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Child growth in the time of drought*

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I. Introduction

It is well known that households in developing countries often experience weather-related and other shocks that drastically affect incomes. A large and growing literature explores the efficacy of *ex ante* and *ex post* responses to these events. One strand examines how households respond to these shocks. Three studies that exemplify work in this area are Udry (1990) on credit as insurance, Fafchamps, Udry and Czukas (1998) on the role of livestock as a means of smoothing consumption, and Kochnar (1999) who examines the role of labour market activity as an *ex post* response to income shocks. A second strand looks at the effectiveness of these strategies in reducing fluctuations in consumption. The principal result that emerges, as summarized in Morduch (1995, 1999) and Townsend (1995), is that some, but not all households can smooth consumption. In particular, households facing liquidity constraints have limited smoothing ability. For these households, therefore, income fluctuations will generate a welfare loss.

This paper contributes to this literature, but differs from the studies listed

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above by focusing on a different outcome, growth in the heights of young children. Although the paper examines growth rates for children aged 12–60 months, particular attention is focused on those aged 12 to 24 months. There are five reasons why such an approach is attractive. First, very young children are believed to be especially vulnerable to shocks that lead to growth faltering (Martorell, 1999; Martorell *et al*. 1994; Beaton; 1993; Waterlow, 1988). Second, both growth rates and height are good indicators of underlying health status, an important welfare outcome in its own right. Third, a focus on growth rates allows us to identify the impact of shocks at the individual level. This is rarely possible with household level data and indeed, to date, only a handful of studies have done so (Foster, 1995; Hoddinott and Kinsey, 1999; Jacoby and Skoufias, 1997; Rose, 1999). Fourth, children experiencing slow height growth are found to perform less well in school, score poorly on tests of cognitive function, have poorer psychomotor development and fine motor skills. They tend to have lower activity levels, interact less frequently in their environments and fail to acquire skills at normal rates (Grantham-McGregor *et al.*, 1997, 1999; Johnston *et al.*, 1987; Lasky *et al.*, 1981). Fifth, it is possible to determine whether these shocks have permanent or transitory effects. This is especially important in light of the epidemiological evidence that stature by age three is strongly correlated with attained body size at adulthood (Martorell, 1995, 1999).[1] Adult height is correlated with earnings and productivity, poorer cognitive outcomes and premature mortality due to increased risk of cardiovascular and obstructive lung disease. Taller women experience fewer complications during child birth, typically have children with higher birthweights and experience lower risks of child and maternal mortality (World Bank, 1993). These findings, discussed further in the concluding section of the paper, together with the impact of slowed height growth on child development more generally, indicate that the costs of growth faltering during drought are especially high if such faltering has permanent effects. As taller (and better educated) women have, on average, taller (and healthier) children, these costs may well be incurred for several generations.

The paper examines this issue by drawing on a panel data set of households residing in rural Zimbabwe. The core finding is that children aged 12 to 24 months lose 1.5–2 cm of growth in the aftermath of a drought. Catch-up growth in these children is limited so that this growth faltering has a permanent effect. By contrast, there is no evidence that older children, those aged 24–60 months, experience a slowdown in growth. There is some

[1]Specifically, from three years of age into the school period, children from even very poor localities will grow as quickly as children in developed economies, neither catching-up nor falling further behind. Some catch-up appears to occur during adolescence but is not sufficient to offset the earlier loss of growth in stature (Martorell, 1999).

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evidence that the loss in growth is unequally distributed, with children residing in poorer households and offspring of women who are daughters of the household head – a disadvantaged group within this sample – appearing to be especially vulnerable. These findings are robust in the face of a wide number of econometric concerns, including those related to sample specification, endogeneity, measurement error and household and maternal level unobservables. A caveat is that it is not possible to control for child unobservables. The concluding section argues that this failure to achieve potential stature has implications for the lifetime earnings of these children in addition to the intrinsic costs associated with poorer health status.

II. Conceptual Framework

Three papers, by Behrman, Deolalikar and Lavy (1995), Foster (1995) and Alderman, Gertler, Strauss and Thomas (1994) outline the relationship between child growth and child, maternal and household resources. This section draws heavily on their work.

Households are assumed to maximize utility over some time horizon subject to a budget constraint and those imposed by the technology through which inputs such as food and child care generate health. This inter-temporal utility function can be written as:

$$U = v(U_1, U_2, \ldots, U_T) \qquad \text{for time periods 1 to T.} \tag{1}$$

Utility in each period is a function of consumption of goods (x), the number of surviving children (n) and a vector indicating the health, or 'quality' of each child (q). This utility may also be affected by household characteristics (A) such as its life cycle position and the education of household members. The utility function for time period t is:[2]

$$U_t = u_t(x_t, n_t, q_t; A) \tag{2}$$

Three assumptions are made. As Deaton (1992) notes, the preferences implied by (1) are extremely general, allowing unlimited complementarities and substitutions across periods. As do Foster (1995) and Alderman *et al.* (1994), these preferences are assumed to be inter-temporally additive, or separable, and individual sub-utility functions are increasing and quasi-concave in their arguments. Second, it is assumed that over the short period considered here, fertility decisions are taken as given and that there is no replacement response to mortality. Third, it is assumed that there exists a household utility function. Although this is questionable on both theoretical

[2]This is closely related to the 'household demand' model of fertility (Becker, 1960; Birdsall, 1988; Behrman and Deolalikar, 1988).

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and empirical grounds (Alderman, Chiappori, Haddad, Hoddinott and Kanbur 1995), our data do not permit implementation of a collective household model.

The household faces a budget constraint in each period. Wealth in period $t + 1(W_{t+1})$ is the sum of wealth in the previous period (W_t) plus the difference between income (y_t) and expenditure (x_t). Denoting prices as p_t and the interest rate on both savings and debt as r_t yields:

$$W_{t+1} = W_t(1 + r_t) + (y_t - p_t x_t) \tag{3}$$

Note that incorporating borrowing constraints, as in Foster (1995), or allowing the return on savings and debt to differ will not significantly affect the relationship to be estimated here.

