Optimal Obesity Investment: Theory and Evidence

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Abstract: This research derives a health economic model to find the optimal level of health investment and mitigate the consequences of overweight and obesity by using the discrete time optimization. The methods used in this research were a state preference model of endowment economy to develop an optimal health model, and the Logit model for robustness. The first finding shows that the optimal level of health investment to mitigate the probability of sickness in the future that the marginal utility of three types of good (high-calorie good, low-calorie good and other consumption good), exercise, and weight in the first period are equal to the expected marginal benefit from spending on health development in the second period in the state preference model of endowment economy under uncertainty with perfect capital market. Secondly, agents are willing to prevent the probability of getting obesity rather than reduce the size of utility loss by purchasing the market insurance. Indeed, agents prefer self-insurance to market insurance. Furthermore, the social planner would collect tax on healthy wealthy people and subsidize the poor people which would satisfy the social optimal condition. Finally, the Logit Model shows the relevant results that gender has a significantly negative effect on the probability of being obese. This means that men have a higher probability of being obese than women. Still, the effect of age on the probability of being obese is positive and statistically significant. Conversely, exercise and the risk-mitigating spending from getting obese negatively impact on the probability of being obese. The estimated coefficients are statistically significant.

Keywords: Overweight, Obesity, Optimal Health Investment, Public Health Model

1. Introduction

Overweight and obesity can lead to serious health consequences. They are defined as abnormal or excessive fat accumulation that may impair health. Typically, the number of both conditions continues to steadily increase. This is to such an extent that the World Health Organization (WHO) projects that by 2015, approximately 2.3 billion of the world’s adults will be overweight, and more than 700 million will be obese. More importantly, once considered a problem only in high-income countries, overweight and obesity are now dramatically on the rise in low-income and middle-income countries, too, particularly in urban setting (WTO, 2006).

Body Mass Index (BMI) is a simple index of weight-for-height that is commonly used to classify underweight, overweight and obesity in adults. It is defined as the weight in kilograms divided by the square of the height in meters (kg/m^2). The WHO defines underweight as a BMI less than 18.5, normal range as a BMI between 18.5 and 24.9, overweight as a BMI equal to or more than 25.0, and obesity as a BMI equal to or more than 30.0 as shown in Table 1.

Table 1 Measurement of Body Mass Index: BMI

BMI:kg/m^2		
Group	WHO	Asia-Pacific Perspective
Underweight	< 18.5	<18.5
Normal	18.5 - 24.99	18.5 - 22.99
Overweight	≥ 25	≥ 23
Pre-obese	25 - 29.99	23 - 24.99(at risk)
Obese level 1	30- < 34.99	25 – 29.99
Obese level 2	35 - < 39.99	≥ 30
Obese level 3	≥ 40.00	

Source: National Health Examination Survey Office, 2008-2009.

In Asians, the cut-offs for underweight (< 18.5), normal range (18.5-22.9), overweight ($\geq$23.0 kg/m^2) and obese ($\geq$25.0 kg/m^2) are lower than the WHO criteria. Some support for these cut-offs comes from data on Chinese living in Hong Kong (Ko GTC *et. al*, 1999). Similar data have been published from the Chinese, Indians and Malays in Singapore (Deurenberg-Yap *et. al*, 1999).

In Thailand, data from many studies suggest that overweight and obesity are increasing in affluent urban populations. Results from the National Health Examination Survey of Thailand conducted in 13,300 adults, age ≥ 20 years during 1991-1992 revealed that 12% of men and 19.5% of women (total 16.7%) had BMI 25-30 or overweight, whereas 1.7% of men and 5.6% of women (total 4.0%) had BMI>30 or obese (Chuprapavarn ,1996). Consistent with a sharp increase in overweight and obesity during 1991-1992, the first report on the National Health Examination Survey of Thailand conducted by the Ministry of Public Health revealed that 12.0% of men and 19.5% of women (total 31.5%) had BMI 25-30 (overweight), and 1.7% of men and 5.6% 0f women (total 7.3%) had BMI > 30 (obese).

The second report on the National Health Examination Survey of Thailand during 1996-1997 also conducted by the Ministry of Public Health, revealed that 19.2% of men and 33.9% of women (total 28.3%) were overweight, whereas 3.5% of men and 8.8% of women (total 6.8%) were obese (Aekplakorn *et. al*, 2004). The third survey of the National Health Examination Survey of Thailand during 2003-2004 on people aged ≥ 15 years showed that an average BMI of 18,836 men was 22.6 kg/m^2, and an average BMI of 20,218 women was 23.8 kg/m^2. More importantly, 17.8% 0f men were overweight, and 4.8% of men were obese. 25.4% of the women were overweight, and 9.0% of women were obese. Similarly, the fourth survey of National Health Examination Survey of Thailand during 2008-2009 on people aged ≥ 15 years showed that an average BMI of 9,683 men were 23.1 kg/m^2, and an average BMI of 10,607 women were 24.4 kg/m^2 as well. 22.3% of the men were overweight, and 6.0% were obese. 29.1% of the women were overweight, and 11.6% were obese.

The prevalence of childhood obesity in a moderately industrialized province in Thailand was 22.7% in urban areas and 7.4% in rural areas in 1997 (Sakamoto *et. al*, 2001). Furthermore, the prevalence of overweight and obesity in the Royal Thai Army (RTA) personnel aged 20-60 years in 2005 were 27.1% and 4.9% respectively. In particular, the mean value of age, weight, BMI, waist, and hip circumference, waist hip ratio, and high blood pressure in overweight and obesity personnel were significantly higher than those of non-overweight personnel (Napradit *et. al*, 2001).

