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Prices, infrastructure, household characteristics and child height*

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The relation between parental characteristics, community characteristics and child height is examined using Brazilian household survey data, matched with information collected at the *municipio* level. Child height is significantly affected by local infrastructure, particularly the availability of modern sewerage, piped water and electricity. Higher sugar and dairy prices are associated with lower child height, although mothers with at least elementary schooling are able to counteract the deleterious impact of prices. Negative price effects are, however, largest for children in higher expenditure households suggesting that the impact of mother's education on child height does not solely reflect resource availability.

1. Introduction

Economists have long been concerned with the efficiency and equity of public investments in the social sector. In recent years, many governments have attempted to reduce public deficits in the face of macroeconomic shocks and structural adjustment programs. In doing so a good deal of attention has been paid to expenditures on social services, in particular health and education [Jimenez (1987)]. Especially during periods of tight budgets, it is critical to know whether investments have had intended, or unintended, consequences on welfare and, if so, who has benefited from these services.

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This seems to us to be especially important in poor economies where many people may not be able to afford services if they are privately provided.

This paper examines the impact of infrastructure and local market characteristics on one indicator of child health and welfare: child height. There is a large literature arguing that child height is a good indicator of long-run child nutritional status [Falkner and Tanner (1986)] and many studies have demonstrated the importance of household characteristics as determinants of child anthropometry [see Alderman (1990) and Behrman (1990a) for reviews]. In contrast, there are rather few studies of the impact of community services on child anthropometry [Horton (1986), Barrera (1990), Strauss (1990), Thomas, Strauss and Henriques (1991)]. By and large, these studies indicate that there are substantial positive returns on child health to investments in the provision of clean water and modern sewerage services.[1]

If distributional issues are of concern, then it is important to also identify those children who are likely to benefit most from the provision of community services. The focus of the child anthropometry literature has been on interactions between community services and maternal education. This is, at least partly, because it is hypothesized that the effect of these inputs into the health production function are related to maternal education [Caldwell (1979), Rosenzweig and Schultz (1982)].

In this study, we extend our previous work which examined the household determinants of child height in Brazil [Thomas, Strauss and Henriques (1990)], and examine the impact of a broad range of community prices and services on child height, conditional on parental income, education and other background controls. We have matched with household survey data, information on local market food prices, the availability of infrastructure (such as piped water and sewerage) in the *municipio* (county) as well as the availability and quality of health and education services.

Using a very large sample of 37,000 children, the effects of household and community characteristics are allowed to vary arbitrarily depending on the area of residence, age of the child and the education of the mother. In addition, interactions between community services and household resources are examined. We can, therefore, identify those children who are most affected by community characteristics.

Among urban children, water and sewerage facilities are associated with healthier children as is access to electricity in the rural sector. These effects tend to rise with maternal education and household expenditure. Prices of

[1]Several studies of child survival have included household use of piped water or sewerage services [for example, Martin et al. (1983), Merrick (1985), Da Vanzo (1988)]. These studies typically do not treat the decision to *use* these inputs in the child health production function as being simultaneously determined with child survival. It has been argued [Rosenzweig and Wolpin (1986)] that the *availability* of services should also be treated as endogenous; in the absence of instruments to explain service placement or migration decisions, we ignore the issue.

dairy products and sugar have a significant negative effect on child height; this effect is (absolutely) smallest for children of better educated mothers suggesting that better educated women allocate resources more effectively. Price effects tend to be absolutely larger for children in higher expenditure households further suggesting that the impact of better educated mothers on child height does not reflect solely the availability of more resources.

2. Model

The biological correlates of child anthropometric outcomes have been extensively studied in the medical literature [see, for example, Martorell and Habicht (1986)]. We can think of child height in the current period, h_t, as depending on current inputs, M_t, into a health production function and, also, on height last period, h_{t-1}. The former might include the duration of breast-feeding, age at introduction of solid foods and the types of foods introduced, calorie and protein intake, disease incidence and severity, use of clean water, sanitary and health care practices. Household characteristics, including the age and sex of the child, z_{it}, as well as parental education and heights, z_{ht}, may also affect child height both directly and, possibly, through their impact on allocation decisions. Finally, conditional on inputs, the environment in the local community, $\tilde{z}_{ct}$, may have a direct impact on child height; of course, many other community characteristics may only affect child height through inputs, M_t. The child anthropometric production function is

$$h_t = f_t(h_{t-1}, M_t, z_{it}, z_{ht}, \tilde{z}_{ct}, v_{it}), \tag{1}$$

where v_{it} are unobservable child, household and community characteristics which affect the child's height.

Estimation of the parameters of this production function is not, however, trivial and requires detailed information on the choice of inputs [Rosenzweig and Schultz (1983)]. In addition, since these choices are simultaneously determined with the anthropometric outcome, an instrument, such as a price, is required for each input included in the production function. There are few datasets which can meet these requirements, but see Akin, Guilkey and Popkin (1990), Barrera (1990) and Cebu Team (1988, 1991) for recent studies.

It is, however, possible to answer important questions even in the absence of such detailed data. In particular, economists have attempted to integrate the bio-medical approach with an economic model of family allocation decisions, in order to examine the impact of exogenous changes in the social and economic environment on health outcomes. Assume parents' preferences are inter-temporally separable, then in the current period, parents choose to maximize a quasi-concave utility function which depends on the consumption of commodities and services, x_t, the leisure of each household member,

ℓ_t, as well as the quantity and quality of children, θ_t, which includes healthiness [Becker (1981)].[2] Child height, h_t, is one element of the child characteristics vector, θ_t. Letting ϕ_t represent unobserved heterogeneity in preferences, then parents choose to

$$\max_{x\ell\theta} U(x_t, \ell_t, \theta_t; z_{ht}, \phi_t) \tag{2}$$

but are constrained by the production function, (1), a time and a current period budget constraint:[3]

$$p_t x_t = w_t(T_t - \ell_t) + y_t, \tag{3}$$

where p_t is a vector of prices, w_t a vector of wages, T_t is a vector of the maximum number of hours each household member can work and y_t is household nonwage income.[4]

Solving the system (1) through (3), then there is a parental demand for child height function which depends only on exogenous child, household and community characteristics:

$$h_t = g(z_i, z_h, y, z_c, \xi_i), \tag{4}$$

where z_c is the set of all community characteristics which affect child height directly, $\tilde{z}_c$, and also through inputs M; unobserved heterogeneity in child height, ξ_i, is assumed to be uncorrelated with the other elements of $g(\ )$. Since lagged height enters the height production function, (1), in the reduced form, (4), the determinants of current height include both their current and lagged values (dating back to at least the birth of the child), except for those characteristics which are time invariant (such as gender or parental height). Estimation of this reduced form (typically using only current observations)

[2]See Schultz (1990) and Thomas (1990) for studies of fertility and child health which test the assumption that parents have identical preferences. Since we have a single cross-section of data on child health, we ignore the dynamics of consumption decisions and their implications for child growth; see Foster (1990).

[3]Some purchases of inputs into the health production function may be valued only for their impact on health and not directly; they will not enter the vector x in the utility function but will enter the budget constraint appropriately defined.

[4]Below, we will maintain that non-wage income is unrelated to current labor supply behavior; this is a strong assumption, but necessary with the data we use to estimate the effect of household resources on child height.

has been the focus of much of the socio-economic literature examining health outcomes including fertility, child mortality and anthropometry.[5]

Our aim in this study is to investigate whether and how community characteristics affect child height. Since higher income households tend to live in neighborhoods with better services, failure to control properly for household resources is likely to lead to biased estimates of the effects of community services.

It is very difficult to accurately measure nonwage income, y, and so income is sometimes excluded or, alternatively, assets are also included [Horton (1986), Strauss (1990)] on the grounds that child health should depend on long-run resource availability. If leisure is (weakly) separable from commodity consumption and health in the utility function,

$$U = U(\psi(\ell_t), v(x_t, \theta_t); z_h, \omega_t), \tag{2'}$$

then it is possible to derive a conditional demand function which includes total income, $Y_t = w_t(T_t - \ell_t) + y_t$, but not its components, wages and unearned income, separately. If households smooth consumption in the face of transitory income shocks, then household expenditure is a better measure of long-run resource availability than total income, especially in rural communities where income often varies substantially year by year.[6] Furthermore, household income is hard to measure, and there is some evidence in expenditure surveys that detailed expenditure accounts are more accurate than income instruments which are typically less detailed.[7]

Household expenditure (or income) should be treated as endogenous in the conditional height demand function since consumption, leisure and time allocation decisions are jointly determined with child health. Under the assumption of weak separability in the utility function, (2'), an appropriate

[5]Recent work [Pitt and Rosenzweig (1989)] has raised the specter of mortality and birth selection. Since we neither know the complete birth history of each mother in the survey nor have any instruments which affect child mortality or the probability of a woman having a child, but not child health, we focus on the estimate of height functions conditional on the child being in the home during the week of the survey.

