

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

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## 1. INTRODUCTION

China experienced a rapid increase in overweight before it adequately reduced food insecurity and underweight during 1991-2000 when a rapid economic growth and rapid changes in lifestyles were observed. The coexistence of under and overweight leads to an increase in the prevalence of diet-related chronic diseases and thus is associated with the significant social and economic costs (see, for example, Popkin et al. (2001) and Gu et al. (2006)). It also offers a major challenge for food and nutrition policy in China because policies for reducing overweight may worsen the prevalence of underweight (Popkin (2001)).

While the coexistence of under and overweight has typically been examined as a problem of public health, it could also be discussed as a result of rational behaviors reacting to the changes in economic conditions associated with rapid economic growth in China<sup>1</sup>. From this standpoint, we examine the relationship between changes in socioeconomic factors and the emerging coexistence of under and overweight in China during 1991-2000.

Our key questions are (1) whether any socioeconomic factor explains both increasing overweight (Body Mass Index (BMI) $\geq 25kg/m^2$ ) and remaining underweight (BMI $\leq 18.5kg/m^2$ )<sup>2</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. To investigate these questions, this paper adopts the semiparametric approach developed by DiNardo et al. (1996) [DFL approach].

The conventional approach has focused on estimating "mean effects" 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>3</sup>. Existing studies also have tended to assume a (log-)linear functional form relationship between nutritional status and socioeconomic factors. However, this as-

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<sup>1</sup>For example, several studies find that changes in income and food prices significantly influence dietary patterns in China (e.g., Guo et al. (1999), Guo et al. (2000), Fang and Beghin (2002), and Yen et al. (2004)).

<sup>2</sup>For simplification, we use constant cut-off values and include obesity in the overweight group.

<sup>3</sup>The conventional approach needs to examine under and overweight populations discontinuously (e.g., using discrete indicators).

sumption is questionable when a sample includes both under and overweight persons because the same changes in socioeconomic factors may affect the nutritional status of under and overweight persons in a different way with a different magnitude.

This study therefore estimates “distributional effects” 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 under, healthy, and overweight populations continuously and simultaneously, and is robust to the choice of cut-off values for these clinical classifications. Based on the theoretical model in Lakdawalla and Philipson (2002) [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.

Section 2 describes the modified LP model and its theoretical implications. A semiparametric estimation method is described in section 3. Section 4 presents our empirical results. Summary and conclusions are provided in Section 5.

## 2. THE MODEL OF WEIGHT MANAGEMENT

Following the framework in Lakdawalla and Philipson (2002), suppose that an individual’s current period utility  $U$  depends on food consumption  $F$ , other consumption  $C$ , and his current BMI  $b$ . His utility,  $U(F, C, b)$ , is monotonically rising in  $F$  and  $C$  but non-monotonic in  $b$ . We assume that he has an “ideal BMI”  $b_o$  at given levels of  $F$  and  $C$ . Thus, all else equal, he prefers to increase BMI when  $b < b_o$  and decrease BMI when  $b > b_o$ . We also suppose  $\frac{\partial^2 U}{\partial F \partial C} \geq 0$ <sup>4</sup>.

BMI is considered as a capital stock that depreciates over time. Let’s  $S$  denote the strenuousness of job-related activities. Assume that  $S$  is a function of average energy ex-

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<sup>4</sup>This condition implies that food and alternative consumption are not substitutes.

penditure required for the job-related activities  $J$  and the income earned from the activity  $y_e$  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  $\delta < 1$  and  $g$  is continuous, concave,  $\frac{\partial g}{\partial F} > 0$ , and  $\frac{\partial g}{\partial S} < 0$ . Then, the individual value function  $v$  can be expressed as:

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

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  $g_F$  denote  $\frac{\partial U}{\partial X}$  and  $\frac{\partial g}{\partial F}$ , respectively. Then, the first order and envelope conditions are:

$$p \cdot U_C - U_F = \beta \cdot g_F \cdot v'(b') \quad \text{and} \quad v'(b) = U_b + \beta \cdot (1 - \delta) \cdot v'(b').$$

A unique and stable equilibrium can be obtained when the marginal utility of food ( $U_{F-p} \cdot U_C$ ) is falling in BMI<sup>5</sup> (see Lakdawalla and Philipson (2002)). The equilibrium choice of BMI and food is obtained as a function of  $p$ ,  $J$ ,  $y_e$ , and  $y_u$ <sup>6</sup>,  $b^*(J, p, y_e, y_u)$  and  $F^*(J, p, y_e, y_u)$ .