In addition, the relationship of socio-demographic characteristics, psychological factors, knowledge, attitude and behavior with obesity among the metropolitan Waterworks Authority (MWWA) officers, aged 20-60 years, were of significantly higher risk to be obese, especially the older age group. Furthermore, persons with unhealthy behaviors, moderately healthy behaviors, such as watching televisions or videos, or playing games on the computer continuously for more than 3 hours daily had a higher risk of becoming obese (Kantachuvessiri *et. al*, 2005) including Thai school-age children who watched television for more than 3 hours per day (Ruangdaraganon *et. al*, 2002). More importantly, there were marked relationships between childhood obesity and parents' educational levels and household income including overweight mothers (Sakamoto, 2001).

WTO (2004) reported that the fundamental cause of obesity and overweight is an energy imbalance between calories consumed and calories expended. Global increases in overweight and obesity are attributable to a number of factors such as a global shift in diet towards an increased intake of energy-dense foods that are high in fat and sugar but low in vitamins and minerals and a trend towards decreased physical activity due to the increasingly sedentary nature of many forms of work, changing modes of transportation, and increasing urbanization.

Overweight and obesity can lead to serious health consequences. Risk increases progressively as BMI levels increase, for example, cardiovascular disease (heart disease, stroke), diabetes, musculoskeletal disorders (especially osteoarthritis) and cancer (WTO, 2006). Most evidence suggests that increases in mortality among the obese are evident for several life-threatening diseases including Type 2 diabetes, cardiovascular disease, gallbladder disease, and hormone-sensitive and gastrointestinal cancers (WTO, 2006).

The cost of obesity to a community and individuals may be divided into the direct cost to the health system and the indirect cost or social cost to the individual and community, but little data is available for the Asia-Pacific region. The direct costs depend in the main part on the disease caused by obesity and the cost of the consequences of obesity. For example, the direct costs of obesity in New Zealand (1996) equalled NZ$ 135 million, in Australia (1994) AUD$ 464 million, in the Netherlands (1995) NG 1 billion, in France (1995) FF 12 billion, and in the United States (1998) US$ 51.6 billion. However, the indirect costs vary widely (Kantachuvessiri, 2005).

The three major components of weight loss therapy are dietary therapy, increased physical activity, and behavior therapy. A study of behavior modification in the treatment of obesity showed that 70 obese persons, aged 18-75 years, had lost weight from fat tissue. There are also three approaches to prevention: universal prevention, selective prevention, and targeted prevention, for example, a summer camp for childhood obesity in Thailand was held at the Clinic Research Center, Department of Pediatrics at the Faculty of Medicine in Siriraj Hospital at Mahidol University in 1992. After the program, all participants had lost about 5% of their initial weight (Jirapinyo *et. al*, 1995).

In fact, there are few studies in Thailand which emphasize whether public policy should play an important role in overweight and obesity control, especially preventing behavior for such conditions. Consequently, this paper characterizes the model for the optimal level of health investment and the public policy of healthcare subsidies to mitigate the consequences of overweight and obesity.

The rest of the paper is organized as follows: Section 2 presents a model of behavior including weight. Market insurance in state preference model is shown in section 3. Section 4 develops a health economic model under government intervention and simplifies to the reduce forms. Section 5 demonstrates the empirical results from panel data regression model and Logit regression model. Section 6 concludes with the key findings and discusses such models as well.

2. A Model of Behavior Including Weight

Similar to previous studies, Drenowski (2003), Jacobson and Brownell (2000), this paper focuses on the role of public policy on calorie consumption. It is because an increase in calorie consumption will actually induce the prevalence of obesity, then it will be a problem of public health. However, we capture the model by following the framework of Philipson and Posner (1999), and Lakdawalla and Philipson (2009) who proposed entering body weight into the utility function.

The modeled economy assumes that there is a simple two-period endowment economy where each period the agent is endowed with a fixed quantity of good with no possibility of borrowing or lending across periods (Basu and Rosenman, 2007).

In the first period the agent can consume the multiple goods and exercise, including a function of body weight as Schroeter, Lusk and Tyner (2008), or spend some of it on health lifestyle (risk-mitigating spending), which yields no utility but reduces the probability of getting sick in the second period.

Consequently, utility is specified as a function of an agent's weight, which in turn is specified as a function of the quantity of goods consumed and exercise. In addition, we assumed that an agent's weight, W, is affected by three factors: the consumption of a high-calorie good $\left(F^H\right)$, a low calorie-good $\left(F^L\right)$, and exercise $\left(E\right)$; i.e. $W = W(F^H, F^L, E)$. Weight is strictly increasing in both goods and decreasing in exercise, $\frac{\partial W}{\partial F^H}, \frac{\partial W}{\partial F^L} > 0, \frac{\partial W}{\partial E} < 0$, and further assumes that the changes in weight diminish with a high-calorie good and a low-calorie good but increases in exercise, $\frac{\partial^2 W}{\partial (F^H)^2}, \frac{\partial^2 W}{\partial (F^L)^2} < 0, \frac{\partial^2 W}{\partial E^2} > 0.$ In addition, both good intakes and exercise are complementary like Philipson and Posner (1999); $\frac{\partial^2 W}{\partial F \partial E} > 0.$