[6]Both current and past levels of household resources enter the height function; these might be split into long-run (permanent) and short-run (transitory) components. With a single cross section, we are unable to measure shocks and instead include expenditure as our best measure of long run resource availability. The effects (on savings) of income shocks are discussed in Deaton (1989) and Paxson (1989); Udry (1990) presents evidence that communities share risks so that household consumption is smoothed in the face of shocks.

[7]This assertion is based on the fact that in many expenditure surveys, population weighted expenditure is closer to estimated GDP than weighted income which in most surveys is somewhat lower. The reasons are far from clear. It may be because in budget surveys more attention is paid to the collection of expenditure data, frequently in several hundred categories, whereas income is usually reported in only a small number of categories. It has also been suggested that respondents are inclined to under-report income for fear of incurring taxes.

instrument is that part of income which is unaffected by these choices, which we assume to be unearned income.[8] The use of household expenditure, rather than income, is common in the demand literature [Deaton (1982)], although recently there has been renewed awareness of the need to instrument [Leviatan (1961), Blundell, Browning and Meghir (1989)]. The theoretical underpinnings of this approach may be traced back, at least, to Pollak's (1969) work on conditional demand functions. It has recently been applied in the health literature by Thomas, Strauss and Henriques (1990, 1991) and Sahn (1990).

Since parents are likely to trade-off between the quality and quantity of their children [Becker (1981)], household size cannot be treated as exogenous. Nevertheless, it is possible to control, at least crudely, for household size by adopting household *per capita* expenditure, *PCE*, as the income measure,[9] partition z_h into $\{PCE\, \tilde{z}_h\}$, then:

$$h_i = h(z_1, PCE_i, \tilde{z}_h, z_c, \varepsilon_i). \tag{5}$$

The vector of parental characteristics, $\tilde{z}_h$, are assumed to be time-invariant and will include their education and height. The latter will capture genetic differences, including ethnic heterogeneity which will be important since the survey data we study reports no information on the background of household members. In addition, parental height will also proxy for human capital, over and above observed levels of education.

We examine four groups of community characteristics, z_c. Local market price indices and child anthropometric information are derived from the same household survey data. There is enormous inter-regional and inter-sectoral heterogeneity in prices in Brazil [see V. Thomas (1982) and the discussion below]. While price levels certainly change over time, we assume that inter-regional variation in *relative* prices swamp inter-temporal variation during the decade preceding the survey.[10] We include price indices for six food groups, which are likely to have an impact on child healthiness. They are dairy products and eggs (hereafter dairy products), beans, cereals, meat,

[8]Productive assets, if available, would also be appropriate instruments although they share the same potential problem with lagged labor supply. In principle, covariates which affect wages but not child height directly may be additional valid instruments. Community variables measuring demand side influences may be candidates; however, this requires that community covariates which do belong in the child height demand function, (4), are measured perfectly, a strong requirement.

[9]Since we use per capita expenditure, we have only one endogenous variable. We can thus use nonlabor income to instrument for it. If we had instruments, we could also include a series of covariates for household composition.

[10]For Brazil, during the 1970s, no other consumer price data exist which are as detailed or available at such a disaggregated level for both urban and rural areas. Thus lagged prices are not included.

fish and sugar. Evidence on the significance of price effects on child health is, at best, ambiguous.[11]

In contrast, the level of urbanization and community infrastructure, such as water and sewerage services, have been shown to significantly affect child height in previous studies.[12] We include, therefore, the per capita number of buildings with water connections, sewerage hookups and electricity connections in the community; as more general measures of infrastructure, we include the per capita number of buildings and population density.

The effects of the quantity and quality of health services on child health are also ambiguous.[13] In addition to measures of availability (the per capita number of hospitals and clinics in the *municipio*), we include (crude) indicators of quality. In particular, we have information on the per capita number of doctors and nurses as well as a measure of the average size of health facilities: the number of beds per hospital.

The final group of community characteristics included in z_c, are measures of the quality of education services available in the community; they include student teacher ratios in elementary and post-elementary classes, elementary school sizes and the per capita number of teachers living in the community. These variables proxy for the quality of education available in the community. In the model above, child nutritional status (height) and education are both elements of θ and are likely to be jointly determined; there is no information on quality of an individual's education in the household survey data. We use community level measures of education quality to capture the possibility of substitutability or complementarity between it and other dimensions of human capital development. Higher quality primary education, for example, may raise the expected returns to education [Behrman and Birdsall (1983)] as well as raise the probability of advancing to higher levels [Behrman and Sussangkarn (1989)].

[11]Barrera (1990) finds no effect of the price of rice, cooking oil, kerosene or milk in a reduced form model of child height; Rosenzweig and Schultz (1982) report that a food price, as reported by a local agricultural agent, has no effect on fertility or mortality in urban Colombia but has a negative impact on mortality in rural areas. Behrman and Deolalikar (1989a) on the other hand, show that in India the prices of sorghum, pulses and rice have positive effects on child weight for height in the lean season and little effect in the surplus season; price effects on nutrient intakes are also significant but in the *opposite* direction. Finally, Foster (1990) finds that child growth is negatively correlated with changes in rice prices.

[12]Using Philippine data, Horton (1986), Barrera (1990) and Akin, Guilkey and Popkin (1990) show that water sources, excreta disposal and toilet facilities affect child height. Strauss (1990) reports water sources matter in the Côte d'Ivoire, while Behrman and Wolfe (1987) report that toilet facilities matter in Nicaragua. Thomas, Strauss and Henriques (1991) find that garbage disposal, water and sewerage services matter in the Northeast of Brazil.

[13]Strauss (1990) finds the presence of a traditional healer in the Côte d'Ivoire reduces child height, as does the absence of drugs and congestion problems in the nearest health clinic. Barrera (1990) finds the further away an outpatient clinic, the taller a child. Rosenzweig and Schultz (1982) report that fertility and mortality do not respond to the availability of health facilities in rural Colombia but are lower in urban areas with more clinics and, possibly, hospitals.

Since the availability and quality of infrastructure, health and education services tend to change only slowly, lagged and current values of these measures are likely to be very similar. Assuming also, that there is little migration of families with small children, then the inclusion of only current information is not likely to result in substantial mis-specification bias.

The effects of both household and community characteristics on child height will, almost surely, vary in a systematic way with child characteristics [Barrera (1990)]. For example, increases in the price of milk are likely to have different impacts on the heights of children of different ages. We will, therefore, stratify the data on child's age.

There may also be important interactions between maternal education and the availability (and quality) of community services [Caldwell (1979), Rosenzweig and Schultz (1982)]. The direction of these interactions is not, however, a priori obvious. On the one hand, if better educated mothers are more able to process information, then they may better understand the advantage of using local services. Their children will therefore benefit more from community services in which case maternal education and community characteristics might be considered 'complements'.[14] On the other hand, uneducated mothers may use services which are locally available (such as piped water), and in the absence of other inputs (such as modern sewerage), these services could have a larger impact on the health of their children relative to those of better educated mothers; in this case community characteristics and education would be 'substitutes'.

In spite of the important implications about who gains most from public investments, few studies have examined the impact of interactions between maternal education and community characteristics on child health.[15] In addition to interactions between maternal education and community services, there may be interactions between her education and her partner's education [Behrman and Sussangkarn (1989)]. We will, therefore, examine the determinants of child height, stratifying on three levels of mother's education.

Finally, not all community services are free and so, for some households, there may be resource constraints on their usage. In fact, a positive interaction between maternal education and community characteristics may have nothing to do with better information processing but simply reflect the

[14]In a gross sense since preferences as well as technology affect the signs of the reduced form coefficients.

[15]Rosenzweig and Schultz (1982) report there are no significant interactions between community characteristics and maternal education on fertility and mortality in rural Colombia but among urban women, the uneducated gained most from community services. Strauss (1990) also found no significant interactions in the determination of child anthropometry in rural Côte d'Ivoire. In Bicol Province, in the Philippines, children of less educated mothers gained most from an absence of excreta disposal and least from modern toilet facilities [Barrera (1990)]. Children of uneducated mothers gained least from higher quality health facilities and most from modern sewerage systems in the northeast of Brazil [Thomas, Strauss and Henriques (1991)].

fact that better educated mothers tend to live in better off households who either can afford these services or live in neighborhoods with better quality services. To examine this issue directly, we will permit interactions between community service availability and household per capita expenditure (treating the interaction as endogenous). Education and expenditure interactions of opposite signs would be prima facie evidence against the resource availability interpretation of the benefits of maternal education.