While food prices and average energy expenditure required for the 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  $S$  while  $y_u$  does not. Denote the partial effect of  $y_u$  by  $b_{y_u}^* = \frac{\partial b^*}{\partial y_u} \geq 0$ . Then, 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  $b_S^* S_{y_e} = \frac{\partial b^*}{\partial S} \frac{\partial S}{\partial y_e}$ <sup>7</sup>. 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.

<sup>5</sup>This condition implies that foods are not addictive.

<sup>6</sup>Here, earned income is treated as a predetermined endogenous factor.

<sup>7</sup>Lakdawalla and Philipson (2002) assume an inverted U-shaped unearned income effects such that  $b_{y_u}^* > 0$  for the underweight and  $b_{y_u}^* < 0$  for the overweight. They also assume that the earned income effect will be statistically positive (negative) if job activity is 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:

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

The four terms in this equation represent the effect of food price, 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 this equation, we empirically decompose changes in the BMI density into the effects of selected socioeconomic factors.

### 3. ESTIMATION METHOD

First, we present the framework for estimating counterfactual densities of BMI associated with socioeconomic changes. Second, we describe how we decompose changes in the densities.

#### 3.1 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 per capita income  $y$ , 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 attributes at date  $t$  is  $F(b, k|t; p_t)$ . Let's  $t_\alpha$  represents a date of observation  $\alpha$ . Then, the density of BMI at date  $t$ ,  $f_t(b)$ , is:

$$\begin{aligned} f_t(b) &= \int \int \int f(b|y, J, x, t_b=t; p_t) dF(y|J, x, t_{y|J, x}=t) dF(J|x, t_{J|x}=t) dF(x|t_x=t) \quad (1) \\ &\equiv f(b; t_b=t, t_{y|J, x}=t_{J|x}=t_x=t, p_t) \end{aligned}$$

For example,  $f(b; t_b=00, t_{y|J, x}=t_{J|x}=t_x=00, p_{00})$  is the actual BMI density in 2000.

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 their 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.

$$f(b; t_b=00, t_{y|J,x}=91, t_{J|x}=t_x=00, p_{00}) = \int \int \int f(b|y, J, x, t_b=00; p_t) \psi_{y|J,x}(y, J, x) dF(y|J, x, t_{y|J,x}=00) dF(J|x, t_{J|x}=00) dF(x|t_x=00), \quad (2)$$

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:

$$\psi_{y|J,x}(y, J, x) = \sum_{c=1}^C I(y = c) \cdot \frac{Pr(y = c|J, x, t_{y|J,x} = 91)}{Pr(y = c|J, x, t_{y|J,x} = 00)}, \quad (3)$$

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 (2), 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:

$$\psi_{J|x}(J, x) = \frac{dF(J|x, t_{J|x} = 91)}{dF(J|x, t_{J|x} = 00)} = \sum_{d=1}^D I(J = d) \cdot \frac{Pr(J = d|x, t_{J|x} = 91)}{Pr(J = d|x, t_{J|x} = 00)}, \quad (4)$$

$$\psi_x(x) = \frac{dF(x|t_x = 91)}{dF(x|t_x = 00)} = \frac{Pr(t_x = 91|x)}{Pr(t_x = 00|x)} \cdot \frac{Pr(t_x = 00)}{Pr(t_x = 91)}, \quad (5)$$

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

Food prices also potentially influence nutritional status. 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 a semi-log linear functional form (individual attributes are controlled). Then,  $f(b|k, t_b=00; p_{91}) = f(b - \Delta \hat{b}_m | k, t_b=00; p_{00})$ . The counterfactual density of BMI in 2000 had only food prices remained as it was in 1991 can be obtained by integrating