In the second period the agent is either healthy or sick (obese). If healthy he gets the full utility from consuming the endowment. If sick he faces two losses: risk-mitigating spending and the level of utility. Therefore, the agent utility can derive from weight (W), the intake of goods (F^H, F^L), exercise (E), and other consumption good (C), as follows:

$$U = U(W(F^H, F^L, E), F^H, F^L, E, C) \tag{1}$$

Assume that the utility function is increasing in $F^H, F^L, C, E, (\frac{\partial U}{\partial F^H}, \frac{\partial U}{\partial F^L}, \frac{\partial U}{\partial C}, \frac{\partial U}{\partial E} > 0)$, and decreasing marginal utility of consumption goods and exercise $(\frac{\partial^2 U}{\partial (F^H)^2}, \frac{\partial^2 U}{\partial (F^L)^2}, \frac{\partial^2 U}{\partial C^2}, \frac{\partial^2 U}{\partial E^2} < 0)$. Such utility is also assumed to be increasing in weight up to some ideal weight level, W^I, and decreasing in weight levels greater than W^I such that the agent does not prefer to be above or below such ideal weight level, other things are held constant. Particularly, this ideal weight does not depend on the level of consumption of other goods. Furthermore, gaining weight is more valued the more underweight a person is while losing weight is more valued the more overweight a person is, so W^I is the most preferred weight in the economic sense.

Following Basu and Rosenman (2007), such a state preference model of endowment economy under uncertainty allowed agents to be able to trade their own consumption between periods where we assume that agents are endowed with the state contingent commodity, C, consumption between two periods, and there are two states of nature in the second period.

Thus, the representative agent chooses risk-mitigating spending or lifestyle, h, weight, W, the consumption of a high-calorie good, F^H, a low calorie-good, F^L, exercise, E, and other consumption good, C, to maximize the expected lifetime utility as:

$$U\left[W_1, F_1^H, F_1^L, E_2, C_1\right] + \beta \begin{Bmatrix} p(h)U(W_2, F_2^H, F_2^L, E_2, C_2) \\ +(1-p(h))(1-v_1) \\ U\left[(W_2, F_2^H, F_2^L, E_2, C_2) - v_2\right] \end{Bmatrix} \tag{2}$$

subject to the constraint as follows:

$$\begin{aligned} &W_1 + W_2 + F_1^H + F_2^H + F_1^L + F_2^L \\ &+ E_1 + E_2 + C_1 + C_2 + h = \theta \end{aligned} \tag{3}$$

where h is the direct amount spent on health development (risk-mitigating spending), $h < \theta$, C_1 and C_2 are consumptions in two periods similar to $W_1, W_2, F_1^H, F_2^H, F_1^L, F_2^L, E_1, E_2$. The agents can transfer consumption in the first period to self-insurance (shifting the consumption of all goods), or spending on the health development, h, in the second period, v_1 is the diminished capacity of the agent to enjoy consumption if sick (a non-consumption utility loss); $0<v_1<1$, and v_2 is the income loss or the financial cost of being sick measured in terms of lost consumption possibility. β is the discount factor, $0 < \beta < 1$, p(h) is the probability of not getting sick, $p'(h) > 0, p''(h) < 0$, θ is the total endowment ,and λ is the Lagrange multiplier on the constraint.

Therefore, the necessary first-order conditions for interior solution with respect to $W_1, W_2, F_1^H, F_2^H, F_1^L, F_2^L, E_1, E_2, C_1, C_2, h$ are employed to find the optimal condition. Indeed, such solutions state that the marginal utility in the first period is equal to the expected marginal utility in the second period. Since, the marginal utilities are all the same across periods, then they are satisfied the optimal condition as the followings.

The first order condition show that the marginal utility in the first period is equal to the expected marginal benefit from spending on health development in the second period, or the expected marginal utility of total consumption in the second period.

3. Market Insurance and Weight

By introducing market insurance in state preference model of a lifetime endowment economy, we show how the market insurance influences spending on self-protection (h) and self-insurance ($W_2, F_2^H, F_2^L, E_2, C_2$). Agents pay I as an insurance premium in the first period to get benefit of B in the second period if get sick. Consequently, the expected lifetime utility function (4) is maximized subject to the resource constraint (5) and the fair insurance market (6) as follows.

$$U\left[W_1, F_1^H, F_1^L, E_2, C_1\right] + \beta \begin{Bmatrix} p(h)U(W_2, F_2^H, F_2^L, E_2, C_2) \\ +(1-p(h))(1-v_1)U\left[(W_2, F_2^H, F_2^L, E_2, C_2) - v_2 + B\right] \end{Bmatrix} \tag{4}$$

$$W_1 + W_2 + F_1^H + F_2^H + F_1^L + F_2^L + E_1 + E_2 + C_1 + C_2 + h^{\omega} + t_2 = \Omega^{\omega} \tag{5}$$

$$I = (1 - p(h))B \tag{6}$$

Substituting B into the expected utility function and solving the necessary first order condition for interior solution with respect to $W_1, W_2, F_1^H, F_2^H, F_1^L, F_2^L, E_1, E_2, C_1, C_2, h, I$, respectively, which yield the optimal levels of weight, both types of good, exercise, other consumption good, and spending on health development.

