

Production of Health in Chinese households: Children's overweight and obesity[☆]

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Abstract

Modernization and subsequent changes in lifestyle have caused a dramatic increase in prevalence of overweight and obesity in China (WHO, 2000; Wu, 2006). Since obesity is one of the main forces driving Noncommunicable Diseases (NCDs), increases in prevalence of obesity in children lead to higher incidence of NCDs and reduction in health human capital. I use the China Health and Nutrition Survey (CHNS) to carry out structural estimation of health production function for children in China. Results suggest that calorie intake is the most important input in the production of excessive weight with an impact on weight three times larger than sedentary activities and six times larger than physical activities. Calorie intake also has a more than proportional effect on unhealthy extra weight. These results suggest that public health policies targeting obesity in children must focus on reducing excessive calorie intake.

Keywords: Intrahousehold Allocation, Human Capital, Health, China, Obesity

JEL: I1, D13

1. Introduction

Noncommunicable Diseases (NCDs) represent a significant financial burden for health systems because of the permanent stream of resources they demand. In addition, they harm economic growth through the reduction they impose on health human capital. Both of these effects are stronger when these diseases affect children because the flow of resources has a longer horizon and future workforce's productivity is reduced. One of the NCDs that has become epidemic in many countries is obesity, with Mexico and the US taking the lead (FAO, 2013). For the US, the estimated costs associated with obesity represent 5.7% of the national expenditure in health (Wolf and Colditz, 1998).

The obesity epidemic has also affected developing countries like China. The World Health Organization (WHO) identified increases in prevalence of obesity in the early 2000s (WHO, 2000). Since then, many studies have identified the same trend (Luo and Hu, 2002; Wu, 2006; Chen, 2008; Yan et al., 2012), and obesity has gradually become a public health issue in the country.

A successful intervention requires a good understanding of the drivers behind the epidemic, which comes down to understand how health, in particular healthy weight, is produced in Chinese households. From a technical point of view, this understanding means estimation of structural

parameters of the health production function. This paper estimates health production functions in China, with focus on overweight and obesity in children. Specifically, I estimate the structural parameters of the production of healthy weight associated with three inputs identified in the literature: calorie intake, physical exercise and sedentary activities. To guarantee consistency of the structural parameters, I estimate reduced-form demands for these inputs. Identification of the structural parameters provides an important tool for policy makers, as it allows to identify the most efficient mechanisms to tackle the obesity epidemic.

The focus of this paper is on production of health in the short run, specifically in health issues related to children's overweight and obesity in China. There are some motivations behind this focus. The first one is the significant increase in prevalence of obesity in China during the last couple of decades, which makes the analysis of obesity, its causes and possible effects of interventions a priority for policy makers.

A second motivation has to do with the choice of children instead of adults. It is reasonable to assume that children can make choices regarding calorie intake, physical and sedentary activities. At the same time, they do not have any control of the environment where they grow up, in particular household characteristics such as household size, income, parents' education and labor choices. This fact provides higher flexibility in the estimation, since many variables affecting choices of health inputs can be taken as exogenous for the child.

Data requirements for estimation of dynamic health

[☆]Essay # 2

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production functions (long-run) are extremely demanding, since the data has to fit optimal behavior through life, and it has also to be able to control for changes in the environment that can drive changes in the optimal behavior. For this reason I limit the scope of the analysis to production of health in the short-run.

The dataset I use is the China Health and Nutrition Survey (CHNS)¹, a longitudinal household survey with information at the individual, household and community level. Most of the collected data has to do with objective and subjective measures of health status and demand for health inputs such as health care, time allocation, nutritional intake and physical activities. In addition, the CHNS collects information on basic socioeconomic variables².

The paper is organized as follows. Section 2 provides a theoretical framework for the empirical model presented in Section 3. Section 4 presents estimates of the parameters of the production function and the demands for inputs. Section 5 concludes.

2. Literature

2.1. Theoretical framework

At a micro level, health human capital is determined by choices made by individuals and/or households³ (as well as subsequent outcomes) regarding goods that affect children’s health. Specifically, the literature in health economics suggests that the health status of an individual in the short-run is the result of a production process. In this process, inputs such as medical care or dietary habits are combined to produce health (Rosenzweig and Schultz, 1983). In the long-run health plays the role of capital stock (health human capital) where individuals are endowed with an initial stock that can be changed by investment/divestment⁴ and whose return is healthy time⁵ (Grossman, 1972a)⁶. A comprehensive analysis of both branches of literature is developed by Strauss and

Thomas (2007) and Grossman (2000). As mentioned before, this paper focuses on production of health in the short run⁷. Given this focus, from now on I will refer to short-run health production functions for children as production functions.

The standard approach is to model health as a production function of the household, as proposed by Rosenzweig and Schultz (1983). This function uses three inputs: goods that affect both health and utility directly (e.g. alcohol, food), goods that only affect health (e.g. prevention) and unobservable health endowments. By solving the utility maximization problem subject to the health production function and budget constraints, it is possible to derive reduced-form demand functions for health inputs and health outcomes, that will depend on prices, money income and health endowments.

