



A rational eating model of binges, diets and obesity

Davide Dragone*

Dipartimento di Scienze Economiche, Università di Bologna, Strada Maggiore 45, 40125 Bologna, Italy

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ABSTRACT

This paper addresses the rapid diffusion of obesity and the existence of different individual patterns of food consumption between non-dieters and chronic dieters. I propose a rational eating model where a forward-looking agent optimizes the intertemporal satisfaction from eating, taking into account the cost of changing consumption habits and the negative health consequences of having a non-optimal body weight. Consistent with the evidence, I show that the intertemporal maximization problem leads to a condition of overweightness, and that heterogeneity in the individual relevance of habits in consumption can determine the observed differences in the individual intertemporal patterns of food consumption and body weight. Sufficient conditions for determining when the convergence to the steady state implies oscillations or is monotonic are given. In the former case, the agent optimally alternates diets and binges until the steady state is reached, in the latter a regular intertemporal pattern of food consumption is optimal.

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1. Introduction

Eating behavior exhibits two stylized facts. First, a substantial rise in obesity in the world population. This trend, that originated in the US, is growing at such an alarming pace that the World Health Organization begins treating it as a pandemic (Lakdawalla et al., 2005; Prentice, 2006; Acs and Lyles, 2007; Philipson and Posner, 2008). Second, two typical patterns of individual food consumption behavior are observed. On the one hand some individuals are chronic dieters which tend to alternate periods of low caloric intake and periods in which they accumulate body weight, often indulging in binge eating behavior. On the other hand non-dieter individuals display regular intertemporal patterns of food consumption and body weight (Fairburn and Wilson, 1993; Polivy and Herman, 1987, among others).

In this paper I propose a rational dynamic theory of eating behavior where I generalize the framework proposed in Levy (2002) by allowing for the possibility that individuals have habits in food consumption. The model delivers both oscillatory and monotonic intertemporal patterns of individual food consumption and weight, eventually leading to a condition of overweightness. As a result it allows to rationalize within a unique theoretical framework the evidence on heterogeneity in individual eating behavior and the evidence on the observed tendency to obesity.

Eating behavior is a crucial determinant of individual well-being. Consuming food yields utility and it brings the calories that are necessary for the metabolic activity of the body. An insufficient caloric intake is detrimental to the health of a person as it reduces the efficiency of the physiological activities of the body. When the caloric intake exceeds the energy requirements, the body stores the excess energy by accumulating body mass and fat. The consequent increase in body weight can harm individual health if it leads to a condition of obesity. This condition is well documented to reduce life expectancy by increasing the probability of developing non-communicable diseases such as heart attacks, type 2 diabetes, high blood pressure, osteoarthritis and some forms of cancer.

Rational individuals optimally trade-off the utility from eating and the negative health consequences of having a body weight different from the physiologically optimal one. The optimal eating behavior consists of an intertemporal path of food consumption that maximises expected lifetime utility. Standard analysis implicitly assumes that the level of food consumption can be costlessly adjusted at each moment in time, so that any level of food intake can be chosen. Nonetheless, both empirical evidence and introspection witness the difficulties of rapid changes in eating behavior. For example, casual evidence suggests that for most individuals it is difficult to adhere to a diet that sharply alters the amount of caloric intake. In the model this is rationalized assuming that changing the amount of food consumption is costly to the agent, and it is interpreted as consumption habit. When there are consumption habits, sluggish changes in food intake are desirable, but this can be in contrast with the need of reducing the gap between the actual and the

* Tel.: +39 051 209 2664.

E-mail address: davide.dragone@unibo.it.

optimal weight. As a result of this trade-off, different time patterns of eating behavior can emerge.

In the absence of consumption habits, a forward-looking agent maximizes intertemporal utility by choosing a path of consumption that monotonically drives the agent to the steady state. With consumption habits, however, following a monotonic path can be too costly if it requires too rapid changes in the amount of food consumption. Under these conditions the optimal consumption path requires a slower convergence to steady state and it is associated to fluctuations above and below the steady state body weight. Due to sluggish adjustments in consumption, body weight moves toward the steady state weight but, once this is reached, it is too costly to immediately adjust consumption to the steady state amount. As a consequence, the steady state is overshoot and undershot during the convergence. The intuition for this result is that, when changing eating behavior is costly, it is optimal to change it slowly. As a result agents tend to re-adjust their target to the steady state weight only when they are getting too overweight or too underweight. For example, an overweight agent who is currently losing weight keeps on restraining her food intake until she goes underweight and, conversely, an underweight agent who is gaining weight keeps on getting fat even when the steady state weight is reached. As getting too thin or too fat is undesirable, a forward looking agent will continue adjusting consumption until the direction of the path is reversed. The amplitude of these fluctuations decreases overtime until the steady state is reached. This occurs when, in correspondence of the steady state weight, choosing the steady state amount of food consumption does not require a large adjustment. Finally if consumption habits are very large, that is if changing eating behavior is very costly, then oscillations are no longer optimal because they require too many, and too costly, adjustments. In this case the optimal path requires a very strict eating behavior leading to a monotonic convergence to the steady state.