The first order condition shows that the marginal utilities of spending on health investment, MU_h, are always larger than the marginal utility of insurance premium, MU_I. In other words, the result states that the marginal utility of spending on health development depends also on the sign of the marginal effect of high-calorie good, low-calorie good ,and exercise on weight ($W_{F_2^H}, W_{F_2^L}, W_{E_2}$), so it is likely to be a positive or negative effect of the marginal utility of insurance premium due to $W_{E_2} < 0$.

More importantly, agents will prefer to spend on health investment over purchase of the market insurance, or agents are willing to prevent the probability of getting obesity rather than reduce the size of utility loss by purchasing the market insurance because spending on health development provides a higher marginal utility than buying market insurance. Similarly, agents will prefer self-insurance to market insurance because the marginal utility of the three types of goods; high-calorie good, low-calorie good and other consumption good, are larger than the marginal utility of spending on market insurance, except that the marginal utility of weight is above the ideal weight level, W^I, and the marginal utility of exercise is negative resulting from the marginal effect of exercise on weight which is always negative.

Hence, in case of perfect capital market, self-protection and self-insurance are more beneficial than market insurance, but agents can buy market insurance to share the future risk, except with exercise.

4. Public Policy with Weight

In a perfect capital market, we assume that there are two types of people- wealth people, ω, who contribute to public subsidies but are not eligible for them, and poor people, ρ, who do not contribute to public subsidies but collect them if ill like Rosenman (2008).

There are n_{ω} high income people who have total endowment Ω^{ω} and n_{ρ} low income people who have total endowment, Ω^{ρ}, p(h) is the probability of not getting sick, $p'(h) > 0, p''(h) < 0$, h is the share of period 1 income devoted to building health. The utility of the agent is decreased if getting sick by two parts; a decrease in income to pay for care, s, and a decline in enjoyment, v. The government offers a subsidy to low income people who get sick, G, in the second period, and pays for it by a tax on healthy wealthy, t_2, in the second period also.

4.1 High Income People

The expected lifetime utility function of healthy wealthy people can be stated as

$$U^{\omega}\left[W_1, F_1^H, F_1^L, E_2, C_1\right] + \beta\left\{\begin{matrix} p(h^{\omega})U^{\omega}[(W_2, F_2^H, F_2^L, E_2, C_2) - t_2] \\ +(1-p(h^{\omega})U^{\omega}\left[(W_2, F_2^H, F_2^L, E_2, C_2) - s - v\right]\end{matrix}\right\} \quad (7)$$

The healthy wealthy people choose $W_1, W_2, F_1^H, F_2^H, F_1^L, F_2^L, E_1, E_2, C_1, C_2, h, t_2$ to maximize the expected lifetime utility function (17) subject to resource constraint (18)

$$W_1 + W_2 + F_1^H + F_2^H + F_1^L + F_2^L + E_1 + E_2 + C_1 + C_2 + h^{\omega} + t_2 = \Omega^{\omega} \quad (8)$$

The necessary first order condition for interior solution with respect to $W_1, W_2, F_1^H, F_2^H, F_1^L, F_2^L, E_1, E_2, C_1, C_2, h, t_2$, respectively, are as follows:

$$U_{C_1}^{\omega} = U_{W_1}^{\omega} = \beta p'(h^{\omega})\begin{bmatrix} U^{\omega}((W_2, F_2^H, F_2^L, E_2, C_2) - t_2) \\ -U^{\omega}((W_2, F_2^H, F_2^L, E_2, C_2) - s - v) \end{bmatrix} \quad (9)$$

$$U_{F_1^L}^{\omega} W_{F_1^L} = U_{F_1^H}^{\omega} W_{F_1^H} = \beta p'(h^{\omega})\begin{bmatrix} U^{\omega}((W_2, F_2^H, F_2^L, E_2, C_2) - t_2) \\ -U^{\omega}((W_2, F_2^H, F_2^L, E_2, C_2) \\ -s - v) \end{bmatrix} \quad (10)$$

Equations (19) and (20) state that the marginal utilities of weight and consumption goods (high-calorie good, low-calorie good, other consumption good) in the first period are equal to the marginal benefit from spending on health investment, h, in the second period. That is, marginal utilities are the same across periods, which satisfy the optimal condition.

In other words, an increase in t_2 induces a decrease in the utility in the second period if getting healthy, so results in a decrease in the expected utility of high income people in the second period. Similarly, the higher rate of time preference indicates that the lower discount factor will lead to the lower the total utility in the second period. Conversely, a higher income decrement to pay for cure and enjoy decrement will raise the total utility of high income people in the second period.

4.2 Low Income People

The expected lifetime utility function of low income people can be stated as

$$U^{\rho}\left[W_1, F_1^H, F_1^L, E_2, C_1\right] + \beta\left\{\begin{matrix} p(h^{\rho})U^{\omega}(W_2, F_2^H, F_2^L, E_2, C_2) \\ +(1-p(h^{\rho})U^{\rho}\left[(W_2, F_2^H, F_2^L, E_2, C_2) - s - v + G\right]\end{matrix}\right\} \quad (11)$$

The low income people choose $W_1, W_2, F_1^H, F_2^H, F_1^L, F_2^L, E_1, E_2, C_1, C_2, h, G$ to maximize the expected lifetime utility function (21) subject to resource constraint (22)

$$W_1 + W_2 + F_1^H + F_2^H + F_1^L + F_2^L + E_1 + E_2 + C_1 + C_2 + h^{\rho} - G = \Omega^{\rho} \quad (12)$$