Formally, households’ preferences U are defined over three goods: child health H , n goods that do not affect health X_a (e.g. clothing) and $m - n$ goods that affect health Y_b (e.g. food) as follows:

$$U = U(H, X_a, Y_b), \quad a = 1, \dots, n; \quad b = n + 1, \dots, m. \quad (1)$$

Production of child’s health is represented by:

$$H = \Gamma(Y_b, I_c, \mu), \quad c = m + 1, \dots, r \quad (2)$$

where I_c denotes $r - m$ health inputs that do not have a direct effect on utility (e.g. immunizations), and μ represents family-specific health endowments. To close the model, the household faces a budget constraint:

$$F = \sum_d Z_d p_d \quad d = 1, \dots, r. \quad (3)$$

where F represents income, p_d are the prices of the r goods and $Z = X \cup Y \cup I$. Households choose goods X_a, Y_b, I_c to maximize utility (1) subject to the health technology (2) and the budget constraint (3). The solution is characterized by reduced-form demand functions for all r goods:

$$Z_l = S_l(p, F, \mu) \quad l = 1, \dots, r. \quad (4)$$

with the subsequent reduced-form for health outcomes (also known as health demand function):

$$H = \psi(p, F, \mu) \quad (5)$$

Estimation of equation 4 or 5 alone does not allow to determine causal effects from inputs to outcomes, as there is no direct connection between them. For this reason the literature has proposed to use hybrid health production functions (Mwabu, 2007), where the health outcome H is

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²A detailed explanation of the survey is presented by Popkin et al. (2010).

³Decisions made by households means that some households members made the choice, in contrast with decisions taken by only one member.

⁴Investment is usually related to health inputs as the ones mentioned before. Divestment is related to habits such as smoking or excessive calorie intake, that decrease the stock of health.

⁵Healthy time might be interpreted as Quality Adjusted Life Years - QALYs (Bravo Vergel and Sculpher, 2008).

⁶The differentiation between production of health in the short-run and in the long-run is also known as static and dynamic production functions, respectively.

⁷Grossman (1972a,b) provides a theoretical and empirical framework for production of health in the long-run. Ng et al. (2012) explores some dynamic correlations in a model of weight for China, and Behrman and Rosenzweig (2004) analyze long-term effects of investment in health.

a function of a good (Y_m) that affects health either directly (Y_b) or indirectly (I_c), and the other variables in the reduced form, that is, prices p , income F and health endowments μ , as shown in (6):

$$H = \theta(Y_m, p_l, F, \mu), \quad l = 1, \dots, m-1, m+1, \dots, r \quad (6)$$

Reduced forms (4) and (5), the health production function itself (2) and the hybrid health production functions (6) constitute the theoretical framework in which most of the empirical work regarding production of health in households is based on (Mwabu, 2007). The next step is to define a theoretical framework for the specific health outcome of overweight and obesity.

By definition, obesity is caused by an imbalance between calorie intake and calorie expenditure. Finkelstein et al. (2005) review the economic causes and consequences of obesity identified in the literature. The imbalance has been caused mostly by technological change (Cutler et al., 2003; Lakdawalla et al., 2005; Philipson and Posner, 2003), that has reduced the relative price of mass-produced calorie-dense foods, increased the value of time and reduced the calorie expenditure.

The reduction in relative prices of this type foods has caused an increase in consumption of carbohydrates (including soft drinks) and changes in eating patterns. New eating patterns are characterized by more people consuming snacks, higher frequency of consumption of snacks per day and increases in the size of portions in each meal. The increase in real wages has led to an increase in the opportunity cost of time, which induces substitution of home-cooked meals in favor of foods eaten away from home (restaurants and prepackaged foods), which in turn have a higher calorie density. At the same time, higher wages induces substitution of time exercising in favor of time working (substitution effect). Finally, technology has reduced the energy expenditure in the workplace by shifting away manual employment, as well as energy expenditure at home through the increased use of labor-saving devices.

Most of the work has been focused on developed countries, specially on the US where the prevalence of obesity is particularly high. However, the WHO has identified the expansion of this epidemic to other developing countries (WHO, 2000) which has motivated research of the obesity epidemic in these countries (Arroyo et al., 2004; Philipson and Posner, 2008; Loureiro and Nayga, 2005).

One of the countries reached by the epidemic is China, and as the country has quickly caught up with the industrialization process of the Western countries, the causes and consequences of obesity identified in the literature follow very close the ones already explained for the US and developed countries. In particular, Chen (2008) describes the recent trends of obesity in China and analyzes how this has affected the prevalence of chronic diseases. Wu (2006) identifies reductions in physical activity and labour intensity. Reductions in physical activity are associated to

lower expending of energy on traditional forms of transportation (e.g. walking, cycling) and the increasing popularity of cars, buses and motorcycles.

In general the causes behind obesity fit in the model described by equations 4-6. The reduction in relative prices of processed food is captured by changes in the price vector p . The reduction of calorie expenditure can be captured by how individuals allocate time. The main categories regarding time allocation are doing chores, working, attending school, exercising, sleeping and doing leisure activities (e.g. watching tv, internet). The first four activities contribute significantly to calorie expenditure⁸, while the contribution of the last two is marginal⁹. Thus, time allocation can be included as other good with some categories having a direct effect on health and other categories having an indirect effect through individual's preferences (e.g. leisure). As for the price of this good, it can be measured through the opportunity cost of time. An example of the use of this theoretical framework to analyze physical activities is the work by Cawley (2004) and Brad and Jane (2011).

