

# Economic Growth, Lifestyle Changes, and the Coexistence of Under and Overweight in China: A Semiparametric Approach

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During 1991-2000 when a rapid economic growth and rapid changes in lifestyles were observed, China experienced a rapid increase in overweight while still experiencing significant food insecurity and underweight. This coexistence of under and overweight increases the prevalence of diet-related diseases and thus is associated with the significant social and economic costs (e.g., productivity loss and health care cost)<sup>1</sup>. It also offers a major challenge for food and nutrition policy in China because policies for reducing overweight (e.g., increasing the price of sugar) may adversely affect underweight people. Although the Chinese government has initiated activities to reduce the prevalence of under and overweight<sup>2</sup>, the improvement to date has been limited to reductions in underweight.

To examine potential drivers of the emerging coexistence of under and overweight, this article focuses on the changes in socioeconomic conditions associated with rapid economic growth in China during 1991-2000. While the coexistence of under and overweight has typically been analyzed as a problem of public health, it could also be discussed as an economic phenomenon. Economic theories provide at least three explanations for why people may become underweight or overweight in a medical sense: (1) people could rationally choose being thin or fat under certain economic conditions (e.g., Lakdawalla and Philipson (2002)); (2) people could rationally be thin or fat because foods are addictive (Becker and Murphy (1988)); and (3) people

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<sup>1</sup>He et al. (2005) find that 6.8% and 5.2% of total deaths among Chinese adults could be attributed to physical inactivity and underweight in 1999 and 2000, respectively.

<sup>2</sup>The State Council of China issued *the National Plan of Action for Nutrition* in 1997, which includes *the new Dietary Guidelines for Chinese Residents*. Moreover, the Ministry of Agriculture and the Ministry of Commerce promoted the intakes of soybeans and vegetables through subsidies, the development of a soybean industry, and the promotion of rural garden activities (Zhai et al. (2002)).

could be fat due to a self-control problem caused by a time delay in health losses from overeating (Culter et al. (2003)). Because our focus is the linkage between economic growth and the changes in the prevalence of under and overweight rather than individual behavior, we examine the role of socioeconomic conditions in nutrition transitions relating to the first explanation.

Our key questions are (1) whether any socioeconomic factor explains both increasing overweight (Body Mass Index (BMI)  $\geq 25\text{kg}/\text{m}^2$ ) and remaining underweight (BMI  $\leq 18.5\text{kg}/\text{m}^2$ )<sup>3</sup>, (2) whether China's continuing economic growth leads to further increase in the prevalence of overweight, and (3) whether China's rapid economic growth alone can lead to commensurate decrease in its remaining underweight. This article empirically investigates these questions adopting a new approach - the semi-parametric approach developed by DiNardo et al. (1996) [DFL approach].

The conventional approach has focused on estimating *mean influences* of socioeconomic changes on nutritional status. However, this approach supplies limited information required to analyze the relationship between socioeconomic changes and the emerging coexistence of under and overweight<sup>4</sup>. Moreover, existing studies have tended to assume a (log-)linear functional form relationship between nutritional status and socioeconomic factors. This assumption is questionable in the context of a sample that includes both under and overweight persons since it is plausible that the same changes in socioeconomic factors affect the nutritional status of under and overweight persons in a different way with a different magnitude.

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<sup>3</sup>For simplification, we use constant cut-off values and include obesity in the overweight group.

<sup>4</sup>The conventional approach needs to examine under and overweight populations discontinuously (e.g., using discrete indicators).

This study therefore estimates *distributional influences* of socioeconomic changes on nutritional status adopting the DFL approach. This approach provides a visually clear estimate of the effects of socioeconomic changes on the distribution of nutritional status without specifying their functional form relationships. Note that this approach allows us to analyze the effects on underweight, healthy weight, and overweight populations continuously and simultaneously, and is robust to the choice of the cut-off values for these clinical classifications. Based on the theoretical framework in Lakdawalla and Philipson (2002) (the LP model), we decompose changes in the distribution of BMI into the effects of the following explanatory factors: (i) the distribution of per capita income, (ii) the pattern of job-related activity, (iii) the distribution of other individual attributes (e.g., education level), (iv) food prices, and (v) residual.

The rest of the article is organized as follows. In section 2, we discuss potential linkages between economic growth and nutrition transitions in China during 1991-2000. Section 3 formalizes the relationship between body weight and key socioeconomic factors based on the theoretical framework in the LP model. In section 4, we briefly describe the semiparametric estimation technique that will be used to decompose changes in the distribution of BMI. Section 5 presents the data used and the estimation results. Summary and conclusions are provided in Section 6.

## **Potential Linkages between Economic Growth and Nutrition Transitions in China, 1991-2000**

The socioeconomic changes associated with economic growth in China during 1991-

2000 could mainly be characterized by the following three features: (1) income growth, (2) technological innovation, and (3) urbanization. Another important feature of recent economic growth in China is that these socioeconomic changes have unequally influenced different socioeconomic groups and regions.

First, based on common economic logic, income growth could lead to an increase in food consumption and thus an increase in weight, while it might also motivate people to be healthier by increasing the investment in health (e.g., healthy food and exercises). Because underweight people could improve their health status by increasing their weight, we expect that income growth leads to an increase in their weight. However, it is ambiguous how income growth influences the weight of healthy weight and overweight people since further increases in their weight may worsen their health status.