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

$$f(b; t_b = 00, t_k = 00, p_{91}) = \int f(b - \Delta \hat{b}_m | k, t_b = 00; p_{00}) dF(k | t_k = 00). \quad (6)$$

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 (2) based on a random sample  $B_1, \dots, B_n$  of size  $n$  are

$$\hat{f}(b; t_b = 00, t_{y|J,x} = 91, t_{J|x} = t_x = 00, p_{00}) = \sum_{i \in T_{00}} \frac{1}{n h} \psi_{y|J,x}(J_i, x_i) K\left(\frac{b - B_i}{h}\right), \quad (7)$$

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 probit 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 (3), (4), and (5).

### 3.2 Density Decompositions

To examine the effect of each factor on changes in the BMI density, we adopt a sequential decomposition method. There are five components in the decomposition: per capita income, job-related activity, other individual attributes, food prices, and residual components. One drawback of this method is that the effect of a given factor generally depends on the order of the decomposition. Thus, we also consider a decomposition in reverse order.

Estimation of the counterfactual densities in the sequential decomposition are obtained by substituting in equation (7) combinations of reweighting functions in Table 1. The reweight-

ing functions  $\psi_{J|y}$ ,  $\psi_y$ , and  $\psi_{x|J,y}$  in the reverse order decomposition are defined in the way similar to that in equations (3), (4), and (5).

## 4. EMPIRICAL RESULTS

### 4.1 Data

We use data from the CHNS in 1991 and 2000.<sup>8</sup> We focus on the major working age group in China (i.e., age 18 to 60). As explanatory factors, we include per capita income, indicators for job-related activities, age in year, education level, household demographics, region of residence and community-level food prices. We exclude pregnant women from our sample. An indicator for breastfeeding is included for women to control recent childbirth.

### 4.2 Results

To illustrate our decomposition method, Figure 1 depicts (i) the estimated actual density of log BMI in 1991, (ii) that in 2000, (iii) the estimated counterfactual density associated with changes in income distribution, and (iv) that associated with changes in income distribution and other individual attributes for men. We decompose the actual change in the BMI density (i.e., the difference between (i) and (ii)) into the effects of changes in socioeconomic factors. For example, the difference between (ii) and (iii) represents the effect of changes in the income distribution on the BMI density. Similarly, the difference between (iii) and (iv) represents the effect of changes in the distribution of other individual attributes.

Figure 2 presents the estimated effects of changes in each explanatory factor on the density of log BMI for men (solid line) and women (plus sign '+'). During 1991-2000, average income levels increased in all under, healthy, and overweight groups (+10% on average), 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 density, although the effects on the upper tail was negligible among women (Fig.2a). These findings imply an inverted U-shaped relationship between BMI and income levels. This result is also consistent

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<sup>8</sup>Details of the survey are found at the CHNS website (<http://www.cpc.unc.edu/projects/china>).



with previous results for undernutrition (Haddad et al. (2003)) and may explain why income and nutrition inequality is negatively correlated in some countries (Sahn (2003)).

We also observed a shift toward sedentary jobs and away from strenuous jobs. The dispersion in job-related activity increased twice more rapidly among women than among men. These shifts contributed to a fattening of the lower and upper tails and a decline of the middle of the distribution among women, while there were little influences on the density among men (Fig.2b). This finding implies that changes in the pattern of job-related activity contribute to increasing both under and overweight.

Over the period, we observed a significant increase in the proportion of the population living in the coastal region and urban areas. This change in other individual attributes contributed to a shift of a whole distribution toward a heavier level (Fig.2c). Decreasing food prices (-23% on average) contributed to a similar shift (Fig.2d). These shifts explain a large part of an increase in overweight and a decrease in underweight. Lastly, the residual factor indicates that there exist unobserved factors that increase the mass at underweight level and decrease the mass in the middle of the density, which counteracts the downward effects of other factors on the prevalence of underweight.

To provide numerical values for the graphical results in Figure 2, Table 2 presents the decomposition of summary measures of the prevalence and inequality (i.e., under and overweight rates, and the Gini index). On the whole, changes in the socioeconomic factors examined in this paper explain increasing overweight much better than remaining underweight. Because only 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.

