A Growth Model of Weight Preferences, Food Consumption and Public Policy

Evangelos V. Dioikitopoulos[*], Marina-Selini Katsaiti[†], Philip Shaw[‡]

December 29, 2012

Abstract

In this paper we unify existing theories and empirical evidence on the origins of obesity and examine the effects of fiscal policy on the dynamic evolution of weight. We build a dynamic general equilibrium growth model, with two sectors, one producing food and the other producing a composite consumption good. Weight is a function of rational choice as well as labor allocation between the two sectors. By estimating utility from weight and calibrating the US economy we show that (i) technological advances in agriculture decrease food prices and increase weight but not necessarily through higher food consumption but through lower calorie expenditure, (ii) reducing capital taxation, initially depresses weight levels through higher food prices; however, in steady state food consumption and weight soar due to greater income levels, (iii) reducing taxation on food increases food consumption and weight levels in equilibrium. Labour reallocation towards the less sedentary sector on one hand and lower food prices and higher income on the other function as counteractive forces. However, in equilibrium the second effect prevails.

JEL classification: O11, O41, H55, E62.

Keywords: Macroeconomics of Obesity, Rational Eating, Weight preferences, Taxation

[*]Department of Economics, Brunel University London, evangelos.dioikitopoulos@brunel.ac.uk.

[†]Department of Economics and Finance, United Arab Emirates University, selini.katsaiti@uaeu.ac.ae.

[‡]Department of Economics, Fordham University, New York, US, pshaw5@fordham.edu.

1 Introduction

The rapid increase in obesity rates within the past century, but essentially after World War II, has caused dramatic escalation in the attention of scientists and researchers. Obesity is primarily an issue of public health, and it has mainly been treated as such, but has several aspects closely associated with other disciplines. Among them one can identify, economics, psychology and public policy. The rising interest of economists on obesity comes not only as a consequence of the severe health complications and medical costs associated with it, but also from its numerous implications for productivity, consumption theory, allocation of leisure time or labor choice. Despite the extensive literature centered around the obesity epidemic, research has still not produced a convincing theoretical foundation explaining the facts and suggesting policy interventions towards solutions.

Philipson and Posner (1999) show, using a theoretical micro model, that technological advances have had twofold implications towards weight accumulation. Tremendous gains in agricultural productivity and food processing have significantly contributed to the decrease in food prices and increase in food consumption present in US data. This shift from agricultural economies to ones centered around capital intensive production, such as manufacturing and services, slashed calorie expenditure since exercise is no longer a byproduct of work, making it more costly.

Along the same lines, Lakdawalla and Philipson, (2002) and Lakdawalla et al. (2005) provide theoretical and empirical evidence that increased food consumption has a less exalted role in the skyrocketing upturn of obesity rates compared to changes in the strenuousness of work and leisure, both at home and in the market. The distribution of labor across sectors impacts calorie expenditure and obesity rates. In the same vein, Cutler et al. (2003) propose a theory based on the division of labor in food preparation. The driving force is technological innovation that has enabled mass production of food. Their empirical findings show that increased calorie intake is largely a result of consuming more meals rather than more calories per meal.

Literature on rational choice theory pertaining to food consumption has reached the following conclusions. Levy (2002) provides a theoretical micro model of rational eating in the presence of a trade-off between food consumption and probability of death, and shows that in the absence of psychological, physiological, environmental and socio-cultural reasons for divergence from the physiologically optimal weight, overweightness is a steady state outcome. When socio-cultural norms are added to the model, steady state weight of fat people is lower and of lean people is higher than otherwise. Dragone (2009) elaborates on the model of Levy (2002) by allowing agents to have habits in food consumption. Both oscillatory and monotonic patterns in food consumption arise, and both lead to overweightness in equilibrium, even when heterogeneity in eating behavior is taken into consideration. In a more comprehensive modelling approach Dragone and Savorelli (2011) provide a framework under which rational eating can lead individuals to either overweightness or underweightness in equilibrium. When individuals are heterogeneous in their healthy weights but are affected by the same ideal body weight, then increasing the thin ideal might be welfare improving but the obesity epidemic might be overstated.

Leicester and Windmeijer (2004) discuss the implementation and the expected consequences of a "fat tax" and express doubts regarding the effectiveness of the measure in reducing obesity levels in the UK. Similar findings are reported by Chouinard et al. (2005). Allais, Bertail and Nichele (2008) using French data find that a "fat tax" has small and ambiguous effects on nutrients consumption, and slight effect on body weight in the short run, with a bigger effect in the long run. Yaniv, Rosin and Tobol (2009) examine the effects of a "fat tax" and a thin subsidy in a theoretical model. Their findings show that for non-weight conscious individuals a food tax will unambiguously reduce obesity, but a thin subsidy might have the opposite result. For weight conscious and physically active individuals, such a tax might have an undesirable effect, and increase obesity levels. Andreyeva, Long and Brownell (2010) review 160 studies on price elasticity of demand for food. Across these studies there is evidence of persistence in food purchasing behavior. Mean price elasticity estimates range between 0.27 and 0.81. One USDA study estimates that a 10% price increase from a national sales tax could reduce body weight between 0.1-0.5 kg per year. Although demand is relatively inelastic, the power of small price changes should not be underestimated, especially since the effects accumulate across the population. Tiffin and Arnoult (2011) provide empirical evidence on the effectiveness of a "fat tax" in reducing obesity in the UK. Although the tax is able to increase the intake of fruit and vegetable to the recommended daily levels, it fails to achieve this goal for fat intakes. The effect of the policy is found to be negligible.