Next, we specify a health production function that allows for growth. In a static context, child health is a function of physical inputs such as nutrients, time spent caring for children and illness (Behrman and Deolalikar, 1988). The technology by which these inputs are combined will be affected by characteristics of the principal care-giver such as education and age. In adapting this framework to growth in stature, it is necessary to note that – unlike other stock variables – height cannot fall from one period to the next. Further, inputs into child growth may themselves be influenced by recent health history, so that for example the household may provide additional resources to children who have recently suffered health shocks. Growth is also affected by children's age and sex. Specifically, growth rates slow as children age and are slightly higher for boys than for girls. Lastly, past growth may also affect current growth. Consider a well-nourished, healthy child that is growing along a biologically predetermined growth path. Now suppose this child experiences an illness that temporarily reduces growth. Given the pre-ordained nature of this child's growth, she will grow faster, or 'catch up', in the post-illness period in order to return to her long run growth path.

Accordingly, a general formulation of the determinants of child height in period $t + 1$ has two components: investments associated with increases in child health, the first term in (4), and initial child health, the second term:

$$H_{t+1} = h(H_t, g_t, c_t, M_t, A, Z_t, \varepsilon_C) + H_t \tag{4}$$

where: H_t is child height at period t; g_t are physical inputs such as nutrients used to produce health (m_t is partly a subset of x_t) and non-physical inputs such as child care, c_t are child characteristics such as age and sex, M_t captures characteristics of the principal care giver and Z_t refers to the health and sanitation environment which is assumed to influence illness and therefore growth. ε_C captures characteristics of the child such as inherent healthiness, growth potential or inherited immunities that are unobserved by the social scientist but which may, or may not, be known to the household.

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Finally, note that at some future date, children may contribute to household income via providing labour time, remittances or other transfers. These contributions are a function of expected future wages that will vary by sex (given labour market discrimination), age, health (via the links between health-child quality and productivity reviewed in Strauss and Thomas, 1995) and community or cultural factors (θ). For example, when daughters of the household head are married, the groom and his family are required to transfer resources in the form of cattle and money to provide compensation for the woman. These contributions can be expressed as (again suppressing the child subscript):

$$R_t = r(c_t, q_t, \theta) \tag{5}$$

Maximizing (1) subject to (2), (4) and (5) generates a set of first order conditions that can be solved out to yield a set of reduced form commodity and child health demand functions. Maintaining the assumption of intertemporal separability, the discounted expected value of additional income is constant, implying as Alderman *et al*. (1994) and Foster (1995) note, that analogous to a consumer durable, households will seek to smooth fluctuations in child health. But unlike commodity demands, child growth is affected by the height of the child, since the extent to which child growth can be increased between t and t + 1 is itself affected by the level at t. It therefore takes the form:

$$H_{t+1} - H_t = h_t(H_t, c_t, M_t, W_t, A, Z_t, \theta_t, \varepsilon_C) \tag{6}$$

III. Data and Model Specification

The sample

The individuals in this sample reside in three resettlement areas of rural Zimbabwe. The initial sampling frame was all resettlement schemes established in the post-Independence period in Zimbabwe's three most important agro-climatic zones.[3] These are Natural Regions (NR) II, III and IV and correspond to areas of moderately high, moderate and restricted agricultural potential. One scheme was selected randomly from each zone: Mupfurudzi (which lies to the north of Harare in NRII), Sengezi (which lies south east of Harare in NRIII) and Mutanda (which lies south east of Harare, but farther away than Sengezi and in NRIV). Random sampling was then used to select villages within schemes, and in each selected village, an attempt was made to cover all selected households.

[3]Further details are found in Gunning, Hoddinott, Kinsey and Owens (2000), Kinsey, Burger and Gunning (1998) and Kinsey (1982).

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These households were first interviewed over the period July–September 1983 to January–March 1984. They are located in 22 different villages. Just over half (57%) are found in Mupfurudzi with 18 percent located in Mutanda and 25 percent found in Sengezi. They were re-interviewed in 1987 and annually, during January to April, from 1992 onwards. There is remarkably little sample attrition. Approximately 90 percent of households interviewed in 1983/84 were re-interviewed in 1997. There is no systematic pattern to the few households that drop out. Some were inadvertently dropped during the re-surveys, a few disintegrated and a small number were evicted by government officials responsible for overseeing these schemes.

This sample has a set of properties that are desirable from the point of view of examining the determinants of child growth. First, there is no requirement to address biases brought about by *household* sample attrition. Second, as Rosenzweig and Wolpin (1988) have argued, examination of the impact of any public intervention is hampered by considerations of selective migration. There are strong *a priori* grounds for believing that this will not affect these results. Relocation of these households preceded, by a significant period of time, the droughts that occurred in the 1990s that are the principal focus of the study. Third, the availability of repeated observations makes it possible to control for any correlation between explanatory variables and fixed, unobserved characteristics. Fourth, as the survey is conducted at the same time each year, the impact of seasonality considerations is minimized. Fifth, a component of the resettlement programme was the random allocation of households to plots of land. This, together with prohibitions on transfers, means that certain land characteristics such as distance to plots, number of plots, soil types and land slope, can be treated as exogenous. Sixth, a requirement of resettlement was that beneficiaries were limited in their ability to engage in non-agricultural activities. This, together with the fact that each household received an identical quantity of land, implies that data on agricultural capital stock and livestock will provide a good proxy for household wealth and permanent income.[4] Seventh, each survey carefully records deaths that have occurred in the previous 12 months. As there are relatively few child deaths, on the order of one to three per year, it is unlikely that our results will be affected by selective mortality amongst young children. Finally, it was not until 1992 that adult males were permitted to out-migrate. Rural-urban migration by males is an important mechanism by which HIV is passed from urban areas – where the disease is widespread – to rural areas. The presence of this prohibition, which has been strictly enforced, provides an *a priori* reason for believing that HIV infection will play a much smaller

[4]Hoddinott, Owens and Kinsey (1998) find that every additional dollar of agricultural capital stock raises annual household income by about 30 cents.

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part in explaining trends in child health. Although direct evidence on HIV rates is not available, there are relatively few adult deaths from diseases such as tuberculosis, which are often HIV related, which is also suggestive of relatively low HIV prevalence in these areas.[5]

Trends in rainfall, child, maternal and household characteristics, 1993–97

Table 1 provides some basic descriptive statistics for this sample. The top section indicates rainfall levels by resettlement scheme, and incomes, for four agricultural seasons: 1992/93 to 1995/96. These are normalized against mean levels observed since measurements were first taken in these localities in the 1980s. The first two seasons are average relative to this longer-term trend. The third year is a major drought and the final agricultural year a good one in terms of rainfall and crop production. Crop income fell substantially as a consequence of the drought. Other sources of income, including public and private transfers, did not fully offset this shock.