There is a clear differentiation in the economic and epidemiologic literature between health in children and in adults. From the epidemiological point of view, there is more consensus about the standard measures and cut-off values of Body-Mass Index and another measures of obesity for adults. This point will be discussed in Section 2.2. From the economic point of view, the discussion is about who makes children's choices. This raises the question of how choices are made inside the household, which is the central topic of the literature on intrahousehold allocations (Behrman, 1997; Thomas and Strauss, 1995; Haddad et al., 1997; Browning et al., 2011). Mwabu (2007) discusses this issue in the context of health human capital. In this paper, I assume children make choices about health inputs, that is, calorie intake and time spend in physical and sedentary activities. Under this assumption, any other variable at household level represents exogenous changes in the environment.

2.2. Empirical work

Since health is multidimensional and hard to measure (Strauss and Thomas, 2007), the first issue to address regarding empirical work is how to define health, specifically the health outcome to be analyzed. Most of studies in production of health and demand for health have concentrated on estimation of demand for health care (Cameron

⁸Colman and Dave (2013) highlight the fact that, contrary to the common belief, recreational exercise only accounts for about 3-4% of total daily physical exertion. Thus, other activities such as doing chores and activity at work/school play a fundamental role in calorie expenditure.

⁹Time spent in leisure activities might be complementary to consumption of calorie-dense foods such as snacks. Thus, leisure can contribute to obesity directly through low calorie expenditure and indirectly through higher consumption of calories.

et al., 1988; Dow, 1999; Heller, 1982; Lindelow, 2005; Mogan et al., 2004).

The emphasis has been less strong when it comes to analyze health issues related to nutrition. There are two possible outcomes regarding nutrition: i) overweight and obesity and ii) underweight and thinness. The reasons driving obesity and thinness barely overlap, which makes it hard to model both at the same time. For this reason, this paper limits its scope to address the health issue of overweight and obesity.

The measure of health I use is the Body Mass Index (BMI), which is the ratio between weight in kilograms and height in meters squared. There are more precise measures of overweight and obesity (Burkhauser and Cawley, 2008); however, information to calculate most of these measures is hard to collect in household or health surveys¹⁰. Most of them are used in clinical studies (e.g. Eisenkolbl et al. (2001)) or in specific studies where the information is collected only for a selected subsample of a survey (e.g. Deurenberg-Yap and Deurenberg (2003)). One exception is the waist circumference and the waist-to-height ratio. Information for these indicators is easy to collect, making it available in many household/health surveys. In addition, waist circumference and weight-to-height ratio seem to be better predictors of cardiovascular disease in children (Savva et al., 2000).

Once a measure of health is defined, the next step is to identify the empirical challenges of estimating a health production function and how the literature has dealt with those challenges. The main two challenges are endogeneity of health inputs and heterogeneity of patients (Mwabu, 2007). Instrumental variables (IV) has been the method used to obtain consistent estimates with endogenous inputs¹¹, while fixed-effects with panel data¹² allow to take care of time-invariant unobservable heterogeneity¹³.

The work by Rosenzweig and Schultz (1983) was one of the first attempts to estimate a health production function. The health outcome in this study was the weight of a child at birth, and the inputs were the number of months the mother worked while pregnant, months of elapsed pregnancy before visiting a doctor, consumption of cigarettes, order of the live births and age. They dealt with the problem of endogeneity of inputs by using instrumental variables (IV) in 2SLS. As instruments they used prices

¹⁰For example, one way to measure body fat is by underwater weighing. The costs of measuring obesity in this way for a significant number of households are by far higher than the benefits of having a more precise measure.

¹¹IV also allows to control for observable heterogeneity, as observable characteristics of the individual and the household can be included as control variables in the reduced-form demand equations. In addition, joint estimation of the production function and demand equations by 2SLS allows to improve efficiency (Rosenzweig and Schultz, 1983)

¹²An exception is the work by Team (1992), that uses random-effects with instrumental variables to get consistency.

¹³This includes health endowments (μ in equation (2)) and the shadow price of health.

at community-level, husband's income and parents' education. The absence of panel data did not allow them to control for unobservable heterogeneity. Even though Rosenzweig and Schultz (1983) does not deal with obesity issues, it develops the standard methodology for estimation of health production functions.

Other papers have explored obesity issues for adults in developed countries. Rashad (2006) uses three waves of the National Health and Nutrition Examination Survey (NHANES) to estimate BMI in US adults as a function of activity-adjusted calorie intake and smoking, using prices, cigarette tax, temperatures and indoor air laws at the state-level as instruments. The way she controls for observable heterogeneity is by including characteristics such as education, income, marital status and state of residence as controls in the second stage of the 2SLS estimation. By not including these characteristics in the first stage, she fails to account for the effect of heterogeneity on demand for health inputs. As pointed out by Rosenzweig and Schultz (1983), missing to account for this effect introduces significant bias in the estimates.