We construct an agent based computable two-sector dynamic general equilibrium macroeconomic model. Utility depends positively on the consumption of food and a composite consumption good, and is a non-monotonic inverted U-shaped function of weight. The peak of the curve represents the individual's ideal weight and any deviations lower individual utility. On the relationship between utility and weight, we borrow the fundamental intuition of Philipson and Posner (1999) and we verify it using data.

In this paper lower food prices can increase calorie intake, but this response may be sensitive to preferences for food versus low weight. To this end, we model food consumption and weight choices explicitly, so that food consumption results from rational choice. The inverted U-shape relationship between weight and utility, makes demand elasticity of food to vary, since preferences vary according to weight level at any time period. The allocation of labor to each sector of production, agriculture and services, depends on equilibrium wages and prices. We assume that agriculture is labor intensive and less sedentary relative to services, so in a sense workers are paid to exercise. Public policy outcomes are investigated under the imposition of a) a tax on capital earnings and b) a tax on food.

The contribution of our paper is twofold, positive and normative. Our positive analysis presents a modeling approach which unifies the aforementioned explanations regarding the causes of obesity and verifies the dynamics of the empirical and theoretical literature, present in the US data. In particular, this framework provides a full quantitative exercise where technological advances in agricultural production of the US economy lower the price of food, shift labor towards the more sedentary sector and result to an increase in the weight level consistent with the dynamics of the US economy. The contribution of our technique stands in that we are able to offer an approach which bundles up the dynamics leading to the obesity epidemic providing two novel elements to the literature: (i) we calibrate the US economy and (ii) we estimate the functional form of the utility dependence on weight. Using regression analysis applied on US data we are able to confirm the preceding assumption of Philipson and Posner (1999) regarding the inverted U-shaped relationship between utility and weight.

Second, the ability of our modeling framework to replicate the dynamics present in the

US data enables the investigation of public policy instruments in that same environment and allows for a normative aspect of our analysis. We investigate two separate taxation instruments, a capital earnings tax and a food tax. With regards to the capital earnings tax, we contribute to the literature by addressing and investigating its potential impact on food consumption and weight levels. A reduction in capital taxation increases the capital stock in the economy and as a consequence labor productivity in the sedentary sector. In turn, the relative price of food increases, food consumption falls and the weight level drops. In our quantitative exercise for the US economy the reduction in capital earnings tax results to a higher income effect and in turn higher wage rate. This exercise is important as it provides a baseline framework of analysis applicable to other countries and provides theoretical justification for the mixed empirical evidence regarding the relation of food prices, income and weight.

Investigating the effect of food taxation is an imperative need since existing literature has brought to light several contradictory findings (Leicester and Windmeijer (2004), Chouinard et al. (2005), Allais, Bertail and Nichele (2008), Yaniv, Rosin and Tobol (2009), Andreyeva, Long and Brownell (2010), Tiffin and Arnoult (2011)). Our quantitative method is able to unravel the relationship between food tax and food consumption. By calibrating US data and the elasticity of demand for food we find that the net effect is an increase in weight in equilibrium. Due to the general equilibrium nature of our model two effects take place simultaneously. In particular, following the food tax cut, after tax real wage increases, food consumption and weight increase. At the same time labour reallocates towards the agricultural sector increasing calorie expenditure which in turn decreases weight. This fact points to a trade off between production and consumption of food. The increase in production results in higher calorie expenditure reducing weight whereas greater food consumption increases weight. Our method complements the literature by identifying the prevalence of the consumption over the production effect, based on the trade off, for the US economy.

Last, but not least, our normative analysis inevitably highlights the difference between the two policy instruments investigated. Decreasing the food tax brings about contradictory results, the net effect of which depends on their dominance. Thus weight can either increase or decrease in equilibrium. However, decreasing capital earnings tax has an indisputable decreasing effect on weight, due to lack of counteracting forces. Policy makers should therefore consider the effectiveness gap between the two policy instruments, since the capital earnings tax seems to be working better.

The paper is organized as follows. Section 2 presents the model. Section 3 describes the data and the calibration exercise. Simulations and results are shown in Section 4. Section 5 concludes.

2 The Model

In this paper we attempt to model and explain the escalating obesity patterns that have been observed in recent decades across the globe. Due to the complexity of the issue, one cannot identify a single cause and certainly the answer is not a simple one. However, incorporating key elements in the model, we can evaluate some of the competing claims about the sources of increasing obesity rates.