In China, per capita Gross Domestic Product rapidly grew at an 8.9% average annual rate during 1991-2000 (World Bank (2005)). Several studies have shown that recent income growth has significantly influenced the Chinese diet. For example, Guo et al. (2000) show that as people become richer they demand less rice and wheat and more pork and edible oil in China during 1989-1993, which results in positive income elasticities of total calories, protein and fat. Yen et al. (2004) also observe high expenditure elasticities for beef, fish and milk (1.40~1.41) among Chinese urban households in 2000. On the other hand, Fang and Beghin (2002) find that as income increases, the share of animal fat in total fat and oil consumption decreases among Chinese urban households during 1992-1998. This may imply that Chinese people start shifting their diets toward healthier ones when they become rich enough.

Second, technological innovation could lead to an increase in weight by simultaneously decreasing the cost of calories and increasing the cost of physical activity (Lakdawalla and Philipson (2002)). Improving production technology of agricultural commodities increases food production and supply, which can lead to a decline in the price of food (i.e., calories) and thus an increase in food consumption. At the same time, improving technology at work places makes job-related activity more sedentary and thus decreases daily energy expenditure. As a result, people need to give up leisure time and pay fees for undertaking physical activity (e.g., gym) rather than being paid for undertaking physical activity. In addition, technological innovation may increase the demand on skilled workers and thus increase the proportion of people who are engaged in more sedentary jobs.

According to the Food and Agriculture Organization (FAO) indices of agricultural production, per capita food production in China increased by 55% between 1991 and 2000<sup>5</sup>. At the same time, real producer prices for most food items declined. In particular, the prices of eggs, wheat and rice declined rapidly (FAO (2005)). A number of studies have found a significant and negative association between food prices and food consumption in China. For example, Guo et al. (1999) find that pork and oil tended to have high own-price elasticities (-0.38 and -0.30) in China during 1989-1993. Yen et al. (2004) find high own-price elasticities for milk and beef (-1.40 and -0.96) and low own-price elasticities for pork and fish (-0.21 and -0.37) among Chinese urban households in 2000. These results indicate that price elasticities of foods could be

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<sup>5</sup>Among the top 20 sources of per capita calories per day, the per capita supply of soybeans, pork, fruits, vegetables and eggs increased rapidly. As a result, per capita calorie supply increased by 10%, and the per capita supply of protein and fat per day (in grams) increased by 27% and 55%, respectively.

different by economic status, regions and time periods. It is especially important to note that changes in food prices influence the poor and the rich differently, and the influence on the poor tends to be larger (Guo et al. (1999)).

Occupation structure also shifted dramatically in China during 1991-2000. The proportion of employees in tertiary industry increased from 18.9% to 27.5%, while that of employees in primary industry decreased from 59.7% to 50.0%. In terms of sectors, we observed a rapid decrease in the proportion of employees in mining and geological prospecting sectors and a rapid increase in the proportion of employees in real estate, wholesale and retail services, and social services sectors (National Bureau of Statistics of China (NBS) (2003)).

Third, urbanization can be associated with several environmental changes contributing to an increase in body weight which are not captured by the factors examined above. For example, in urban environments, people tend to have less physical activity due to better transportation and tend to have more western diets containing more refined and high-fat foods due to the influence of the modern food industry and the mass media (Popkin (2001)). In addition, physical disconnection between places of work and residence and smaller households can cause a decrease in free time and thus the time for food preparation and exercise.

In China, urbanization proceeded rapidly during the 1990s. The number of public transportation vehicles per 10,000 people increased from 2.1 to 6.1, TV coverage rate of population increased from 77.9% to 94.2%, and average household size decreased from 3.96 to 3.44 during 1989-2001 (NBS (2003)). The proportion of people living in urban areas also increased from 28% to 36% during 1991-2000 (World Bank

(2005)). Popkin (1999) shows the associations between urbanization, changes in diet and physical activity and increasing overweight in China during 1989-1993.

Lastly, it would be important to note that the influence of economic growth has been unequally distributed across different socioeconomic groups and regions in China (e.g., Jones et al. (2004) and Kanbur and Zhang (2005)). Thus, other socioeconomic factors (e.g., education level) and the place of residence are also important determinants of the effects of economic growth in China. For example, household expenditure grew faster in urban areas (+93.2%) than in rural areas (+73.6 %) during 1991-2000, which exacerbated the expenditure gap between urban and rural areas. In 2000, average household expenditures of rural and urban areas were 2,037 yuan and 7,402 yuan<sup>6</sup>, respectively (NBS (2003)). The occupation structure is also diverse across regions. The proportion of employees in primary industry (tertiary industry) ranges from 8.5% (60.7%) in Beijing to 73.3% (17.9%) in Yunnan in 2002 (NBS (2003)). These gaps may explain why remaining underweight is observed mostly in rural areas rather than in urban areas. In the following section, we formalize the relationship between body weight and selected socioeconomic factors in an economic framework.

## **The Model of Weight Management**

Following the theoretical framework in Lakdawalla and Philipson (2002), this section formalizes the linkages between, income, job-related activity, food prices and body weight. Suppose that an individual's current period utility  $U$  depends on food consumption  $F$ , other consumption  $C$ , and his current BMI  $b$  (i.e.,  $U = U(F, C, b)$ ). We

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<sup>6</sup>The effect of price differentials between urban and rural areas is not controlled.



assume that he is monotonically better-off with higher levels of food and other consumption, while he has an “ideal BMI”  $b_o$  at given levels of  $F$  and  $C$  such that he is better-off by increasing his BMI when  $b < b_o$  and by decreasing his BMI when  $b > b_o$ . We also suppose  $\frac{\partial^2 U}{\partial F \partial C} \geq 0$ , which implies that food and alternative consumption are not substitutes.