When examining these data, it is important to place them within the context of the seasonal cycles of these households. The Zimbabwean agricultural year runs from July to June. Planting typically occurs in October/November with harvesting occurring in May and June. The household survey takes place in February and March. Drought in the 1994–95 agricultural year implies that households potentially face severe food shortages in the year that *follows* as it will be a full 12 months before the next harvest is ready. It should also be noted that the 1994/95 drought was somewhat unusual in that rainfall in the early part of the growing season was consistent with long term averages. The drought only began to manifest itself in February 1995 when mid and end season rains failed. Consequently, when examining the impact of this drought on child growth, the relevant period of observation will be 1995 to 1996.

We match these rainfall data to five rounds of this ongoing panel, 1993 to 1997 inclusive, yielding four sets of growth rates. These are expressed as an annual figure by adjusting for the duration of observation. They are reported in the second section of Table 1. Children initially aged 12–24 months in 1995–96 (the 'drought cohort') grow on average about 1 cm less than their peers who were in this age range in non-drought years. Children in older age groupings do not appear to experience a similar slow down.

Table 1 also outlines selected maternal and household characteristics. The most striking change in maternal characteristic over time is that the propor-

[5]Indirect evidence supporting this claim comes from the 1997 survey round. Households were asked if they knew of anyone whom they believed had died from AIDS and if they knew of anyone who was living with HIV/AIDS, locally and elsewhere. Mean values to these questions were: 3.22 deaths altogether; 0.92 deaths locally; 0.58 people living with HIV/AIDS; and 0.21 living locally.

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TABLE 1
Basic Descriptive Statistics

Per cent of long term mean rainfall in relevant agricultural year by scheme	*Relevant agricultural year*			
	1992/93	*1993/94*	*1994/95*	*1995/96*
Mupfurudzi	107	116	74	131
Mutanda	106	104	68	156
Sengezi	142	104	80	111
Incomes by crop year				
Gross crop income (1992 Zimbabwe $)	5815	4857	1817	6055
Total income (1992 Zim$)	6982	6296	4051	8146
	Period observed			
Annualized growth rates in cm per year	1993–94	1994–95	1995–96	1996–97
(Sample size)				
Children initially aged 12–24 months	10.09	9.61	8.67	9.42
	(53)	*(47)*	*(48)*	*(78)*
Children initially aged 24–36 months	9.55	8.71	8.72	8.31
	(54)	*(56)*	*(50)*	*(55)*
Children initially aged 36–48 months	7.72	7.10	7.82	7.34
	(60)	*(67)*	*(68)*	*(47)*
Children initially aged 48–60 months	7.73	6.51	6.97	6.90
	(33)	*(53)*	*(59)*	*(57)*
	Year of initial observation			
Maternal characteristics	1993	1994	1995	1996
Mean height (cm)	159.9	160.2	160.1	160.2
Mean years of schooling	5.2	5.9	5.9	6.2
Mean age	32.4	31.6	31.0	30.6
Per cent spouse of head	68.4	57.8	55.0	50.8
Per cent daughter of head	10.7	16.7	14.0	14.2
Per cent daughter-in-law of head	20.9	25.5	31.0	35.0
Household characteristics				
Real value of livestock (1992 Zim$)	1771	2334	3467	3947

tion of children whose mother is the spouse of the household head declines markedly and an increasing number of children whose mother is either a daughter or daughter-in-law of the head. Several factors account for this. At the time of settlement male heads were aged between 25 and 50. As the sample literally ages, these men become less and less likely to have children aged 12 to 24 months. Concurrently, there are an increasing number of

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women in these households who are daughters-in-law of the head. They, and their spouses find themselves in these households for two reasons. First, deteriorating economic prospects in urban areas are reducing the incentive to migrate. Second, the absence of a clear policy regarding land succession rights in these resettlement areas means that there is no land for these sons to operate that is separate from the land operated by their fathers. Daughters of the household are either young women who have had children out of wedlock, or increasingly women who have either separated or divorced their husbands and have returned to their natal homes. The important distinction lies between children whose mothers are spouses or daughters-in-law of the household head, and those children whose mothers are daughters of the head. Rights and obligations regarding the former are clear-cut – these children belong to the family. But the position of children born out of wedlock, or whose parents have divorced, is considerably more ambiguous. They may, or may not, be receiving support from the father and the father's family. They may be considered part of the father's or mother's family. If the mother marries, or re-marries, these children will leave the household and the family will have no claim on them for future labour, transfers or bridewealth payments (Armstrong, 1997). These considerations provide an *a priori* reason for suspecting that, *ceteris paribus*, these children may have poorer access to household resources.[6]

Finally, note that these households appear to be accumulating livestock over this period. There are significant advantages to holding livestock. They have maintained their real value in a period of high inflation, are a source of income, a source of food and can be easily liquidated if a household experiences an income shock. It might, therefore, seem surprising that livestock holdings do not fall in the aftermath of the 1994/95 drought. However, respondents themselves state that livestock were the principal means of coping with this drought, with more than 60 per cent reporting a sale. Income from these sales comprised 37 per cent of the self-reported 'sources of cash used to buy food'.[7] Approximately 40 per cent of households experienced either a decline or no change in their holdings. Lastly, a small number of households made significant acquisitions of cattle. Excluding the ten per cent of households who had the largest increases in holdings, mean values for the remaining sample fell after the 1994/95 drought.

[6] Alternatively, these mothers may have little bargaining power within the household. Though entirely plausible, as noted above this explanation cannot be distinguished from the 'efficiency' argument presented here.

[7] Another 43 per cent was raised from *ex post* actions such as taking temporary jobs and engaging in petty crafts or trading. Less than 2 per cent of these funds came from borrowing. See Kinsey, Burger and Gunning (1998) for a detailed discussion of the role of livestock in coping with rainfall shocks.

