry occurs among households highly dependent on farm income. While we have argued that such a result stems from seasonal income patterns among agricultural households, such households are also generally poorer than those with non-agricultural income sources. In order to disentangle the effects of seasonal income and poverty, we divide the sample based on both agricultural income and income level.

Table 6 breaks down our results into six groups based on household per capita income: below and above-median, households from (i) the full sample; (ii) farm-dependent households; and (iii) non-farm-dependent households. The cutoff of an agricultural share of income greater or less than 25 percent determines whether a household is considered farm dependent or not.[10]

For each of these six groups, we re-estimated equation (1) and tested the null hypothesis of no birth season effect presented in equation (2).

For the full sample (column one), the null of no seasonal effect is rejected for the below median households at the one percent level, but not for the above median households. Non-farm dependent households (column three), whether below or above the median level of per capita household income, do not exhibit a statistically significant relationship between child *wfa* z-score on the season of birth. In contrast, *wfa* in farm dependent households (column two) above and below the median income level does significantly depend on season of birth.

The results in Table 6, therefore, support the view that household dependence on farm income, rather than merely low wealth, drives the observed variation in *wfa* by season of birth. Among high income farm dependent households, the large magnitude of the *wfa* advantage enjoyed by those born in the rainy season relative to the dry season—a full standard deviation—suggests that households most likely to have very high seasonal variations in income demonstrate commensurate seasonal variation in child health. Irrespective of income, seasonal variations in the child's *wfa* do not manifest themselves among households that do not depend significantly on farm income.

Semi-Parametric Estimation

To provide some robustness and better illustrate the preceding results, we also estimate a semi-parametric version of equation (1) over the whole range of months of birth. We estimate the following equation:

$$wfa_{ij} = g(M_{ij}) + \upsilon_j + X_{ij}\beta + \varepsilon_{ij} \qquad (3)$$

where the function $g(\cdot)$ imposes no assumptions on the functional form of the relationship between *wfa* and month of birth *M*, X is a vector of child characteristics identical to that in equation (1) and ε_{ij} is a mean-zero error term. All other variables still enter linearly. Our main interest here is to illustrate whether and how the function $g(\cdot)$ varies over the different months of birth, and we estimate this function using LOWESS (locally weighted scatterplot smoothing). The estimation of the function $g(\cdot)$ is provided in Figure 3.[11]

The graphical depiction of the estimation of equation (3) given in figure 3 illustrates the disparity in the health effects of birth timing between agriculturally dependent and non-dependent households. The sample composed of those in households with an agricultural share of an income greater than one half, given by the solid line, exhibits a starkly seasonal pattern. The z-score *wfa* falls to its lowest point during the dry season months (February-June), and then rises until reaching its peak at the end of the rainy season and the harvest season. The variation in *wfa* for this sample is quite large, with amplitude (peak to peak) of over three quarters of a standard deviation. The weakly agricultural dependent sample, represented by the dotted line, hews to the same general pattern. However, the seasonal relationship is slightly flatter, with amplitude (peak to peak) of just over one half. In contrast, the non-farm dependent sample, shown by the dashed line, exhibits a much weaker seasonal pattern. In the non-farm dependent sample, the dashed line reaches its nadir during the rainy season, though the peak to peak amplitude of the curve barely exceeds one quarter of a standard deviation.

VI. Malaria, Epidemiological Environment and Selection Bias

Thus far, we have attributed the observed seasonal fluctuation in child health outcomes primarily to seasonal fluctuations in mother's consumption. However, our mother fixed effect estimation may not fully remove the effect of other factors that are also consistent with the observed seasonal patterns in child health. Two factors of particular concern for our identification strategy are malaria and selective mortality. Malaria and other vector-borne illnesses are potentially confounding variable in our analysis because prevalence of these maladies also vary by season in accordance with the rains.[12] And since malaria infection is not time invariant, the mother-fixed effects estimation does not sweep away its potential confounding effects. Selective mortality is another worry because low nutrition and malaria prevalence may interact in ways that could make our observed sample non-representative. We cannot rule out with complete certainty the effects of these factors and the different epidemiological environments experienced by children born in different seasons. Nonetheless, to the extent allowed by our data set, we now carefully examine the potential implications of alternative explanations to our results.

The most salient alternative explanation is that seasonal variations in disease, particularly malaria, drive the observed patterns. For example, since the risk of contracting malaria increases during the rainy season, higher infant mortality rates during the rains may claim relatively 'weaker' children, leaving a healthier sample of children born in the rainy season and driving the results in table 2. Furthermore, the risk of malaria may be systematically higher among the agriculturally dependent, since such households tend to live in highly malarious areas and have lower total income with which to prevent and treat the disease. However, Moore et al (1997), using a sample of 3,102 birth and death records from three rural Gambian villages, do not find that child mortality varies significantly with season of birth.

Income and Malaria

Koram et al (1995) show that malaria risk is indeed higher for the poor in Gambia. Consequently, if malaria were the chief driver of seasonal variation in child health, we would expect to see seasonal differences decline at higher household income levels. However, Table 6 shows the opposite: birth seasonality is stronger for the wealthier agricultural households. The higher degree of seasonal variation in *wfa* among high income agriculturalists is consistent with the view that seasonal variation in consumption drives the results. Wealthier agricultural households are more likely to demonstrate higher variation in seasonal consumption, as they are more able to have very high consumption levels following harvest.

Geography and Malaria

Another element of the malaria hypothesis is that the agriculturally dependent population is at a higher geographic risk of malaria. While malaria patterns in the Gambia are highly localized, it is generally true that rural areas suffer more severely from malaria. One testable implication of this line of reasoning is that seasonal variation in child health should be present in the rural population regardless of agricultural dependence. Table 7 shows the results of estimating the relationship for non-agriculturally dependent households living in rural areas. For this regression the null hypothesis of no seasonal effect cannot be rejected, and the coefficients estimates do not conform to the pattern in tables 4 and 5. A similar result is obtained for the non-farm dependent households living in the most agriculturally dependent districts, as in column 3. As before, these results do not support the malaria hypothesis.

Rainfall Levels

Higher rainfall levels increase malaria prevalence due to higher vector population levels. If malaria were driving the observed seasonal variation in anthropometry, higher rainfall during the year of birth should lead to more malaria, and hence a larger seasonal effect. The interaction between rainfall shocks and seasons of births should be positive and significant if the malaria mortality among newborns were the primary drivers of our results.

In table 8, interaction terms between season of birth and rainfall levels, expressed as deviations from average district levels, are added to the basic specification. The signs on the interaction terms of higher rainfall are ambiguous and insignificant. The results of table 8, therefore, do not support the notion that malaria is driving the results.

