Consumer Behaviour, Labour Supply and Diabetes: The Complex Case

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Key Words: Consumption behaviour; Labour supply; Limit cycles; Health.

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Abstract: This article examines the behaviour of a consumer diagnosed with diabetes. It is shown that the medical treatment of the disease creates incentives that make diabetic's consumption and weight display cyclical patterns. One implication is that labour supply can be cyclical as well.

1. Introduction

Diabetes is a chronic disease that affects around 5% of the US population. It is the seventh leading cause of death in the United States. Diabetics are likely to develop other several diseases, since diabetes increases cardiovascular, renal, neurologic, circulatory and ocular complications. With such a huge health impact and potential market, there has been an impressive improvement in medications and treatments for diabetes over the last decades.

The treatment of diabetes is based on three principles. The diabetic has to ingest medications (such as insulin), follow a strict diet and practise physical exercises (see Krall, 1978). Therefore, the diagnosed diabetic has to modify his habits in order to fight the disease. However, the rise of new and powerful drugs and medical treatments, and the proliferation of new food products with low sugar and cholesterol can have a negative impact on the diabetic behaviour. As a result of these medical and food innovations the diabetic may be "lulled" into thinking that he does not have to follow strictly the whole
treatment. That is, he has an incentive to do less physical exercises or to relax in his diet. On the other hand, the medical treatment has welfare costs associated to adjustments in the labour supply and consumption habits. These costs may induce the diabetic to keep his diet adherence and exercises. The issue tackled in this paper is to analyse how a diagnosed diabetic behaves under such incentives.

This paper investigates the conditions that can generate a complex consumption behaviour of the diagnosed diabetic. A cyclical intertemporal consumption pattern emerges from the model analysed here. Dockner and Feichtinger (1993), Wirl and Feichtinger (1995), and Wirl (1996), show that addiction can induce cyclical behaviour in consumption. In the model presented below it is shown how the incentives related to the medical treatment of diabetes can lead to a cyclical behaviour in the weight and consumption habits of the diabetics. The model has implications on the diabetics’ labour supply. One important consequence of the cyclical pattern in consumption is that labour supply can be cyclical as well.

The cyclical pattern of consumption and labour supply does not contradict recent empirical findings. Kahn (1999) has found evidence that diabetics are modifying their consumption behaviour. They do smoke less and consume less cholesterol, sweets and alcohol than their non-diabetic counterparts. A cyclical consumption does not mean that consumption habits of diabetics are less healthier than non-diabetics. Concerning to labour supply, Khan (1998) has documented improvements in diabetic labour market performance. In the same vein, diabetics’ cyclical labour supply do not imply that their performance in the labour market is inferior than their non-diabetic counterparts.

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1 See Viscusi (1985) and Viscusi and Cavallo (1994) on the “lulling” effect.
The model is general enough to be adapted to other diseases, which similarly to diabetes require continuous medical treatment, adherence to strict diet and practise of physical exercises. The paper is organized as follows. The next section presents the basic model. The conditions for the existence of a limit cycle between weight and consumption are derived and the consequences on the labour supply are explored. Section three contains the concluding remarks.

2. The Model

The representative consumer is a diagnosed diabetic. He has to follow a medical treatment \( T \), keep a tight diet adherence and do physical exercises. Medical treatment has two welfare effects. The first affects negatively the labour supply \( l \), since the diabetic spends more time taking care of his health, besides the treatment can have collateral effects that can affect his productivity. The second welfare cost is related to the rigorous time constraints associated to medication and food control. Diabetic's choice of diet and exercise is captured by weight \( y \) and consumption \( c \). His consumption \( c \) depends on the difference between his actual weight and the optimum weight \( \bar{y} \) determined by his medical adviser. His consumption also varies positively with his medical treatment. This assumption captures the "lulling" effect of more powerful drugs and food products. Diabetic's weight is an increasing function of consumption. Given these characteristics, the representative consumer problem is the following:

\[
\text{Max} \int [u(c) - vl(T) - \Omega(T)] e^{-rt} \, dt \quad (1)
\]
\[ y = c - \phi \, y \quad (2) \]
\[ \dot{c} = T \, (\overline{y} - y) \quad (3) \]

This model can display a limit cycle between weight \((y)\) and consumption \((c)\). That is, the optimal consumption and weight are oscillatory. These results come from the impact of the incentives related to medical treatment on consumption and physical exercises. On the one hand, better drugs and food products low in fat and sugar can make the diabetic relax his diet adherence and physical obligations. This can increase his consumption and weight. On the other hand, intensive medical treatment has a welfare cost, which can decrease his weight and consumption. The balance between both effects of medical treatment can lead to a cycle in weight and consumption.

As pointed out above, medical treatment decreases the supply of labour. A simple linear relationship between \(l\) and \(T\) is assumed:

\[ l(T) = \bar{l} - b \, T \, , \quad b > 0 \quad (4) \]

The second welfare cost of medical treatment is captured through a simple quadratic adjustment cost:

\[ \Omega(T) = \frac{a}{2} \, T^2 \, , \quad a > 0 \quad (5) \]

The utility function is assumed to be:

\[ U(c) = \ln c \quad (6) \]

Substituting equations (4), (5) and (6) into (1), the Hamiltonian function for the problem is:

\[ H = \ln c - n \bar{l} + \lambda \, v \, T \, c - \frac{a}{2} \, T^2 + \lambda \, (c - \phi \, y) + \mu \, T \, (\overline{y} - y) \quad (7) \]
The first order conditions are:

\[ H_r = 0 \Rightarrow T = \alpha \left[ vb + \mu \left( \overline{y} - y \right) \right], \text{ where } \alpha = a^{-1} \quad (8) \]

\[ \dot{\lambda} - r \lambda = \lambda \varphi + \mu T \quad (9) \]

\[ \dot{\mu} - r \mu = -c^{-1} - \lambda \quad (10) \]

The representative diabetic consumer takes his medication, thus \( T > 0 \), which implies by equation (8) that: \( T = \alpha \left[ vb + \mu \left( \overline{y} - y \right) \right] > 0 \).