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Model specification

The dependent variable, growth in stature of children aged 12–24 months at the time of first observation, is measured in centimetres per year. There are 243 children in this sample. A small number of children are recorded as having either 'negative' growth – they lose stature from one period to the next – or implausibly high rates of growth, such as the two children who grew almost 30 cm in a 12 month period. The heights of these children have either been measured or recorded with error. Since initial height appears as both a regressor and as part of the dependent variable, this leads to parameter estimates that are biased and inconsistent. This would suggest that a sensible strategy would be to omit those observations for which there is *prima facie* evidence that measurement error exists. To do so, we use the estimates of minimal and maximal growth rates in stature for children aged 12–24 months found in Roche, Guo and Moore (1989) and Roche and Himes (1980). Allowing for rounding errors, minimal growth is 2 cm and maximal growth is 24 cm. Also excluded are children whose initial height-for-age z scores are less than −6 or greater than 6.[8] These extreme measures are indicative of errors in measures of height or of age. Four women who claim to have given birth at ages 48 or older are also excluded. These exclusions reduce the sample size from 243 to 222, a reduction of about 8 per cent. The benefit of excluding cases where the likelihood of measurement error is high must be set against two costs: the slight reduction in sample size and the possibility of introducing a selectivity bias into the estimates. The latter issue is returned to later in the paper.

Child characteristics include initial height, sex, age at first observation, duration of observation, and the product of age and duration of observation. Given that children's growth velocity slows with age, it is expected that age and duration of observation will negatively affect growth. Maternal characteristics are height, age and dummy variables representing different years of completed schooling. Household characteristics include log of real value of livestock, soil type and acres of land holdings that are sloped or steeply sloped, the latter two variables acting as proxies for land quality. Note that the random allocation of households to localities and plots of land implies that it is plausible to treat land slope and soil type as exogenous. It is assumed that the stock of household assets at time t can be treated as pre-determined in a model considering growth between period t and t + 1. Replacing these variables with the lagged values, in order to provide further separation

[8] The z score is calculated by standardizing a child's height given age and sex against an international standard of well nourished children. A z score of −1 indicates that given age and sex, the child's height is one standard deviation below the median child in that age/sex group.

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between them and the dependent variable (or using lagged values as instruments for the values at time t) does not alter our results.

Community and cultural factors affecting future transfers from child to parent are captured by dummy variables denoting the relationship of the child's mother to the household head. As discussed above, mothers are spouses, daughters or daughters-in-law of the head and these different relationships hold different possibilities for future transfers. Lastly, we include a set of village dummy variables to control for time invariant characteristics such as distances to roads, markets, clinics, water and fuel supplies.

It should be noted that the inclusion of a number of additional child, maternal and household characteristics, none of which were significant, does not alter the results reported here. These include: child's immunization history; child possesses up-to-date health card; mother can correctly identify cause of diarrhoea; household experiences death of adult member (a crude proxy for a household specific shock); log of real value of agricultural capital stock; distances to water supply or fuel source; number of plots of land; age of household head (following Deaton's (1992) remark that preferences may be affected by household life-cycle position); and a measure of parental attitudes towards use of medical facilities. Finally, variables capturing quality of services at local health clinics – whether these had experienced staff or drug shortages – were also included but were found to have no significant effect on child growth.

IV. Results

Basic findings

The next step is to specify an estimable version of (6): This is written as:

$$(\mathrm{H}_{t+1} - \mathrm{H}_t) = \beta_h' \cdot \mathrm{H}_t + \boldsymbol{\beta}_C' \cdot \mathbf{X_{Ct}} + \boldsymbol{\beta}_M' \cdot \mathbf{X_{Mt}} + \boldsymbol{\beta}_H' \cdot \mathbf{X_{Ht}} + \boldsymbol{\beta}_V' \cdot \mathbf{X_V} + \varepsilon_C + \varepsilon_M + \varepsilon_H + \varepsilon_t \quad (7)$$

H_{t+1}, H_t is child height at periods t_{+1} and $\mathbf{X_{Ct}}$ is a vector of child characteristics at period t, $\mathbf{X_{Mt}}$ is a vector of maternal characteristics at period t, $\mathbf{X_{Ht}}$ is a vector of household characteristics at period t, and $\mathbf{X_V}$ is a vector of village dummies. β_h, $\boldsymbol{\beta}_C'$, $\boldsymbol{\beta}_M'$, $\boldsymbol{\beta}_H'$ and $\boldsymbol{\beta}_V'$ are parameters to be estimated (vectors are indicated in bold). ε_C, ε_M, & ε_H are unobserved characteristics of the child, her mother and household that are assumed to not vary over time and ε_t is a white noise disturbance term.

Least squares results of estimating (7) are reported in Table 2. The inclusion of a full set of village dummies implies that these results are robust to village, time invariant effects. The F statistic rejects the null that all

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TABLE 2
Least Squares (Village Effects) Determinants of Annual Rate of Growth in Child Height, Children 12–24 Months

Variable	Estimated coefficient	Absolute value of asymptotic t statistics: based on Huber-White standard errors	robust to sampling (cluster) effects	based on jackknife (Mackinnon-White, 1985) standard errors
Child characteristics				
Initial child height	−0.332	4.484**	3.974**	4.057**
Boy	−0.277	0.542	0.512	0.493
Age at first observation	−1.568	1.431	1.493	1.290
Duration of observation	−2.688	1.705*	1.955*	1.521
Age x duration	0.148	1.602	1.716*	1.438
Maternal characteristics				
Height	0.190	4.023**	4.041**	3.615**
Age	−0.050	1.009	1.662*	0.936
Schooling	0.245	0.760	0.900	0.700
Schooling squared	−0.028	1.030	1.169	0.949
Mother is daughter of head	−1.048	1.393	1.386	1.327
Mother is daughter−in-law of head	0.014	0.020	0.045	0.364
Household characteristics				
Log of real value of livestock holdings	0.076	0.632	0.598	0.556
Acres of land holdings that are sloped or steeply sloped	−0.063	1.107	1.773*	1.023
Soil is red or black clay	1.111	1.674*	1.875*	1.549

estimated coefficients are jointly zero. Standard errors are calculated using the method outlined by Huber (1967) and White (1980). However, recall that this sample was constructed by first randomly selecting villages, then interviewing households within these localities. Since households in the same village will share some common characteristics, in a statistical sense, the disturbance terms are not independent. Also, Thomas (1994) argues that these estimates can be adversely affected by a small number of outliers in the weighting matrix and that this can lead, on occasion, to dramatically understating standard errors. Accordingly, the last two columns of Table 2 present additional estimates of coefficients' standard errors reported in terms of their asymptotic t statistics. The first, based on Rogers (1993) calculates robust standard errors in the presence of intra-cluster correlation. The second, based