BMI is considered as a capital stock that depreciates over time because it decreases without additional food intakes. Let  $S$  denote the strenuousness of job-related activities. Assume that  $S$  is a function of the average energy expenditure required for the job-related activities  $J$  and the income earned from the activities  $y_e$  such that  $S_J = \frac{\partial S}{\partial J} > 0$  and  $S_{y_e} = \frac{\partial S}{\partial y_e} \geq 0$ . The transition equation for BMI is:  $b' = (1 - \delta)b + g(F, S(J, y_e))$ , where  $\delta$  is a depreciation rate and less than one, and  $g$  is a continuous and concave function that is increasing in food consumption (i.e.,  $\frac{\partial g}{\partial F} > 0$ ) and decreasing in the strenuousness of job-related activity (i.e.,  $\frac{\partial g}{\partial S} < 0$ ). Then, the individual value function  $v$  can be expressed as:

$$\begin{aligned}
v(b) &= \max_{F, b'} \{U(F, C, b) + \beta \cdot v(b')\} \\
\text{s.t.} \quad & p \cdot F + C \leq y_e + y_u \\
& b' = (1 - \delta)b + g(F, S(J, y_e))
\end{aligned} \tag{1}$$

where  $y_u$  is unearned income and  $p$  is a food price. Suppose that  $U(\cdot)$  is continuous, strictly concave, differentiable and bounded. Then, the value function  $v(\cdot)$  is continuous, strictly concave and differentiable. Let  $U_X$  and  $g_X$  denote  $\frac{\partial U}{\partial X}$  and  $\frac{\partial g}{\partial X}$ ,

respectively. Then, the first order and envelope conditions are:

$$p \cdot U_C - U_F = \beta \cdot g_F \cdot v'(b') \quad \text{[First Order Condition]} \quad (2)$$

$$v'(b) = U_b + \beta \cdot (1 - \delta) \cdot v'(b') \quad \text{[Envelope Condition]}. \quad (3)$$

A unique and stable equilibrium can be obtained when the marginal utility of food ( $U_{F-p} \cdot U_C$ ) is falling in BMI (see Lakdawalla and Philipson (2002)). This condition implies that foods are not addictive. The equilibrium choice of BMI and food is obtained as a function of  $p$ ,  $J$ ,  $y_e$  and  $y_u$ ,  $b^*(J, p, y_e, y_u)$  and  $F^*(J, p, y_e, y_u)$ .<sup>7</sup>

While food prices and an average energy expenditure required for job-related activities are negatively correlated with the steady-state BMI  $b^*$  (i.e.,  $b_p^* = \frac{\partial b^*}{\partial p} < 0$  and  $b_J^* = \frac{\partial b^*}{\partial J} < 0$ ), the partial effect of income on  $b^*$  is ambiguous. Moreover, earned income  $y_e$  and unearned income  $y_u$  affect  $b^*$  differently because  $y_e$  influences job-related activities (i.e.,  $S$ ) through the labor market while  $y_u$  does not. Denote the partial effect of  $y_u$  on  $b^*$  by  $b_{y_u}^*$ . Lakdawalla and Philipson (2002) assume an inverted U-shaped relationship between unearned income and weight such that  $b_{y_u}^* > 0$  for the underweight and  $b_{y_u}^* < 0$  for the overweight. The effect of  $y_e$  is expressed as:  $b_{y_e}^* = \frac{\partial b^*}{\partial y_e} = b_{y_u}^* + b_S^* S_{y_e} \geq 0$ , where  $b_S^* S_{y_e} = \frac{\partial b^*}{\partial S} \frac{\partial S}{\partial y_e}$ . The first term is the direct income effect on BMI and equals the unearned income effect. The second term is the effect of earned income on BMI through the labor market. Lakdawalla and Philipson (2002) assume that the earned income effect will be statistically positive (negative) if job

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<sup>7</sup>Here, we assume that per capita income and occupational choice are endogenous but predetermined. In subsection 5.5, we examine the potential endogeneity of per capita income by comparing the results from using the asset index developed by Sahn and Stifel (2003).

activities are less (more) strenuous than leisure-time activity.

The total change in BMI over time is influenced by simultaneous changes in food prices, job-related activity, and income. Then, movements of  $b^*$  over time  $t$  are determined by:

$$\partial b^* / \partial t = b_p^* p'(t) + b_S^* S_J J'(t) + [b_{y_u}^* + b_S^* S_{y_e}] y_e'(t) + b_{y_u}^* y_u'(t) \quad (4)$$

The four terms on the right hand side of equation (4) represent the effects of food prices, job-related activity, earned income, and unearned income, respectively. Since  $b_{y_u}^* \geq 0$  and  $S_{y_e} \geq 0$ , the movements of  $b^*$  are ambiguous. Based on equation (4), we empirically decompose changes in the BMI density into the effects of selected socioeconomic factors and further investigate the partial effect of each socioeconomic factor on the BMI density.

## Estimation Method

This section presents how we decompose changes in the distribution of BMI into the effects of changes in socioeconomic factors adopting the semiparametric approach developed by DiNardo et al. (1996). First, we present the framework for estimating counterfactual densities of BMI associated with socioeconomic changes. Second, we describe how we decompose changes in the BMI density.