The necessary first order condition for interior solution with respect to $W_1, W_2, F_1^H, F_2^H, F_1^L, F_2^L, E_1, E_2, C_1, C_2, h, G$, respectively, are as follows:

Therefore, we get the optimal condition.

$$U_{F_1^H}^{\rho} W_{F_1^H} = U_{F_1^L}^{\rho} W_{F_1^L} = \beta p'(h^{\rho})\begin{bmatrix} U^{\rho}(W_2, F_2^H, F_2^L, E_2, C_2) \\ -U^{\rho}((W_2, F_2^H, F_2^L, E_2, C_2) \\ -s - v + G) \end{bmatrix} \quad (13)$$

Expressions (13) states that the marginal utilities of weight and consumption goods (high-calorie good, low-calorie good, other consumption good) of low income people in the first period are equal to the marginal benefit from spending on health investment, h, in the second period. That is, marginal utilities are the same across periods, which satisfy the optimal condition.

In other words, an increase in G induces a decrease in the utility in the second period if getting sick, then results in a decrease in the expected utility of low income people in the second period. Similarly, the higher rate of time preference indicates the lower discount factor will lead to the lower the total utility in the second period. Conversely, a higher income decrement to pay for cure (s) and enjoy decrement (v) will raise the total utility of high income people in the second period. These results and the resource constraint will help to determine the equilibrium value.

4.3 Social Utility Function

Following Rosenman (2008), the social utility function is determined as the weighted sum of agent expected utility. Let V^{ω}, V^{ρ} be the relative weights placed on the wealthy and poor people utility, respectively. If such relative weights are equal for all agents then this optimal is Pareto optimal. Thus, the social planner would choose $G, t_2, h^{\omega}, h^{\rho}$ to maximize the social utility function (14) subject to the fair insurance market (15), the high income people's resource constraint (16) and the low income people's resource constraint (17).

$$V^{\omega}n^{\omega}\left\{\begin{array}{l} U^{\omega}\left[W_1, F_1^H, F_1^L, E_2, C_1\right] \\ +\beta\left\{\begin{array}{l} p(h^{\omega})U^{\omega}[(W_2, F_2^H, F_2^L, E_2, C_2)-t_2] \\ +(1-p(h^{\omega})) \\ U^{\omega}\left[(W_2, F_2^H, F_2^L, E_2, C_2)-s-v\right] \end{array}\right\} \end{array}\right\}$$
$$+V^{\rho}n^{\rho}\left\{\begin{array}{l} U^{\rho}\left[W_1, F_1^H, F_1^L, E_2, C_1\right] \\ +\beta\left\{\begin{array}{l} p(h^{\rho})U^{\omega}(W_2, F_2^H, F_2^L, E_2, C_2) \\ +(1-p(h^{\rho})) \\ U^{\rho}\left[(W_2, F_2^H, F_2^L, E_2, C_2)-s-v+G\right] \end{array}\right\} \end{array}\right\} \tag{14}$$

$$t_2 p(h^{\omega})n^{\omega} = G(1p(h^{\rho})n^{\rho} \tag{15}$$

$$W_1 + W_2 + F_1^H + F_2^H + F_1^L + F_2^L$$
$$+E_1 + E_2 + C_1 + C_2 + h^{\omega} + t_2 = \Omega^{\omega} \tag{16}$$

$$W_1 + W_2 + F_1^H + F_2^H + F_1^L + F_2^L$$
$$+E_1 + E_2 + C_1 + C_2 + h^{\rho} - G = \Omega^{\rho} \tag{17}$$

Define λ as the Lagrange multiplier on fair insurance market, μ as Lagrange multiplier on the high income people's resource constraint (the marginal utility of high income people's wealth), and ϕ as the Lagrange multiplier on the low income people's resource constraint (the marginal utility of wealth of poor people). Thus the necessary first order conditions for interior solution with respect to $G, t_2, h^{\omega}, h^{\rho}$, respectively, are computed. As a result, for poor people, the social optimal conditions are as follows:

$$\frac{V^{\omega}U^{\omega}_{W_1}}{p(h^{\omega})} + V^{\omega}\beta U^{\omega}_{t_2} = \frac{V^{\rho}U^{\rho}_{W_1}}{1-p(h^{\rho})} + V^{\rho}\beta U^{\rho}_{G} \tag{18}$$

$$V^{\omega}\left[\frac{U^{\omega}_{W_1}}{p(h^{\omega})} + \beta U^{\omega}_{t_2}\right] = V^{\rho}\left[\frac{U^{\rho}_{W_1}}{1-p(h^{\rho})} + \beta U^{\rho}_{G}\right] \tag{19}$$

$$\beta\rho'(h^{\omega})\left[\begin{array}{l} U^{\omega}((W_2, F_2^H, F_2^L, E_2, C_2)-t_2) \\ -U^{\omega}((W_2, F_2^H, F_2^L, E_2, C_2)-s-v \end{array}\right]$$
$$+\frac{\lambda t_2 p'(h^{\omega})}{V^{\omega}} = U^{\omega}_{W_1} \tag{20}$$

$$\beta\rho'(h^{\rho})\left[\begin{array}{l} U^{\rho}(W_2, F_2^H, F_2^L, E_2, C_2) \\ -U^{\rho}((W_2, F_2^H, F_2^L, E_2, C_2)-s-v+G \end{array}\right]$$
$$+\frac{\lambda G p'(h^{\rho})}{V^{\rho}} = U^{\rho}_{F_1^H} W_{F_1^H} \tag{21}$$