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TABLE 2
(continued)

Variable	*Estimated coefficient*	*Absolute value of asymptotic t statistics* — *based on Huber-White standard errors*	*robust to sampling (cluster) effects*	*based on jackknife (Mackinnon-White, 1985) standard errors*
Period observed				
1994–95	−0.278	0.359	0.280	0.323
1995–96 (Child in drought cohort)	−1.727	2.029**	1.795*	1.819*
1996–97	−0.643	0.736	0.556	0.652
Constant	35.153	1.622	1.620	1.431
F Statistic	29.26**			
Adjusted R2	0.22			

Notes:
1. Dependent variable is annual (12 month) growth rate in child height.
2. Sample is children age 12 to 24 months at time of first observation whose increase in stature is between 2 and 24 cm per year, whose initial height, in terms of z score lies between −6 and +6, whose mother is less than 49 years old and is either spouse, daughter or daughter-in-law of household head.
3. Omitted category is a child who is a girl, whose mother is spouse of head, observed over 1993–94, residing in Chitepo village (Mupfurudzi resettlement scheme). Village dummies are included but not reported.
4. Breusch-Pagan Lagrange Multiplier test for heteroscedasticity = 55.52 (prob value = 0.026).
5. * significant at the 10% level; ** significant at the 5% level.
6. Expressing the dependent variable in log terms yields the same basic results as those reported here in levels.
7. Sample size is 222.

on Mackinnon and White (1985), is robust in the presence of leverage points. These alternative constructions have only minimal effect on the estimated standard errors.

The coefficient on initial height is negative, significant and lies between zero and minus one. A coefficient not significantly different from zero would have indicated that *height growth* is independent of initial height. A coefficient equal to −1 would have indicated complete catch-up in the sense that with this value, *height* in period t + 1 is independent of *height* in period t. A value between 0 and −1 is consistent, therefore, with partial but not complete catch-up.[9] There are no gender differences in the growth rates of these young

[9] An F test under the null hypothesis that this coefficient equals −1 is easily rejected, F(1, 175) = 70.67.

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children. Children's growth velocity slows as they age, a characteristic captured both directly by the age variable and indirectly via the duration covariate.[10]

There is a well-defined relationship between growth and maternal height, capturing the fact that children with taller mothers will tend to be taller and therefore will grow faster, *ceteris paribus*. Neither maternal age nor education has a significant impact on growth. The latter finding is surprising, and somewhat at odds with much of the existing literature (Strauss and Thomas, 1995). We return to it later in the paper. Children whose mother is a daughter of the head grow more slowly relative to children whose mother is the spouse of the head. This effect is not, however, especially well measured. None of the three observed household characteristics examined here – livestock, acres of land sloped and soil type – have a well-measured impact on child growth.

We now turn to the impact of the 1994–95 drought on growth of children aged 12 to 24 months. Relative to the omitted group (children measured in years of close to average rainfall, 1993 and 1994), children in the 'drought cohort' – that is, children whose growth was measured in 1995 and 1996, grew more slowly. The slowdown in growth, −1.73 cm, is equivalent to a loss of about 15–20 percent in growth velocity. The effect is well measured irrespective of the method used to calculate the standard errors.

Table 3 reports the results of running identical regressions for children in three older age groups: 24–36 months; 36–48 months; and 48–60 months.

TABLE 3

Impact of Drought on Growth by Age Group

Age group	*Estimated coefficient on period of observation being 1995–96 (drought cohort)*	*Asymptotic t statistics based on Huber-White standard errors*	*Sample size*
Children initially aged 12–24 months	−1.727	2.029**	222
Children initially aged 24–36 months	−0.745	0.910	209
Children initially aged 36–48 months	0.068	0.142	239
Children initially aged 48–60 months	−0.173	0.254	194

Notes:
1. Dependent variable is annual (12 month) growth rate in child height.
2. Specification and omitted group as per table 2.
3. * significant at the 10% level; ** significant at the 5% level.
4. Full results available on request.

[10]The interaction term is included because the effects of age and duration of observation are not independent of each other.

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The 1994–95 drought had no impact on the growth rates of these older children. Together, Tables 2 and 3 establish two core results; that children aged 12 to 24 months in this 'drought cohort' grew more slowly than comparable children in a non-drought cohort; and that this effect did not occur amongst older children.

Robustness checks: Selection effects, measurement error, endogeneity of initial height and the role of maternal unobservables

We now consider four objections to these results: selection biases brought about via the deletion of observations that are assumed to contain significant measurement error; more general concerns regarding measurement error; the endogeneity of initial height; and the role of household, maternal and child unobservables.

Recall that considerations of measurement error caused about 20 observations to be discarded. This may lead to selectivity biases if children with recorded negative growth tend to be children who grow slowly. A Heckman (1979) type correction is infeasible because there are no variables that affect the likelihood that height, child or maternal age is mis-measured but do not affect measured growth. As an alternative, Table 4 reports the results for

TABLE 4

Drought Effects Under Different Sample Restrictions, Children 12–24 Months

Variables	*All observations*	*Exclude children with 'negative' growth*	*Exclude children with growth < 2 cm p.a. or > 24 cm and whose initial z scores are > -6 and < 6*	*Exclude children with growth less than 2 cm p.a. or greater than 24 cm & whose mothers are 49 or older (results from table 2)*
Child in drought cohort	−1.958 (1.884)*	−1.469 (1.711)*	−1.483 (1.719)*	−1.726 (2.029)**
Initial height	−0.593 (7.668)**	−0.387 (5.810)**	−0.366 (4.901)**	−0.331 (4.484)**
Mother's age	−0.074 (1.342)	−0.047 (1.101)	−0.046 (1.067)	−0.049 (1.009)
Sample size	243	228	226	222

Notes:
1. Dependent variable is annual (12 month) growth rate in child height.
2. Specification and omitted group as per table 2.
3. Asymptotic t statistics based on Huber-White standard errors in parentheses.
4. * significant at the 10% level; ** significant at the 5% level.
5. Full results available on request.

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three variables – the drought cohort, initial height and maternal age – under different sample restrictions. The coefficient on the drought cohort remains negative and remains constant across the four samples. The coefficient on initial height does become progressively larger as restrictions on the sample are reduced, but never becomes close to -1.