3. Data

To study the household and community level determinants of child height, we have drawn data from two sources. Household survey data provide information on child, parent and local market characteristics. Information on service availability and quality is extracted from a special community level dataset.

The *Estudo Nacional da Despesa Familiar* (ENDEF) is a household socio-economic survey carried out by the Brazilian statistical agency, IBGE, during 1974/1975. The survey is very large, covering just under 55,000 households, and also very rich. In addition to detailed expenditure and income modules, the survey collected information on, inter alia, demographic and anthropometric characteristics of *all* household members.

We will examine data collected from the poor Northeast of Brazil and the relatively better off South[16] which accounts for some 80% of households in the sample. In the model section above, it was argued that in order to estimate effects of community services on child height, it is crucial that good controls for household characteristics and parental background be included in the regressions. In addition to parental education, parental height has been shown to be a very good predictor of child height [Horton (1986), Barrera (1990), Strauss (1990)] and may also serve as a measure of family background [Thomas, Strauss and Henriques (1990)]. So that maternal and paternal height may be included in the regressions, the sample is restricted to include children with both parents present.[17]

Summary statistics of child and household characteristics for the 36,980 children aged under eight years included in the sample are presented in panel A of table 1. Since child height is systematically related to age and sex, it makes sense to control for these characteristics when comparing children. We follow a simple and parsimonious approach and relate each child's height to

[16]Rio de Janeiro, Sao Paulo, Santa Catarina, Rio Grande do Sul, Paraná and Brasilia. In this paper, the excluded regions are the Center-West and the North; only urban households were surveyed in the latter.

[17]If parental height is excluded from the regression, then the results based on the sample used here and a larger sample (which includes female headed households) are essentially identical. This suggests that sample selection based on presence of the father is not important. For the reasons discussed in the text, we report those estimates which include paternal height.

Table 1

Summary statistics: Means and standard deviations.

A: Household, child and local market characteristics (based on ENDEF survey data)

	All children		Rural children		Urban children	
	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)
Household characteristics						
Household per capita expenditure	276.27	(362.87)	143.90	(115.93)	352.42	(426.74)
log(household per capita expenditure)	5.22	(0.83)	4.76	(0.63)	5.48	(0.82)
Dummy(1) if mother						
Literate	0.43		0.39		0.45	
Completed elementary school	0.15		0.06		0.21	
Completed secondary school/higher	0.07		0.01		0.10	
Dummy(1) if father						
Literate	0.44		0.44		0.44	
Completed elementary school	0.15		0.06		0.21	
Completed secondary school/higher	0.08		0.01		0.12	
Mother's height (% U.S. median)	94.50	(3.91)	94.01	(3.84)	94.78	(3.92)
Father's height (% U.S. median)	94.29	(3.94)	93.83	(4.01)	94.57	(3.87)
Child characteristics						
Standardized height (% U.S. median)	94.79	(6.51)	93.25	(6.22)	95.68	(6.51)
Dummy (1) if male	0.51		0.51		0.51	
Dummy (1) if aged						
6–11 months	0.05		0.05		0.05	
12–17 months	0.05		0.05		0.05	
18–23 months	0.05		0.05		0.05	
2 years	0.11		0.11		0.11	
3 years	0.11		0.11		0.11	
4–5 years	0.23		0.23		0.23	
6–8 years	0.34		0.34		0.34	
Local market price indices						
Beans	1.00	(0.14)	0.93	(0.11)	1.04	(0.14)
Cereals	1.02	(0.14)	0.94	(0.09)	1.06	(0.14)
Dairy products	0.95	(0.09)	0.86	(0.08)	1.01	(0.05)
Fish	1.03	(0.12)	0.94	(0.11)	1.08	(0.08)
Meat	1.01	(0.07)	0.95	(0.04)	1.04	(0.06)
Sugar	0.97	(0.08)	1.01	(0.09)	0.94	(0.07)

B: Community service quality and availability (based on *municipio* level data)
Weighted by *municipio* population

	Municipios in ENDEF					All municipios in South and NE Brazil
	All municipios			Region		
	Mean	(s.d.)	% = 0	South	NE	
Urbanization						
% population urban (1970 census)	65.32	(2.31)	0.0	70.23	55.28	48.82
Population density (persons/km^2)	1,361.68	(14,212.62)	0.0	1,466.77	1,147.00	786.17
Community infrastructure						
Per 100,000 capita no. buildings	173.51	(621.35)	0.0	190.95	137.89	131.19
Per 100,000 capita no. buildings w/water	94.22	(491.14)	5.1	111.84	58.22	70.00
Per 100,000 capita no. buildings w/sewerage	46.82	(408.92)	31.7	63.02	13.71	33.61
Per 100,000 capita no. electricity connections	156.24	(660.73)	0.0	188.87	89.58	110.69
Health services						
No. hospital beds per hospital	120.01	(1,953.33)	4.8	142.96	73.14	81.05
Per 100,000 capita no. hospitals	4.96	(0.26)	4.8	4.91	5.04	4.99
Per 100,000 capita no. clinics	5.01	(0.54)	1.8	5.01	5.03	5.95
Per 100,000 capita no. doctors	10.11	(0.70)	1.0	10.81	8.70	6.59
Per 100,000 capita no. nurses	19.98	(0.21)	14.2	22.17	15.50	12.60
Education services						
Elementary student/teacher ratio	26.09	(46.57)	0.0	25.74	26.81	26.69
Elementary student/school ratio	311.22	(1,756.83)	0.0	377.76	175.28	205.80
Post elementary student/teacher ratio	12.71	(51.44)	4.6	13.46	11.18	9.95
No. teachers per 100,000 capita	12.03	(37.48)	0.0	12.97	10.12	10.37
No. municipios	603			363	240	2,756

the height of a well nourished United States child of the same gender and age in months (based on the NCHS, 1976, tables).[18] In Brazil, child height is, on average, about 95% of the median height of a well-nourished United States child and the average is slightly higher in the urban sector. About 20% of all children are stunted (below 90% of the median, Waterlow et al., 1977) and this proportion is higher (25%) in rural households. Parental heights are slightly less than 95% of U.S. median heights.

Mean household per capita expenditure is Cr$276[19] per month; the average urban household spends about two and half times as much as the average rural household per person. Relative to the rural sector, the distribution of *PCE* in the urban sector is both shifted to the right and is fatter tailed.

The household survey reports education levels only in discrete intervals: illiterate, some elementary school (can read or write a little; referred to as literate in the text), completed elementary school, completed secondary school and completed university level or higher. The latter two categories have been aggregated to avoid sparse cells. In comparison with other countries at a similar level of national income, Brazil has invested little in human capital. About half of the rural children have mothers and fathers who are illiterate; less than 10% of parents have completed elementary school. Between 20 and 25% of urban children have parents who cannot read and about 10% of their parents have attended at least secondary school.

For over 500 individual commodities, the ENDEF survey collected information on both amounts spent and quantities consumed, so that it is possible to calculate implied prices paid by households. It is not appropriate, however, to treat the ratio of expenditure to quantity as a market price; as expenditure rises, households tend to switch into higher quality commodities [Deaton (1988)] and there is inevitably measurement error in any survey so that several of the implied 'prices' are very large outliers. We have, therefore, created a series of local market price indices for a set of commodity groups.

The definition of market boundaries is, however, far from clear since prices are likely to vary because of heterogeneity in transportation and information costs. With survey data, the appropriate definition is partly an empirical question and depends on the choice of commodity aggregation as well as regional aggregation. We were guided by two principles: there not be too much spread in the prices of highly disaggregated commodities within a market area and that there be enough households within each area who

[18] Results are reported for the percentage of median height; results based on Z scores are essentially the same in all cases.

[19] Approximately U.S.$35 per month in 1975. Household expenditure is defined as monetary and imputed expenditure excluding savings, expenditure on durables and housing semi-durables such as large appliances. Since annual inflation was about 30% during the survey period, all income and expenditure data have been deflated using indices compiled by IBGE.

consume the good to compute a meaningful measure of central tendency [see Thomas, Strauss and Barbosa (1992) for a description].