The expression (19) states that the social planner would choose t_2 and G which satisfies the socially optimal condition. That is, the weighted marginal utility of weight of the wealthy people divided by the probability of being healthy in period 2, plus the weighted expected marginal utility of tax of the wealthy people equal to the weight marginal utility of weight of the poor people divided the probability of being sick in the second period of poor people, plus the weighted expected marginal utility of subsidy of the poor people. In other words, the marginal cost of policy is equal to the marginal benefit of the policy if the marginal utility of weight of the wealthy people and poor people are equal to zero.

Equations (30) and (31) show that the marginal utility of healthy wealthy and poor people in the first period in the social optimality are larger than the marginal utility with free choice due to the externality, so the socially optimum spending on healthy lifestyle choice of wealthy and poor people h^{ω}, h^{ρ} exceed h^*.

4.4 Reduced Form

Following Philipson and Posner (1999), an illustrative reduced form of utility function is a quasi-linear function with introducing weight, food and exercise. That is,

$$U\left(W, F^H, F^L, C, E\right) = -\frac{\alpha}{2}\left(W - W_0\right)^2 + \delta\left(F^H + F^L\right) + C + E \quad (22)$$

where α is the important of weight concerns to the individual. δ is the value calorie intake per se.

In addition, weight is the proportional to the net consumption of calorie as follows:

$$W\left(F^H, F^L, E\right) = F^H + F^L - E \quad (23)$$

In fact, weight is a linear function of a high-calorie good, a low-calorie good, and exercise which are measured in a unit of other consumption good. Therefore, weight is equal to a high-calorie good plus a low-calorie good minus exercise.

Previously, the findings show that weight depends substantially on spending on the health development in the second period, the diminished capacity of the agent to enjoy consumption if sick, the expected utility function in the second period, and the expected utility function with benefit from insurance in the second period.

As a result, the key contributions of this research in different cases demonstrate that the optimal condition with market insurance in the state preference model that weight depends considerably on spending on the health development in the second period, the diminished capacity of the agent to enjoy consumption if sick, and the expected utility function in the second period. In case of public policy, the results show that weight depends slightly differently on spending on the health development of high income people in the second period and the net expected utility function in the second period of high income people. Besides, the weight depends dramatically on spending on the health development of low income people in the second period and the net expected utility function in the second period of low income people. In the case of social utility, the weight depends also on spending on the health development of high income people and low income in the second period. These results are relevant for the next empirical research.

5. Empirical Result

Table 2 presents the descriptive statistics of the body mass index, income and exercise. The data for studying come from the first, second, third and fourth reports on the National Health Examination Survey of Thailand conducted by the Ministry of Public Health during 1991-1992, 1996-1997, 2003-2004, and 2008-2009. An average BMI of 23.37 km/m^2 is overweight with standard deviation of 2.84.The maximum and minimum BMI are 31.5 and 19.3, respectively. The monthly mean individual income is equal to 4,618.61 baht with standard deviation of 1,940.71. The maximum and minimum incomes are 8,906.00 and 1,991.00 baht, respectively. Deficiency exercise has a mean of 28.49% with standard deviation of 14.87. It has maximum deficiency exercise of 59.6% and minimum deficiency exercise of 8.9%.

More importantly, data from a survey of 2,500 samples in over 50 administrative districts of Bangkok in 2012 showed the following characteristics: most samples were female — 52.2%, and the rest are male: 47.8%. 97.7% of samples were aged 13 to 75, 70.3% of those were singles, and 63.1% of those were studying. Most samples had gained diploma or bachelor degree — 76.8%, currently working — 70.3%, employees — 65.2%, income between 10,001 to 20,000 baht — 42.2%, members of families of between 1 to 11 persons — 97.2%, and carried the burden of caring for a family of between 0 to 7 persons — 62.9%.

In particular, most samples were highly obese. In fact, an average of currently BMI is 37.10 kg/m^2 with standard deviation of 7.64 kg/m^2. The average BMI last-year was 36.77 kg/m^2 with standard deviation of 7.60 kg/m^2. A mean BMI three years ago was 35.76 kg/m^2 with standard deviation of 7.46 kg/m^2. A mean BMI five years ago was 35.14 kg/m^2 with standard deviation of 8.19 kg/m^2.

Table 2 Summary of statistics for BMI, Income and Deficiency Exercise.

	BMI(km/m^2)	INCOME(baht)	Deficiency Exercise(%)
Mean	23.37	4618.61	28.50
Median	23.00	3948.50	24.53
Max.	31.50	8906.00	59.60
Min	19.30	1991.00	8.90
Std. Dev.	2.84	1940.71	14.87
Skewne	1.35	0.79	0.59
Kurtosis	5.31	2.73	2.18
Jarque-Bera	9.49	1.91	1.56
Prob.	0.008	0.38	0.46
Sum	420.60	83135.00	512.96
SumSq. Dev.	137.12	64028378	3758.87

Samples' activities in their spare time was usually using computers or mobiles for surfing the internet, chatting, watching television, watching movies, etc. (72.5%). In contrast, most samples chose to get some exercise (63.5%) when they responded the question, "If you have only one choice to take care of your health, what choice do you choose?" The second choice was having healthy food (30.8%). The mean of monthly spending on expensively healthy food was 19.60% of income with standard deviation 19.59%. When we asked the question, "How much would you prefer to spend on risk alleviation?", most respondents were willing to spend 5% monthly (32.1%). Besides, the risk-mitigating spending from getting sick, which was less than or equal to 5% per month (37.8%). In addition, such spending which is between 6-10% per month was 32.1%.