Rainfall Timing

One implication of the seasonal nutrition hypothesis is that a longer time period between harvests should exacerbate seasonal health variation by extending the hungry season. While precise harvest timing data is unavailable, we can make rough estimates based on monthly rainfall levels. In each district, we determine the ratio of the amount of rainfall in the months of October, November and December to the total amount of rainfall in the calendar year.[13] A higher ratio of late season rainfall to total rainfall, which we term the late rain ratio, indicates a later harvest. The late rain ratio of the calendar year preceding the child's birth is then divided by the late rain ratio of the calendar year coinciding with the child's birth to form the variable *shrtrat*, which is our proxy for the length of the hungry season during the time period closest to birth. A higher value for *shrtrat* indicates a shorter hungry season.

Note that for children born in the rainy season, an extended rainy season in the year preceding birth would increase the risk of malaria infection during gestation, which would complicate our identification strategy since this effect could vary over time. An implication of this possibility is that late rains would cause the malaria season to overlap with the gestation of period of rainy season births. As such, the malaria selection hypothesis would suggest that children born in the rainy season in a year following late rains should be more subject to attrition. Early rains during the season of birth would compound this risk. Hence, children with higher values of *shrtrat* should exhibit an even stronger rainy season advantage if the malaria effect were strong.

Conversely, the seasonal nutrition hypothesis suggests the opposite. If preconception nutrition is important to child health, late rainfalls in the previous year should reduce the relative advantage of rainy season births as the length of the ‘hungry season’ is shortened.

To test these differing hypotheses, we run the regressions with only one seasonal dummy, rainy season births, and interact this dummy variable with *shrtrat*[14]. This gives the following specification:

$$wfa_{ijk} = \beta_0 + \beta_1 RS_{ijk} + \beta_2 shrtrat_{ik} + \beta_3 RS * shrtrat_{ik} + X`\Gamma + e_{ijk} \qquad (4)$$

The reasoning above yields the following predictions for the malaria and seasonal nutrition hypotheses:

Malaria: β_3>0

Nutrition: β_3<0

Estimating this regression, we find that the coefficient on the interaction term is indeed negative and significant (table 9). At the mean value of the ratio, 1.3, a longer hungry season in the year of birth reduces the rainy season advantage by approximately .17, or 25 percent, for the sample of households with an agricultural income of at least 10 percent. Consequently, a closer examination of the timing of rainfall provides further evidence that seasonal variation in maternal nutrition, as opposed to seasonal patterns in infectious disease, causes child anthropometry to vary by season of birth.

The Role of Other Selection Effects in Seasonal Differences in Child Health

Beyond malaria, rural or farm-dependent households may have different patterns in live births, conception rates or child mortality across seasons from non-farm dependent households for reasons. While our data does not contain complete pregnancy histories, in this section, we evaluate these alternative explanations as fully as the data permits.

Potential sources of selection bias may arise before birth. Conception and fetal death rates can be affected by nutrition (Panter-Brick 1996; Eidelman 2001). In the developed country context, Dehejia and Lleras-Muney (2004) and Buckles and Hungerman (2008) suggest that seasonal variation in child health may stem from seasonal selection of parentage. However, these concerns are not especially relevant to our results due to the use of a within mother identification strategy. In the developing country context, Artadi (2006) suggests that families select into birth season of children according to the seasonal need for female labor. Again, as long as female labor needs remain constant between the birth of siblings, the mother fixed effects strategy alleviates this source of potential selection bias. Indeed, Sear, Mace and McGregor (2002) find the timing of birth intervals in rural Gambia to exhibit a high degree of mother level heterogeneity. Furthermore, both Sear et al (2002) and Bledsoe et al (1994) find birth timing efforts are generally related to maintaining an approximately 2.5 year birth interval. This spacing pattern is reflected in our data in *both* the farm and non-farm sample, where the median birth spacing between non-twin siblings is 29 months.[15]

Nevertheless, we compare observed birth month frequencies based on the relative dependency on agriculture as a source of income.[16] As the histograms in figure 4 shows, the birth month frequencies for children under the age of thirteen months—the sample least affected by attrition from mortality—are similar across these groups, though not identical. In particular, children from farm dependent households are slightly less likely to be born in the rainy season and more likely in the harvest season, which is consistent with other studies of births in rural Gambia (see, for example, Billewicz and McGregor (1981)). For the sample less dependent on agriculture, births during the rainy season are slightly more frequent, at the expense of dry season births, which are relatively less frequent.

Could the small discrepancy in birth patterns explain the seasonal health effect among agriculturists? Figure 5, which plots the birth patterns of the non-farm dependent sample according to household per capita income, suggests the answer is unlikely. Despite the large discrepancies in birth patterns between richer and poorer households, the results from table 7 indicate that the seasonal health effect for both samples is similarly small and insignificant.

As an additional robustness check, equation (1) was estimated for children born only during months that border other seasons. That is, only children born during the first or last month of a season are included in the regression. This estimation strategy takes advantage of natural deviations in gestation periods to minimize potential prenatal birth season selection bias since children born in bordering months that happen to fall in different seasons should have similar conception timing. If such selection bias is indeed driving the observed seasonal effect, seasonal variation in child health should diminish. However, the estimated coefficients from this specification, shown in table 10 do not exhibit attenuation, and are consistent with those in tables 2 and 4. Though the restriction to border month children dramatically reduces the power of the test for a seasonal effect and causes the p-value in the farm dependent sample to substantially increase, the disparity between the farm and non-farm results mirrors earlier estimations.

Trivers-Willard Effects

Recent studies (Almond and Mazumder 2008; Mathews, Johsnon and Neil 2008) have garnered support for the hypothesis that conception during periods of maternal hunger results in a higher probability of a female fetus. Evolutionary biologists argue that such a characteristic increases species survival during periods of extreme stress. If true, it would provide a natural test of the hypothesis that agriculturally dependent Gambian women experience extreme seasonal nutritional variation that affects their unborn children while their non-agriculturally dependent do not. Farm-dependent women who conceive during the rainy season should have a higher probability of producing a female, while sex of non-farm dependent children should not vary with the season.

Table 11 displays the results of such a test. Indeed the probability of having a female child is significantly higher when conception—assumed to be a normal gestation period—occurs during the rainy season. No other variables are significantly related. The same is not true, however, for the non farm-dependent sample. For them (column 2), conception timing has no effect on gender. This result is therefore consistent with the hypothesis that nutritional levels are significantly different across seasons and this has a causal impact on child health.

The Timing of Mother's Nutritional Deficit on Child Health

From our results, children born in the rainy season (roughly between July and October) are healthier in terms of having higher *wfa* relative to the dry season (February-June). The results also suggest an advantage over the dry season in *wfa* and *hfa* for those born during the harvest season (November-January).[17] The fact that birth during these months appears relatively advantageous gives some hints as to when educed maternal calorie affects a child's health.

