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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; steady state food consumption decreases due to a price substitution effect but weight soars due to lower calorie expenditure, (iii) reducing taxation on food increases food consumption and weight levels in equilibrium. Labor reallocation towards the less sedentary sector on one hand and higher income on the other function as contradictory forces.

JEL classification: O41, H20, E62.

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

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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 its severe health complications and medical costs, but also from its numerous implications for productivity, consumption theory, allocation of leisure time or labor choice. Baum and Ruhm (2009) and Baum (2011) provide a thorough review of the micro literature on the obesity epidemic. However, research is still needed to produce a unified macroeconomic theoretical framework explaining the empirical facts and suggesting policy interventions towards solutions.

From a positive view, in an attempt to suggest such a modeling framework, Philipson and Posner (1999) show, in a theoretical micro model, that technological advances have had twofold implications towards weight accumulation. In particular, tremendous gains in agricultural productivity and food processing have brought about significant decrease in food prices followed by higher calorie intake. At the same time, they have contributed to the reallocation of labor from agriculture to more sedentary jobs, such as services and manufacturing. This fact slashed calorie expenditure since exercise is no longer a byproduct of work, making it more costly. In the same vein, Lakdawalla and Philipson, (2002) and Lakdawalla et al. (2005) provide theoretical and empirical evidence that increased food consumption has had 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. Cutler et al. (2003) elaborate on this argument suggesting technological innovation as the driving force that has enabled mass production of food and increasing obesity rates.

From a normative view, 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. (2007). Allais, Bertail and Nichele (2010) 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. Tiffin and Arnoult (2010) 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 fruits and vegetables 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), which we verify 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-shaped 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. In particular, we extend the intuition of Philipson and Posner (1999), Lakdawalla and Philipson, (2002) and Lakdawalla et al. (2005) and propose a computable dynamic macroeconomic

framework 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.

Second, the ability of our modeling framework to replicate the dynamics of the US economy 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 tax has a positive effect on steady-state weight through a non-monotonic dynamic effect. A reduction in capital taxation increases the capital stock in the economy and as a consequence the relative labor productivity in the sedentary sector. In turn, the relative price of food increases, food consumption falls and the weight level drops. At the same time, in our quantitative exercise for the US economy the reduction in capital earnings tax results to a positive income effect and in turn to higher wage rate and a more sedentary work which raises weight. 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.

Existing research on the relationship between food consumption and food tax has brought to light contradictory findings (Leicester and Windmeijer (2004), Chouinard et al. (2007), Allais, Bertail and Nichele (2010), Yaniv, Rosin and Tobol (2009), Andreyeva, Long and Brownell (2010), Tiffin and Arnoult (2010)). Our quantitative method is able to unravel this relationship. By calibrating the US economy we find that the net effect of a food tax cut is an increase in weight in equilibrium. The general equilibrium nature of our model induces two simultaneous effects. Following the food tax cut, real wage and food consumption increase activating a mechanism for weight gain. At the same time labor reallocates towards the agricultural sector increasing calorie expenditure which works in the direction of weight loss.

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.

Our study complements the analysis of Yaniv, Rosin and Tobol (2009) in two ways. First, following rational choice theory (Dragone (2009), Dragone and Savorelli (2011)) we take into consideration the direct effect of weight on utility and, second, we incorporate it in a macroeconomic quantitative environment. In addition to the fat tax we investigate the effect of capital income taxation on weight gain in a dynamic framework. Both taxes, once reduced, cause an increase in income and food consumption. However, the difference between the two policy instruments investigated is highlighted in our dynamic analysis. Following the reduction in capital tax, food price increases suppressing food consumption, while labor reallocation from agriculture to the capital intensive sector decreases calorie expenditure. This prompts contradictory forces on weight accumulation, however, in steady state weight surges. On the other hand, following the food tax reduction, after tax price of food increases causing food consumption to shrink while labor reallocates towards the agricultural sector instigating weight loss. Policy makers should therefore consider the effectiveness gap between the two policy instruments, since the capital earnings tax seems to be working better towards the decrease in food consumption but favors labor reallocation to the sedentary sector. Our results show that weight is slightly more responsive to capital taxation rather than food taxation.