An additional drawback comes from using adults as the unit of observation. when this is the case, it is not possible to use some control variables as exogenous. The best example is household income, as it is determined by adults' labor choices, even though the variable is at household-level¹⁴. Finally, Rashad does not specify a production function, which makes the estimates of the second stage difficult to interpret.

Contoyannis and Jones (2004) uses data from the Health and Lifestyle Survey (HALS) in the UK to estimate structural parameters of the production function for adults. This study exploits the panel structure of the data to use lags of inputs and outcome as regressors in a cross-sectional multivariate probit model. One important limitation is that the dataset only allows to measure all the lifestyle variables or health inputs¹⁵ as binary variables, with all the loss of information implied by that¹⁶. Also, the explained variable is a self-reported health indicator that takes the value of 1 is the individual rates his health as excellent or good and zero otherwise. This is a problem, as the meaning of excellent and good changes depending on socioeconomic status and the question does not even ask for a specific morbidity (Strauss and Thomas, 2007). An additional problem comes with the seven years elapsed between the waves of the survey used to fit the model. It is hard to believe that lifestyles today will have an effect on health only after seven years.

¹⁴An additional complication is given by the fact that labor market outcomes are affected by health status (Strauss and Thomas, 2007, sec. 2.1.3). Thus, not only income is endogenous, but also it is determined by health status, which is endogenous.

¹⁵Specifically, they include diet, smoking, exercise, alcohol consumption, sleep and absence of obesity.

¹⁶One of the lifestyle variables is whether or not the individual is obese, based on measurements of BMI. Since BMI is by itself a measurement of health, the introduction of this variable adds simultaneity bias in the model.

As better data has become available, more recent studies have been able to control for additional factors and to study the influence of more specific variables. One example is [Brad and Jane \(2011\)](#), (but this one is just an estimation of demand for physical activity for adults in US using IV for income. Survey by phone. [Colman and Dave \(2013\)](#))

Leaving aside adults as the unit of observation, some authors have focused their attention on health in newborns ([Rosenzweig and Schultz, 1983, 1982](#); [Schultz, 1984](#); [Team, 1992](#)). In these studies, the health outcome variable is birth weight, gestational age, child mortality, or some illness such as diarrhea or Febrile Respiratory Infection, while the inputs are parents choices such as whether they smoke or not, number of children, parent’s age and time elapsed before the mother visited a medical doctor. The method of estimation is 2SLS to obtain consistent estimates of the parameters of the production function (structural parameters). Unfortunately, the lack of panel data information did not allow them to control for unobservable genetic endowments.

Children have received less attention in the literature of estimation of health production functions. Some authors have only limited the attention to measure the economic cost of overweight children ([Johnson et al., 2006](#)). Others have restricted the sample to exclude children from the analysis ([Colman and Dave, 2013](#)) in order to simplify the model¹⁷.

There are two studies that empirically address the obesity issue in children. The first one is [MacInnis and Rausser \(2005\)](#) who study the effect of high-energy density in food on childhood obesity in the US. The study includes children aged two to ten years and uses household-level fixed-effects to get rid of unobservable determinants of health. As pointed out by the authors, they do not intend to establish causality, which is the main reason for not accounting for the endogeneity of energy intake. The second study by [Chou et al. \(2008\)](#) analyzes the effect of television fast-food restaurant advertising on children (ages 3-11) and adolescents’ (ages 12-18) overweight in the US.

This paper contributes to the literature in obesity in several aspects. First, it provides consistent estimates of structural parameters for health production functions in children regarding obesity issues. As pointed out in previous paragraphs, most studies have focused on adults and newborns, leaving aside children. Consistent estimation of these structural parameters allows to identify which inputs have a higher impact on children’s health and therefore they represent a rich source of information to prioritize public health policies.

A second contribution is to exploit the information for health collected by the CHNS to carry out this estimation. The CHNS has many advantages for estimation of production functions, including the panel-data structure, which

¹⁷Exclusion of children simplifies the model, as the decisions sets for adults and children are not the same.

allows to control for unobservable heterogeneity, objective measures of health outcomes and inputs, individual and household-level information to control for observable heterogeneity, and community-level information that provides good instruments for endogenous inputs. I am not aware of any study that has exploited all these characteristics of the survey in order to carry out estimation of health production functions. The use of the CHNS also contributes in providing information of how the obesity epidemic has reached a developing country like China. As mentioned before, most of studies have used data for developed countries, in particular the US.

3. Econometric Model

3.1. Data

The China Health and Nutrition Survey is a longitudinal survey covering about 4.400 household and 26.000 individuals in nine provinces in China. The survey collects information at the individual, household and community level. Up to now, the survey has collected information in eight waves: 1989, 1991, 1993, 1997, 2000, 2004, 2006, and 2009¹⁸. The CHNS team introduced some changes in the questionnaire after 2000. In order to use only consistent information, I use data from the three last waves.

The sample of interest are children, defined by the survey as individuals between 6 and 17 years old. To control for unobservable health endowments, I use children who have at least two observations across time (panel) in two consecutive surveys¹⁹. The CHNS has 1596 children in 1321 households satisfying these conditions²⁰.