2.1 Households

The economy is made up of a large number of identical, infinitely lived households, normalized to unity. Agents value consumption of food, f, and a composite consumption good, c, and derive utility from their weight level, $\Omega(W)$. Food thus impacts utility directly through consumption and indirectly through weight. Households save in the form of capital assets, k, and supply labor inelastically.[1] The representative agent seeks to maximize lifetime utility given by

$$\max U = \sum_{t=0}^{\infty} \beta^t [\theta \ln(f_t) + (1-\theta)\ln(c_t) + \Omega(W_t)] \tag{1}$$

[1] The allocation of this unit amount of labour to the two sectors depends on the relative wage as determined by labour demand. In particular, in our modeling of a two-sector economy where one good has a minimum required consumption, we follow Alonso (2007) and Bond (1996). Under the assumptions of perfect competition in goods and factor markets and the equalization of factor returns across sectors, factor rewards are determined by output prices alone, independent of factor supplies, as in the factor price equalization property of trade models.

where $\beta \in (0,1)$ is the discount factor and $\theta \in (0,1)$ measures agent valuation of food versus consumption of the composite good. The objective function is subject to the intertemporal budget constraint

$$k_{t+1} = (1 + r_t(1-\tau^k))k_t + w_t + T_t - c_t - p_t(1+\tau^f)f_t \tag{2}$$

where r denotes the interest rate of capital stock, w is the wage rate, p is the relative price of food, τ^k is a tax rate on capital income, τ^f denotes the tax rate on food consumption and T are lump-sum transfers given by the government. Individual weight evolves according to the following law of motion

$$W_{t+1} = \xi f_t - \eta(1-u_t) + (1-\delta)W_t \tag{3}$$

Equation (3) shows that next period weight, W_{t+1}, depends on current weight, W_t, net of its depreciation, $\delta \in (0,1)$ and food consumption, f_t. In addition, we assume that work in agriculture is more strenuous and thus allow for a differential $\eta(1-u_t)$ in the calorie expenditure between the two sectors. [2] Parameter $\xi > 0$ transforms calories into weight.

On the relationship between utility and weight we follow the intuition of Philipson and Posner (1999) on the inverted U-shape:

$$U(W) = \alpha_0 + \alpha_1 W + \alpha_2 W^2 \tag{4}$$

where the α_0 and α_1 are positive and α_2 is negative. Individuals are assumed to have an ideal weight W^*. When $W < W^*$ increases in weight lead to an increase in $U(W)$, while for $W > W^*$, $U'(W) < 0$. The sign of the above parameters is verified through regression analysis.

The household acts competitively by taking prices and policy instruments as given. The interior solution of the household problem including constraints (2) and (3), gives the optimal path of consumption for f_t and c_t as follows:

$$c_t = \frac{c_{t+1}}{\beta(1 + r_{t+1}(1-\tau^k))} \tag{5}$$

[2] Several studies (among others Philipson and Posner, 1999) argue that less sedentary jobs, like agricultural occupations, offer "free" exercise time to the worker and hence lower obesity levels. In environments with more service oriented industries, agents are expected to have higher weight levels.

$$\frac{\theta}{\xi f_t} = \frac{(1-\theta)p(1+\tau^f)}{\xi C_t} + \beta(1-\delta)(\frac{1}{\xi})(\frac{\theta}{f_{t+1}} - (1-\theta)(1+\tau^f)\frac{p_{t+1}}{C_{t+1}}) - \beta(a_1 + 2a_2 W_{t+1}) \quad (6)$$

Equation (6) shows that the marginal utility from food at time t has to be equal to the marginal loss from the reduction in c_t, the marginal loss in c_{t+1} and the gain/loss in W_t and W_{t+1}.

2.2 The Firms

On the production side we have two sectors. Sector 1 produces the composite consumption good. We follow Alonso (2007) in that we split labor in the two sectors, without making any human capital specific demands for either of them. The production function in the composite good sector is:

$$Y = AK_1^{\alpha}(u)^{1-\alpha} \quad (7)$$

A stands for total factor productivity, K_1 is sector 1 specific capital and u is the fraction of the labor force employed in Sector 1.

$$Z = \gamma K_2^{\phi}(1-u)^{1-\phi} \quad (8)$$

Sector 2 produces food, Z. Total factor productivity in the production of food is denoted by γ, K_2 is the capital used in the production of food. Fraction $(1-u)$ of the labor force works in food production.

The profit maximization problem of the firm producing c is given by

$$\max \pi_1 = AK_1^{\alpha}(u)^{1-\alpha} - r_1 K_1 - w_1 u \quad (9)$$

Under perfect competition, both factors of production earn their marginal products and hence:

$$w_1 = A(1-\alpha){K_1}^{\alpha} u^{-\alpha} \quad (10)$$

$$r_1 = A\alpha u^{1-\alpha} {K_1}^{\alpha-1} \tag{11}$$

The firm producing food has the following objecting function:

$$\max \pi_2 = \gamma K_2^{\phi}(1-u)^{1-\phi} - r_2 K_2 - w_2(1-u) \tag{12}$$

Consequently, factors of production are paid the following earnings:

$$w_2 = p\gamma(1-\phi){K_2}^{\phi}(1-u)^{-\phi} \tag{13}$$

$$r_2 = p\gamma\phi {K_2}^{\phi-1}(1-u)^{1-\phi} \tag{14}$$

A word of caution at this point. Capital stocks are determined from aggregate individual savings. But in equilibrium the two rates of return have to be equal to prevent any arbitrage opportunity. In order for this to happen we allocate capital stocks in the two sectors such that their marginal returns are equal. This is done after the individuals make their savings decisions, so that this equilibrium condition does not alter individual choices.