Exploiting the detail of the survey, prices were calculated for 135 commodities, distinguishing each of 26 states in Brazil and three levels of urbanization (metropolitan, non-metropolitan urban and rural). In order to minimize the influence of outliers, median prices for each good in each market were calculated. These were then aggregated into Tornquist price indices using expenditure shares on the same 135 commodities. The dairy price, for example, is based on the share weighted aggregate price of fresh unpasteurized milk, pasteurized milk, canned milk, cheese, yogurt, eggs and other dairy products.

Local market food price indices are included as the determinants of child height; the all country index[20] is 100 for each food group. There is a good deal of heterogeneity in prices: the standard deviations are high in all cases. Most foods are less expensive in rural areas presumably because marketing margins are smaller or because they involve little processing; sugar, which does require industrial processing, is the only food which is more expensive in rural areas.

In order to examine the impact of community services and infrastructure on the heights of young children, the household survey data have been matched with community level information on infrastructure as well as the availability and quality of health and education services. The 1974 *Informacoes Basicas Municipais* (IBM), released by IBGE on micro-fiche, provides information for each of 4,000 *municipios* (counties).[21] In addition to special data reported by the administration in each *municipio sede*, the IBM includes data from several other sources including the 1970 Demographic, Agricultural and Industrial Censuses and, for example, the 1974 *Assistencia Medico-Sanitaria* which is an annual census of health facilities. There are 860 *municipios* included in the ENDEF household survey data, of which 604 are in the South and Northeast, and these have been matched with the 1974 IBM.[22]

[20] Including the Center West and North.

[21] Just as the definition of market boundaries is not obvious, nor is it clear how to define a community. We have chosen the *municipio* as our definition; since some large cities have several *municipios*, reported infrastructure will vary within these cities.

[22] The 1974 IBM was purchased from IBGE on microfiche, one for each of 4,000 *municipios*; these data have been transferred to machine readable form but since the fiches are old, and some of the data were hand-written, many of the fiches were quite difficult to read. We have, therefore, taken great care to clean the data manually. In 1974, the city of Rio de Janeiro was divided into several *municipios*; since then, it has been aggregated into a single *municipio*. Unfortunately, the microfiches for the city of Rio are missing from both the master copy in the IBGE library and the copy we purchased. The IBM survey instrument changed between 1974 and the next survey in 1978 so that a good part of the information used in this study is not available for Rio in the 1978 data. Thus, we have been forced to exclude metropolitan Rio de Janeiro from the analysis and use data from 603 *municipios*.

Panel B of table 1 describes characteristics of community services based on the *municipio* data, weighted by population. For the *municipios* included in this study, the first three columns report the weighted mean and standard deviation of each characteristic as well as the proportion of *municipios* with any of the services. Means distinguishing the South from the Northeast are in the fourth and fifth columns and the means for all 2,800 *municipios* in the Northeast and South of Brazil are in the final column.[23]

Municipio boundaries traverse the rural–urban dichotomy so that rural households may live in communities which are partially urban. On average, about half the people in each *municipio* live in an urban center; since urban areas were over-sampled in ENDEF, the proportion is higher (65%) for our sample. In ENDEF, rural households live in *municipios* which are, on average, about one quarter urban; urban households live in *municipios* which are one third rural. As evidenced by the large standard deviations of the community infrastructure indicators, there is substantial heterogeneity in their availability in Brazil. The quantity of services is much greater in the South, relative to the Northeast. Whereas all *municipios* are on an electricity grid, almost all have some modern water services but 30% of people in the sample live in communities without any modern sewerage services in the *municipio sede*.

There are, on average, five hospitals and five clinics in each *municipio*, in the South, Northeast and for all Brazil. Relative to the Northeast, in the South, hospitals have twice as many beds, about twenty percent more doctors and fifty percent more nurses, given the population of the community. There are just over ten teachers per thousand people in the Northeast and almost 13 per thousand in the South. Class sizes in both regions are about the same; schools, however, are about twice as large in the South.

4. Results

Tables 2 through 4 report the estimated effects of household and community characteristics on (the logarithm of) child height, standardized for age and gender. All variance–covariance matrices are estimated with the jackknife [Efron (1982)] which is robust to heteroskedasticity of unknown form and also downweights the influence of leverage points. The first column of tables 2 and 3 reports the estimates from a regression of (log) height for all 36,974 children in the sample on child, household and community

[23]The means based on the sample data (that is weighted by number of children under eight years old in the sample instead of total population) are quite similar. For example, in the (population) weighted *municipio* sample, there are 10.1 doctors per hundred thousand people on average; in the child level sample, there are 9.9 doctors per hundred thousand people. Rural households tend to have more children and there is a lower level of services available in the rural sector; this is reflected in the child sample means. In the urban sector, the child weighted mean number of doctors is 14.1 and in the rural sector only 2.5.

characteristics. In order to permit flexibility in the effects of covariates, the data have been stratified by residential location (columns 2 and 3), the child's age (columns 4–7) and the education level of the mother (columns 8–10) and the regressions re-estimated with all the covariates (both household and community) included in each regression.[24] In addition, the conditional height function has been estimated with all the household and community covariates, together with interactions between all community factors and the logarithm of per capita expenditure, $\ln PCE$. Results are reported in table 4 for those interactions with $\ln PCE$ which turn out to be significant, namely prices and infrastructure; because of differences in the estimates, these regressions are reported separately for the urban and rural sectors.[25]

4.1. Household characteristics

We begin with the household determinants of child height, reported in table 2, focussing primarily on the interactions between these characteristics and mother's education. The other results are similar to those discussed in Thomas, Strauss and Henriques (1990) which used the same survey data but did not include community characteristics; we will describe these results only briefly.

The logarithm of per capita expenditure is included as a measure of household resource availability. It should be treated as jointly determined with parents' time allocation decisions and child healthiness and is, therefore, instrumented with a quadratic in unearned income, which is assumed to be exogenous.[26]

There is some uncertainty in the literature about the size and significance of income effects on child anthropometry. Conditional on community

[24]This is equivalent to allowing interactions between the stratifying variable and all other covariates. We also compared the effects of community characteristics on the heights of boys and girls but found that none was significantly different.

[25]All expenditure interactions are treated as endogenous. Interactions of non-labor income with community covariates are added to the instrument set.

[26]Two thirds of the variation in $\ln PCE$ (and $\ln PCE^2$) is explained in the first stage regressions. Taking all the covariates together, they are clearly significant with an $F_{71,36902}$ of 1,023 in the $\ln PCE$ regression and an F of 1,073 in the $\ln PCE^2$ regression. Household non-labor income and its square is each individually significant (with t statistics of over 20) and also jointly significant: higher non-labor income is associated with higher per capita expenditure but at a decreasing rate. 38% of all households in the sample report some unearned income – and these households are not only at the top of the expenditure distribution. A quarter of households in the bottom decile of PCE report some unearned income and this proportion rises with PCE. Maternal and paternal education are also powerful predictors of log per capita expenditure, as are parental heights (representing, in part, the effect of family background). The month of the survey is included in the instruments to control for seasonality of income and, therefore, expenditures; these dummies also control for the effects of inflation. Infrastructure and relative prices are much weaker predictors, although some are significant. The instruments also include a housing price index and some additional local infrastructure measures (per capita number of post offices, telephones and vehicles as well as a dummy for the existence of a major highway in the *municipio*) together with a dummy for each state (to account for unmeasured

characteristics, the expenditure elasticity of the demand for child height in Brazil is small but significant, although this significance disappears when the data are stratified on sector.[27] Whereas expenditure has no effect on the height of babies and infants, it has a positive, significant influence on the height of children two years or older.

There is a complicated non-linear relationship between child height, maternal education and expenditure. Expenditure is a significant determinant of child height for illiterate and literate mothers but not for mothers who have at least some elementary education. Resources in the hands of mothers with none or very little education will have a large positive impact on their children's height but additional per capita expenditure in households with better educated mothers will not significantly affect their children's height.[28]

There is a good deal of evidence that children of better educated parents are healthier and our results are consistent with this evidence. Although we can say nothing about the exact mechanisms through which parental education affects child height, these effects are robust to the inclusion of controls for both other indicators of family background (parental heights) and for household income (*PCE*). Relative to being illiterate, the size of maternal and paternal education effects are not significantly different and they are much larger in the urban sector for both parents. The impact of maternal education is largest on the recumbent length of babies and declines with the child's age. Father's education has no impact on length of babies and has its largest impact on infants (6–23 month olds).