The output for the health production function is the deviation from ideal BMI. I measure this deviation as the difference between child’s BMI and ideal BMI for his age and gender. To define the ideal BMI, I use the classification of BMI in four categories: underweight, normal, overweight and obesity. These categories are defined based on the 85th, 90th and 95th percentiles of the distribution of BMI in a sample of individuals. Thus, the critical values defining the categories change according to the population represented in the distribution. Standard values are usually based on samples of individuals in developed countries²¹. For example, [Cole et al. \(2007\)](#) define categories of

¹⁸Information was already collected for 2011 but not all datasets are available.

¹⁹One way to relax this inclusion restriction is to include children with two observations in any survey, which would increase the number of children in the sample. This introduces additional complications, as it is necessary to assume that the health endowments are constant across different periods of time. However, the problems of consistency of information across surveys significantly limit the potential gains that can be obtained from relaxing the restriction.

²⁰The number of observations in the econometric results might change due to missing values in some variables.

²¹The [World Health Organization](#) and the [Center for Disease Control and Prevention \(CDC\)](#) use these standard values to define standard categories for weight.

BMI based on a sample of children and adolescents from Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States.

In spite of the popularity of these standard measures, the significant variation in anthropometric characteristics across regions in the world has undermined their relevance, and new studies suggest to use cut-off values based on distributions representing people from the same region (Deurenberg-Yap and Deurenberg, 2003). I use the cut-off values for children in Shanghai proposed by Jiang et al. (2006) to define normal weight, overweight and obesity by age and gender.

I define the ideal BMI as the lower bound of the interval defining normal weight for each age and gender. Thus, the measure I use as health outcome for each individual is the deviation from the lower bound of normal weight. Since the focus of the study is obesity, I exclude all children whose BMI is below normal (thinness).

The inputs of the production function are calorie intake (calories per day), time doing physical activity and time spent in leisure activities, the last two measured in hours per day. Regarding calorie intake, the survey collects information of food consumption for every individual in the household for three consecutive days, and calculates the calorie intake based on consumption of carbohydrates, protein and fat.

Physical activity is measured as the number of hours per day spent on doing exercise, working and doing chores. Exercise includes the time spent in school and outside school doing physical exercise as well as the time spent in transportation by walking or biking in round trip from home to school²². Working includes the time the child spent in a job as well as the time in other occupations such as home gardening, collective and household farming and fishing, raising livestock, handicraft and household business. Regarding chores, the survey asks for the number of hours per day the child spent in buying food for the household, preparing and cooking food, washing and ironing clothes and cleaning the house.

Leisure time is the number of hours per day the child spends in watching tv, playing video games, using the computer, reading books, playing with toys and sleeping. Additional variables are the instruments for the health inputs and the ones that account for observable heterogeneity. A description of health outcome, health inputs, instruments and heterogeneity for the sample of interest is presented in Table 1.

It can be seen that in average children in the sample deviate 2.85 kilograms per square meter from their ideal BMI. The average calorie intake is around 1952 kilocalories per day, and children in average spend 1.41 hours per day doing physical activities and 3.89 hours per day in

²²The survey does not collect information on how much time the child spend in school. Attending school is also a physical activity. This introduces some measurement error in the model, that is partially compensated by the inclusion of the time exercising at school.

Table 1: Descriptive statistics

Variable	Mean	Standard Deviation		
		Overall	Between	Within
BMI Deviation	2.85	2.42	2.40	0.56
Calories	1952.34	719.86	646.81	338.46
Physical Act.	1.41	1.90	1.93	0.61
Sedentary Act.	3.89	2.11	2.01	0.91
Age	12.89	2.49	2.44	0.90
Male?	0.55	0.50	0.50	0.00
Education Head	8.37	4.48	4.35	0.87
HH Income	9.06	9.92	10.03	3.11
Price Fish	4.91	2.03	2.05	0.21
Price Grain	5.78	1.85	1.71	0.77
Assets Sedentary?	2.16	1.78	1.67	0.82
Urban?	0.97	0.16	0.16	0.05

sedentary activities. The table also shows that most of variation in the sample comes from between variation: for most of the variables the between variation is around five times the within variation. This suggests the Fixed-Effects estimator might not perform well in this sample. The next section further explores this issue.

3.2. Econometric Model

The model has two components: the health production function (equation 2) and the demands for health inputs (equations 4). The health production function for child i in household j in year (wave) t is:

$$DBMI_{i,t} = \Omega(Y_{i,t}, \mu_i | Het_{i,t}) + \varepsilon_{i,t} \quad (7)$$

where $DBMI_{i,t}$ is the deviation of ideal BMI, $Y_{i,t} = [C_{i,t}, E_{i,t}, L_{i,t}]$ is the vector of health inputs, $C_{i,t}$ is the calorie intake per day, $E_{i,t}$ is the number of hours per day spent in physical activities (exercise), $L_{i,t}$ is the number of hours per day spent in leisure activities, μ_i are the health endowments, and $Het_{i,t}$ is a conditioning variable representing heterogeneity. Reduced-form demands²³ for health inputs are represented in the set of equations 8:

$$Y_{i,t} = \Lambda(p_t, F_{j,t}, \mu_i | Het_{i,t}, Exo_{i,t}) + \xi_{i,t} \quad (8)$$

where p_t is a vector of prices in year t , $F_{j,t}$ is the income of household j in year t and Exo represents exogenous variables affecting the demand for health inputs (instruments). $\varepsilon_{i,t}$ and $\xi_{i,t}$ are idiosyncratic errors.