As discussed earlier, maternal nutrition can potentially affect child health during three stages: at conception, during pregnancy and during lactation. Children born in the dry season tend to have lower *wfa* and are likely conceived between July and September. As shown in figure 2, this conception period falls in the middle of the rainy season, when Gambian women suffer a large deficit in net energy intake. And as Ronnenberg et al. (2003) show, low preconception body weight is a significant determinant of low birth weight, which tends to persist into infanthood.

It is unlikely that conception weight of the mother is the only factor. Children born during the dry season undergo their first six months of lactation during the lean months of the rainy season. As Prentice (1980) shows, while there seems to be no adverse effect on milk production during the first two months of lactation, there is a significant reduction in milk production between the second and the sixth months. Therefore, the seasonal variation in child health shown here is consistent with changes in maternal nutrition degrading child nutrition via lactation.

For a child born between March and May, the period of the pregnancy that coincides with the 'hungry season' is the first trimester. While we cannot definitively rule out the importance of this period to child health, we are not aware of studies that show a strong link between reduced birth weight or child health and diminished food intake of the mother during the first trimester. Therefore, the evidence from our results is consistent with the two mechanisms found in the medical literature through which reduced calorie intake of the mother affects the child: nutritional status at conception and during lactation.

VII. Conclusion

Our paper looks at the health effects of birth in different seasons among a sample of Gambian children below the age of six. Unlike previous health studies on The Gambia, we use two nationally-representative samples from 1994 and 2003 and find that children born between February and June tend to have smaller z-scores of weight-for-age (*wfa*) and height-for-age (*hfa*) relative to children born during other months of the year. By using mother fixed effects, our estimation allows us to isolate the seasonal effect from confounding factors such as genetic endowment and socioeconomic status. Our results suggest that the significant effect of season of birth on child health measures is driven by rural, agricultural-dependent households and not simply by low levels of wealth. While we cannot completely rule out the role played by confounding seasonal effects such as malaria and other epidemiological factors, further examinations of our data show that our results are most consistent with the hypothesis that seasonal dips in maternal consumption measurably reduce child anthropometry.

The pattern of our results and previous research strongly suggests that the inability of households to borrow and save drives seasonal variation in consumption among women. That variation, in turn, affects the health of children through their mothers' nutritional status at birth and during lactation.

The results presented here suggest a positive relationship between the availability of mechanisms for households to borrow and save and child health. Policies that improve access to financial markets and commodity storage technology should help alleviate these seasonal imbalances. However, it should be noted that the seasonal consumption patterns referred throughout this paper derive from studies of female consumption in The Gambia. Therefore, we cannot discount the possibility that the inability to smooth consumption is confined to Gambian women only and thus largely driven by intrahousehold imbalances. Indeed, under such conditions improvements in access to credit and storage may not alleviate the seasonal consumption problem if not accompanied by reforms that enhance female empowerment.

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Table 1: **Summary Statistics**

	All	Urban (Greater Banjul)	Peri-Urban/ Rural Town	Rural	Aginc<0.1	Aginc>0.1	Number of Obs.
Child Variables							
Child Age(months)	31.04	29.86	30.5	31.7	30.99	31.03	2755
	(18.57)	(18.09)	(19.10)	(18.61)	(18.48)	(18.66)	
Female	0.5	0.52	0.48	0.49	0.49	0.49	2755
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	
z-scores of Weight	-1.11	-1.01	-0.96	-1.20	-1.03	-1.16	2432
for Age (*wfa)*	(1.43)	(1.37)	(1.55)	(1.42)	(1.41)	(1.43)	
z-scores of Height	-1.00	-0.91	-0.93	-1.05	-1.04	-0.99	1459
for Age *(hfa)*	(1.45)	(1.34)	(1.49)	(1.48)	(1.27)	(1.50)	
Household Variables							
Household Size	14.02	11.02	12.37	15.78	11.6	14.89	2730
	(8.47)	(6.84)	(8.20)	(8.73)	(7.44)	(8.71)	
Per Capita Household	1943.17	2604.66	2053.37	1494.1	3207.67	643.46	1535
Income†*	(4824.54)	(5370.87)	(4800.81)	(4398.13)	(6351.51)	(969.51)	
*Aginc (*agricultural income	0.29	0.03	0.16	0.48	0.01	0.51	1491
as % of total HH Income)*	(0.38)	(0.11)	(0.31)	(0.38)	(0.02)	(0.28)	
Wageinc (Wage income	0.19	0.31	0.24	0.1	0.3	0.09	1276
as % of total HH Income)*	(0.34)	(0.38)	(0.36)	(0.27)	(0.39)	(0.23)	
Number of Observations	2755	705	434	1616	809	682	

†These figures are in 2003 Dalasi values. In 2003, $1 ≈ 27 Dalasi.
*This variable is available for only a subset of households from the 2003 sample.
Means with standard deviations in parentheses. ***Aginc*** denotes the percentage of household income derived from farming.

Table 2: Estimation Results for wfa (Equation (1)) by Survey Year and Location

	Full Sample	1994 Sample	2003 Sample	Rural Households	Urban Households
	(1)	(2)	(3)	(4)	(5)
Born in Rainy Season (RS)	0.320***	0.372***	0.210	0.314**	0.192
	(0.101)	(0.130)	(0.157)	(0.135)	(0.194)
Born in Harvest Season (HS)	0.304***	0.188	0.379**	0.237*	0.169
	(0.107)	(0.135)	(0.165)	(0.136)	(0.225)
Child's Age (Months)	-0.003	-0.0009	-0.009*	-8.83e-05	-0.005
	(0.003)	(0.005)	(0.005)	(0.00413)	(0.007)
Female	0.153*	0.270**	0.0344	0.189*	0.197
	(0.0845)	(0.112)	(0.126)	(0.114)	(0.156)
Rain Shock (prebirth)	0.0002	0.0006*	-7.57e-05	0.0004	-0.0002
	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0004)
Rain Shock (postbirth)	0.0004*	0.001***	-4.75e-05	0.0004	0.0002
	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0004)
Middle Child	-0.212	-0.302	-0.136	-0.210	-0.181
	(0.180)	(0.249)	(0.255)	(0.301)	(0.277)
Youngest Child	-0.138	-0.0317	-0.337	-0.241	-0.133
	(0.198)	(0.272)	(0.282)	(0.323)	(0.327)
Constant	-1.152***	-1.297***	-0.725**	-1.282***	-0.924**
	(0.220)	(0.311)	(0.315)	(0.332)	(0.397)
Observations	2371	1128	1243	1379	621
Degrees of Freedom	1117	534	575	643	289
F-Test of the Joint Significance of RS and HS (p-value)	0.002	0.018	0.069	0.054	0.586

Robust standard errors in parentheses. Dependent variable is *wfa*. Mother fixed effects in all regressions. ***, **, * denote significance at 1, 5 and 10 percent level, respectively.