### *Estimating Counterfactual Densities of BMI*

Each individual observation  $(b, k, t)$  belongs to a joint distribution  $F(b, k, t)$  where  $b$  is a BMI,  $k$  is a vector of individual attributes, and  $t$  is a date.  $k$  consists of three

factors: per capita income  $y$ <sup>8</sup>, an average energy expenditure required for job-related activities  $J$ , and a vector of other attributes  $x$  (i.e.,  $k=(y, J, x)$ ). This distribution also depends on a vector of community-level food prices  $p$ . Thus, the joint distribution of BMI and individual attributes at date  $t$  is  $F(b, k|t; p_t)$ . Let  $t_\alpha$  represent a date of observation  $\alpha$ . Then, the density of BMI at date  $t$ ,  $f_t(b)$ , can be expressed as:

$$\begin{aligned} f_t(b) &= \int \int \int f(b|y, J, x, t_b=t; p_t) dF(y|J, x, t_{y|J, x}=t) dF(J|x, t_{J|x}=t) dF(x|t_x=t) \quad (5) \\ &\equiv f(b; t_b=t, t_{y|J, x}=t_{J|x}=t_x=t, p_t) \end{aligned}$$

Thus, for example,  $f(b; t_b=00, t_{y|J, x}=t_{J|x}=t_x=00, p_{00})$  represents the actual BMI density in 2000, and  $f(b; t_b=00, t_{y|J, x}=91, t_{J|x}=t_x=00, p_{00})$  represents the counterfactual density of BMI in 2000 had the income distribution remained as it was in 1991.

We first construct the counterfactual density of BMI in 2000 had only the distribution of  $y$  remained as it was in 1991 (i.e.,  $f(b; t_b=00, t_{y|J, x}=91, t_{J|x}=t_x=00, p_{00})$ ). We then examine what would have happened if only  $y$  and  $J$  had remained at the 1991 level. Finally, we examine the case that all  $y$ ,  $J$ , and  $x$  had remained at the 1991 level.

The counterfactual density  $f(b; t_b=00, t_{y|J, x}=91, t_{J|x}=t_x=00, p_{00})$  can be obtained by reweighting the actual density of BMI in 2000.

$$\begin{aligned} f(b; t_b=00, t_{y|J, x}=91, t_{J|x}=t_x=00, p_{00}) &= \quad (6) \\ &\int \int \int f(b|y, J, x, t_b=00; p_t) \psi_{y|J, x}(y, J, x) dF(y|J, x, t_{y|J, x}=00) dF(J|x, t_{J|x}=00) dF(x|t_x=00), \end{aligned}$$

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<sup>8</sup>Because of the limited data availability, our empirical analysis uses per capita income as the sum of earned and unearned income.

where the reweighting function  $\psi_{y|J,x}(y, J, x)$  is defined as  $\psi_{y|J,x}(y, J, x) = \frac{dF(y|J,x,t_{y|J,x}=91)}{dF(y|J,x,t_{y|J,x}=00)}$ .

Applying the Bayes' rule,  $\psi_{y|J,x}(y, J, x)$  can be expressed as:

$$\psi_{y|J,x}(y, J, x) = \sum_{c=1}^C I(y = c) \cdot \frac{Pr(y = c|J, x, t_{y|J,x} = 91)}{Pr(y = c|J, x, t_{y|J,x} = 00)}, \quad (7)$$

where  $I(\cdot)$  is an indicator function that takes the value 1 if the condition in parentheses is satisfied and 0 otherwise.  $y$  is divided into  $C$  classes.

Using the derivation similar to that for  $y$  in (6), we can also express  $f(b; t_b=00, t_{y|J,x}=t_{J|x}=91, t_x=00, p_{00})$  and  $f(b; t_b=00, t_{y|J,x}=t_{J|x}=t_x=91, p_{00})$  by reweighting the actual density of BMI in 2000, where reweighting functions  $\psi_{J|x}(J, x)$  and  $\psi_x(x)$  are expressed as:

$$\psi_{J|x}(J, x) = \frac{dF(J|x, t_{J|x} = 91)}{dF(J|x, t_{J|x} = 00)} = \sum_{d=1}^D I(J = d) \cdot \frac{Pr(J = d|x, t_{J|x} = 91)}{Pr(J = d|x, t_{J|x} = 00)}, \quad (8)$$

$$\psi_x(x) = \frac{dF(x|t_x = 91)}{dF(x|t_x = 00)} = \frac{Pr(t_x = 91|x)}{Pr(t_x = 00|x)} \cdot \frac{Pr(t_x = 00)}{Pr(t_x = 91)}, \quad (9)$$

where  $I(\cdot)$  is as defined above.  $J$  is divided into  $D$  categories.

Food prices also potentially influence body weight. We divide population into 11 region-district cells and estimate the mean shift in BMI due to changes in food prices for each cell  $m$ ,  $\Delta \hat{b}_m$ , using the translog functional form (individual attributes are controlled)<sup>9</sup>. Then,  $f(b|k, t_b=00; p_{91})$  will equal  $f(b - \Delta \hat{b}_m|k, t_b=00; p_{00})$ . The counterfactual density of BMI in 2000 had only food prices remained as it was in

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<sup>9</sup>We evaluate the effect of food prices on BMI at each cell's average level of food price changes using the estimated coefficients on food prices and regional dummies.

1991 can be obtained by integrating  $f(b - \Delta\hat{b}_m|k, t_b=00; p_{00})$  over the distribution of individual attributes  $k$ :

$$f(b; t_b=00, t_k=00, p_{91}) = \int f(b - \Delta\hat{b}_m|k, t_b=00; p_{00}) dF(k|t_k=00). \quad (10)$$

We estimate the actual and counterfactual density of BMI adopting the weighted kernel density estimator. For example, the estimate of the counterfactual density  $\hat{f}(b; t_b=00, t_{y|J,x}=91, t_{J|x}=t_x=00, p_{00})$  in (6) based on a random sample  $B_1, \dots, B_n$  of size  $n$  are

$$\hat{f}(b; t_b=00, t_{y|J,x}=91, t_{J|x}=t_x=00, p_{00}) = \sum_{i \in T_{00}} \frac{1}{n h} \psi_{y|J,x}(J_i, x_i) K\left(\frac{b - B_i}{h}\right), \quad (11)$$

where  $T_t$  is the set of indices of the sample at date  $t$ ,  $h$  is the bandwidth, and  $K(\cdot)$  is the kernel function.  $h$  is determined by the Sheather-Jones plug-in method. The kernel function used is Gaussian.  $f(b; t_b=00, t_{y|J,x}=t_{J|x}=91, t_x=00, p_{00})$ ,  $f(b; t_b=00, t_{y|J,x}=t_{J|x}=t_x=91, p_{00})$ , and  $f(b; t_b=00, t_k=91, p_{91})$  are estimated similarly.