Despite these results, legitimate concerns regarding the role of measurement error remain. Measuring the heights of young children is a difficult exercise, and so it would not be surprising if there were some measurement error in all these data. Further, note that this is not a standard errors-in-variables problem because h_t appears in both the left and right hand sides of (7).[11] Additionally, note that initial height is a stock variable that reflects all past inputs into child health as well as the influence of unobserved child characteristics. If the latter are positively correlated with both the *level* of height in period t and *growth* from period t to t + 1, the estimate of catch-up will biased towards zero.

Resolving these concerns using instrumental variables estimation is difficult because it requires identifying variables that affect the stock of height but not subsequent growth. It also assumes that these unobserved effects are treated as random variables. If this latter assumption is incorrect, parameter estimates will be inconsistent. Our approach is to assume that birth weight is uncorrelated with the measurement error in height, is associated with initial stock of height, and is uncorrelated with subsequent growth.[12] The first assumption is plausible. Birth weights for these children were measured prior to their first height measurement by staff in local health clinics, not the teams conducting these household surveys. Ashworth, Morris and Lira (1997) suggest that these latter two assumptions hold in their epidemiological study of growth of heights and weights in low and normal birth weight children in Brazil. The validity of birth weight as an instrument can be tested formally using the approach outlined by Bound, Jaeger and Baker (1995). We obtain an F statistic of 10.30 on the significance of birth weight as an instrument in the first stage regression, exceeding their rule of thumb figure of 10. An over-identification test based on Davidson and MacKinnon (1993) indicates that the joint null hypotheses, that the instruments are uncorrelated with the errors and that the second stage equation is correctly specified, cannot be rejected. Table 5 indicates that these two stage least squares estimates produce little

[11] If (7) were estimated using only h_t as a regressor, the effect of this measurement error would be even greater attenuation of the bias towards zero than that obtained from a standard errors-in-variables problem. Details are available on request.

[12] Birthweight data are taken from children's health cards and are based on measurements taken by health clinic staff at the time of birth. Because birth weights are only recorded for about 70 per cent of the sample, two variables are used. The first is a 0/1 dummy indicating whether birth weight is known. The second interacts this variable with the birthweight recorded on the health card.

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TABLE 5
Drought Effects Treating Initial Height as Endogenous, Children 12–24 Months

Variables	*Estimates treating initial height as exogenous*	*Estimates treating initial height as endogenous*
Child in drought cohort	−1.726	−1.724
	(2.029)**	(1.997)**
Initial height	−0.331	−0.438
	(4.484)**	(2.015)**

Notes:
1. Dependent variable is annual (12 month) growth rate in child height.
2. Specification, sample size and omitted group as per table 2.
3. Asymptotic t statistics in OLS results are based on Huber-White standard errors in parentheses. Asymptotic t statistics for 2SLS results use a Huber type correction to generate robust standard errors based on Over, Jolliffe and Foster (1995).
4. Instruments for initial child height are: dummy variable = 1 if child's birthweight is known and child birthweight interacted with birthweight known. F test on excluded instruments: $F(2, 183) = 10.30^{**}$. Davidson-MacKinnon overidentification test on joint hypothesis that instruments are uncorrelated with errors and model is correctly specified: chi-squared(1) = 0.477 (prob value = 0.49). F test on inclusion of predicted residual from first stage regression in structural regression (equivalent to Hausman test): F(1, 183) = 0.29 (prob value = 0.59).
5. * significant at the 10% level; ** significant at the 5% level.
6. Full results available on request.

change on the coefficient for the drought cohort, though they do lead to a substantially larger catch-up effect.[13]

Equation (7) lists three unobservables, ε_C, ε_M, and ε_H relating to unobserved characteristics of the child, her mother and the household respectively. To take full account of their influence, one should estimate a series of fixed effects models at the level of the household, mother and child. Unfortunately, this is infeasible. There are only 45 households in this sample with more than one child aged 12 to 24 months and only 25 mothers with two such children.

Rather than ignore these effects altogether, an alternative approach is adopted here. The first step is to pool the children in this sample with a second cohort of older children aged 24 to 36 months. We estimate a maternal fixed effects model, including child characteristics as well as maternal and household characteristics that vary over time (Table 6). OLS is easily rejected in favor of maternal fixed effects estimation and a Hausman (1978) test favors fixed effects over a random effects specification. The

[13]The two stage least squares standard errors reported here are robust to heteroscedasticity following the extension to Huber's (1967) method proposed by Over, Jolliffe and Foster (1995).

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TABLE 6
Maternal Fixed Effects Estimates of Determinants of Annual Rate of Growth in Child Height, Children 12–36 Months

Variables	*Maternal fixed effects estimation*	*OLS results from table 2*
Height	−0.812	−0.332
	(9.738)**	(4.484)**
Drought interacted with 12–24 cohort dummy	−2.452	−1.727
	(1.733)*	(2.029)*
Drought interacted with 24–36 cohort dummy	−1.153	–
	(0.831)	
Livestock interacted with 12–24 cohort dummy	0.286	0.076
	(1.820)*	(0.632)
Livestock interacted with 24–36 cohort dummy	0.198	–
	(1.185)	
F statistic on joint significance of maternal fixed effects	1.690**	–
Lagrange multiplier test comparing OLS and (not reported) random effects	0.050	–
Hausman test comparing (not reported) random and fixed effects estimates	92.93**	–

Notes:
1. Other regressors included but not reported: child sex, age, height, duration of observation and age-duration interaction; and period of observation dummies interacted with age cohort dummies.
2. Sample size is 326. There are 162 different mothers.
3. Asymptotic t statistics in parentheses.
4. * significant at the 10% level; ** significant at the 5% level.
5. Full results available on request.

drought cohort dummy interacted with a dummy equaling one if the child is in the 12–24 month cohort remains negative is now somewhat larger in magnitude and significant at the 7 percent level. Second, controlling for unobserved village, household and maternal characteristics, livestock holdings now have a positive impact on the growth rates of these younger children.[14] Third, the coefficient on height is much larger in magnitude, though still statistically different from −1. Altering the specification used here by interacting all covariates with age cohort dummies or by changing the omitted year dummy, does not alter these findings. However, these results should be treated with some caution as they do not control for unobservable

[14]Livestock holdings may enhance child growth via their impact on income and therefore resources available to promote child growth. Alternatively, households with livestock may consume a more diverse diet, and a diet with a greater quantity of milk and protein, and this pathway may be the causal link between livestock holdings and child growth.