Table 3: Estimation Results for *hfa* (Equation (1)) by Sample Year and Location

	Full Sample	1994 Sample	2003 Sample	Rural Households	Urban Households
	(1)	(2)	(3)	(4)	(5)
Born in Rainy Season (RS)	0.0740	-0.258	0.199	0.246	-0.0362
	(0.322)	(0.393)	(0.439)	(0.438)	(0.558)
Born in Harvest Season (HS)	0.481	0.139	0.649	0.893*	-0.147
	(0.336)	(0.362)	(0.510)	(0.495)	(0.673)
Child's Age (Months)	0.011	0.007	0.006	0.019	0.015
	(0.010)	(0.017)	(0.014)	(0.013)	(0.015)
Female	0.273	0.221	0.248	0.366	0.174
	(0.254)	(0.314)	(0.361)	(0.354)	(0.583)
Rain Shock (prebirth)	0.0004	0.0007	0.0001	0.0004	0.0002
	(0.0007)	(0.001)	(0.001)	(0.001)	(0.001)
Rain Shock (postbirth)	4.98e-05	0.0007	-8.85e-05	-0.0001	-2.06e-05
	(0.0006)	(0.001)	(0.0001)	(0.0009)	(0.001)
Middle Child	0.145	-0.270	0.353	-0.135	0.588
	(0.551)	(0.730)	(0.744)	(0.718)	(1.077)
Youngest Child	-0.115	-0.101	-0.0817	-0.560	0.656
	(0.620)	(0.780)	(0.852)	(0.775)	(1.267)
Constant	-1.908**	-1.279	-1.802	-2.233**	-2.097
	(0.761)	(1.021)	(1.200)	(1.083)	(1.257)
Observations	1420	653	767	824	360
Degrees of Freedom	288	113	167	162	61
F-Test of the Joint Significance of RS and HS (p-value)	0.306	0.623	0.444	0.164	0.975

Robust standard errors in parentheses. Dependent variable is *hfa*. Mother fixed effects in all regressions. ***, **, * denote significance at 1, 5 and 10 percent level, respectively.

Table 4: Estimation Results for weight-for-age (*wfa*) by Source of Income.

	Farm Dependent			Not Farm Dependent		
	aginc≥0.1	*aginc≥0.25*	*aginc≥0.5*	*aginc<0.1*	*aginc<0.25*	*aginc<0.5*
	(1)	(2)	(3)	(4)	(5)	(6)
Born in Rainy Season (RS)	0.576***	0.624***	0.662***	0.0785	0.145	0.178
	(0.166)	(0.178)	(0.206)	(0.232)	(0.216)	(0.196)
Born in Harvest Season (HS)	0.216	0.350	0.428	0.132	0.126	0.0624
	(0.196)	(0.221)	(0.275)	(0.219)	(0.198)	(0.183)
Child's Age (Months)	0.007	0.001	-0.0001	-0.015*	-0.015*	-0.006
	(0.006)	(0.007)	(0.008)	(0.008)	(0.008)	(0.007)
Female	0.116	0.0648	-0.0108	0.118	0.247	0.299**
	(0.152)	(0.161)	(0.201)	(0.168)	(0.155)	(0.145)
Rain Shock (prebirth)	0.001**	0.001**	0.001*	0.0004	0.0001	0.0001
	(0.0005)	(0.001)	(0.001)	(0.0005)	(0.0005)	(0.0004)
Rain Shock (postbirth)	0.001	0.0004	0.001*	0.001	0.001	0.001*
	(0.0004)	(0.0005)	(0.0006)	(0.0005)	(0.0004)	(0.0004)
Middle Child	-0.571	-0.349	0.00634	-0.362	-0.249	-0.302
	(0.442)	(0.484)	(0.677)	(0.334)	(0.314)	(0.304)
Youngest Child	-0.201	-0.164	0.275	-0.429	-0.333	-0.110
	(0.460)	(0.505)	(0.693)	(0.365)	(0.341)	(0.324)
Constant	-1.357***	-1.302**	-1.528**	-0.410	-0.582	-1.009***
	(0.488)	(0.535)	(0.727)	(0.419)	(0.392)	(0.367)
Observations	601	491	367	576	705	815
Degrees of Freedom	282	228	168	264	323	377
F-Test of Joint Significance of RS and HS (p-value)	0.003	0.002	0.006	0.832	0.771	0.637

Robust standard errors in parentheses. Dependent variable is *wfa*. *aginc* denotes the share of total household income derived from agricultural activities. ***, **, * denote significance at 1, 5 and 10 percent level, respectively. Mother fixed effects in all regressions.

Table 5: Estimation Results for height-for-age (*hfa*) by Source of Income.

	Farm Dependent			Not Farm Dependent		
	aginc≥0.1	*aginc≥0.25*	*aginc≥0.5*	*aginc<0.1*	*aginc<0.25*	*aginc<0.5*
	(1)	(2)	(1)	(2)	(1)	(2)
Born in Rainy Season (RS)	-0.142	-0.0629	0.173	-0.126	0.0282	-0.0107
	(0.646)	(0.695)	(0.867)	(0.474)	(0.487)	(0.471)
Born in Harvest Season (HS)	0.529	0.494	1.154	0.0676	0.0718	0.147
	(0.570)	(0.560)	(0.719)	(0.496)	(0.473)	(0.466)
Child's Age (Months)	0.027	0.025	0.022	0.007	0.030	0.008
	(0.018)	(0.020)	(0.030)	(0.023)	(0.023)	(0.021)
Female	-0.006	-0.076	0.081	0.302	0.370	0.347
	(0.641)	(0.704)	(0.871)	(0.340)	(0.340)	(0.339)
Rain Shock (prebirth)	0.0009	0.0013	0.0004	0.0005	0.0006	0.0005
	(0.0013)	(0.002)	(0.002)	(0.001)	(0.0013)	(0.001)
Rain Shock (postbirth)	-0.0005	-0.001	-0.001	0.001	0.0001	0.0003
	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Middle Child	-1.446	-1.460	-0.743	0.314	0.157	0.180
	(1.116)	(1.141)	(1.857)	(0.671)	(0.670)	(0.669)
Youngest Child	-1.169	-1.264	-0.966	0.342	0.0187	0.154
	(1.306)	(1.413)	(1.980)	(0.639)	(0.689)	(0.692)
Constant	-1.019	-0.776	-1.652	-1.853	-1.559	-1.907*
	(1.351)	(1.390)	(2.330)	(1.122)	(1.132)	(1.083)
Observations	340	281	209	339	419	478
Degrees of Freedom	55	45	31	58	70	80
F-Test of Joint Significance of RS and HS (p-value)	0.455	0.578	0.255	0.924	0.987	0.916

Standard errors in parentheses. Dependent variable is *hfa*. *aginc* denotes the share of total household income derived from agricultural activities. Mother fixed effects in all regressions. ***, **, * denote significance at 1, 5 and 10 percent level, respectively.