The 61.8% of respondents paid for costs of medical care via the right of social welfare such as social security, rights of government officials, and health insurance. 18.5% of respondents paid for one by themselves. Furthermore, what if the government collects income tax from high-income people in order for curative care of the lowest-income people (less than 2,910 baht per month each)? 42.2% of respondents agreed to income tax of ≤ 5%. And if the government allocates resources to support the lowest-income people for curative care? 48.7% of respondents agreed to resource allocation of ≤ 50% of each curative payment. These results were the particular characteristics of the respondents. Further details of characteristics from such surveys are not presented here, however, because of the limitation of space.

Table 3 shows the next empirical findings that there are significant effects on the body mass index (BMI) employed by the Logistic Regression Model. Data come from a survey of 2,500 samples over 50 administrative districts of Bangkok in 2012. In fact, all explanatory variables can statistically explain the body mass index with a likelihood ratio statistic of 42.76, p-value of 0.000, and pseudo R^2 of 0.0769.

Most importantly, the relationship between explanatory variables and the probability of being obese is consistent with the derived model in this research. That is, gender(Gen), marriage status(Mar), occupation(Occ), exercise per week(E), activity in spare time(Act), curative care(HC), and risk-mitigating spending from getting sick (RM) which are negatively related to the probability of being obese. In contrast, age(Age), education level(Edu), personal income level per month$(Income)$, and monthly spending on expensively healthy food (Exp) are positively correlated with the probability of being obese.

Table 3 Logistic Regression Model of the Reduced Form

bmi	Coef.	Std. Err.
Gen	-0.88	0.24
Age	.056	0.017
Mar	-0.48	0.27
Edu	0.09	0.19
Occ	-0.09	0.09
Income	0.16	0.14
E	-0.18	0.07
Act	-0.06	0.06
HC	-0.15	0.16
Exp	0.000	0.006
RM	-0.16	0.099
_cons	-0.47	1.01

Even though there are several factors which effect on the probability of being obese, the significant variables are composed of gender, age, marriage status, exercise per week, and risk-mitigating spending from getting sick. In fact, gender has a significantly negative effect on the probability of being obese. The estimated coefficient is statistically significant at 0.01significant level. In particular, a change in probability is equal to -0.1828. This implies that a change in gender from male to female leads to a decline of 0.1828 in probability of being obese.

In addition, age is positively related to the probability of being obese. The estimated coefficient of -0.88374 is statistically significant at a 0.01 significant level. A computed change in probability is equal to 0.01. It means that if people in Bangkok are older by one year, the probability of being obese will go up 0.01. It also implies that the older people are, the more people get the probability of being obese.

The other finding states that marriage status has a negative effect on the probability of being obese. The average slope on marriage status of -0.48 is statistically significant at a 0.10 significant level. A computed change in probability is equal to -0.11. It implies that if people change status from single to married, the probability of being obese will reduce by 0.01

The day per week of exercise is negatively related to the probability of being obese. This negative relationship is statistically significant at the 0.01 level. The estimated coefficient is -0.18. A computed change in probability is equal to -0.04. It means that a decline in probability of being obese for an increase in a day per week of exercise is 0.04.

Furthermore, risk-mitigating spending from getting sick has a statistically negative effect on the probability of being obese at a 0.10 significant level. The estimated coefficient is -0.16. A computed change in probability is equal to -0.04. It means that a decline in probability of being obese for an increase 1% in risk-mitigating spending from getting sick is 0.04.

As a result, there is only a positive relationship between age and the probability of being obese, but the others have a statistically negative effect on the probability of being obese.

6. Conclusion

In the state preference model of endowment economy under uncertainty with perfect capital market, this paper shows the optimal level of health investment to mitigate the probability of sickness in the future that the marginal utility of three types goods (high-calorie good, low-calorie good and other consumption good), exercise, and weight in the first period are equal to the expected marginal benefit from spending on health development in the second period.

More importantly, these findings demonstrate that agents are willing to prevent from the probability of getting obesity rather than reduce the size of utility loss by purchasing the market insurance because spending on health development provides a higher marginal utility than buying market insurance. Similarly, agents will prefer self-insurance to market insurance because the marginal utility of three types of goods; high-calorie good, low-calorie good and other consumption good, are larger than the marginal utility of spending on market insurance except that the marginal utility of weight is above the ideal weight level, WI, and the marginal utility of exercise is negative resulting from the marginal effect of exercise on weight, which is always negative. Therefore, self-protection and self-insurance are more beneficial than market insurance, except in the case of exercise, but agents can buy market insurance to share the future risk.

In terms of public policy, the social planner would collect tax on healthy wealthy people and subsidize the poor people which would satisfy the social optimal condition. That is, the marginal cost of policy adjusted by the marginal utility of weight, high-calorie good, low-calorie good, other consumption good, or exercise is equal to the marginal benefit of the policy adjusted by the marginal utility of weight, high-calorie good, low-calorie good, other consumption good, or exercise including the probability of being healthy or sick in the second period. If the marginal utility of weight of the wealthy people and poor people are equal to zero, the marginal cost of policy is equal to the marginal benefit of the policy as in Rosenman (2008).