A key question now is what the unobserved factors hindering underweight rates from decreasing in China during 1991-2000 are. We first examine additional socioeconomic factors that are available only in 2000 and thus 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%), which 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, and thus diseases may partially explain remaining underweight. Other potential explanations could be differences in the variety and quality of available food and available health care services.

One issue of the DFL approach is that the magnitude of estimated effects depends on the order of decomposition. Thus, we implement the same analysis with reverse order weighting presented in Table 1. 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). Another issue is the potential endogeneity of income. We use the asset index to control a reverse effect from body weight. The shape of the effects on the BMI density was similar between per capita income and the asset index.

## 5. SUMMARY AND CONCLUSIONS

Adopting a semiparametric technique, this paper visually clarifies how the distribution of BMI is affected by socioeconomic changes 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. However, their estimated effects are sensitive to the order of decomposition. Also, considering that the factors examined in this paper explain a large share of increasing overweight but have limited explanatory power for remaining underweight, key explanatory factors for remaining underweight are likely to be different from those for increasing overweight.

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 regions 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. It is also indicated that food price policies may have significant effects on nutritional status in China although it seems difficult to reduce the prevalence of both under and overweight simultaneously.

Overall income growth, although it exacerbates income inequality, decreases both under and overweight and thus results in less nutrition inequality. However, because the effect of income growth is much weaker than that of food prices, priority might be given to food price policies to improve nutritional status in China.

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 in 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 paper 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 Indiv-	(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 Indiv-	(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 (3), (4), and (5). 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

Figure 1: An Illustration of the Decomposition of Changes in the log BMI Density in China during 1992-2000

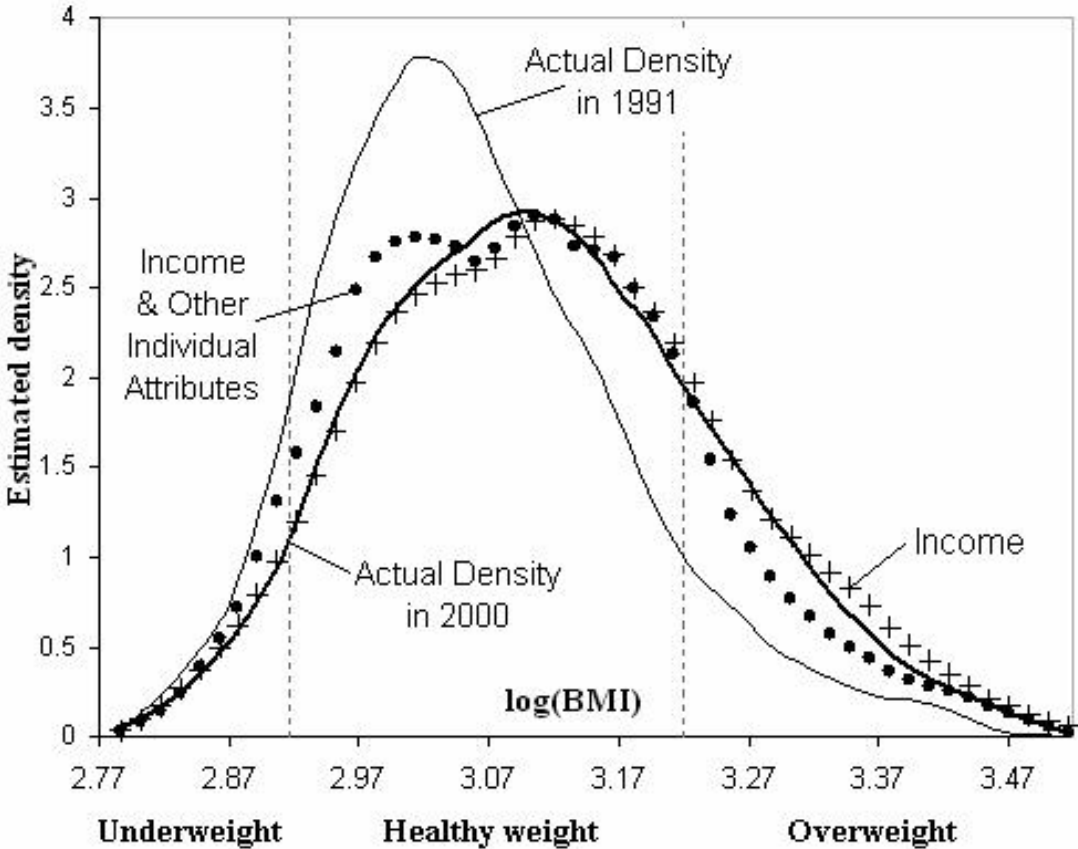
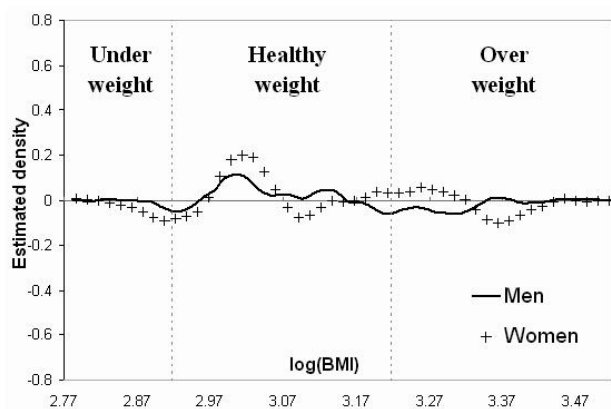
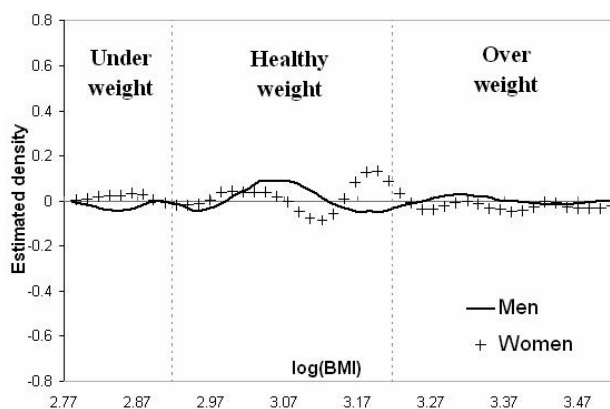