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

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

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

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

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

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

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

¹The allocation of this unit amount of labor to the two sectors depends on the relative wage as determined by labor demand. In particular, 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.

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:

$$\Omega(W) = \alpha_0 + \alpha_1 W + \alpha_2 W^2 \quad (4)$$

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 $\Omega(W)$, while for $W > W^*$, $\Omega'(W) < 0$. 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:

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

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

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-Carrera and Raurich (2007) in that we split labor in the two sectors, without making any human capital specific demands for either of them. The production

²Several 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.

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

$$\max \pi_1 = AK_1^\alpha(u)^{1-\alpha} - r_1K_1 - w_1u \quad (9)$$

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

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

$$r_1 = A\alpha u^{1-\alpha} K_1^{\alpha-1} \quad (11)$$

The firm producing food has the following objecting function:

$$\max \pi_2 = \gamma K_2^\phi(1-u)^{1-\phi} - r_2K_2 - w_2(1-u) \quad (12)$$

Consequently, factors of production are paid the following earnings:

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

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

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 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:

$$\tau^k r_t k + \tau^f p_t f_t = T_t \quad (15)$$

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:

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

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

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

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

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

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

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

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

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

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.

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

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

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

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

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

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

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

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

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

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 $U(w) = a_0 + a_1W + a_2W^2$, 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. The instrument we use is individual height, which is exogenous to happiness and endogenous to BMI. F-stats on the instrument are significantly bigger than 10 and hence we can follow our estimates. 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 labor 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 labor 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 stylized facts for the US economy 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 (2002) and Lakdawalla et al. (2005)), 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 increases supply of the agricultural

good and leads to a reduction in food price and increase in real wage. As a consequence, food consumption jumps upwards. The agent then finds himself to be overweight with reference to his ideal weight, a fact that in turn induces lower food consumption. This decreases the demand for labor in agriculture and induces a shift of labor to the sedentary sector (higher u) until it reaches its new steady-state level (Table B). 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 steady state weight (Table B).

This finding, initiated by a change in agricultural productivity, tests the performance of our theoretical framework. In particular, our model performs well in that it replicates dynamics in agreement with the stylized facts of the US economy (Lakdawalla and Philipson (2002) and Lakdawalla et al. (2005)). Lakdawalla and Philipson (2002), Cutler et al. (2003) and Lakdawalla et al. (2005) argue that food consumption has had a less exalted role in the skyrocketing upturn of obesity rates compared to changes in the strenuousness of work. This is justified from our quantitative exercise where a decrease in calorie expenditure is followed by an increase in average weight level. These facts urge for further applications of our model on normative questions regarding policy instruments that could defeat the upsurge of obesity.

Last, our results are highly robust to different calibration exercises, except one. When we calibrate the economy at very low individual weight levels, i.e. average 38.5 kilograms (kg) instead of 71 kg, lower food prices result in greater food consumption (the dynamics and comparative statics of all other variables remain the same, as in Table B). The difference in those results stems from the inverted U-shaped weight-utility relationship and its' relation with direct utility from food consumption. In particular, for our benchmark case described above where the economy is calibrated at the real average weight for the US economy, that is $W^* = 71$ kg, the marginal disutility of weight increases due to lower food price is high, and thus, the individual finds himself reducing food consumption in the long run. However, when we calibrate the economy for average weight 38.5 kg the disutility from additional weight is lower than the direct utility from food consumption. Hence, individual weight level activates different mechanisms of decision making that satisfy utility maximization, a fact that 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 stimulates contradictory forces on weight accumulation, the net effect of which is positive in equilibrium.

In particular, two channels are activated following the decrease in capital taxes. First, greater savings bring about higher levels of capital stock. Thus, labor becomes relatively more productive in the capital intensive sector, increasing wages and resulting in the reallocation of labor from agriculture to the capital intensive sector. This decrease in the supply of food, prompts an increase in its' price reducing food consumption. On the other hand, the reallocation of labor leads to more sedentary lifestyles. Second, capital tax decrease allows for higher after tax income triggering greater food consumption. As shown in Table B, the net effect of the above dynamics is a permanent increase in steady state weight.