2.3 Government

On the revenue side, the government taxes return on capital at a rate $0 < \tau^k < 1$ and food consumption by $0 < \tau^f < 1$. On the expenditure side, it provides lump-sum transfers to agents, T. The following equation represents the government balanced budget:

$$\tau^k r_t k + \tau^f p_t f_t = T_t \tag{15}$$

2.4 The Dynamic Competitive Equilibrium

In this section we solve for a competitive equilibrium which holds for any feasible policy and analyze its properties.

Definition 1 *The competitive equilibrium of the economy is defined for the exogenous policy instruments* τ^k *and* τ^f*, factor prices* r_1, r_2, r, w_1, w_2, w, *and allocations* K_1, K_2, u, s_t, k_t, f_t, c_t, W_t *such that:*

i) Individuals solve their intertemporal utility maximization problem by choosing c_t, f_t and W_t, given the policy instruments and factor prices.

ii) Firms choose K_1, K_2, and u in order to maximize their profits, given factor prices

iii) All markets clear i.e.

a) the labor market clears $u + (1-u) = 1$,

b) the capital market clears $K_1 + K_2 = k$. We use s_t to analyze the allocation of capital to sectors as follows

$$K_1 = s_t k_t \text{ and } K_2 = (1-s_t)k_t$$

c) the food market clears

$$f_t = \gamma K_2^{\phi}(1-u)^{1-\phi}$$

and the composite good market clears by Walras law.

iv) No arbitrage opportunity exists, $r_1 = r_2 = r$ and $w_1 = w_2 = w$.

v) The government budget constraint holds.

Using the market clearing conditions, no arbitrage conditions and the government budget constraint, after some algebra, the dynamics of the competitive equilibrium are obtained as follows:

$$\frac{C_{t+1}}{C_t} = \beta(1 + r_{t+1}(1-\tau^k)) \tag{16}$$

$$W_{t+1} - W_t = \xi f_t - \eta(1-u_t) - \delta W_t \tag{17}$$

$$\left(\frac{\theta}{\xi f_t} - \frac{(1-\theta)p(1+\tau^f)}{\xi C_t}\right) = \beta(1-\delta)\left(\frac{1}{\xi}\right)\left(\frac{\theta}{f_{t+1}} - (1-\theta)(1+\tau^f)\frac{p_{t+1}}{C_{t+1}}\right) - \beta(a_1 + 2a_2 W_{t+1}) \tag{18}$$

$$r_t = A\alpha(s_t K_t)^{\alpha-1} u_t^{1-\alpha} \tag{19}$$

$$w_t = (1-\alpha)A(s_t K_t)^{\alpha} u_t^{-\alpha} \tag{20}$$

$$A\alpha(s_t^{\alpha-1}K_t^{\alpha-1})u_t^{1-\alpha} = p_t\gamma\phi(1-s)^{\phi-1}K^{\phi-1}(1-u)^{1-\phi} \tag{21}$$

$$(1-\alpha)As_t^{\alpha}K_t^{\alpha}u_t^{-\alpha} = p_t\gamma(1-\phi)(1-s_t)^{\phi}K_t^{\phi}(1-u_t)^{-\phi} \tag{22}$$

$$k_{t+1} = (1+r_t)k_t + w_t - C_t - p_t f_t \tag{23}$$

$$f_t = \gamma((1-s_t)K_t)^{\phi}(1-u_t)^{1-\phi} \tag{24}$$

3 Data and Calibration

Our objective is to calibrate the US economy and examine the changes in economic variables and weight after a permanent change on income tax rate. After replicating the empirical facts we will try to address the effect of other policy instruments as a decrease in the tax rate on food in order to provide some policy implications. We start by finding the stationary solution of the competitive equilibrium given by the following equations.

$$1 = \beta(1+\tilde{r}(1-\tilde{\tau}^k)) \tag{25}$$

$$\tilde{W} = \frac{\xi\tilde{f} - \eta(1-\tilde{u})}{\delta} \tag{26}$$

$$\left(\frac{\theta}{\xi\tilde{f}} - \frac{(1-\theta)p(1+\tau^f)}{\xi\tilde{c}}\right) = \beta(1-\delta)\left(\frac{1}{\xi}\right)\left(\frac{\theta}{\tilde{f}} - (1-\theta)((1+\tau^f))\frac{\tilde{p}}{\tilde{c}} - \beta(a_1 + 2a_2\tilde{W}\right) \tag{27}$$

$$\tilde{r} = A\alpha(\tilde{s}\tilde{k})^{\alpha-1}\tilde{u}^{1-\alpha} \tag{28}$$