An estimate of the reweighting functions can be obtained by estimating the conditional probabilities  $Pr(y=c|J, x, t_{y|J,x}=t)$ ,  $Pr(J=d|x, t_{J|x}=t)$  and  $Pr(x|t_x=t)$  using the multinomial logit model. The unconditional probability  $Pr(t_x = t)$  is equal to the number of observations in  $t$  divided by the number of observation in two time periods. The estimates  $\hat{\psi}(y|J, x)$ ,  $\hat{\psi}(J|x)$ , and  $\hat{\psi}(x)$  are computed using equations (7), (8), and (9).

### *Density Decompositions*

To examine the effect of each factor on changes in the density of BMI between 1991

and 2000, we adopt the following sequential decomposition:

$$\begin{aligned}
f_{00}(b) - f_{91}(b) = & \tag{12} \\
& [f(b; t_b=00, t_{y|J,x}=t_{J|x}=t_x=00, p_{00}) - f(b; t_b=00, t_{y|J,x}=91, t_{J|x}=t_x=00, p_{00})] \\
& + [f(b; t_b=00, t_{y|J,x}=91, t_{J|x}=t_x=00, p_{00}) - f(b; t_b=00, t_{y|J,x}=t_{J|x}=91, t_x=00, p_{00})] \\
& + [f(b; t_b=00, t_{y|J,x}=t_{J|x}=91, t_x=00, p_{00}) - f(b; t_b=00, t_{y|J,x}=t_{J|x}=t_x=91, p_{00})] \\
& + [f(b; t_b=00, t_{y|J,x}=t_{J|x}=t_x=91, p_{00}) - f(b; t_b=00, t_{y|J,x}=t_{J|x}=t_x=91, p_{91})] \\
& + [f(b; t_b=00, t_{y|J,x}=t_{J|x}=t_x=91, p_{91}) - f(b; t_b=t_{y|J,x}=t_{J|x}=t_x=91, p_{91})].
\end{aligned}$$

The five components on the right hand side of this equation represent the effect of per capita income, job-related activity, other individual attributes, food prices, and residual factors, respectively. One drawback of this method is that the estimates of the effect of each factor generally depends on the order of the decomposition. Thus, we will consider a decomposition in reverse order.

Estimation of the counterfactual densities in the sequential decomposition are obtained by substituting in equation (11) combinations of the estimates of the reweighting functions in Table 1. The reweighting functions in the reverse order decomposition are defined in the way similar to that in equations (7), (8), and (9).

## Empirical Results

### *Data*

We use data from the China Health and Nutrition Survey (CHNS) collected in nine

provinces<sup>10</sup> in China in 1991 and 2000. This survey is designed to examine the effect of socioeconomic changes on health status in China and well-suited to the issue analyzed in this article. This survey contains the information on anthropometry measures, per capita household income, occupations, education histories, household composition, and community-level food prices.<sup>11</sup>

In our analysis, we focus on individuals of age 18 to 60, which is the major working age group in China. Only individuals who reported information on all required explanatory factors are kept in our sample. We also exclude pregnant women from our sample because it is difficult to define their nutritional status using BMI.

We create the indicators for per capita income level: Very Low, Low, Lower Middle, Upper Middle and High levels. We deflate the value of per capita income using Consumer Price Index (1991=100) and divide a sample into five income levels using four percentiles (20th,...,80th) of the distribution of deflated per capita income in 1991 and 2000.

We also classify primary occupations into four categories (Sedentary, Light, Medium and Hard) as the indicators for an average energy expenditure required for job-related activities. We define these categories based on the criteria in the Dictionary of Occupational Titles (the U.S. Department of Labors Bureau of Labor Statistics).

As other individual attributes, we include age in year, indicators for highest education level attained, household size, proportion of children in the household, and region of residence. In addition, to control recent childbirth, we include an indicator

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<sup>10</sup>Heilongjiang is surveyed only in 2000.

<sup>11</sup>Details of the survey are found at the CHNS homepage (<http://www.cpc.unc.edu/projects/china>).



for breastfeeding for women.

We also include community-level market prices of eight food items: grain, sugar, eggs, vegetables, pork, chicken, beef, and fish. Food prices are deflated using Consumer Price Index (1991=100).

#### *Estimated Effects of Explanatory Factors on the BMI Density*

Figure 1 presents the kernel estimates of the actual densities of log BMI in 1991 and 2000 for men (Figure 1a) and women (Figure 1b). These figures show the raw changes in the density of log BMI which will be decomposed. In both gender groups, we observe a more mass at BMI above 22 and a less mass at BMI below 22 in the 2000 density than in the 1991 density.

To illustrate our decomposition method, Figure 2 depicts three kernel estimates of the log BMI density: (1) the actual log BMI density in 2000 (bold solid line); (2) the counterfactual log BMI density associated with changes in income distribution ('×' sign); and (3) the counterfactual log BMI density associated with changes in income distribution and other individual attributes (dotted line). The difference between estimates (1) and (2) represents the effect of changes in the income distribution on the log BMI density. Similarly, the difference between estimates (2) and (3) represents the effect of changes in the distribution of other individual attributes on the log BMI density.