Table 6: Estimation Results by Source and Level of Income

		All Households	Farm Dependent Households	Non-Farm Dependent Households
		1	2	3
<u>Below</u> Median Per Capita Household Income	Born in Rainy Season (RS)	0.492***	0.476**	0.378
		(0.165)	(0.197)	(0.334)
	Born in Harvest Season (HS)	0.112	0.204	0.0348
		(0.184)	(0.234)	(0.359)
	Joint Significance of RS and HS (p-value)	.010	0.056	0.886
	Observations	702	406	406
	Degrees of Freedom	327	188	188
<u>At or Above</u> Median Per Capita Household Income	Born in Rainy Season (RS)	0.249	1.006**	0.100
		(0.213)	(0.431)	(0.241)
	Born in Harvest Season (HS)	0.197	0.696	0.103
		(0.206)	(0.641)	(0.222)
	F-Test of Joint Significance of RS and HS (p-value)	0.481	0.077	0.886
	Observations	646	83	563
	Degrees of Freedom	298	30	260

Robust standard errors in parentheses. Dependent variable is *wfa*. Farm dependent households are defined by *aginc*≥.25 Non farm dependent households are defined by *aginc*<.25 ***, **, * denote significance at 1, 5 and 10 percent level, respectively. Mother Fixed Effects in all regressions. Control variables are identical to tables 2,3,4, and 5.

Table 7: Malaria and Geography.

VARIABLES			Non Farm Dependent and District Agricultural Dependence Above Median
	aginc<0.1	*aginc*<0.25	*aginc*<0.25
	1	2	3
Born in Rainy Season	-0.146	0.124	0.251
	(0.542)	(0.421)	(1.011)
Born in Harvest Season	-0.560	-0.374	-0.470
	(0.390)	(0.323)	(0.816)
Child's Age	-0.0279	-0.000652	-0.0227
	(0.0230)	(0.0146)	(0.0493)
Middle Child	0.287	-0.129	-0.822
	(0.898)	(0.814)	(1.246)
Youngest Child	-0.352	0.156	-1.332
	(0.989)	(0.822)	(1.635)
Female	0.200	0.306	0.103
	(0.396)	(0.331)	(0.957)
Rain_prebirth_shock	0.0013	0.0008	0.0009
	(0.001)	(0.0009)	(0.003)
Rain_postbirth_shock	0.0008	0.0008	-0.001
	(0.001)	(0.0007)	(0.003)
Constant	-0.115	-1.340	0.582
	(1.154)	(0.863)	(2.345)
Observations	177	261	70
F-Test: Joint Significance of RS and HS (p-value)	0.222	0.186	0.771
Degrees of Freedom	72	112	22

Robust standard errors in parentheses. The sample used here is restricted to rural households. The dependent variable is *wfa*. ***, **, * denote significance at 1, 5 and 10 percent level, respectively. Mother fixed effects in all regressions.

Table 8: Rainfall Levels: The dependent variable is *wfa* and robust standard errors are in parentheses.

	aginc≥0.1
VARIABLES	(1)
Born in Rainy Season	0.569***
	(0.178)
Born in Harvest Season	0.225
	(0.188)
Harvest-birth*pre-birth_shock	-0.001
	(0.001)
Harvest-birth*post-birth_shock	-0.0004
	(0.001)
Rainy-birth*pre-birth_shock	-0.0009
	(0.001)
Rainy-birth*post-birth_shock	-0.0005
	(0.001)
Child's Months	0.006
	(0.006)
Middle Child	-0.544
	(0.429)
Youngest Child	-0.181
	(0.434)
Female	0.110
	(0.151)
Rain_prebirth_shock	0.0015**
	(0.0007)
Rain_postbirth_shock	0.001
	(0.0008)
Constant	-1.369***
	(0.475)
Observations	601
Degrees of Freedom	278

Robust standard errors in parentheses. Dependent variable is *wfa*. ***, **, * denote significance at 1, 5 and 10 percent level, respectively. Mother fixed effects in all regressions.

Table 9: **Rainfall Timing and Length of the Hungry Season**

	(1)	(2)	(3)	(4)
	aginc≥0.1	*aginc*≥0.25	*aginc*<0.25	*aginc*<0.1
Rainy-Season**shrtrat*	-0.129*	-0.146*	-0.0192	0.0175
	(0.0710)	(0.0796)	(0.0630)	(0.0878)
shrtrat	-0.0252	-0.0823	-0.0103	-0.0439
	(0.0476)	(0.0548)	(0.0592)	(0.0842)
Born in Rainy Season	0.667***	0.650***	0.117	-0.0134
	(0.213)	(0.241)	(0.211)	(0.241)
Child's Age	0.006	-0.002	-0.008	-0.018**
	(0.006)	(0.007)	(0.007)	(0.008)
Female	0.089	0.074	0.247	0.221
	(0.156)	(0.171)	(0.152)	(0.164)
Middle Child	-0.435	-0.411	-0.168	-0.179
	(0.475)	(0.504)	(0.315)	(0.320)
Youngest Child	-0.126	-0.294	0.0159	-0.278
	(0.492)	(0.523)	(0.341)	(0.351)
Rain_prebirth_shock	0.0012**	0.0015***	0.0007	0.0007
	(0.0005)	(0.0006)	(0.0005)	(0.0005)
Rain_postbirth_shock	0.0005	0.0002	0.001**	0.0012**
	(0.0005)	(0.0005)	(0.0004)	(0.0005)
Constant	-1.348**	-0.874	-1.006**	-0.408
	(0.538)	(0.571)	(0.406)	(0.416)
Observations	554	453	780	679
Degrees of Freedom	244	196	349	301

Robust standard errors in parentheses. Dependent variable is *wfa*. ***, **, * denote significance at 1, 5 and 10 percent level, respectively. Mother fixed effects in all regressions.

Table 10: Estimation for Children Born on "Border" Months

	(1)	(2)	(3)	(4)	(5)
	Full Sample	*aginc*≥0.1	*aginc*≥0.25	*aginc*<0.25	*aginc*<0.1
Born in Rainy Season (RS)	0.475	0.825*	0.784	-0.0837	0.0989
	(0.316)	(0.475)	(0.590)	(0.691)	(0.604)
Born in Harvest Season (HS)	0.385	0.317	0.150	-0.192	-0.0505
	(0.312)	(0.682)	(0.831)	(0.566)	(0.507)
F-Test: Joint Significance of RS and HS (p-value)	0.302	0.159	0.317	0.937	0.943
Observations	1170	301	239	354	416
Degrees of Freedom	297	71	55	80	96

Sample includes siblings born in first in last month of each season (i.e. January, February, June, July, October, November). Robust standard errors in parentheses. Control variables are identical to tables 2,3,4, and 5. Mother fixed effects in all regressions. ***, **, * denote significance at 1, 5 and 10 percent level, respectively.