$$\tilde{w} = (1-\alpha)A(\tilde{s}\tilde{k})^{\alpha}\tilde{u}^{-\alpha} \tag{29}$$

$$A\alpha(\tilde{s}\tilde{k})^{\alpha-1}\tilde{u}^{1-\alpha} = \tilde{p}\gamma\phi(1-\tilde{s})^{\phi-1}\tilde{k}^{\phi-1}(1-\tilde{u})^{1-\phi} \tag{30}$$

$$(1-\alpha)A(\tilde{s}\tilde{k})^{\alpha}\tilde{u}^{-\alpha} = \tilde{p}\gamma(1-\phi)(1-\tilde{s})^{\phi}\tilde{k}^{\phi}(1-\tilde{u})^{-\phi} \tag{31}$$

$$\tilde{k} = (1+\tilde{r})\tilde{k} + \tilde{w} - \tilde{c} - \tilde{p}\tilde{f} \tag{32}$$

$$\tilde{f} = \gamma(1-\tilde{s})\tilde{k}^{\phi}(1-\tilde{u})^{1-\phi} \tag{33}$$

Equations (25)-(33) form a system of 9 equations with 9 unknowns $\tilde{r}$, $\tilde{w}$, $\tilde{p}$, $\tilde{u}$, $\tilde{s}$, $\tilde{k}$, $\tilde{c}$, $\tilde{f}$, and $\tilde{W}$.

To define the relationship between weight and utility $U(w) = a_0 + a_1 W + a_2 W^2$, we regress happiness on BMI to estimate a_0, a_1, and a_2. Our data come from the 2010 Behavioral Risk Factor Surveillance System database of Centers for Disease Control and Prevention, including observations for approximately $211,000$ individuals. Individual happiness is measured using an index on "Overall life satisfaction" which takes integer values between 1 and 4, with higher values representing greater happiness levels. Due to possible endogeneity issues that could be present in the structural equation and which are verified by the Heckman test, we use instrumental variable analysis in order to avoid invalid inference. Estimated regression coefficients for the quadratic relationship $hap = \alpha_0 + \alpha_1 BMI + \alpha_2 BMI^2$, between happiness (hap) and BMI, confirm our hypothesis of an ideal weight, since α_0 and α_1 are positive and α_2 is negative.

Regarding other parameters, we set the elasticity of capital on industrial production function, $\alpha = 0.34$, as is commonly used by the literature (we also tried parametric range $\alpha = 0.3 - 0.36$ with no change in the results). In addition, we set the capital share on food production function to be $\phi = 0.22$ (our results are robust for $0.15 < \phi < 0.32$), implying a relatively labour intensive sector, while the production function of the composite good, as the existing literature suggests, is capital intensive. θ is set at 0.5 implying identical individual preferences for the two goods. Agents are assumed not to like or dislike one good more compared to the other. This assumption is significant in order for the results not to be driven by exogenous preference parameters. Time preference parameter, β, is set, as usual, to 0.96 (we tried the range $0.95 - 0.98$ given by the literature and the results remain robust). We also set the weight accumulation parameters $\eta = 0.1$, $\xi = 1$ and $\delta = 0.001$ such that we calibrate the average weight for 1960-2010 to 71 kilograms. Last our model is consistent with the labour share employed in agriculture for the same period, that is around 4%.

4 Simulations and Results

4.1 Technological advances in agriculture

Our first aim is to replicate the dynamics present in US data regarding technological advances in agriculture and subsequent changes in food consumption, food price and weight levels. According to the literature (Philipson and Posner (1999), Lakdawalla and Philipson (2001) and Lakdawalla et al. (2006)), the predominant suspect for the increase in obesity rates for the past 50 years is technology. As Figure 1 shows, introducing technological improvements in agriculture in our theoretical model leads to lower food price which reduces real wage in agriculture and induces a shift in labor towards services, increasing u. Despite the decrease in food price food consumption falls, a result triggered by the non monotonic relationship between utility and weight. Rising u boosts sedentary work, shrinks calorie expenditure and imposes an endogenous positive effect on weight.

This finding does test the overall performance of our theoretical framework. In particular, our model performs well in that it replicates dynamics in perfect agreement with the data. This fact urges for further applications of our model on normative questions regarding policy instruments that could defeat the upsurge of obesity.

Here we have to mention an interesting though different finding regarding the effect of technological progress on food consumption, when individuals are initially characterized by very low levels of weight. In particular, when we calibrate the economy at very low individual weight levels, i.e. average 35 kilograms (kg) instead of 71 kg, lower food prices result in greater food consumption as intuitively expected. The difference in our results stems from the inverted U-shaped weight-utility relationship. In particular, for our general case described above where the economy is calibrated at the real average weight for the US economy, that is 71 kg, the individual finds himself on the right of the peak of the curve $W*$ where any increase in weight is utility decreasing. However, when we calibrate the economy for average weight 35 kg the individual finds himself on the left side of $W*$ thus any increases in weight translate into higher utility levels. Hence, the exact position of the individual - left or right - on the inverted U-shaped curve activates different mechanisms of decision making that satisfy utility maximization and highlights the importance of estimating the weight-utility relationship.