Heterogeneity is a conditioning variable in (8) because individuals with different characteristics (e.g. age or gender) will have different demands for health inputs. Inclusion of heterogeneity in (7) is justified by the fact that some characteristics imply significantly different technological-biological processes, which makes necessary to condition the estimates on these characteristics²⁴.

²³The CHNS does not have data for the prices of all inputs and household expenditures, which does not allow to estimate the complete structural demand system (Barnett, 1977; Pollak and Wachter, 1977).

²⁴Rosenzweig and Schultz (1982) include education, husband's income and race as observable heterogeneity in demand of inputs, and only race as heterogeneity conditioning the health outcome.

Ω is the functional form for the health production function, which is the structural equation to be estimated. It represents a technical-biological relationship between behavioral inputs and health outcome. Besides the results obtained in previous work, there is no economic rationality to specify a functional form a priori²⁵. For this reason I use a translog function, which can be interpreted as a second-order Taylor series approximation to a general but unknown production function (Christensen et al., 1973)²⁶. Thus, the production function I estimate is:

$$\begin{aligned} \ln DBMI_{(i,t)} = & \sum_b \alpha_b \ln Y_{b,(i,t)} + \frac{1}{2} \sum_b \gamma_b \ln Y_{b,(i,t)} \ln Y_{b,(i,t)} \\ & + \sum_b \sum_{c \neq b} \beta_{b,c} (\ln Y_{b,(i,t)} \cdot \ln Y_{c,(i,t)}) \quad (9) \\ & + \phi Het_{(i,t)} + \theta \mu_i + \varepsilon_{(i,t)} \end{aligned}$$

OLS estimates of this model are inconsistent because health inputs Y are endogenous and, in theory, health endowments μ cannot be observed by the researcher. I use the IV estimator to deal with the endogeneity of the health inputs. Prices of food²⁷ at community-level work as instruments for demand of calories, as they only affect child's BMI through changes in calorie intake. For leisure time I use a dummy variable for whether the household owns leisure-related assets, that is, VCR, TV (Black/White or Color), Computer, DVD player and Satellite Dish²⁸. Identification of the parameter for physical activities relies on exogenous variation of observable heterogeneity, such as age, gender, parent's education, income, household size and living in urban areas²⁹.

The second issue to deal with is the fact that health endowments are unobservable. There are two ways to deal with this issue. The first one is to assume that μ is constant over time, which makes the model (9) a Fixed-Effects model, and the parameters can be consistently estimated

²⁵In contrast, production functions for firms only represent a technological process, the outcome is a tradable good and market competition leads to zero profits. These conditions allow to impose some structure to the function, such as homogeneity, diminishing marginal returns, etc. In the context of households the function represents a technological and also a biological process of a nontradable good, which does not allow to impose structure in the functional form.

²⁶Boisvert (1982) presents the properties of the translog function and possible interpretations. Kim (1992) analyzes methods of estimation.

²⁷The survey classifies prices of food in six categories: grains, oils, vegetables, meat, milk, processed milk, fish and bean curd.

²⁸The CHNS also asks for self-reported values of these assets. Even though the value has more variation that might help to identify the parameters, it introduces significant measurement error coming from self-reported values. For this reason I prefer to use the dummy variable.

²⁹Bredenkamp (2008) examines the determinants of child nutritional status in seven provinces of China, and find a significant effect of being an only-child and no significant effects of income and access to quality of healthcare. I also included being an only-child as a control variable. However, estimates suggest that variation of this variable is already captured by household size.

by a Fixed-Effects estimator. Unfortunately, within variation in the sample is relatively small, which implies that this strategy might lead to imprecise estimates.

Another way to deal with μ is to exploit the panel nature of the dataset to include good proxies for health endowments. One variable that represents health endowments is the lagged deviation from ideal BMI ($DBMI_{i,t-1}$), as unobservable medical conditions that cause obesity in t should have also caused obesity in $T < t$ ³⁰. Another set of variables has to do with parents' health, in particular, parents' obesity³¹ (current and lagged) and whether the parents have high blood pressure, diabetes, myocardial infarction or apoplexy³². Under this strategy both within and between variation can be used to precisely identify the parameters³³, and Pooled OLS or Random Effects estimators can provide consistent estimates³⁴.

4. Estimation of Health Production Functions

The first result is that the interaction terms and squared terms in the translog production function are neither individually nor jointly significant in any specification. For this reason, from now on I only consider estimates under the Cobb-Douglas production function, that is, assuming $\beta = \gamma = 0$. Tables 2-4 show estimates of the demands for inputs using IV Fixed Effects (IV-FE), IV Pooled OLS (IV-POLS) and IV Random Effects (IV-RE), respectively.