The effect of interactions between parental education on child health has been little studied. Behrman and Sussangkarn (1989) report significant, negative interactions on the probability a child attends school in Thailand. In contrast, we find significant positive interactions suggesting that maternal and paternal education are complementary. This relationship is apparently not linear. If the mother is illiterate, then child height is unaffected by father's education. For all levels of father's education, the effect is largest when the mother has at least some elementary schooling. Education has the biggest impact on the heights of children both of whose parents have some secondary schooling. The positive interaction between parental education does not simply reflect the fact that better educated fathers earn higher wages and so their families tend to have higher levels of per capita expenditure. In fact, as noted above, there is a negative interaction between *PCE* and maternal education. It appears, therefore, that better educated mothers are better able to allocate a given sum of resources to improve their children's health when their husbands are also better educated.

components of infrastructure and price variation). Exclusion of the extra price index and infrastructure information from the instruments has no perceptible impact on the estimated coefficients in the height regression.

[27] For all but the regressions stratified on mother's education, quadratic terms in ln *PCE* are insignificant. If the community covariates are excluded then the expenditure elasticity, for all children, is three times larger at mean *PCE*; it is significant and declines with *PCE* in both the urban and rural sectors. This reflects the fact that household income is associated with more, better facilities in the community.

[28] At median *PCE*, the expenditure elasticity is largest for illiterate mothers (0.025), and smallest for the most educated mothers (0.012). The elasticity rises with *PCE* for both illiterate and literate mothers, faster for illiterate mothers (to 0.049 and 0.026 respectively at the 90th percentile of *PCE*); but declines for mothers with some education.

It has been shown empirically that there is a strong positive correlation between parental and child height, part of which can be attributed to genetics. In addition, however, parental height reflects investments in health and other human capital; it may, therefore, also serve as a proxy for unobserved family background characteristics.[29] The effect of mother's height is about 30% bigger than father's in both the rural and urban sector and for all children six months or older. Paternal height has only a small effect on the length of a baby, which is significantly related to mother's height and presumably reflects her healthiness during pregnancy, as well as factors such as womb size [Mueller (1986)].

Each regression includes dummies for the sex and age of the child; since height has been standardized for age and sex, these coefficients reflect differences relative to the median child in the United States. Data from almost all developing countries reflect a similar child age–height profile [Waterlow et al. (1977)]: relative to the standards, heights decline with age until around two years when they stabilize and, possibly, rise again. The decline is greatest for illiterate mothers but can, for all age groups, be ameliorated by mothers who can read or have received some education. While these differences in heights are significant, the shapes of the child age–height profiles are identical for all three maternal education categories.

4.2. Community characteristics

The impact on child height of prices, infrastructure, the availability and quality of health and education services, all conditional on household characteristics, are reported in table 3 for the pooled sample and stratified by urban–rural location, child age and mother's education. The impact of interactions between ln *PCE* and infrastructure, stratified by sector of residence, are reported in table 4.[30]

There is little correlation across the groups of community covariates, reflecting the large degree of heterogeneity in the extent of services across Brazil. Thus, the results discussed below are robust to the exclusion of one or

[29] There are substantial differences in the racial composition of the people in the Northeast and South of Brazil; in the absence of race controls, parental height should also serve as good indicators of ethnic background.

[30] None of the interactions between health and education services and ln *PCE* was significant and so those groups of covariates are not included in table 4.

Table 2

Household determinants of log(child height for age).[a]

	All	Sector of residence: Urban	Sector of residence: Rural	Age of child in months: 0–5	6–23	24–59	60–107	Education of mother: Illiterate	Literate	Elem +
Parents' characteristics										
ln(per capita expenditure)	0.875	0.137	0.635	−0.265	0.263	1.327	0.901	−8.174	−1.276	5.303
	(3.86)	(0.47)	(1.44)	(0.25)	(0.46)	(3.47)	(2.93)	(1.50)	(0.33)	(1.31)
ln(per capita expenditure)^2	–	–	–	–	–	–	–	1.032	0.308	−0.397
								(1.80)	(0.86)	(1.28)
Dummy (1) mother Literate	0.641	1.134	0.369	1.266	1.102	0.550	0.486	–	–	–
	(6.63)	(8.22)	(2.47)	(2.60)	(3.98)	(3.23)	(3.79)			
Completed Elementary school	1.102	1.735	0.706	1.695	1.658	1.006	0.909	–	–	–
	(7.06)	(8.52)	(2.45)	(2.21)	(3.79)	(3.70)	(4.36)			
Secondary/more	1.618	2.615	1.510	3.538	2.250	1.365	1.421			
	(5.99)	(7.65)	(2.06)	(2.68)	(3.31)	(2.96)	(3.75)			
Dummy (1) father Literate	0.536	0.866	0.397	0.748	1.124	0.592	0.282	0.135	0.577	1.182
	(5.70)	(6.41)	(2.85)	(1.56)	(4.56)	(3.47)	(2.23)	(0.99)	(3.95)	(2.46)
Completed Elementary school	1.197	1.748	0.550	1.063	1.951	1.251	0.896	0.530	0.767	1.836
	(7.89)	(9.11)	(1.90)	(1.45)	(4.87)	(4.69)	(4.31)	(1.56)	(3.52)	(3.31)
Secondary/more	1.817	2.670	1.805	1.043	3.432	1.824	1.327	2.676	1.245	2.998
	(6.83)	(8.25)	(2.37)	(0.78)	(4.96)	(4.10)	(3.68)	(1.61)	(2.85)	(4.15)
ln(height) Of mother	34.426	33.388	36.659	18.432	32.668	34.287	36.554	34.101	33.595	34.806
	(40.67)	(30.65)	(26.59)	(4.58)	(14.67)	(22.41)	(31.53)	(23.85)	(26.51)	(19.18)
Of father	26.112	26.225	27.887	8.480	23.914	26.253	29.073	26.431	24.194	26.863
	(29.42)	(22.26)	(19.80)	(1.94)	(9.90)	(16.39)	(24.48)	(18.08)	(18.17)	(13.54)
Dummy (1) urban	0.580	–	–	2.075	0.387	0.084	0.850	0.231	−0.026	1.504
	(2.61)			(1.94)	(0.66)	(0.22)	(2.76)	(0.64)	(0.07)	(2.63)
Child's characteristics										
Dummy (1) male	−0.328	−0.307	−0.351	−0.831	−0.483	−0.112	−0.392	−0.292	−0.402	−0.250
	(5.39)	(3.93)	(3.55)	(2.77)	(2.91)	(1.03)	(4.73)	(2.65)	(4.48)	(2.08)
Dummy (1) aged 6–11 months	−3.799	−3.531	−4.225	–	–	–	–	−4.547	−3.848	−2.980
	(18.04)	(13.30)	(12.22)					(12.32)	(11.70)	(7.32)
12–17 months	−4.768	−4.218	−5.642	–	–	–	–	−5.955	−5.026	−2.876
	(22.81)	(16.22)	(16.06)					(16.00)	(15.55)	(7.18)
18–23 months	−5.225	−4.783	−5.969	–	–	–	–	−6.437	−5.621	−3.131
	(24.96)	(18.46)	(16.77)					(16.41)	(17.55)	(8.38)
2 years	−4.138	−3.718	−4.804	–	–	–	–	−5.056	−4.448	−2.545
	(22.78)	(16.45)	(15.73)					(15.49)	(15.69)	(7.61)
3 years	−4.613	−4.329	−5.101	–	–	–	–	−5.371	−4.977	−3.147
	(25.62)	(19.37)	(16.79)					(16.69)	(17.82)	(9.24)
4–5 years	−4.737	−4.478	−5.171	–	–	–	–	−5.485	−5.038	−3.479
	(28.45)	(21.80)	(18.29)					(18.67)	(19.17)	(11.11)
6–8 months	−4.619	−4.336	−5.066	–	–	–	–	−5.118	−5.064	−3.489
	(28.79)	(21.98)	(18.52)					(18.07)	(20.01)	(11.51)
2/12–17/36–47/72–83 mths	–	–	–	0.221	−1.041	−0.463	0.263	–	–	–
				(0.41)	(5.07)	(3.43)	(2.15)			
3–4/18–23/48–59/84–95 mths	–	–	–	−0.434	−1.458	−0.563	0.143	–	–	–
				(1.01)	(7.15)	(4.19)	(1.18)			
5/./96–107/96–107 mths	–	–	–	−1.859	–	–	0.021	–	–	–
				(4.32)			(0.18)			
Test statistics										
F (all covariates)	356.54*	213.25*	108.49*	9.36*	63.15*	129.85*	186.82*	73.31*	115.48*	53.54*
χ^2 for										
ln(PCE), ln $PCE^2 = 0$	–	–	–	–	–	–	–	20.87*	54.09*	1.77
Mother educn = 0	55.37*	79.66*	8.58*	8.73*	17.61*	14.54*	20.36*	–	–	–
Father educn = 0	64.06*	86.26*	9.69*	3.02*	30.05*	22.78*	20.60*	4.29*	18.83*	21.52*
Mother = father educn	2.31	3.87	0.41	2.72	3.05	0.99	1.95	–	–	–
No. observations	36,974	22,737	14,237	1,819	5,885	12,534	16,736	12,930	15,857	8,187
Mean height (% median)	94.8	93.3	95.7	98.6	94.8	94.8	94.6	92.5	95.0	97.7

[a]Dependent variable is logarithm of % median height of well nourished child in United States of the same age and sex; all coefficients have been multiplied by 100. t statistics in parentheses and χ^2 test statistics based on jackknifed estimates of variance–covariance matrix. All covariates in tables 2 and 3 included in each regression; ln PCE treated as endogenous.