4.2 Easing taxation on capital

In this section, we investigate steady-state and dynamic effects of a permanent decrease in capital taxation on equilibrium weight as well as other key endogenous variables of the economy. This tax cut prompts an escalation in savings, wages and the relative price of food; as a consequence consumption of food and equilibrium weight increase.

In particular, following the decrease in capital taxes, greater savings bring about higher levels of capital stock. Consequently, labour becomes relatively more productive in the capital intensive sector, increasing wages and resulting in a reallocation of labour from agriculture to the production of the composite good. The decrease in supply of agricultural goods in turn, causes an increase in the relative price of food. However, the decrease in food consumption due to the greater food price is crowded out by increasing food consumption levels stemming from higher income levels. The net effect is greater weight levels. In addition, weight increases further due to the endogenous increase in u leading to more sedentary lifestyles.

Interestingly, the dynamics of our model show a non-monotonic effect of capital taxes on weight. Initially, the relative price of food increases, weight and food initially drop and then increase significantly. At the same time, wages increase responding to the lower tax rate. Intuitively, a decrease in capital taxes leads to an increase in the demand and the price of food which, in turn, decrease food consumption as food production does not respond immediately. Thus the shock is followed by an immediate weight decrease. However, as capital and income increase, consumption of food rises bringing about higher weight levels. In addition, higher levels of capital translate into a relatively greater increase in the wage rate in the capital intensive sector; as a consequence, labor reallocates from Sector 1 to Sector 2. This labor reallocation results in lower calorie expenditure which in turn gradually increases weight. Higher food consumption due to the income effect of lower taxes further increases weight to a higher steady-state level.

We observe that the model is able to replicate in steady-state the effect of a real tax reform that appears in the US data. In fact, the tax reform Act of the mid 1980s translated into a lowering of the personal income tax rates (Gomis-Porqueras and Peralta-Alva, 2008) and was followed by generous increases in the obesity rates in the US.

4.3 Decreasing the fat tax

In this subsection, we examine the steady-state and dynamic effects of a decline in the food tax rate. Overall, following the food tax cut, our steady-state results show that food consumption and weight increase, composite good consumption decreases, while wages and prices remain at the same level. Labour reallocates towards the agricultural sector.

Unlike the consequences of capital tax reduction presented above, here we observe some counteracting forces. On one hand, the decrease in food tax increases food consumption and weight as intuitively expected. On the other hand, labor reallocation towards agriculture, increases calorie expenditure reducing weight. Our calibration of US economy shows that the first effect prevails since the tax cut has a clear positive monotonic effect on weight.

Regarding the dynamic transition to the new steady-state, a lower tax rate on food, causes an immediate increase in food consumption. The lower food tax makes food cheaper motivating a substitution and an income effect which both work in the same direction, increasing food consumption. At the same time the relative price of food and the wage rate jump up. Greater price functions as a disincentive for food consumption whereas the income increase works in the opposite direction. The sudden increase in food consumption following the initial shock is followed by a monotonic and concave decrease. This can be due to two reasons. First, food price and wage rates drop substantially right after the shock. The decrease in wage most likely dominates that of prices. Second, since agents don't have stronger preference for either good, consumption smoothing behavior results in lower food consumption and greater composite good consumption. Despite the reduction in food levels following the initial surge, food converges to a higher steady state level than before the tax cut. The permanently higher levels of food consumption on one hand and the greater calorie expenditure due to labor reallocation on the other, translate into an increasing but concave evolution of weight. Steady state levels of food consumption and weight produced by the dynamics above are in line with US data.

5 Conclusions

In this paper we unify existing theories and empirical evidence on the origins of obesity and examine the effects of fiscal policy on the dynamic evolution of weight. We build a dynamic general equilibrium growth model, with two sectors, one producing food and the other producing a composite consumption good. Weight depends on food consumption and work strenuousness. Agriculture is defined as work that exerts greater physical effort. Our aim is to first replicate the dynamics present in US data regarding the effect of technological advances in food production. Once we successfully complete this first step we dig into the model by investigating the potential impact of alternative public policy tools.

In particular, by empirically estimating utility from weight and calibrating the US economy we show that (i) technological advances in agriculture decrease food prices and increase food consumption and weight; this result establishes the fact that our model performs well and reproduces data dynamics, (ii) reducing capital taxation, initially depresses weight levels through higher food prices; however, in steady state food consumption and weight soar due to greater income levels, (iii) reducing taxation on food increases food consumption and weight levels in equilibrium. Labour reallocation towards the less sedentary sector on one hand and lower food prices and higher income on the other function as counteractive forces. However, in equilibrium the second effect prevails.

6 References

Allais, O., P. Bertail, and V. Nichèle. 2009. "The Effects of a Fat Tax on French Households' Purchases: A Nutritional Approach." American Journal of Agricultural Economics 92: 228-245

Andreyeva T, Long MW, Brownell KD. The impact of food prices on consumption: A systematic review of research on price elasticity of demand for food. American Journal of Public Health. 2010 Feb;100(2):216-222.