As expected, the lack of within variation leads to imprecise estimates. It can be seen that the FE estimator has a very low explanatory power and higher standard errors of the coefficients compared to the IV-POLS and IV-RE estimators. The coefficients have the expected sign. Calorie intake is affected by health endowments, in particular being overweight or obese in the previous wave ($DBMI_{t-1}$) implies a higher calorie intake in the current wave³⁵. Aging increases calorie intake, as a bigger body has more caloric needs. Calorie intake is also increased by household income and price of grains, and it is decreased by price of

³⁰Other studies support the choice of this variables to control for health endowments. For example, Luo and Hu (2002) finds early childhood overweight, parental overweight are good predictors for overweight in children between 10-14 years old. Other good predictors are high income and living in urban areas. Those are included as control variables representing observable heterogeneity in the demands for health inputs.

³¹By definition, it can only be measured for those children in the sample who can be identified as sons. Some children do not live with their parents, which means they have to be excluded when variables for parent's health are used.

³²The survey asks these questions only to children age 12 and older, which does not allow to include these dummy variables of child's health as proxies for health endowments.

³³In addition, it allows to identify the coefficients of time-invariant regressors.

³⁴Compared to Pooled OLS, Random Effects has the advantage of assuming that the individual effects varies across observations, which is more defensible when the endogenous variable is health.

³⁵This also shows that there is no reverse trend of obesity in China. If it were, obese people should be changing their health habits, one of those being a reduction in calorie intake.

Table 2: Demand for Inputs: IV Fixed-Effects

	Calorie Intake	Physical Activity	Sedentary Activity
$DBMI_{t-1}$	0.0268 (0.0225)	-0.0078 (0.0765)	-0.021 (0.0416)
Age	0.0317*** (0.0112)	0.1171*** (0.0382)	-0.0376* (0.0207)
Male?	- -	- -	- -
Education head	-0.0044 (0.0102)	-0.0365 (0.0348)	-0.0076 (0.0189)
HH Income	0.004 (0.003)	0.009 (0.0101)	0.0048 (0.0055)
HH Size	0.0595 (0.0435)	-0.1146 (0.1479)	-0.1044 (0.0803)
Price fish	-0.0135 (0.0115)	0.0593 (0.0391)	0.0161 (0.0212)
Price grains	0.0181* (0.0108)	0.0023 (0.0366)	-0.0125 (0.0199)
Assets for sedentary?	-0.0049 (0.1929)	0.3562 (0.6555)	0.4243 (0.3561)
Live urban?	- -	- -	- -
Constant	6.8502*** (0.3539)	-1.7251 (1.203)	1.7636*** (0.6536)
F	2.41	2.75	0.91
Prob > F	0.016	0.0064	0.51
R2	0.0089	0.0609	0.0176

fish. The remaining variables are not significant, and their sign changes depending on the estimator. As expected, exogenous changes in prices, in particular price of grains and fish, induce significant changes in calorie intake³⁶. In addition, observable heterogeneity represented in age also induces exogenous changes in the demand for calories.

Regarding physical activity, the deviation from ideal BMI in the last wave has a negative effect on the number of hours per day doing physical activity in the current wave. Household income has a positive but not significant effect. In contrast, education of the head of the household has a significant negative effect on this variable³⁷. Also, boys do more physical exercise than girls. Thus, identification of physical activity is provided by variation across children on gender, and also by variation across the sample in education of the head.

Sedentary activity is negatively affected by health status in the last wave; however this effect is not significant. Together with the previous results for this variable, it seems that health endowments do not have an indirect effect on the production function through the demand for health inputs; instead there is only a direct effect in the health production function as expressed in equation 2. The magnitude of this effect will be examined in the results for the second stage. Assets related to sedentary activities have a positive and significant effect on the number of hours children spend in sedentary activities. Also, household size

³⁶The effect of other prices is not as strong as the one from price of fish and grains. In order to avoid introducing additional noise, I exclude the use of other prices as instruments.

³⁷Spouse's education was not included as it was not significant in any specification.

Table 3: Demand for Inputs: IV Pooled OLS

	Calorie Intake	Physical Activity	Sedentary Activity
$DBMI_{t-1}$	0.0107 (0.0081)	-0.04 (0.0275)	-0.0095 (0.0128)
Age	0.0374*** (0.0041)	0.1302*** (0.0141)	-0.0022 (0.0065)
Male?	0.1201*** (0.019)	0.1369** (0.069)	0.0306 (0.0331)
Education head	0.0057** (0.0024)	-0.0139* (0.0083)	0.0007 (0.0042)
HH Income	0.0012 (0.0008)	-0.0002 (0.0037)	0.0016 (0.0015)
HH Size	-0.0046 (0.0051)	-0.0207 (0.0174)	-0.0253*** (0.0083)
Price fish	-0.0164*** (0.0052)	0.0284* (0.0171)	-0.0039 (0.0091)
Price grains	0.0115** (0.0048)	0.016 (0.0171)	0.0054 (0.009)
Assets for sedentary?	0.0255 (0.0691)	0.0825 (0.19)	0.4282*** (0.1452)
Live urban?	-0.0151 (0.0217)	0.0543 (0.0746)	0.1414*** (0.0357)
Constant	6.9783*** (0.1019)	-2.1262*** (0.3139)	0.8878*** (0.1934)
F	17.42	10.91	4.26
Prob > F	0.00	0.00	0.00001
R2	0.1341	0.0856	0.0445