Table 3
Community determinants of log(child height for age).*

	All	Sector of residence: Urban	Rural	Age of child in months: 0–5	6–23	24–59	60–107	Education of mother: Illiterate	Literate	Elem +
Local market prices										
log(price) of										
Dairy products	−5.476	−8.663	−4.551	−7.063	−5.557	−4.086	−6.345	−6.809	−2.455	−4.802
	(6.11)	(5.91)	(2.61)	(1.46)	(2.29)	(2.64)	(5.10)	(4.31)	(1.69)	(2.25)
Beans	0.119	0.533	2.741	−1.384	−0.163	0.028	0.439	1.035	−0.381	0.247
	(0.25)	(0.85)	(2.04)	(0.60)	(0.13)	(0.03)	(0.67)	(1.05)	(0.53)	(0.25)
Cereals	1.364	−0.356	2.887	1.675	3.613	0.937	1.059	2.845	0.542	−0.050
	(2.80)	(0.51)	(3.36)	(0.71)	(2.69)	(1.07)	(1.57)	(3.20)	(0.75)	(0.04)
Meat	0.258	−1.261	12.310	−11.820	0.967	−0.065	1.863	2.660	1.317	−3.239
	(0.21)	(0.79)	(3.73)	(1.92)	(0.29)	(0.03)	(1.11)	(1.20)	(0.69)	(1.26)
Fish	−0.791	0.968	−3.601	0.567	−1.101	−0.309	−1.542	−1.981	−0.455	−0.849
	(1.47)	(0.99)	(3.05)	(0.19)	(0.74)	(0.32)	(2.15)	(2.00)	(0.59)	(0.68)
Sugar	−4.999	−3.163	−2.778	−7.383	−4.285	−6.892	−3.659	−6.057	−5.076	−4.027
	(8.10)	(2.84)	(2.59)	(2.24)	(2.52)	(6.20)	(4.40)	(5.76)	(5.49)	(2.65)
Urbanization										
% urban	0.316	0.897	−0.115	1.559	−0.042	0.241	0.290	−0.638	−0.373	1.584
	(0.86)	(2.05)	(0.14)	(0.78)	(0.04)	(0.36)	(0.60)	(0.87)	(0.67)	(2.31)
Population density	0.007	0.006	−0.016	0.025	0.008	0.008	0.005	0.011	0.010	0.008
	(2.13)	(1.31)	(1.50)	(1.38)	(0.85)	(1.33)	(1.07)	(1.49)	(1.94)	(1.05)
Community infrastructure										
Per '000 capita no.										
Water installations	0.234	0.371	−0.870	−0.795	0.415	0.277	0.283	−0.305	0.744	−0.245
	(1.76)	(2.45)	(2.62)	(1.10)	(1.14)	(1.07)	(1.65)	(1.15)	(4.14)	(0.85)
Sewerage hookups	0.353	0.490	0.040	0.843	−0.109	0.294	0.499	0.384	0.139	0.828
	(2.74)	(3.13)	(0.15)	(1.20)	(0.29)	(1.22)	(3.02)	(1.41)	(0.75)	(3.35)
Electricity connections	0.345	0.358	1.484	1.669	−0.110	0.449	0.270	−0.327	0.412	0.632
	(2.73)	(2.36)	(4.46)	(2.46)	(0.31)	(1.99)	(1.56)	(1.16)	(2.27)	(2.63)
Buildings	−0.312	−0.373	−0.395	−1.190	−0.394	−0.207	−0.259	0.724	−0.515	−0.861
	(2.35)	(2.42)	(1.19)	(1.78)	(1.02)	(0.84)	(1.51)	(2.76)	(2.57)	(3.26)
Health services										
Beds per hospital	−0.040	−0.031	−0.174	−0.108	−0.123	−0.048	−0.008	0.024	−0.054	−0.021
	(2.13)	(1.59)	(1.44)	(0.59)	(0.48)	(1.74)	(0.32)	(0.18)	(1.97)	(0.69)
Per '000 capita no.										
Hospitals	−80.367	−216.433	161.492	−92.554	−139.636	165.047	−241.475	−186.389	−11.341	161.051
	(0.91)	(1.61)	(1.24)	(0.21)	(0.54)	(1.01)	(2.13)	(1.24)	(0.09)	(0.73)
Clinics	−35.929	2.701	−33.868	−868.131	23.672	−105.588	50.812	21.712	−36.993	−5.738
	(0.70)	(0.04)	(0.42)	(2.46)	(0.12)	(1.11)	(0.85)	(0.25)	(0.63)	(0.03)
Doctors	4.441	−0.878	13.028	6.202	32.423	−11.229	7.022	1.449	11.440	10.610
	(0.59)	(0.10)	(0.40)	(0.16)	(1.56)	(0.81)	(0.71)	(0.09)	(1.02)	(0.77)
Nurses	−63.679	−62.843	−51.921	−104.983	−116.359	−53.591	−54.301	1.560	−79.773	−76.476
	(3.13)	(2.71)	(0.74)	(0.91)	(2.00)	(1.40)	(2.08)	(0.03)	(2.62)	(2.03)
Education services										
Elementary students per teacher	−0.572	−0.696	0.311	2.381	−0.866	−1.678	−0.191	−2.741	−0.448	1.224
	(0.76)	(0.58)	(0.28)	(0.61)	(0.43)	(1.24)	(0.19)	(2.14)	(0.40)	(0.70)
Elementary students per school	0.005	0.071	−0.522	−0.134	0.251	0.003	−0.052	−0.126	0.024	0.025
	(0.13)	(1.68)	(3.54)	(0.72)	(2.52)	(0.05)	(1.01)	(1.42)	(0.43)	(0.40)
Post-elementary students/teacher	−0.189	−1.188	1.882	−0.040	−0.395	−0.859	0.012	−0.062	0.341	−0.154
	(0.32)	(1.50)	(2.01)	(0.01)	(0.25)	(0.79)	(0.02)	(0.06)	(0.40)	(0.12)
Per capita no. educators	3.598	0.584	7.323	−0.413	11.119	1.532	2.826	0.707	4.129	3.935
	(2.64)	(0.32)	(3.22)	(0.06)	(3.02)	(0.61)	(1.55)	(0.26)	(2.04)	(1.46)
χ^2 test statistics for significance of										
Prices	212.77*	97.62*	136.36*	12.78*	38.71*	86.26*	8.19*	145.33*	67.85*	11.87*
Urbanization	10.75*	8.63*	2.30	5.46*	0.95	2.55	98.99*	2.53	4.20	13.35*
Infrastructure	32.08*	39.23*	22.27*	9.59*	2.16	12.14*	24.62*	8.15*	35.42*	26.92*
Health services	5.77*	5.28*	4.21	6.35*	2.73	6.23*	5.34*	1.60	4.72*	1.57
Education services	14.87*	5.41*	33.17*	0.95	18.66*	5.16*	5.99*	12.52*	7.71*	2.85
All community covs.	508.33*	303.83*	297.97*	34.20*	95.95*	229.71*	264.84*	242.67*	227.05*	91.03*

*See table 2. All coefficients multiplied by 100 except those on population density, beds per hospital and education services which are multiplied by 10,000. All covariates in tables 2 and 3 included in each regression.

Table 4
Interactions between prices, infrastructure and ln *PCE*.