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child characteristics and some children appear twice in this regression (first in the 12–24 month cohort and subsequently in the 24–36 month group).[15]

Drought impacts disaggregated by household wealth

In addition to confirming the basic OLS results, the maternal level fixed effects estimates indicated that livestock holdings were positively associated with child growth. We have also noted that households report that livestock are an important mechanism for coping with drought. Here, we test this latter idea more formally using a method suggested by Townsend (1995) and Morduch (1999). Specifically, we stratify the sample by livestock holdings as measured in 1995. Recall that these were measured just prior to the realization that 1994/95 would be a drought year for these households.

Table 7 presents the results of dividing the sample of children initially aged 12–24 months into two groups: those residing in households below and

TABLE 7
Drought effects by Pre-Drought Wealth Levels, Children 12–24 Months

	Child resides in household with pre-drought livestock holdings:	
Variables	*below the median*	*above the median*
Child in drought cohort	−2.202	−1.281
	(1.795)*	(0.844)
Height	−0.323	−0.284
	(3.062)**	(2.174)**
Mother's education	0.843	−0.542
	(1.748)*	(1.090)
Mother's education squared	−0.075	0.014
	(1.713)*	(0.353)

Notes:
1. Dependent variable is annual (12 month) growth rate in child height.
2. Specification and omitted group as per table 2.
3. Asymptotic t statistics based on Huber-White standard errors in parentheses.
4. * significant at the 10% level; ** significant at the 5% level.
5. Full results available on request.

[15] There are insufficient observations to estimate the maternal fixed effects model with each child appearing only once.

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above the median value of pre-drought livestock holdings. This produces a stark finding, namely that the drought only affects the growth of children residing in poorer households. The coefficient for the 'drought cohort' is not significantly different from zero for children living in households with pre-drought livestock holdings above the median. We also find that maternal schooling does increase growth, but only amongst children in poor households.[16]

Does the growth slowdown have a permanent effect?

The key finding of this paper is that young children, especially those in poor households, grow more slowly in the aftermath of a drought. The parameter estimates on initial heights lie between 0 and −1, suggesting that growth losses are only partly recouped. However, there are three reasons why one might be reluctant to accept this latter claim. First, it is not possible to control for all child unobservable effects, suggesting that all these estimates may still be biased. Second, the magnitude of the coefficient varies by a factor of almost three, from −0.33 to −0.812. Finally, the coefficient on initial height could be picking up nothing more than some long term process of regression to the mean. In light of these concerns, we now consider a second approach to determining whether the 1994/95 drought had a permanent effect on child height.

Specifically, we examine the determinants of heights of children aged 60 to 72 months. Recall that stature by age three is highly correlated with attained body size at adulthood. For this reason, these heights are good approximations of likely completed heights. The dependent variable is expressed as the child's height for age z score. We estimate a maternal fixed effects model, covariates included are child observables, maternal and household time varying characteristics and dummy variables denoting year of observation. Children aged 60–72 months, measured in early 1999, are the children who were initially aged 12–24 in the year after the 1994/95 drought. These children have a z scores about six tenths of a standard deviation below that of comparable children measured in 1998 (the omitted category; see Table 8).[17] The right hand column interacts the 1999 year dummy with a variable that indicates whether pre-drought, the household had livestock holdings below or above the sample median. Children from wealthier households appear to have suffered no long-term effects from this drought. Children from poorer households, by contrast, appear to have experienced a growth slowdown that has persisted to age 60–72 months.

[16] An earlier version of this paper examined whether public responses to drought had a comparable effect on child growth but found no measurable impact.

[17] Altering the omitted category does not substantially alter these results.

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TABLE 8

Maternal Fixed Effects Estimates of Determinants of Child Height for Age z Score, Children 60–72 Months

Variable	*Specification (1)*	*Specification (2)*
Child was initially age 12 to 24 months during years 1995–96	−0.602 (1.927)*	–
Child was initially age 12 to 24 months during years 1995–96 and pre-drought livestock holdings were below sample median	–	−0.907 (2.201)**
Child was initially age 12 to 24 months during years 1995–96 and pre-drought livestock holdings were above sample median	–	−0.379 (1.028)
F statistic on joint significance of maternal fixed effects	2.60**	2.47**

Notes:
1. Dependent variable is child height for age z score.
2. Other regressors included but not reported are: child sex, mother's age, log value of livestock and dummies for years 1993 to 1997. The omitted year dummy is 1998, representing the cohort directly preceding the drought cohort.
3. Sample size is 265. There are 124 different mothers.
4. Absolute value of asymptotic t statistics in parentheses.
5. * significant at the 10% level; ** significant at the 5% level.
6. Full results available on request.

V. Conclusions

Summary

This paper has examined the impact of the 1994/95 drought on the growth in heights of Zimbabwean children aged 12 to 24 months. This shock lowered annual growth rates for these children by somewhere between 1.5 and 2 cm. Four years after the failure of the rains in 1994/95, these children remained shorter than identically aged children who had not experienced this drought at the 12 to 24 month age range. The impact is greatest amongst children living in poor households in 1995. It is likely that this transitory event will affect these children for the rest of their lives.[18] These results control for a large number of child, maternal and household characteristics. They are robust to a number of econometric concerns, including the treatment of heteroscedasticity, the specification of the sample, measurement error and

[18] Alderman, Hoddinott and Kinsey (2001) show that children affected by the 1982–84 drought in Zimbabwe had, compared to children not affected by this shock, shorter heights as adolescents and young adults.

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endogeneity of initial height and unobserved household and maternal effects. They do not, however, control for unobserved child characteristics.

There are a number of additional findings of note. First, the results are suggestive that children whose mother is a daughter of the head, rather than spouse or daughter-in-law, are particularly vulnerable to this growth faltering, although this is not well measured. Second, older children seem to have been less affected by the drought, reinforcing the view that young children, those aged less than two, are especially vulnerable to growth faltering. Third, livestock appears to play an important role as an asset that buffers the impact of drought in these households.