Chouinard, H.H., Davis, D.E., LaFrance, J.T., and J.M. Perloff. 2007. Fat Taxes: Big Money for Small Change. Forum for Health Economics & Policy 10(2).

Cutler, David M., Edward L. Glaeser, and Jesse M. Shapiro. 2003. "Why Have Americans Become More Obese?" Journal of Economic Perspectives, 17(3): 93–118.

Davide Dragone, 2009. A rational eating model of binges, diets and obesity. Journal of Health Economics 28 (2009) 799–804

Davide Dragonea and Luca Savorelli, 2011. Thinness and obesity: A model of food consumption, health concerns, and social pressure. Journal of Health Economic, forthcoming.

Gideon Yaniv, Odelia Rosin and Yossef Tobol. Junk-food, home cooking, physical activity and obesity: The effect of the fat tax and the thin subsidy. Journal of Public Economics, 2009, vol. 93, issue 5-6, pages 823-830

Lakdawalla, Darius, and Tomas J. Philipson. 2002. "The Growth of Obesity and Technological Change: A Theoretical and Empirical Examination." National Bureau of Economic Research Working Paper 8946

Lakdawalla, Darius, Tomas J. Philipson, and Jay Bhattacharya. 2005. "Welfare-Enhancing Technological Change and the Growth of Obesity." American Economic Review, 95(2): 253–57.

Leicester, A. and Windmeijer, F. (2004) The 'fat tax': economic incentives to reduce obesity. Institute for Fiscal Studies: London, UK.

Levy, A., 2002. Rational eating: can it lead to overweightness or underweightness?

Journal of Health Economics 21, 887–899

Philipson, Tomas J., and Richard A. Posner. 1999. “The Long-Run Growth in Obesity as a Function of Technological Change.” National Bureau of Economic Research Working Paper 7423.

Richard Tiffin & Matthieu Arnoult, 2010. "The demand for a healthy diet: estimating the almost ideal demand system with infrequency of purchase," European Review of Agricultural Economics, Foundation for the European Review of Agricultural Economics, vol. 37(4), pages 501-521, December.

Tomas J. Philipson and Richard A. Posner, 2008. Is the Obesity Epidemic a Public Health Problem? A Review of Zoltan J. Acs and Alan Lyles's Obesity, Business and Public Policy. Journal of Economic Literature 46:4, 974–982.

7 Tables

Table A. Values for the parameters

Parameter	Description	Value
α	share of capital in the composite production function	0.34
ϕ	share of capital the food production function	0.26
η	effect of labour allocation on weight	0.1
θ	preference for f vis a vis c in utility function	0.5
A	aggregate productivity in composite good	1
γ	aggregate productivity in agriculture	$1-$ 1.5
a_1	estimated weight preference	0.222
a_2	estimated weight preference second order effect	-0.00345
ρ	rate of time preference	0.96
τ_r	tax rate on capital	$0.22 - 0.15$
τ_f	tax rate on food	$0.22 - 0.15$
ξ	tranformation rate of food to calories	1
δ	depreciation rate of weight	0.001

Table B. Steady-State Results

W	u	s	f	c	K	p	w	r
Base Line Model								
71.3375	**0.959852**	**0.972264**	**0.0753524**	**2.49043**	**16.3033**	**1.23297**	**1.71244**	**0.0534188**
Increase in Technology of Agriculture ($\gamma = 1$ to $\gamma = 1.2$)								
71.7859	0.966646	0.977007	0.0751213	2.50806	16.339	1.02747	1.71244	0.0534188
Decrease of Capital Tax Rate ($\tau^k = 0.22$ to $\tau^k = 0.15$)								
71.4274	0.961212	0.973216	0.0753062	2.60686	18.5788	1.24588	1.78996	0.0490196
Effect of a Decrease in Food Tax Rate ($\tau^f = 0.22$ to $\tau^f = 0.15$)								
71.4055	0.959814	0.972237	0.0754242	2.49034	16.3031	1.23297	1.71244	0.0464993