The paper delivers several contributions to the literature. The model confirms the prediction of [Levy \(2002\)](#) that the steady state equilibrium implies a condition of overweightness even in the presence of consumption habits. The analysis however shows that, in the absence of consumption habits and with general functional forms, the condition of obesity is actually reached as a steady state with saddle point stability. In such a case the optimal path of consumption and body weight is monotonic over time.¹ When individuals have habits in consumption, in turn, the optimal transition path may also display an oscillatory convergence to the steady state. This implies that agents find it optimal to alternate binges and diets, and that this oscillatory behavior gets dampened over time until the steady state is reached. Finally, the analysis provides a novel formalization of consumption habits which is tractable and intuitive. This approach differs from most of the literature on habits in consumption, which generally assumes that past consumption has effect on the marginal utility of current consumption.² The modeling strategy proposed in this paper, in turn, assumes that changes in food consumption are costly. The emphasis is therefore moved from studying the role of levels of consumption to changes in consumption. This approach appears well suited to study opti-

mal eating behavior since people appear to dislike rapid changes in their level of food intake.

The paper is structured as follows. Next section presents the rational eating model with habits; Section 3 shows that the steady state implies a condition of obesity; Section 4 studies the asymptotic properties of the steady state and the transition paths; Section 5 concludes.

2. A rational eating model with habits

Consider an individual whose utility depends on food consumption $c(t) \geq 0$ according to the instantaneous utility function $U(c(t))$, assumed to be strictly increasing and concave. The existence of habits in consumption is introduced by assuming that changing the level of food consumption is costly, and that the disutility cost is increasing and convex in the rate at which this change occurs. Consumption levels and consumption changes are additively separable, and the instantaneous objective function of the representative agent is as follows:

$$V(c(t), \dot{c}(t)) = U(c(t)) - a \frac{\dot{c}(t)^2}{2}, \quad (1)$$

where $a \geq 0$ is a constant parameter measuring the marginal disutility of changing the amount of food intake. When $a = 0$, we are back to the utility function considered in [Levy \(2002\)](#), in which habits in consumption play no role.

The probability of survival of the agent depends on her physical weight $w(t) > 0$ and on a physiologically optimal weight $w^* > 0$. As in [Levy \(2002\)](#) I assume that deviations from the optimal weight w^* reduce the probability of survival of the agent according to the function $\Phi((w(t) - w^*)^2) > 0$, and that this probability is decreasing in its argument $(w(t) - w^*)^2$, i.e. $\Phi'(\cdot) \equiv \partial \Phi((w(t) - w^*)^2) / \partial ((w(t) - w^*)^2) < 0$. Let also the probability of survival be concave in $w(t)$, at least in the relevant domain.³ The expected lifetime utility of the agent is given by the following expression:

$$\int_0^\infty e^{-\rho t} \Phi((w(t) - w^*)^2) \left[U(c(t)) - a \frac{\dot{c}(t)^2}{2} \right] dt, \quad (2)$$

where $\rho > 0$ is an exogenously given intertemporal discount rate.

To take into account the relation between weight, food consumption and metabolic needs, the following equation of motion of weight is considered:

$$\dot{w}(t) = c(t) - \delta w(t) \quad (3)$$

where $\delta > 0$ represents the rate at which an individual loses weight as a function of the current weight, i.e. it is a proxy of the individual metabolic needs in terms of individual weight, which depend on individual characteristics, as well as on individual lifestyle.

Given an initial body weight $w(0) = w_0$ and the law of motion (3), the agent must find the intertemporal path of food consumption that maximises (2). The problem has one control variable, the level of food consumption at time t , and one state variable, body weight. However, as the objective function contains the rate of change of consumption, it is convenient to transform the original problem into an equivalent one where there are two state variables, the body weight and the consumption level, together with the respective laws of motion, and one new control variable, the rate of change in consumption ([Feichtinger et al., 1994; Wirl, 1996](#)). Let $x(t)$ denote

¹ The derivation of this result with generic functional forms is presented in [Appendix A](#). For a derivation using the functional forms adopted by [Levy \(2002\)](#), see [Dragone \(2009\)](#).

² An alternative approach to formalize habits in consumption, originated by the contributions by [Boyer \(1978, 1983\)](#), [Pollack \(1970, 1976\)](#) and [Ryder and Heal \(1973\)](#) and, with reference to addiction, by [Becker and Murphy \(1988\)](#), [Iannaccone \(1986\)](#); [Stigler and Becker \(1977\)](#), stresses the role of non-separabilities in the levels of consumption at different points in time, which implies that marginal utility from current consumption is indeed affected by past levels of consumption.

³ Denoting with Φ_w and Φ_{ww} , respectively, the first and the second partial derivative of the probability of survival w.r.t. weight, i.e. $\Phi_w \equiv \partial \Phi(\cdot) / \partial w$ and $\Phi_{ww} \equiv \partial^2 \Phi(\cdot) / \partial^2 w$, this amounts to requiring $\Phi_{ww} < 0$ for all $w(t)$ in the relevant domain.

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