The dynamics of our model bring to light a non-monotonic effect of capital taxes on weight. Initially, the relative price of food increases, weight and food drop and then increase. 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 thus price of food which, in turn, decreases food consumption while food production does not respond immediately. Thus the shock is followed by an immediate weight decrease (Figure 2). 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 (Table B).

We observe that the model is able to replicate in steady-state the effect of a real tax reform. In fact, the tax reform Act of the mid 1980s translated into lower 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 (after tax price increases).

Similar to the consequences of capital tax reduction presented above, we observe opposite forces resulting from a food tax cut. 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 food tax makes food cheaper initiating a substitution and an income effect, the effects of which 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 stylized facts given by Lakdawalla and Philipson (2002) and Lakdawalla et al. (2005).

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 stylized facts for the US regarding 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, we analyze and quantify the steady-state and dynamic trade-offs between, food prices, income levels and calorie expenditure as given by sectoral reallocation of labor. 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; in steady state food consumption decreases due to a price substitution effect but weight soars due to lower calorie expenditure, (iii) reducing taxation on food increases food consumption and weight levels in equilibrium. Labor reallocation towards the less sedentary sector on one hand and higher income on the other function as opposite forces. However, in equilibrium the second effect prevails. Our results show that weight accumulation mechanisms are marginally more responsive to capital taxation as compared to food taxation.

6 References

- Allais, O., Bertail P., and Nichèle, V., 2010. The Effects of a Fat Tax on French Households' Purchases: A Nutritional Approach. *American Journal of Agricultural Economics* 92, 228-245
- Alonso-Carrera, J., and Raurich, X., 2007. Growth, Sectoral Composition, And The Wealth Of Nations. *Cama working papers 2007-15*, Australian National University, Centre

for Applied Macroeconomic Analysis.

Andreyeva T., Long M.W., Brownell K.D., 2010. The impact of food prices on consumption: A systematic review of research on price elasticity of demand for food. *American Journal of Public Health*, 100 (2), 216-222.

Baum II, C.L., and Ruhm, C.J., 2009. Age, socioeconomic status and obesity growth. *Journal of Health Economics*, 28(3), 635-648.

Baum II, C.L., 2011. The Effects of Food Stamps on Obesity. *Southern Economic Journal*, Southern Economic Association, 77(3), 623-651.

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

Cutler, D.M., Glaeser, E.L., and Shapiro, J.M., 2003. Why Have Americans Become More Obese?. *Journal of Economic Perspectives*, 17(3), 93–118.

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

Dragone, D. and Savorelli, L., 2011. Thinness and obesity: A model of food consumption, health concerns, and social pressure. *Journal of Health Economics*, forthcoming.

Gomis-Porqueras, P., and Peralta-Alva, A., 2008. A Macroeconomic Analysis of Obesity. Federal Reserve Bank of St. Louis, Working Paper 2008-017A.

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

Lakdawalla, D., Philipson, T.J., and Bhattacharya, J., 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.

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

Tiffin, R. and Arnoult, M., 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, 37(4), 501-521.

Yaniv, G., Rosin, O., and Tobol, Y., 2009. Junk-food, home cooking, physical activity and obesity: The effect of the fat tax and the thin subsidy. *Journal of Public Economics*, 93(5-6), 823-830.

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 labor 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								
71.33	0.96	0.9723	0.07535	2.4904	16.303	1.23	1.71	0.053
Increase in Technology of Agriculture ($\gamma = 1$ to $\gamma = 1.2$)								
71.78	0.966	0.977	0.07512	2.51	16.33	1.03	1.71	0.0534
Decrease of Capital Tax Rate ($\tau^k = 0.22$ to $\tau^k = 0.15$)								
71.42	0.961	0.973	0.07530	2.61	18.57	1.25	1.79	0.049
Effect of a Decrease in Food Tax Rate ($\tau^f = 0.22$ to $\tau^f = 0.15$)								
71.40	0.959	0.9722	0.07542	2.4903	16.30	1.23	1.71	0.053

Table C. Sensitivity Analysis for the Effect of Agricultural Technology on Weight