8 Figures

Figure 1: Agricultural Productivity and Weight

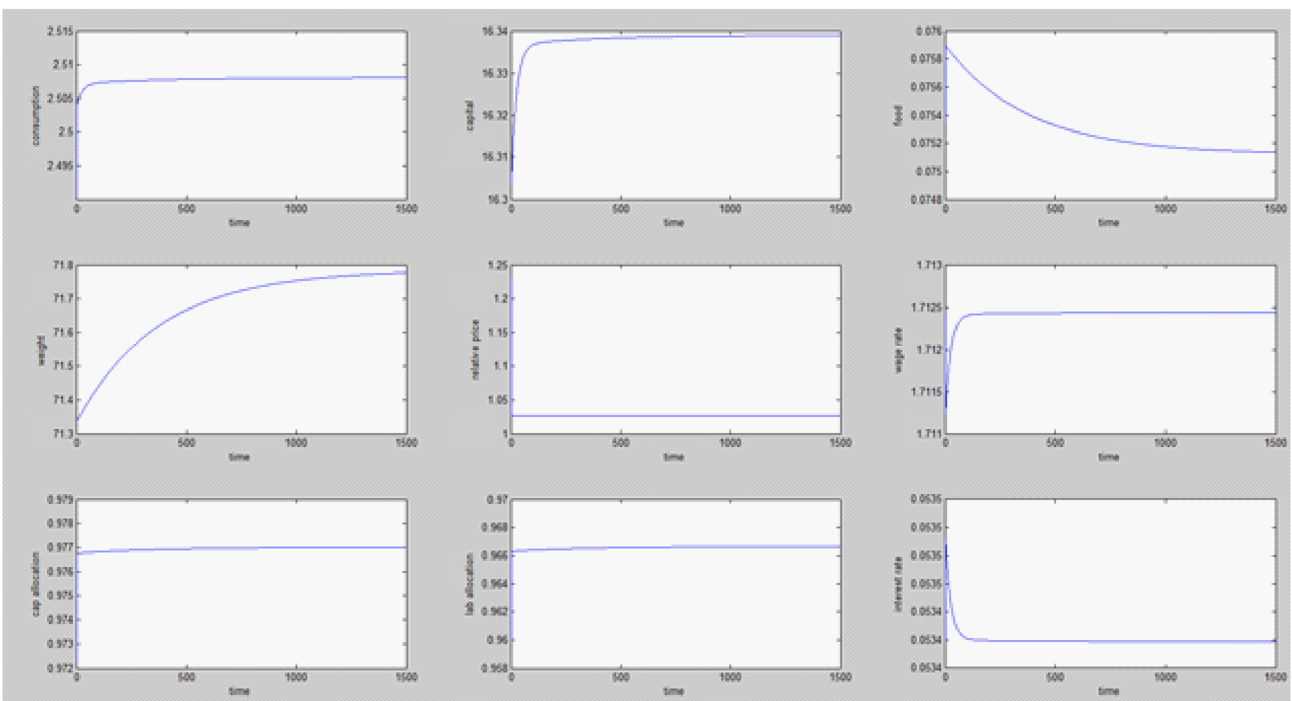

Figure 2: Tax Rate on Capital and Weight

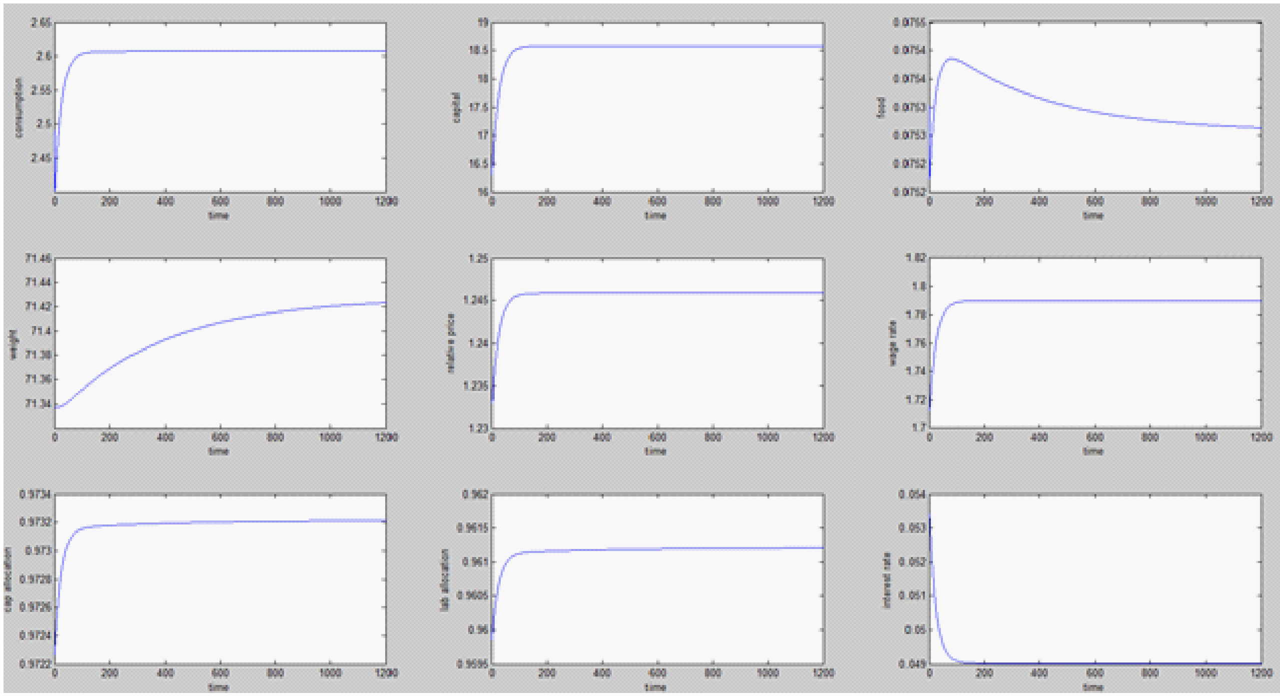

Figure 3. Tax Rate on Food and Weight