	Coefficient estimates			Estimated effect evaluated at quartiles of *PCE*		
	Direct	Interaction with ln *PCE*	χ^2	Bottom	Median	Top
		Urban				
Local market prices						
log(price of)						
Dairy products	−18.702	1.559	28.933	−10.99	−10.23	−9.36
	(0.64)	(0.29)	(0.00)			
Beans	57.348	−10.238	16.623	6.70	1.74	−4.03
	(3.82)	(3.74)	(0.00)			
Cereals	8.133	−1.593	0.813	0.25	−0.52	−1.42
	(0.60)	(0.64)	(0.74)			
Meat	−42.651	−9.926	5.269	−91.75	−96.57	−102.16
	(1.27)	(2.18)	(0.04)			
Fish	55.216	6.715	5.603	88.44	91.69	95.47
	(2.31)	(1.10)	(0.06)			
Sugar	16.699	−4.335	22.865	−4.75	−6.85	−9.29
	(0.61)	(0.87)	(0.00)			
Community infrastructure						
Per '000 capita no.						
Water installations	−0.157	0.094	4.509	0.31	0.35	0.41
	(0.03)	(0.10)	(0.06)			
Sewerage hookups	−8.118	1.521	8.487	−0.59	0.14	1.00
	(1.72)	(1.81)	(0.01)			
Electricity connections	−3.574	0.772	14.101	0.25	0.62	1.05
	(1.03)	(1.22)	(0.00)			
Buildings	6.069	−1.168	9.073	0.29	−0.28	−0.93
	(2.20)	(2.33)	(0.01)			
Wald χ^2 test statistics for joint significance of:						
Prices		34.57	98.69			
Infrastructure		8.55	45.20			
Prices and infrastructure		41.37	215.21			
		Rural				
Local market prices						
log(price of)						
Dairy products	42.641	−11.077	8.818	−5.19	−9.74	−14.42
	(0.49)	(0.60)	(0.01)			
Beans	50.971	−9.036	11.200	11.95	8.24	4.43
	(0.82)	(0.69)	(0.00)			
Cereals	105.639	−22.165	8.111	9.93	0.82	−8.53
	(2.46)	(2.35)	(0.01)			
Meat	63.292	−4.937	0.680	41.97	39.94	37.86
	(0.55)	(0.54)	(0.82)			
Fish	19.668	−11.917	0.487	−31.79	−36.69	−41.72
	(0.45)	(0.47)	(0.97)			
Sugar	23.396	−6.938	6.410	−6.56	−9.41	−12.34
	(0.45)	(0.63)	(0.02)			

Table 4 (continued)

	Coefficient estimates			Estimated effect evaluated at quartiles of *PCE*		
	Direct	Interaction with ln *PCE*	χ^2	Bottom	Median	Top
		Rural				
Community infrastructure						
Per '000 capita no.						
Water installations	−20.556	3.948	9.824	−3.51	−1.89	−0.22
	(2.27)	(2.18)	(0.00)			
Sewerage hookups	−24.185	4.846	4.792	−3.26	−1.27	0.78
	(2.15)	(2.16)	(0.06)			
Electricity connections	−4.886	1.191	3.557	0.26	0.75	1.25
	(0.44)	(0.53)	(0.12)			
Buildings	13.887	−2.849	2.404	1.59	0.41	−0.79
	(1.55)	(1.55)	(0.24)			
Wald χ^2 test statistics for joint significance of:						
Prices		17.68	112.18			
Infrastructure		11.18	21.53			
Prices and infrastructure		21.45	215.30			

χ^2 column is test statistic for joint significance of direct effect and interaction term. [p value below χ^2.] Wald test rows are for joint significance of interaction terms (first column) and of direct and interacted terms (second colum) for covariates in each group; all these Wald test statistics have p-values less than 0.002. All coefficients multiplied by 100. Also see notes to table 2.

more of the groups of characteristics. In many cases, however, there is a fair amount of correlation within groups of characteristics and so χ^2s for the joint significance of all covariates in each group are reported at the foot of table 3.

Taken together, prices have a significant effect on child height, in both the rural and urban sector and in all age groups. Prices are significant for all three levels of maternal education, although the χ^2 is much larger for illiterate mothers. Since the prices are measured in logarithms, the estimated effects can be interpreted as elasticities.[31]

Higher price indices for dairy products and sugar are associated with shorter children and this effect is greater for urban children.[32] The dairy

[31]Replacing per capita expenditure with household nonwage income then the estimated effects of community characteristics in the reduced form (4) are about 10% larger than in the conditional output function (5); the largest changes are observed in the rural sector. Since price elasticities in the reduced form model are not conditional on consumption choices, the price effects differ the most, in some cases by 20%. Nevertheless, in almost all cases, inference remains the same in both models. We focus, therefore, on results including controls for *PCE*.

[32]Sugar products are the source of approximately 13 percent of per capita caloric intake in Brazil according to ENDEF tabulations.

price has a significant impact only on children aged 6 months or older, that is after children are weaned.[33] In fact, the impact of both price indices varies with the age of the child in a non-linear manner. Higher fish prices are associated with short children, but only in the rural sector. The negative effects of increases in the prices of dairy, sugar and fish are greatest for children whose mothers are illiterate suggesting that educated mothers are better able to protect their children from the deleterious effects of these price rises. Even the healthiness of children of the most educated mother is, however, significantly affected by higher prices for these commodities.

The prices of cereals (mostly rice), beans and meat have positive effects on the height of rural children. If farmers are net suppliers of these foods, then this may reflect an income effect not fully captured by per capita expenditure. Other work [Thomas, Strauss and Barbosa (1989)] has shown that, relative to households with small children, cereals and meat are consumed more by households with older household members, especially males; if a rise in the price of these foods results in switching to foods which are consumed by small children (and these include dairy products), then child health may improve as a result of the increase in meat and cereals prices.[34]

Price effects, including interactions with ln *PCE* are reported in table 4. In addition to the coefficient estimates and a χ^2 test statistic for the significance of both the direct and interacted effect, the estimated impacts evaluated at quartiles of *PCE* are presented.

In both the urban and rural sectors, the price–expenditure interaction terms are jointly significant (χ^2 are 34.6 and 17.7, respectively) as are all direct and indirect price effects taken together (χ^2 are 98.7 and 112.2 respectively). Interactions between *PCE* and the prices of beans and meat in the urban sector, and the price of cereals in the rural sector are significant: all these interactions are negative. In the urban sector, a rise in the price of beans is associated with taller children at the bottom of the expenditure distribution and a decline at the top; the same is true of a rise in the price of cereals in the rural sector. All urban children are adversely affected by higher meat prices.

[33]According to the 1986 Demographic and Health Survey data, the median duration of breastfeeding is about three months for all women in Brazil and is shorter for the better educated, higher income and urban dwellers [Barros and Victora (1990)]. In spite of a campaign to increase the prevalence of breastfeeding in the early 1980s, the time breastfed appears to have been stable since the mid-seventies [Rea and Berquo (1990)]. Perhaps more important is the fact that very few children are exclusively breastfed (only 6% of 0–1 month old infants were exclusively breastfed in the 24 hours preceding the survey). Among children aged four to five months, over half were given milk and by six months of age, over three-quarters of babies received milk and solid foods [Barros and Victora (1990)]. Solid foods are mostly cereals and their derivatives, beans and perhaps meat [Wright and de Oliveira (1986)].

[34]There is evidence that higher food prices can be associated with higher nutrient intakes [see Pitt (1983), Pitt and Rosenzweig (1985) and also Behrman (1990b) for a review]. This is also true in the data used in this study [Thomas, Strauss and Barbosa (1992)].

The fact that children from households at the top of the expenditure distribution are more affected by some prices contrasts with results on the demand for nutrients and demand for health which indicate that price elasticities decline with expenditure [Timmer (1981), Strauss (1982), Pitt (1983), Behrman and Deolalikar (1989b), Gertler and van der Gaag (1990)]. Furthermore, since children of better educated mothers are least affected by price rises, the positive price–expenditure interactions suggest that maternal education does not simply proxy for resource availability. Part of the benefits of maternal education in Brazil presumably operate through information processing channels [Kottak (1988), Thomas, Strauss and Henriques (1991)].

Urban children tend to be taller, especially those of mothers with at least elementary education (table 3). In the urban sector, child height is positively associated with population density and also the degree to which the *municipio* is urbanized. These variables are probably picking up effects of factors other than those we are able to measure directly.

The per capita number of buildings with water, sewerage hookups and electricity connections may be interpreted as measures of the availability, and to some extent quality, of basic infrastructure and services in a community.[35] They are all positively associated with the height of Brazilian children. The positive impact of sewerage hookups is significant only for children aged five years or older whereas the number of electricity connections is significantly positively associated with the length of babies. Both sets of services are complementary with maternal education: the effects are largest, and significant, for children whose mothers have at least some elementary education.