Table 11: Sex Selection (*Trivers-Willard Effects*). The dependent variable is *wfa* and robust standard errors are in parentheses.

	(1)	(2)
	Farm Dependent	Non-Farm Dependent
Rainy-Season Conception	0.0863*	0.0228
	(0.0510)	(0.0332)
Observations	505	1337

*** p<0.01, ** p<0.05, * p<0.1 The variable, *Rainy-Season Conception*, indicates birth occurred during April, May, or June. Controls include age, birth order dummy variables, urban, number of siblings, mother's education, and rainfall in year before and after birth expressed as a deviation from the 10 year district average. Farm dependence is defined by an agricultural share of income greater than or equal to .25.

Table A1: Estimation of Equation (1) Using Month of Birth in Place of Season of Birth.

	All	***aginc*≥0.1**	***aginc*<0.1**
February Dummy	-0.061	0.490	0.095
	(0.193)	(0.386)	(0.427)
March Dummy	-0.188	-0.263	-0.189
	(0.177)	(0.306)	(0.316)
April Dummy	-0.009	0.165	-0.241
	(0.181)	(0.349)	(0.306)
May Dummy	0.013	0.170	0.238
	(0.199)	(0.365)	(0.346)
June Dummy	-0.149	-0.055	-0.092
	(0.214)	(0.446)	(0.354)
July Dummy	0.222	0.816**	0.234
	(0.198)	(0.355)	(0.373)
August Dummy	0.179	0.396	0.106
	(0.179)	(0.358)	(0.300)
September Dummy	0.582***	1.027***	0.352
	(0.190)	(0.335)	(0.303)
October Dummy	0.002	0.499	-0.143
	(0.180)	(0.355)	(0.312)
November Dummy	0.458**	0.833**	0.040
	(0.194)	(0.326)	(0.307)
December Dummy	0.292	0.185	0.202
	(0.185)	(0.377)	(0.329)
Observations	2371	601	705
Degrees of Freedom	1108	273	314
F-test of Joint Significance (p-value)[§]	0.001	0.001	0.843

[§]This is joint test of whether the month dummies (Feb. to Dec) are jointly significant.
The dependent variable is the z-score of *wfa*. Standard errors are in parentheses. *aginc* denotes the share of total household income derived from agricultural activities. Mother fixed effects in all regressions. Control variables are identical to tables 2,3,4, and 5.. ***, **, * denote significance at 1, 5 and 10 percent level, respectively.