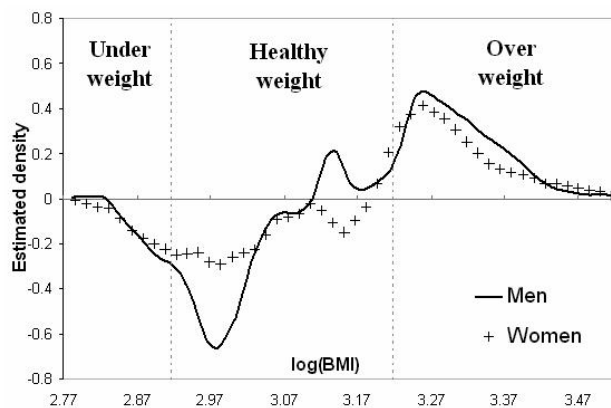
Figure 2: Estimated Effects of the Changes in Explanatory Factors on the Density of log BMI in China, 1991-2000



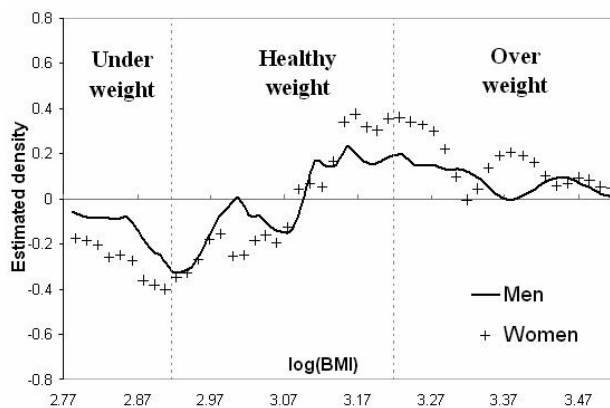
a) Per Capita Earned Income



b) Job-related Activity



c) Other Individual Attributes



d) Food Prices