The positive correlation between all three sets of services and child height is also observed in urban Brazil but the height of rural children is positively associated only with the number of electricity connections and is inversely associated with the number of water connections. This most probably reflects problems in our measures of the health environment in rural areas; modern water and sewerage infrastructure is likely to be available primarily in urban areas and so it would be useful to have more detailed information on, for example, water sources in rural areas (recall that *municipios* in general contain both urban and rural areas). Unfortunately, these data are not available at a *municipio* level. We suspect that in the rural sector the number of electricity connections is indicative of the existence of a broader range of services.

Conditional on this level of infrastructure, the per capita number of buildings in the *municipio* may be interpreted as indicative of the number of

[35]For each *municipio*, the IBM reports the number of buildings, the number with water connections, and so on. To the extent that buildings are underreported, for instance in *favellas*, errors will be encountered. We have no information on these errors, but do know there is enormous heterogeneity in the availability of infrastructure (see table 1); this variation should help minimize any effects of misreporting.

buildings *without* modern water or sewerage facilities. They have a negative impact on child height which is significant in the urban sector. The impact is (absolutely) large and significantly negative for children with educated mothers, but positive for children with illiterate mothers. Maternal education and the number of buildings in a community are apparently substitutes.

When expenditure interactions are included in the model (table 4) the per capita number of water and sewerage hook-ups are significant determinants of child height. In the rural sector, water and sewerage services are complementary with per capita expenditure and this is also true of sewerage in the urban sector. Higher expenditure households apparently gain more from the availability of modern services as do children of better educated women. This may reflect the existence of better quality water and sewerage services in areas where higher income households live. More buildings (without modern services) and *PCE* are substitutes in both sectors, the interaction being significant for urban children.

Whereas the infrastructure discussed above is informative about the environment in which a child is raised, the per capita number of hospitals and clinics, doctors and nurses are measures of the availability and quality of health services. Among these, only the number of nurses per capita has an impact on child height – and the effect is negative, holding all other services constant. This effect is significant for urban children but not for children whose mothers are illiterate: for these women, presumably, whatever is behind the negative effect of nurses is offset by the availability of greater access to health care. The number of beds per hospital is an indicator of the size of each unit; larger institutions are associated with shorter children suggesting that children do not benefit from being near large centralized health facilities. These results may arise because health service quality is measured rather poorly. An alternative explanation could be that larger health facilities (with relatively more nurses) locate in poor areas (or where children are less healthy), in which case these services are not exogenous [Rosenzweig and Wolpin (1986)].

It has been argued that the quality of community education services may affect parents' investments in other dimensions of child human capital, including health. The effects of the quality of education services are reported in the bottom panel of table 3. None of the education services covariates is significant in the urban sector. Among rural children, the number of teachers per capita in the *municipio* is positively associated with child height, and this effect is strongest for better educated mothers; there may be complementarities between investments in human capital at home and at school.

5. Discussion

Our results demonstrate that local market prices and community infra-

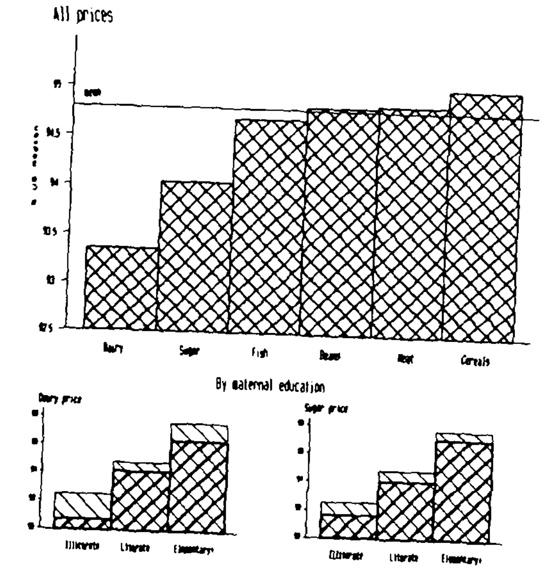

Fig. 1. Effect of two standard deviation changes in prices, on child height for age.

structure do have significant effects on child height, but it is difficult to infer the relative magnitudes of these effects from the tables. The standardized heights (as percentage of the U.S. median) associated with raising prices and improving access to infrastructure are presented in figs. 1 and 2.

Using the coefficients in the first column of table 3, the upper panel of fig. 1 displays the effect on the height of an average child when each price is raised by two standard deviations from the mean. Dairy and sugar prices have a sizable impact on child height. If the price of dairy products rises by two standard deviations, then mean standardized height falls from 94.8% of the U.S. median to 93.3%; for a boy aged five years, this is equivalent to about a 2 cm decline in height. A similar rise in sugar prices would reduce mean standardized height to 94%. A two standard deviation rise in cereal prices is associated with a *rise* of about 0.2% in average height.

The lower half of fig. 1 presents the effects of changes in dairy and sugar prices, distinguishing children of mothers with different levels of education, using the estimates in the last three columns of table 3. Since the height of an average child varies with maternal education, the base for each group is different: this base is represented by the bars with downward sloping lines. The height of the child after a two standard deviation rise in the price is represented by the bars with (heavier) upward sloping shading and so the

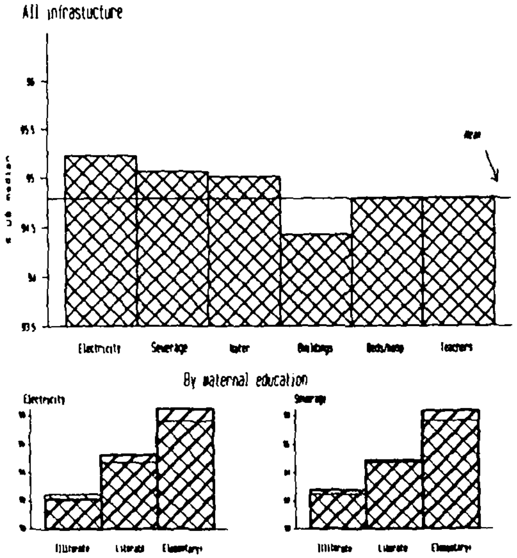

Fig. 2. Effect of two standard deviation changes in infrastructure on child height for age.

portion of the bars with single lines represents the *change* in height associated with the rise in price. (Notice the scales are different in the upper and lower halves of the figure.)

A two standard deviation rise in the dairy price will reduce the standardized height of a child with an illiterate mother by 1.8% to 90.7% of the U.S. median. The declines for children with better educated mothers are also large, although not quite as dramatic: 0.7% if the mother is literate and 1.3% if she has some schooling. A similar rise in the price of sugar is associated with a reduction in average child height of about 1% if the mother is illiterate; the reduction declines to 0.6% if the mother has some schooling. In Brazil, then, better educated mothers are able to partially offset the deleterious effects of higher food prices. Recall, however, that children of higher income households are more affected by some prices suggesting that these maternal education effects do not purely reflect the role of income.

The magnitudes of the changes in height associated with a two standard deviation increase in infrastructure are displayed in fig. 2 (with the same scales as in fig. 1 and again using the estimates in the first column of table 3). The effects are not as dramatic as those for prices. Increasing the availability of electricity is associated with average height rising 0.4%. The impact is, however, substantially larger in the rural sector, where the rise in height is

almost 2% (equivalent to over 3 cms in a five year old boy). Greater access to modern water and sewerage services is associated with a 0.2% increase in height (and these effects are slightly larger in the urban sector). These results add to the growing evidence that investments in basic infrastructure are likely to have a substantial payoff in their impact on child health.

Children of better educated mothers, and in higher income (urban) households, benefit more from the availability of sewerage and electricity. For example, whereas the height of a child of an illiterate mother will be increased by 0.3% with a two standard deviation rise in sewerage services, the rise for a child with a mother who has at least some elementary schooling is more than double that (0.7%). Similarly, a rise in electricity services is associated with a *decline* (of 0.4%) in the average height of a child with an illiterate mother, but a large increase (of 0.8%) if the mother has some schooling.

In contrast to the effects of water and sewerage *sanitation*, there is little evidence in these data of correlations between child height and the availability and quality of health services. Nor is there evidence that the quality of education services is associated with the height of children.

In sum, this paper has demonstrated that, over and above household characteristics, local prices and infrastructure affect child height. In addition to varying with the age of the child, the effects of community characteristics are systematically correlated with maternal education and household resources. We have been able to identify those (public and private) investments which are likely to have the largest return to (long-run) child health as well as identify the probable distributional impact of these investments.

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