Figure 1: Kernel Density of Weight for Age

Figure 1A: Kernel density of weight-for-age by gender

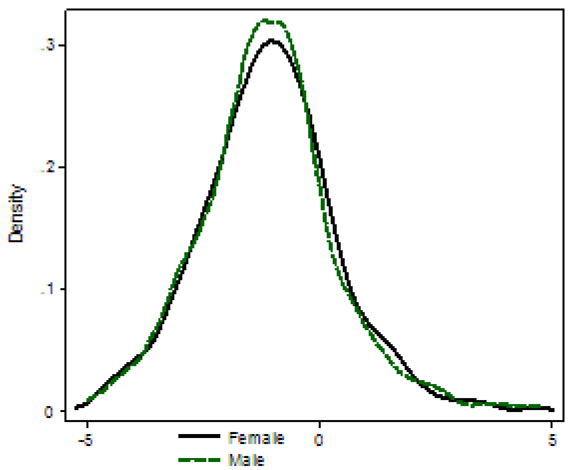


Figure 1B: Kernel density of weight-for-age by survey year

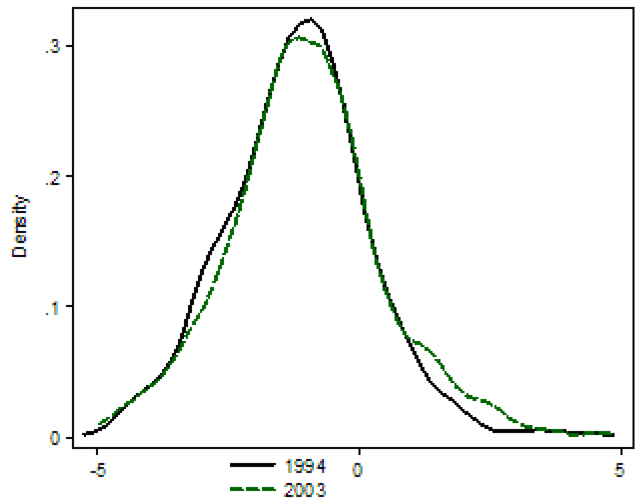


Figure 1C: Kernel density of weight-for-age by location

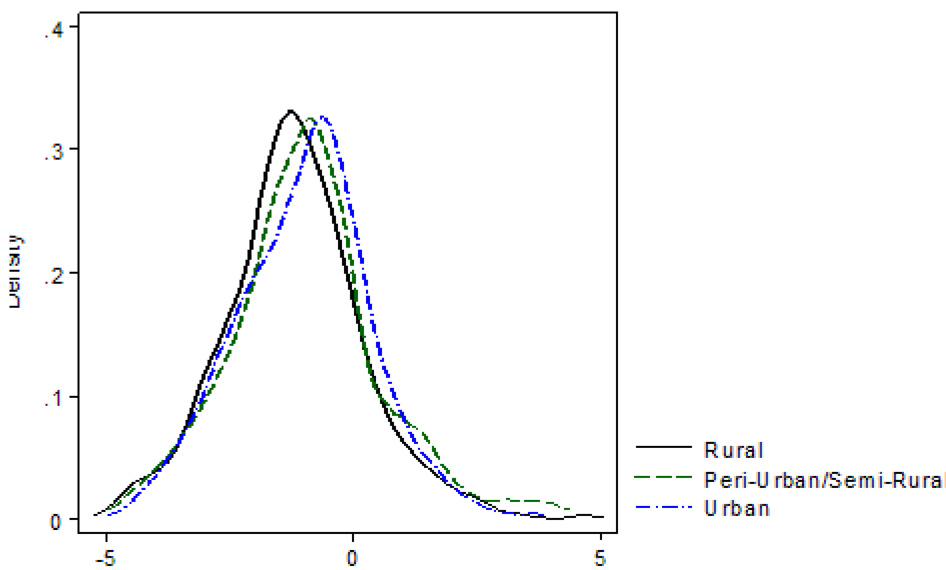
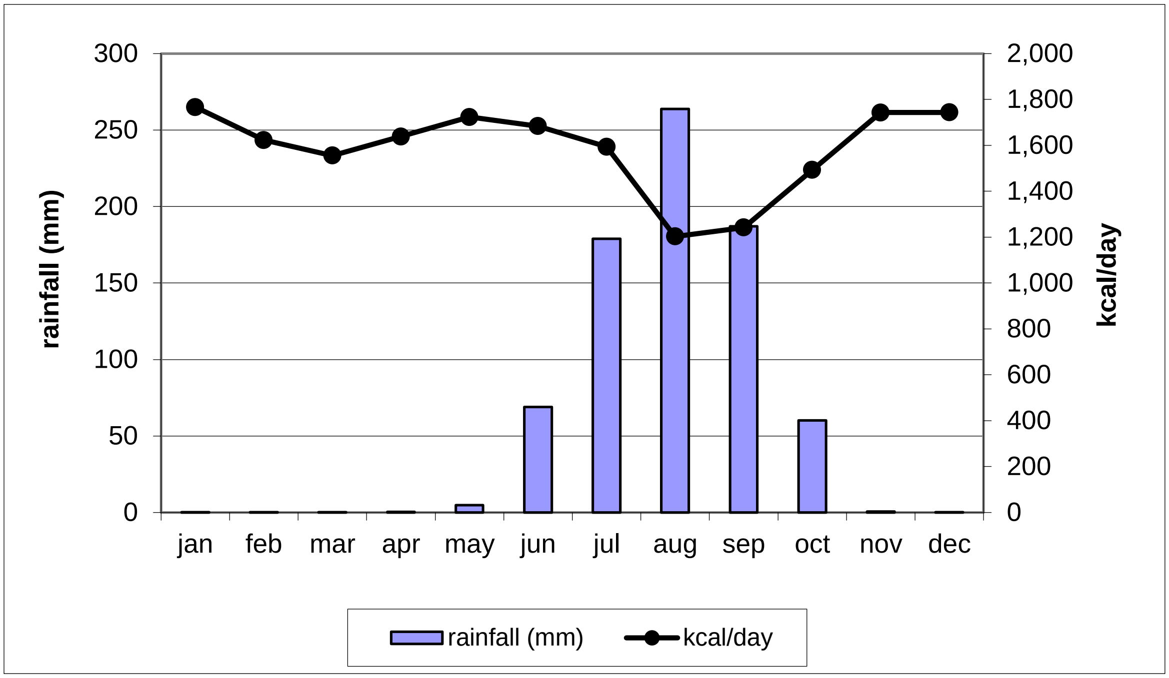


Figure 2: Calorie Intake and Average Rainfall (1980-2003) Throughout the Year in The Gambia



Source : (calorie data): Prentice et. al. (1981); (rainfall data): Department of Water Resources, The Gambia.

Figure 3: The nonparametric component $g(\cdot)$ of equation (3)

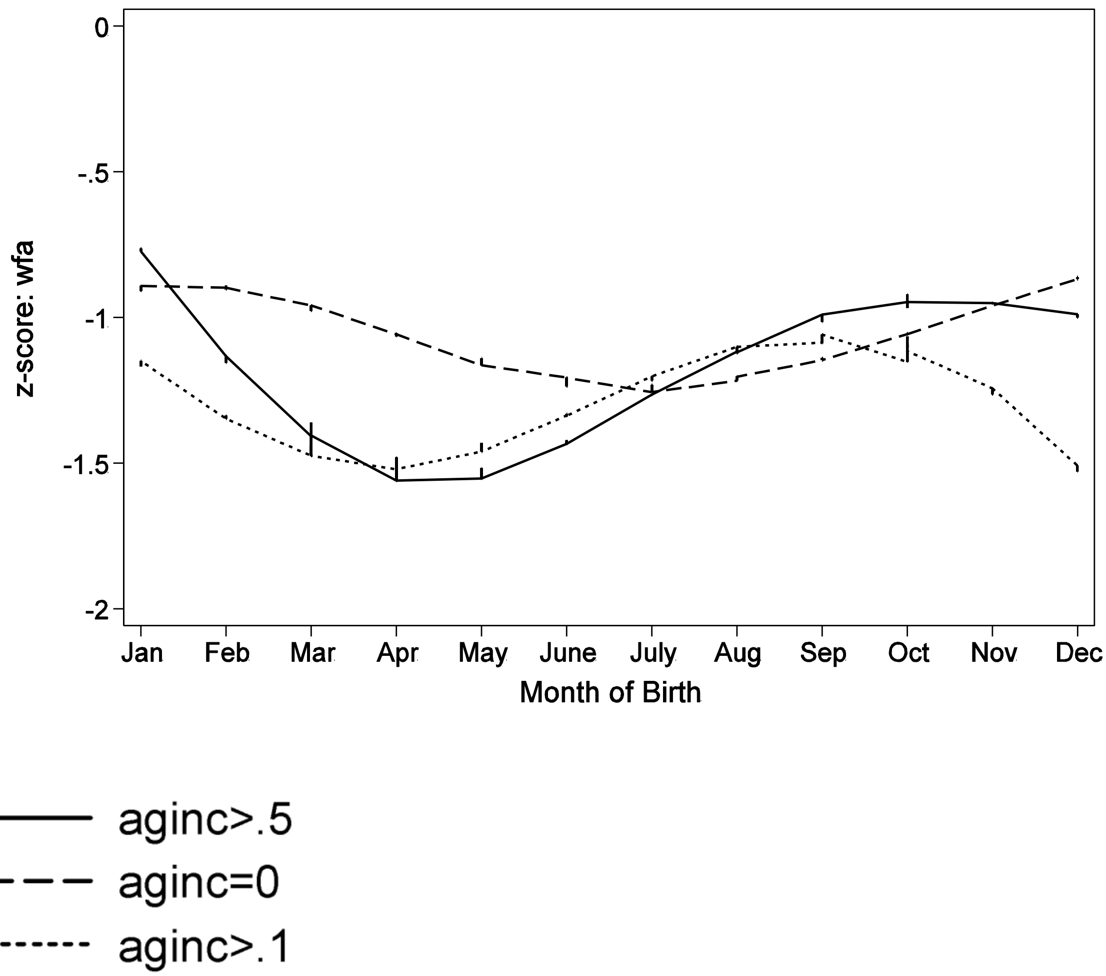


Figure 4: Percentage of Children Under 13 Months in Each Season of Birth by Farm Dependence