Figure 3 presents the estimated effects of changes in each explanatory factor on the density of log BMI for men (solid line) and women ('+' sign). During 1991-2000, average income levels increased in all groups of underweight (+4.6%), healthy weight (+10.6%) and overweight (+37.3%), while the income distribution became

more unequal. These changes contributed to the decline of the lower and upper tails and the additional mass in the middle of the BMI density in both gender groups (Figure 2a). These findings imply the inverted U-shaped relationship between BMI and income levels, which reduces both under and overweight rates when overall income increases. This result is consistent with previous results for undernutrition (Haddad et al. (2003)) and may explain why income and nutrition inequality is negatively correlated in some countries such as India (Sahn (2003)).

We also observed a shift toward sedentary jobs and away from hard jobs. The dispersion in energy expenditures required for job-related activities increased twice more rapidly among women than among men. These shifts contributed to the decline of the lower tail and the fattening of the upper tail among men, and vice versa among women. These shifts also contributed to the additional mass in the middle of the BMI density in both gender groups (Figure 2b). These explain a decrease in underweight and an increase in overweight among men, and an increase in underweight and a decrease in overweight among women.

A key socioeconomic change in other individual attributes is a significant increase in the proportion of the population living in the coastal region and urban areas. This change contributed to a shift of a whole distribution toward a heavier level (Figure 2c), which explains a significant shift from underweight toward overweight.

On average, the deflated community-level prices of all food items except for vegetables declined during 1991-2000. In particular, the prices of eggs, fish and sugar decreased rapidly. Only the price of vegetables increased by 17%. These changes in food prices (-23% on average) contributed to a shift of a whole distribution toward a

heavier level (Figure 2d). The changes in food prices explain a significant shift from underweight toward overweight.

Lastly, the residual factor contributed to the additional mass at underweight level and the decline in the middle of the BMI density<sup>12</sup>. This indicates that there exist unobserved factors that counteract the downward effects of other factors examined above on the prevalence of underweight.

### *Quantitative Measures*

To provide numerical values for the graphical results in Figure 2, Table 3 presents the decomposition of summary measures of the prevalence and inequality of nutritional status (i.e., underweight and overweight rates and the Gini coefficient). On the whole, changes in the socioeconomic factors examined in this article explain increasing overweight much better than remaining underweight. Because a small share of remaining underweight is explained, changes in the factors have limited explanatory power for increasing nutrition inequality.

Table 3 also shows that changes in food prices and other individual attributes are main drivers of decreasing underweight and increasing overweight. Changes in the pattern of job-related activity are the only observed factor that explains remaining underweight. We also find that changes in other individual attributes play a key role in an increase in nutrition inequality, which is consistent with previous findings that regional gaps play an important role in increasing inequality in China (e.g., Jones et al. (2004)). It may also be worth noting that, contrary to the widely held belief, changes in income distribution contributes to a decrease in nutrition inequality.

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<sup>12</sup>The semiparametric estimate of the residual factor is not presented in this article. The effect of the residual factor is numerically presented in Table 3.

### *What Hinders Underweight Rates from Decreasing?*

A key question now is what the unobserved factors hindering underweight rates from decreasing in China during 1991-2000 are. We examine additional socioeconomic factors whose data are available only in 2000. Due to the limited data availability, these factors are not included in our analysis above. A key finding is that underweight rates are significantly higher in villages of national minorities (with no Han nationality) in Guangxi and Guizhou (13.6%) than in other villages with Han nationality (4.5%). This may imply the existence of community-level discrimination. We also examine the possibility of diseases that are not associated with socioeconomic status. 3.1% (0.8%) of respondents got somewhat (seriously) sick or injured during the past four weeks before their interviews, and thus diseases may partially explain remaining underweight. Other potential explanatory factors for remaining underweight could be differences in the variety and quality of available food and available health care services.

### *Supporting Evidence*

A drawback of the DFL approach is that the estimates of effects depend on the order of decomposition. Thus, we repeat the same analysis with reverse order weighting presented in Table 1. While the magnitude of the estimated effects of each explanatory factor changes, the qualitative effects of all factors except for job-related activity are not affected. In the reverse order decomposition, the effects of job-related activity and other individual attributes increase while those of income and food prices decrease. A key change in the qualitative effects is that changes in the pattern of job-related activity contribute to the fattening of the upper and lower tails of the BMI density (U-

shaped effect). This effect leads to an increase in both under and overweight. Table 4 presents the reverse order decomposition of summary measures of the prevalence and inequality of nutritional status.

Another concern is the potential endogeneity of per capita income. To control the endogeneity, we use the asset index<sup>13</sup> instead of per capita income. Because the asset index represents a long-term economic status, it may be less affected by current body weight compared to per capita income. When we use the asset index instead of per capita income, while the magnitude of the estimated effects of income slightly decreased, the qualitative effects are not affected.

## Summary and Conclusions

Adopting a semiparametric technique, this article visually clarifies how the distribution of BMI is affected by socioeconomic changes associated with rapid economic growth in China during 1991-2000.