Comparison with previous studies

It is instructive to compare these results to existing studies. These fall into two broad categories: those that compare groups of individuals across time, relying on comparisons of group means; and those that examine these impacts via multivariate regressions. Summaries of the first category are found in (Martorell, 1995, 1999), and Martorell, Khan and Schroeder (1994), with Simondon *et al*. (1998) providing a recent example. These are based on longitudinal panels of individuals who are measured as pre-schoolers, and subsequently as young adults. The samples are disaggregated according to the degree of malnutrition of these individuals as pre-school children. Adult heights, as well as growth rates between childhood and adult hood, are then compared across groups. For catch-up growth to occur, the malnourished group of individuals should be observed to grow faster than those individuals who have better initial nutritional status. These studies show little evidence of this; growth rates for the malnourished group of children are only slightly higher, and certainly insufficient to overcome their initial height disadvantage. However, while this literature produces findings consistent with those presented here, the underlying methods are not completely satisfactory. As stunted children are not a random sample, it is possible that these children share some parental or community characteristic which causes them to be both short, given their ages, as preschoolers and also causes them to grow more slowly than children who are initially taller.

Three studies control for such confounding factors. Foster (1995) and Deolalikar (1996) find only limited evidence of catch-up. However, both papers consider the impact of shocks on weight, not height. Unlike the large literature linking the consequences of slower child height growth to adult height, and to productivity and lifetime earnings, no such similar literature exists for lower child weight. So, the *economic* importance of their findings is unclear.

A third study, by Behrman, Deolalikar and Lavy (1995), finds that catch-

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up of lost height growth is complete in sample drawn from rural India and the rural Philippines. However, their estimates are based on a pooled sample of children aged less than three years with older pre-schoolers and children aged 6 to 13 years. Beyond age three, short-run shocks that temporarily reduce child growth appear to be reversed, see Dagnelie *et al.* (1994), Martorell (1999), Martorell, Khan and Schroeder (1994) and Neumann and Harrison (1994). So their results may differ from those presented here because their sample conflates two groups: children for whom catch-up growth might be expected (those older than 3 years); and those for whom catch-up growth might not be expected (those younger than 3 years).

Why shocks to child growth matter

We end by considering the significance of these findings beyond the intrinsic value of improving children's health. Recall that there is considerable epidemiological evidence that stature by age three is strongly correlated with attained body size at adulthood (Martorell, 1995, 1999), and that taller adult women experience fewer complications during child birth, have children with higher birth weights and experience lower risks of child and maternal mortality. This points to the possibility of the intergenerational transmission of poorer health status resulting from drought shocks. In addition, one could appeal to the instrumental role health plays as a determinant of productivity and earnings. There are four mechanisms through which reduced height as a child is correlated with lower productivity and lifetime earnings as an adult.[19]

Behrman and Deolalikar (1989), Deolalikar (1988), Foster and Rosenzweig (1993), Glick and Sahn (1997), Haddad and Bouis (1991), Schultz (1996), and Thomas and Strauss (1997) find that lower adult height is associated with reduced earnings as an adult. In related, rather grim work, Margo and Steckel (1982) found that the value of an American slave fell by roughly 1.5 per cent for every reduction in height of one inch.

Children experiencing slow height growth are found to perform less well in school, score poorly on tests of cognitive function and have poorer psychomotor development and fine motor skills, lower activity levels, interact less frequently in their environments and fail to acquire skills at normal rates (Grantham-McGregor *et al.*, 1997, 1999; Johnston *et al.*, 1987). Poor cognitive function as a child is associated with poorer cognitive achievement as an adult, see Martorell (1995), Martorell, Rivera and Kaplowitz (1989), Haas, *et al.* (1996), Martorell (1999) and Martorell, Khan and Schroeder (1994). Alderman *et al.* (1996), Boissiere, Knight and Sabot (1985), Glewwe (1996),

[19]This discussion draws on a larger body of work summarized in Behrman and Hoddinott (2000).

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and Lavy, Spratt and Leboucher (1997) find that reduced cognitive skills as an adult lowers earnings.

Shorter stature as a child is associated with slower progress through schooling, see Jamison (1986), Moock and Leslie (1986), Behrman (1993), Leslie and Jamison (1990) and Pollitt (1990). In related work, Alderman *et al.* (2001), Alderman, Hoddinott and Kinsey (2001), Glewwe and Jacoby (1995), and Glewwe, Jacoby and King (2001) all find that poorer stature as a pre-schooler is associated with delays in beginning school. An increase in the age at which a given grade of school is completed reduces the benefits of schooling because post-schooling benefits are delayed and are available for a shorter period. Such losses of benefits may occur because of entry into school when older and/or because of slower progression rates through grades while in school. Where these mechanisms result in the completion of fewer years of schooling, as is the case in Zimbabwe (Alderman, Hoddinott and Kinsey, 2001) there is an additional, negative effect through the impact of reduced grades completed on wages.[20]

Fourth, again recall that stature by age three is strongly correlated with attained body size at adulthood. Fogel (1994) presents evidence that links short stature amongst males to the early onset of chronic diseases and to premature mortality. Although comparable evidence from developing countries does not yet exist, Fogel's evidence is consistent with a view that shorter adult stature reduces lifetime earnings either by reducing life expectancy – and thus the number of years that can be worked – or by reductions in physical productivity brought about by the early onset of chronic diseases.

All four mechanisms adduce links between child height and adult productivity. Ideally, one would like to complement these arguments with direct evidence from Zimbabwe. As such evidence does not exist, consider the estimates found in Thomas and Strauss (1997). They find that for male workers in Brazil, a one percent reduction in height leads to a 2.4 percent loss in adult male earnings. Suppose that there is strong persistence in changes in small children's anthropometric development; that is, a loss in growth – 1.5–2.0 cm – such as observed here is never recouped. Given that the average Zimbabwean adult is about 165 cm tall, the persistence in this loss of growth implies a reduction in adult height of about 1 per cent. Using the Thomas and Strauss results, this would imply a loss of earnings of about 2.4 percent. Under the assumption that there is less persistence of changes in small children's anthropometric development so that the percentage changes for adults is halved, the impact would fall to a loss of 1.2 percent in lifetime earnings. Because there are significant negative effects occasioned by other

[20]The relationship between schooling and wages is surveyed in Psacharopoulos (1994) and Rosenzweig (1995).

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mechanisms, these estimates, conditional on the extent of persistence from childhood to adults in anthropometric measures, are probably *lower* bounds of the economic costs that would be obtained if all four channels were considered.

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