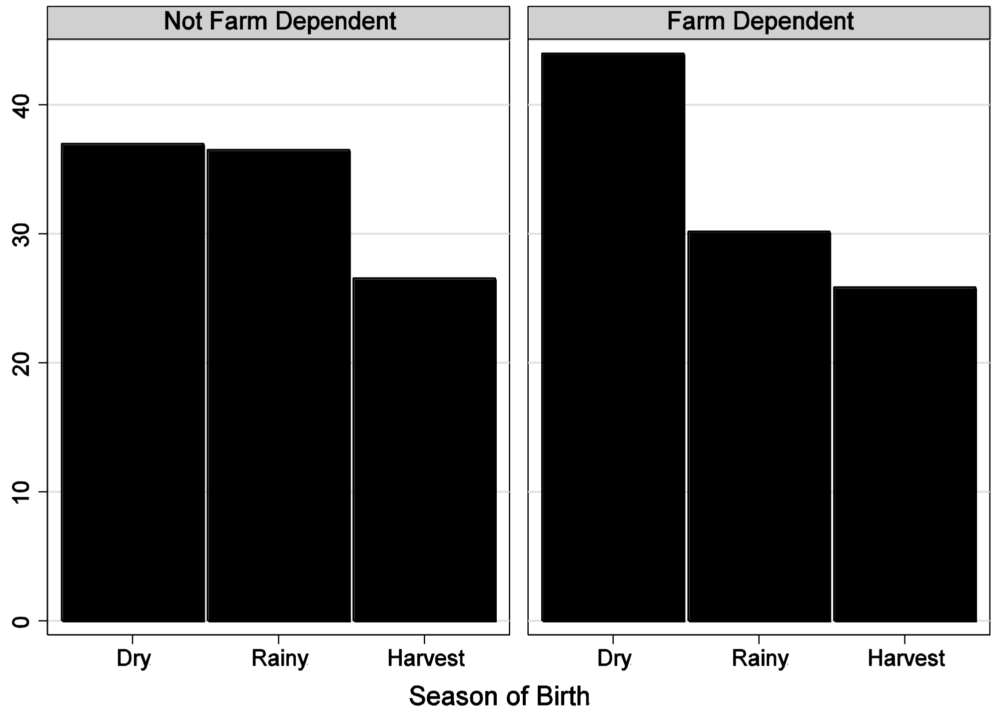
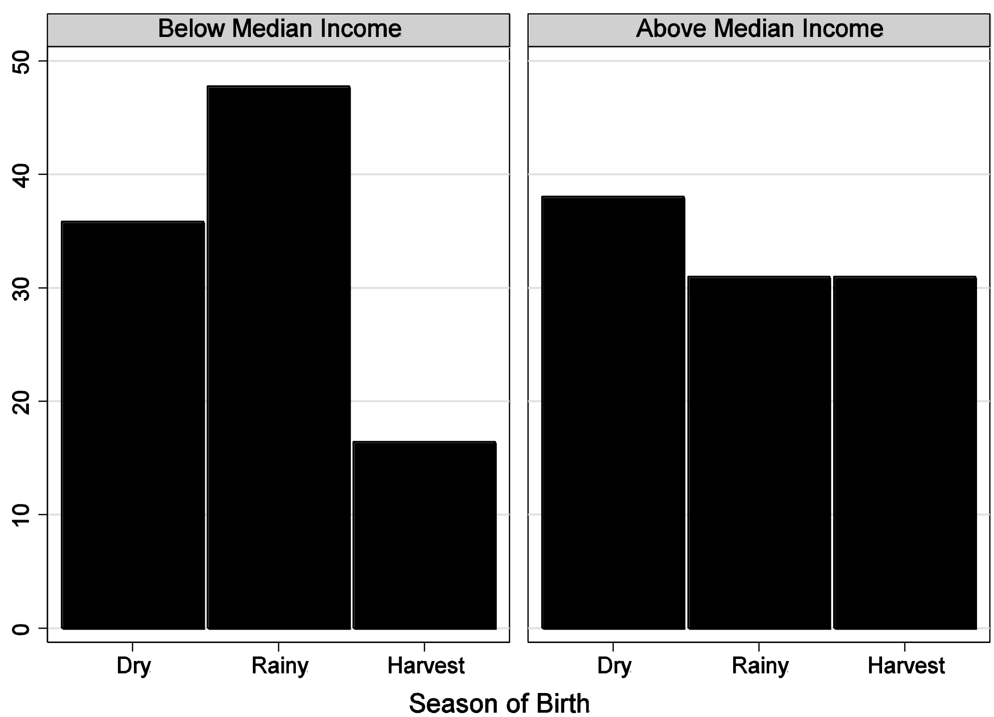


Figure 5: Percentage of Children Under 13 Months Old from Non Farm Dependent Households in Each Season of Birth by Household Income



[1] For example, storage losses for rice, the staple food in the Gambia, have been estimated at between six and twenty-four percent (Grolleaud, 2002). Groundnuts, a cash crop grown widely in The Gambia, deteriorate substantially when storage conditions do not regulate moisture and temperature adequately (Nautiyal 2002).
[2] Enumerators were equipped with measuring tapes to measure heights (centimeters) and scales to measure weights (grams). Both heights and weights were measured up to one decimal point.
[3] The discrepancy between the number of children in the sample and the number with a *wfa* measurement is due to either missing weight measures (222) or z-scores outside of the -5 to 5 range (101).
[4] The data source for figure 2 is Prentice (1981). For more recent studies that have noted the same consumption pattern see Cole (1993) and Lawrence et al (1989).
[5] Previous research has shown malaria prevalence and risk of transmission patterns in the Gambia to be extremely localized. See Clarke et al (2002) for a review of this literature.
[6] In later sections, we address potential identification issues due to malaria.
[7] We divide the year in to three seasons: rainy season (July-October), dry season (February-June) and harvest season (November-January). Our excluded seasonal dummy in all our estimation is the dry season dummy.
[8] In a later estimation, we interact these variables with seasons of birth to further capture this effect.
[9] Results obtained using standard errors calculated under the assumption of homoscedasticity indicate that harvest season coefficients in the *hfa* estimations are significantly different for the full and rural samples.
[10] Estimations using similar cutoffs (not shown here) yielded similar results.
[11] The results of the parametric component of the estimation are available on request.
[12] For simplicity we will explicitly discuss malaria, though the arguments that follow hold for other diseases that follow similar seasonal patterns.
[13] Rainfall in November and December is a relatively rare event, but indicative of a late harvest. To construct the variable, the rainfall levels in October, November and December are summed and divided by the total amount of rainfall that year.
[14] The specification of only one seasonal dummy is used in order to maintain consistency in the identification of a single relevant hungry season. Further, for children not born during the rainy season, the predictions of the malaria hypothesis become more ambiguous as the timing of rainfall relative to birth does not necessarily alter the length of gestational malaria risk exposure, but does change intra-gestational timing of that risk. Since the medical literature does not provide unambiguous predictions regarding the consequences of malarial risk at earlier or later stages of pregnancy, only rainy season births generate a clear prediction relating timing of rainfall to mortality.
[15] Statistical tests failed to reject the hypotheses that the means, medians and distributions of birth spacing intervals differed between the farm and non-farm samples at significance levels below 50 percent.
[16] Again, for consistency, we employ the cutoff for farm dependency as the agricultural share of income exceeding 25 percent. The analysis goes through with similar cutoffs.
[17] In a much smaller study of rural Gambian women, Cole (1993) also finds evidence that the dry season is the least favorable time of year to be born.