Changes in the pattern of job-related activity are potential factors that may partly explain both remaining underweight and increasing overweight, although their estimated effects are sensitive to the order of decomposition. This finding may result from China's labor market segmented by sectors and regions due to its legal regulations (e.g., the *hukou* system). However, considering that the factors examined in this article explain a large share of increasing overweight but have limited explanatory

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<sup>13</sup>Following the framework in Sahn and Stifel (2003), we include the following factors: indicators for ownership of radios, color TVs, VCRs, washing machines, refrigerators, cameras, electric rice cookers, bicycles, and motorized transportation (motorcycle and/or cars); indicators for the sources of drinking water, toilet facilities, cooking fuel, and ownership of high quality houses; and the years of education of household heads.

power for remaining underweight, key explanatory factors for remaining underweight are likely to be different from those for increasing overweight.

Overall income growth, although it exacerbates income inequality, decreases both under and overweight and thus results in less nutrition inequality. This result indicates a positive association between income and body weight among underweight people. It may also imply that overweight people, who tend to be relatively rich in China, start changing their lifestyle to healthier one when they become rich enough. Although income-generation policies might be effective to reduce the prevalence of both under and overweight, the effect of income growth is much weaker than that of food prices, and thus priority might be given to food price policies.

The main factors shifting Chinese population from underweight toward overweight are decreasing food prices and the increasing proportion of the population living in the coastal region and urban areas. As long as economic growth is accompanied by these changes, continuing economic growth is likely to lead to further increase in overweight in China. It is also implied that food price policies may have significant effects on nutritional status in China although it may be difficult to reduce the prevalence of both under and overweight simultaneously. A key challenge is the choice of foods such that it reduces energy intake of overweight people while increasing energy and nutrient intake for underweight people.

In addition, our results indicate that there exist some unobserved factors that significantly counteract the downward effects of economic growth on underweight rates and therefore increase nutrition disparity. Such unobserved factors could be some kind of discrimination (e.g., ethnic minorities) and diseases. This result indicates

that, besides the effects of economic growth, further investment on more direct interventions may be needed to more effectively reduce remaining underweight in China. Such interventions could be micronutrient supplementation (e.g., iron) and nutrition education.

Finally, the method presented in this article would advance our understanding of the relationship between economic growth and the emerging coexistence of under and overweight which has been observed in an increasing number of low and middle-income countries. Applying this method to other countries and additional research for the causes of remaining underweight in China are important areas for future research.

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Table 1: Weights Used in Density Decomposition

	(1)	(2)	(3)	(4)
<b>Primary</b>		(1)+	(2)+Other Individ-	(3)+
<b>Orders:</b>	Income	Job-related	idual Attributes	Food Prices
$b$	$\psi_{y J,x}$	$\psi_{y J,x}\psi_{J x}$	$\psi_{y J,x}\psi_{J x}\psi_x$	—
$b - \Delta\hat{b}_j$	—	—	—	$\psi_{y J,x}\psi_{J x}\psi_x$
<b>Reverse</b>		(1)+Other Individ-	(2)+	(3)+
<b>Orders:</b>	Food Prices	idual Attributes	Job-related	Income
$b$	—	0	0	0
$b - \Delta\hat{b}_j$	1	$\psi_{x J,y}$	$\psi_{x J,y}\psi_{J y}$	$\psi_{x J,y}\psi_{J y}\psi_y$

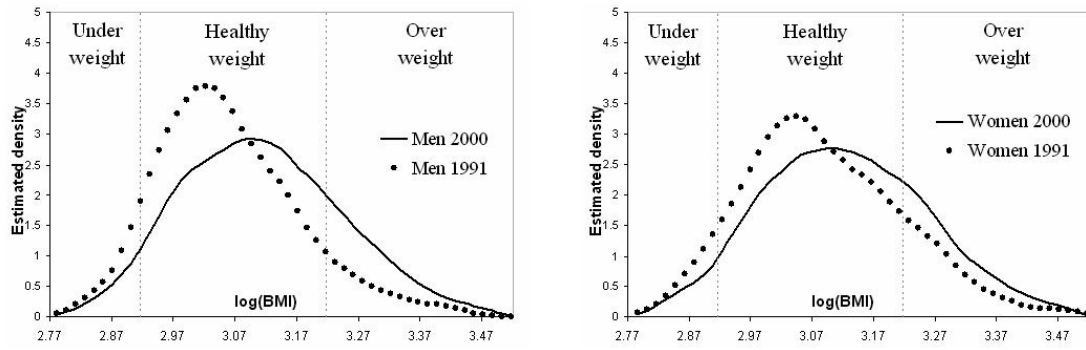
Note: The reweighting functions  $\psi_{y|J,x}$ ,  $\psi_{J|x}$ ,  $\psi_x$  are defined by equations (7), (8), and (9). The reweighting functions  $\psi_{x|J,y}$ ,  $\psi_{J|y}$ , and  $\psi_y$  are defined similarly.

Table 2: Primary Order Decomposition of Changes in Measures of the Prevalence and Inequality of Nutritional Status in China, 1991-2000

Primary Order Index	Total Change in Index	The % of the total change explained by:				Unexplained Change (%)
		Income	Job- related Activity	Other Individual Attributes	Food Prices	
MEN:						
Underweight Rate	-2.17	-0.9	-12.4	-61.8	-98.2	73.3
Overweight Rate	11.70	-5.0	0.43	59.5	23.9	21.3
Gini Coefficient	$0.29 \times 10^{-2}$	-4.1	-7.6	34.7	-6.9	70.1
WOMEN:						
Underweight Rate	-3.61	-10.2	15.5	-43.7	-109.1	47.8
Overweight Rate	9.72	-2.7	-8.6	58.4	40.7	12.1
Gini Coefficient	$0.12 \times 10^{-2}$	-17.7	-9.3	19.0	-5.3	113.3

Table 3: Reverse Order Decomposition of Changes in Measures of the Prevalence and Inequality of Nutritional Status in China, 1991-2000