W	u	s	f	c	K	p	w	r
Base Line Model								
38.5	0.782	0.840	0.407	2.03	15.37	1.23	1.71	0.0534
Increase in Technology of Agriculture ($\gamma = 1$ to $\gamma = 1.2$)								
39.1	0.818	0.977	0.409	2.12	15.55	1.027	1.71	0.0534

Figure 1: Effects from a permanent increase in agricultural productivity

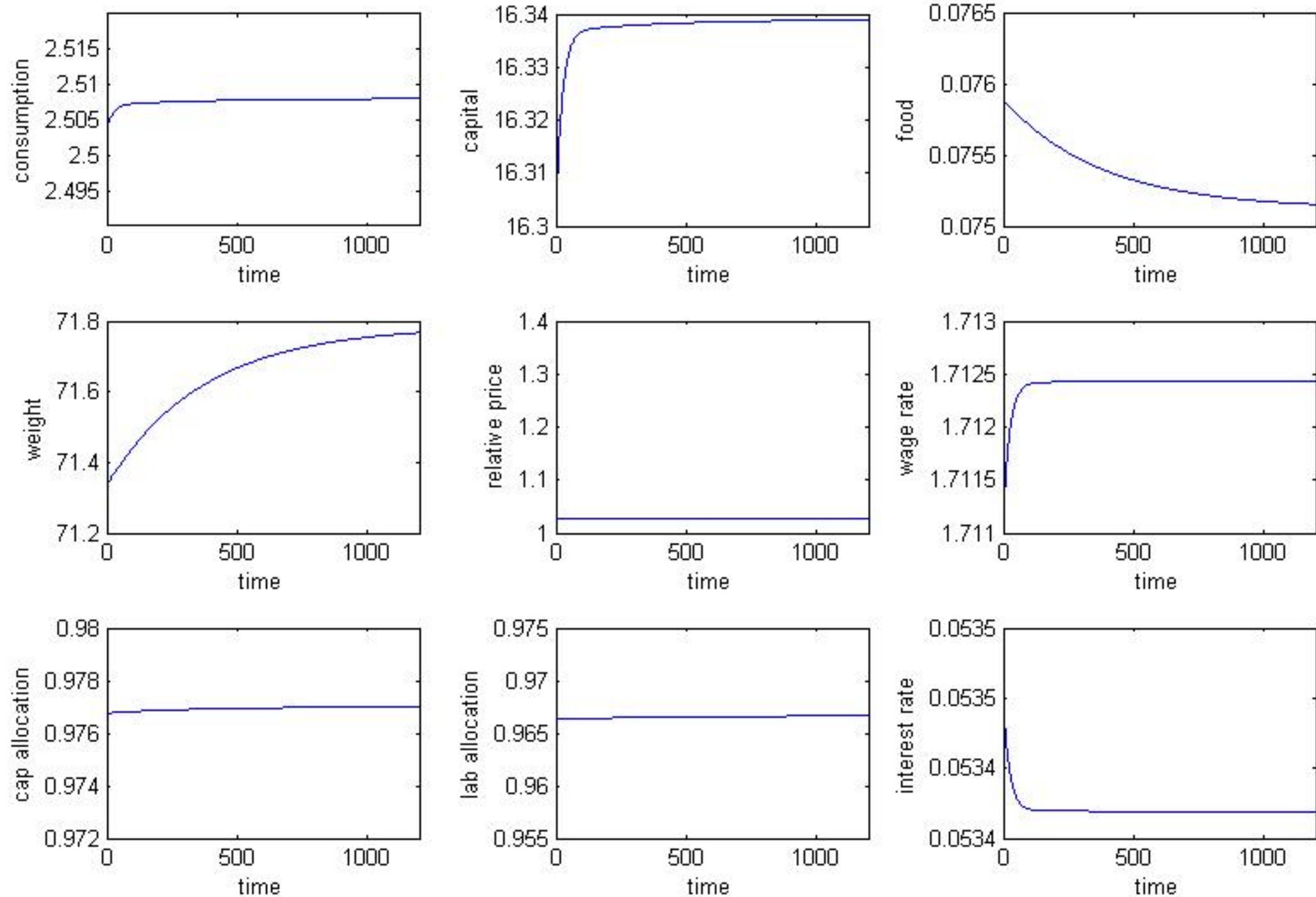


Figure 2: Effects from a permanent decline of the tax rate on capital

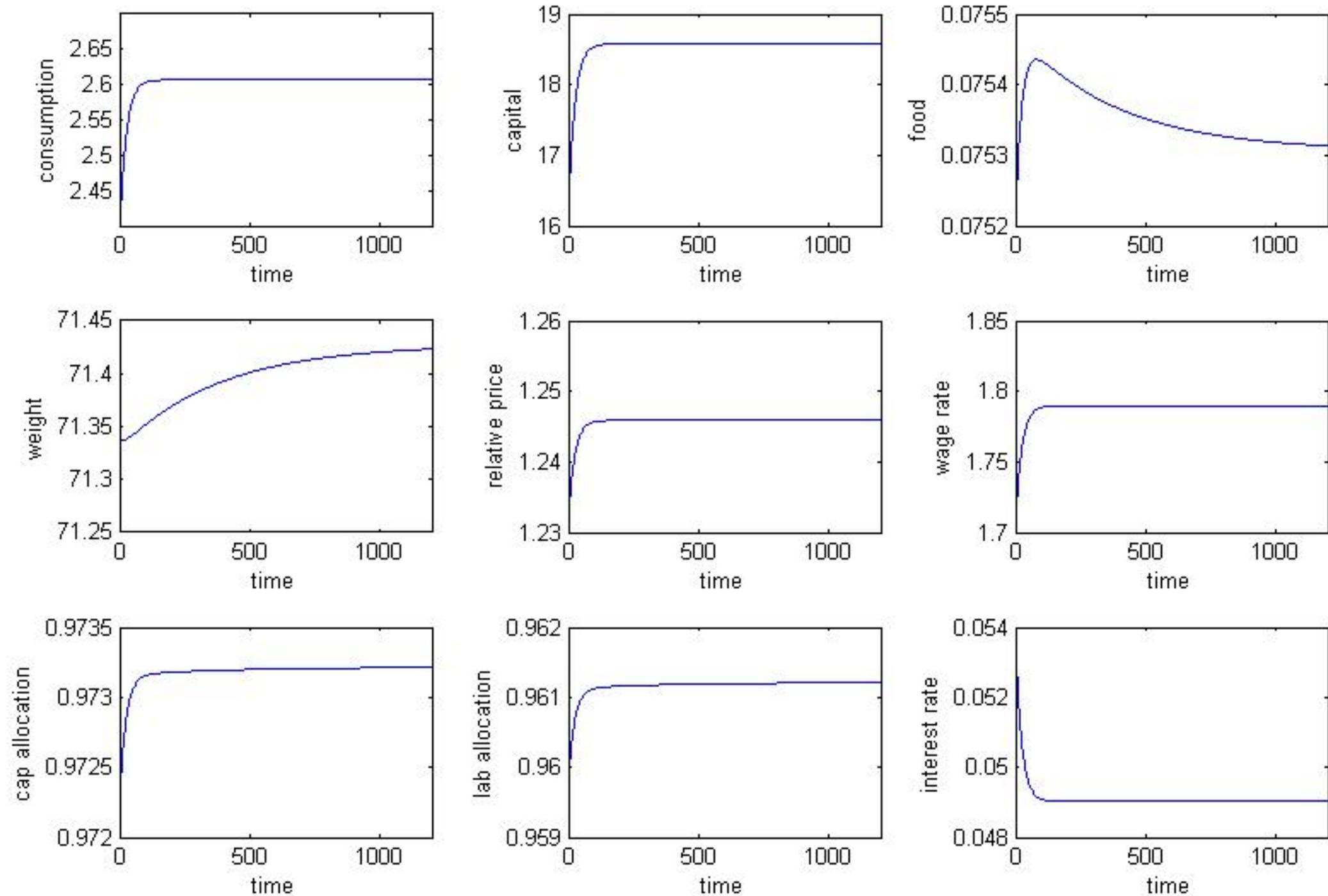


Figure 3: Effects of a permanent decline on the tax rate of food