As a result, the marginal utility of healthy wealthy and poor people in the first period in the socially optimal are higher than the marginal utility with free choice due to the externality, so the socially optimum spending on healthy lifestyle choice of wealthy and poor people exceeds the health investment of high income ,or low income people.

In particular, these results do not demonstrate that the social planner should tax and subsidize on what type of good is, so it will be useful to extend that considering the type of tax and subsidy with the dynamics problem of weight. Another possible extension could consider the supply side, especially the technological change.

To illustrate the determinants of the probability of being obese, a reduced form equation will be employed to show that obesity depends mainly on parameters, a non-consumption utility loss, spending on the health development in the next period, and several types of utility in the next period. Therefore, the relationship between these factors and the probability of being obese will examine empirically.

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References:

[1] Aekplakorn, W., Chaiyaporn, Y., Neal B., Chaiyalertsak, S., Kunanusont, C., Phoolcharoen, W., et al., Prevalence and determinants of overweight and obesity in Thai adults: Results of the Second National Health Examination Survey. Journal of the Medical Association of Thailand, Vol .87, 2004, pp 685-693.

[2] Basu, R. and Rosenman, R., Health lifestyle and disease prevention, Manuscript,Washington State University, 2007.

[3] Chuprapavarn, J. , First report on survey of health status in Thai populations by questionnaires and physical examination, 1991-1992. Bangkok: Institute of Public health, 1996.

[4] Deurenberg-Yap, M., Yian, T.B., Kai, C.S., Deurenberg, P., Van Staveren, W.A., Manifestation of cardiovascular risk factors at low levels of body mass index and waist-to-hip ratio in Singaporean Chinese. Asia Pacific

Journal of Clinical Nutrition, Vol.8, 1999, pp. 177-183.

[5] Drenowski, A., Fat and sugar: an Economic analysis. The Journal of Nutrition, Vol.133, 2003, pp.838s-840s.

[6] Jacobson, M.F., Brownell, K.D. (2000). Small Taxes on soft drinks and snack foods to promote health. American Journal of Public Health, 90(6), 854-857.

[7] Jirapinyo, P., Limsathayourat, N., Wongarn, R., Limpimwong, V., Bunnag, A., Chockvivatvanit, S., A summer camp for childhood obesity in Thailand. Journal of the Medical Association of Thailand, Vol.78, 1995, pp.238-246.

[8] Kantachuvessiri, A., Obesity in Thailand. Journal of the Medical Association of Thailand, Vol.88, No.4, 2005, pp. 554-562.

[9] Kantachvessiri, A., Sirivichayakul C., Kaewkungwal J., Tungtrongchitr R., Lotrakul M., Factor associated With obesity among workers in metropolitan waterworks authority. The Southeast Asian Journal of Tropical Medicine and Public Health, Vol, 36, No.4, 2005, pp. 1057-1065.

[10] Ko, G.T.C., Chan, J.C.N., Cockram, C.S., Woo, J., prediction of hypertension, diabetes, dyslipidaemia or abluminuria using simple anthropometric index in Hong Kong Chinese. International Journal of Obesity, Vol.23, 1999, pp.1136-1142.

[11] Lakdawalla, D., Philipson, T. The Growth of Obesity and Technological Change. Economic of Human Biology, Vol.7, No.3, 2009, pp.283-293.

[12] Napradit, P., Pantaewan, P., Nimitarnun, N., Souvannakitti, D., Rangsin, R., Prevalence of Overweight and obesity in Royal Thai Army personnel. Journal of the Medical Association of Thailand, Vol.90, No.2, 2007, pp.335-340.

[13] National Health Examination Survey Office, The First National health examination Survey of Thailand in 1991-1992, 1992.

[14] National Health Examination Survey Office, The Second National health examination Survey of Thailand in 1996-1997, 1998.

[15] National Health Examination Survey Office, The Third National health examination Survey of Thailand in 2003-2004, 2006.

[16] National Health Examination Survey Office, The Fourth National health examination Survey of Thailand in 2008-2009, 2010.

[17] Philipson, T.J., Posner, R.A., The long-run growth in obesity as a function of technological change. National Bureau of Economic Research Working paper 7423, 1999.

[18] Rosenman, R., The public policy of healthcaresubsidies. Manuscript, Washington State University, 2008.

[19] Ruangdaraganon, N, Kotchadhakdi, N, Udomsubpayakul, U,Kunanusont, C, Suriyawongpaisal, P.,The association between television viewing and childhood obesity, Anational Survey in Thailand.Journal of the Medical Association of Thailand, Vol.65, Suppl 4, .2002, pp.S1075-1080.

[20] Sakamoto, N., Wansorn, S., Tontisirin, K. and Marui, E., A social epidemiologic study of obesity among preschool children in Thailand. International. Journal of Obesity, Vol. 25, pp. 389- 394, 2001.

[21] Schroeter, C., Lusk, J., Tyner, W. Determining the impact of food price and income change on body weight. Journal of Health Economics, Vol.27, 2008, pp. 45-68.

[22] World Health Organization. Report of a WTO consultant on Obesity. Geneva, Switz, 2006.