Reverse Order Index	Total Change in Index	The % of the total change explained by:				Unexplained Change (%)
		Food Prices	Other Individual Attributes	Job- related Activity	Income	
MEN:						
Underweight Rate	-2.17	-88.0	-101.4	16.6	-0.5	73.3
Overweight Rate	11.70	31.6	34.2	13.4	-0.5	21.3
Gini Coefficient	$0.29 \times 10^{-2}$	6.9	9.3	14.4	-0.7	70.1
WOMEN:						
Underweight Rate	-3.61	-89.5	-82.6	25.7	-1.1	47.8
Overweight Rate	9.72	68.1	10.8	11.7	-2.8	12.1
Gini Coefficient	$0.12 \times 10^{-2}$	-6.2	-31.9	30.1	-5.3	113.3



a) Men

b) Women

Figure 1: Kernel Estimates of the Actual Densities of log BMI in China in 1991 and 2000

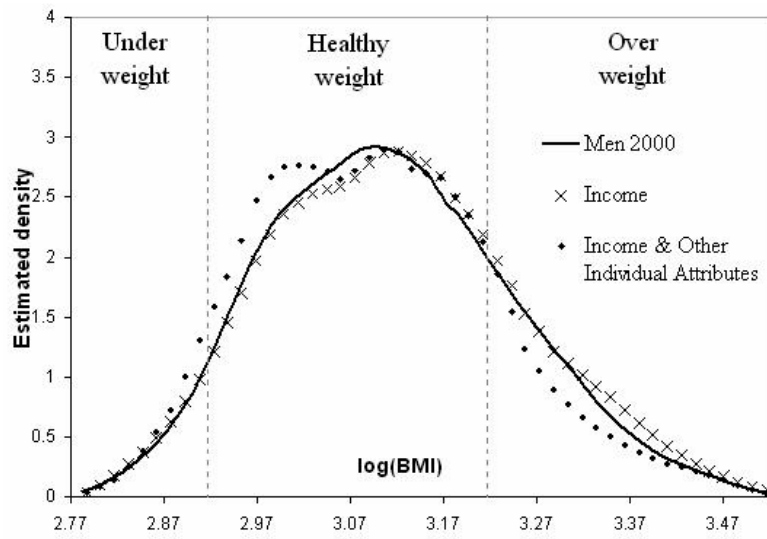
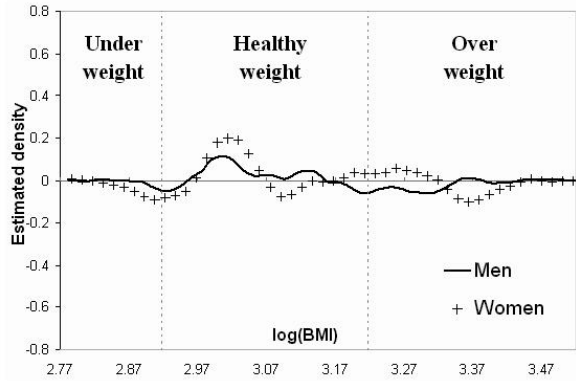
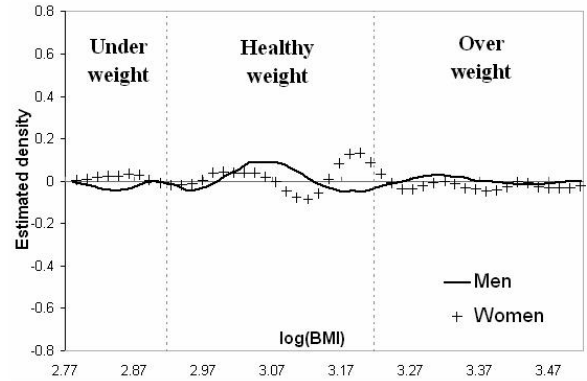


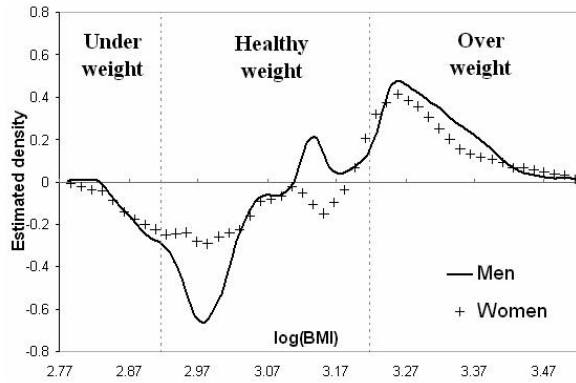
Figure 2: An Illustration of the Decomposition of the log BMI Density in China in 2000



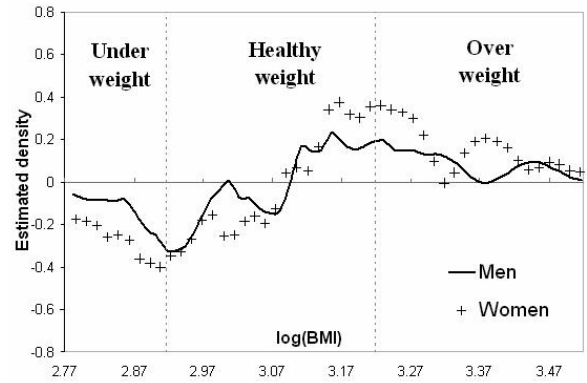
a) Per Capita Income



b) Job-related Activity



c) Other Individual Attributes



d) Food Prices

Figure 3: Estimated Effects of the Changes in Explanatory Factors on the Density of log BMI in China, 1991-2000