Table 4: Demand for Inputs: IV Random-Effects

	Calorie Intake	Physical Activity	Sedentary Activity
$DBMI_{t-1}$	0.0102 (0.0078)	-0.037 (0.0281)	-0.0103 (0.0136)
Age	0.0368*** (0.0038)	0.1315*** (0.0137)	-0.0034 (0.0066)
Male?	0.1213*** (0.0196)	0.1233* (0.0704)	0.0258 (0.034)
Education head	0.0058** (0.0024)	-0.0136 (0.0086)	0.0008 (0.0042)
HH Income	0.0012 (0.001)	-0.0001 (0.0035)	0.0017 (0.0017)
HH Size	-0.0048 (0.0052)	-0.019 (0.0187)	-0.0261*** (0.0091)
Price fish	-0.0156*** (0.0052)	0.0297 (0.0185)	-0.0026 (0.009)
Price grains	0.0122** (0.0052)	0.0121 (0.0186)	0.0033 (0.009)
Assets for sedentary?	0.0266 (0.0589)	0.08 (0.2117)	0.4017*** (0.1022)
Live urban?	-0.019 (0.0218)	0.0494 (0.0783)	0.1414*** (0.0378)
Constant	6.9786*** (0.0941)	-2.1462*** (0.3384)	0.933*** (0.1635)
Wald	175	110	49
Prob > Wald	0.00	0.00	0.0001

has a negative and significant effect on this variable, as bigger households have more chores to do and more people, specially adults, will be using the assets related to leisure. Also, households located in urban areas spend significantly more time in doing sedentary activities. These instruments allow to identify the coefficient for sedentary activities in the production function.

The lack of within variation that causes the Fixed-Effect estimator to be imprecise also causes low values in the F-statistics testing the relevance of instruments. In contrast, the IV-POLS and IV-RE estimators provide a better global fit of the model and the instruments for calorie intake and physical activity seem to be relevant instruments, as the F-statistic is higher than 10. In contrast, instruments for sedentary activity seem to be weak instruments.

Results for the second stage are presented in Table 5. To show the importance of accounting for the endogeneity of health inputs, I include two additional estimators: OLS and Pooled OLS (POLS).

Table 5: Health Production Function

	OLS	Pooled OLS	IV-FE	IV-Pooled OLS	IV-RE
Calorie intake	0.201** (0.08)	0.188** (0.083)	-0.001 (1.275)	1.39*** (0.448)	1.337*** (0.451)
Physical activity	-0.023 (0.023)	-0.019 (0.024)	0.177 (0.272)	-0.285* (0.156)	-0.256* (0.151)
Sedentary activity	0.084* (0.048)	0.084* (0.046)	-1.246 (0.892)	0.496* (0.257)	0.547* (0.308)
DBMI _{t-1}	0.378*** (0.022)	0.36*** (0.027)	-0.275*** (0.078)	0.348*** (0.034)	0.316*** (0.03)
Constant	-1.145* (0.607)	-1.041* (0.627)	2.289 (10.337)	-10.662*** (3.353)	-10.305*** (3.354)
Obs.	1402	1402	1203	1203	1203

The first two columns show that missing to account for endogeneity of inputs introduces a huge bias in the estimates. For example, the estimates from the IV-POLS are in average six times bigger than the ones from OLS or Pooled OLS, and something similar happens when comparing IV-RE with OLS and Pooled OLS. As expected, individuals with higher calorie intake and who spend more time in sedentary activities have a higher deviation from their ideal BMI, and more time in physical activity helps individuals to get closer to the ideal BMI. Also, the standard errors for the IV-FE estimator are two or three times bigger than the standard errors in other models, which mostly reflects the imprecision derived from the lack of within variation in the sample. For this reason I exclude the FE estimator from the subsequent discussion.

Estimates show that the most important input for unhealthy increase of weight is calorie intake. The estimate has a value higher than one, which suggests increases in daily calorie intake have a more than proportional effect on unhealthy weight. Out of the three inputs, calorie intake is not only the one with magnitude higher than one but also the one with highest level of statistical significance.

Sedentary activities and lack of physical activities also contribute significantly to increases in extra weight. Since

both variables are measured in hours, the coefficients can be compared directly. The results suggest that the positive impact on extra weight of one additional hour in sedentary activities is almost twice the negative impact of one additional hour doing physical exercise.

5. Conclusion

Overweight and obesity have become a public health issue in China. I estimate the structural parameters of the health production function for children's overweight and obesity in China. Estimation of these parameters provide valuable information for policymakers because they identify the inputs with higher impact in the production of health in the household.

Estimations suggest that calorie intake is the most important input for unhealthy extra weight in children. The impact of reducing calorie intake is six times higher than the one from increasing physical activities and three times higher than the one from reducing sedentary activities. These results imply that the most effective way to tackle children's obesity in China is through policies targeting calorie intake.

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