Introducing equation (8) into (3) and (9) yields:

\[ \dot{c} = \alpha \left[ vb + \mu \left( \overline{y} - y \right) \right] \left( \overline{y} - y \right) \quad (11) \]

\[ \dot{\lambda} - r \lambda = \lambda \varphi + \mu \alpha \left[ vb + \mu \left( \overline{y} - y \right) \right] \quad (12) \]

The analysis of the complex dynamics of consumption habits is made on the system formed by equations (2), (11), (12) and (10). The steady state equilibrium \((y^*, c^*, \lambda^*, \mu^*)\) of this system is:

\[ \dot{c} = 0 \Rightarrow y^* = \overline{y} \Rightarrow T^* = \alpha vb \quad (13), \text{ since } T > 0 \]

\[ \dot{y} = 0 \Rightarrow c^* = \varphi \overline{y} \quad (14) \]

\[ \dot{\lambda} = 0, \text{ and } \dot{\mu} = 0 \Rightarrow \lambda^* = -\left( \frac{r(\varphi + \alpha)}{\alpha vb + 1} \right) (c^*)^{-1}, \text{ and } \mu^* = \left( \frac{(c^*)^{-1} + \lambda^*}{r} \right) \]

In order to generate endogenous cycles between \( y \) and \( c \), it is necessary to show that the signs of:
\[
|J| = \begin{vmatrix}
\frac{\partial y}{\partial y} & \frac{\partial y}{\partial c} & \frac{\partial y}{\partial \lambda} & \frac{\partial y}{\partial \mu} \\
\frac{\partial c}{\partial y} & \frac{\partial c}{\partial c} & \frac{\partial c}{\partial \lambda} & \frac{\partial c}{\partial \mu} \\
\frac{\partial \lambda}{\partial y} & \frac{\partial \lambda}{\partial c} & \frac{\partial \lambda}{\partial \lambda} & \frac{\partial \lambda}{\partial \mu} \\
\frac{\partial \mu}{\partial y} & \frac{\partial \mu}{\partial c} & \frac{\partial \mu}{\partial \lambda} & \frac{\partial \mu}{\partial \mu}
\end{vmatrix}
\]  
(16)

\[
K = \begin{vmatrix}
\frac{\partial y}{\partial y} & \frac{\partial y}{\partial \lambda} \\
\frac{\partial \lambda}{\partial y} & \frac{\partial \lambda}{\partial \lambda}
\end{vmatrix} + \frac{\partial c}{\partial \mu} + 2 \frac{\partial \mu}{\partial \mu}
\]  
(17)

are positive when calculated with the steady state solutions \((y^*, c^*, \lambda^*, \mu^*)\). Furthermore, the value of the bifurcation parameter given by the condition below:

\[
|J| = \left( \frac{K}{2} \right) + r^2 \left( \frac{K}{2} \right)
\]  
(18)

must be positive as well. These are the conditions for the existence of a limit cycle between weight and consumption stated by the Hopf bifurcation theorem (see Feichtinger et Al., 1994, and Wirl, 1994).

Equation (16) yields: \( |J| = \alpha v b [r (r + \phi) + \alpha v b] > 0 \)  
(19).

Equation (17) yields: \( K = 2 \alpha v b - \phi (r + \phi) > 0 \iff 2 \alpha v b > \phi (r + \phi) \)  
(20).

From equations (19) and (20) a necessary and sufficient condition for the model above to generate a limit cycle between consumption and weight is: \( 2 \alpha v b > \phi (r + \phi) \). This inequality has an intuitive appeal. The condition holds true for low values of \( \phi \) and \( r \) or large values of \( \alpha, v, b \). That is, if the diabetic has large welfare costs in adapting to the
medical treatment (large $\alpha, v, b$) or if he has a low rate of time preference ($r$), or if he has problem in controlling his weight (given by a low $\varphi$), the model is more likely to produce a limit cycle between weight and consumption. Concerning the last condition, the bifurcation parameter $\alpha$ is positive and satisfies equation (18).

An important implication of the cycle between $y$ and $c$ is that actual weight oscillates around ($\bar{y}$). This makes the medical treatment ($T$) fluctuate as well. However, one condition must be observed, that is $T > 0$, which is verified only if: $vb > \mu (y - \bar{y})$. Fluctuations in ($T$) impact on the labour supply ($l$). As a result, the diagnosed diabetic labour supply will also oscillate. Therefore, the model presents two remarkable characteristics: consumption and labour supply are both cyclical.

**Concluding remarks**

This paper has modelled the behaviour of a person diagnosed with diabetes. It is shown that the medical treatment of the disease creates incentives that make consumption and weight display cyclical patterns. On the one hand new powerful drugs and food products induce the diabetic to relax his adherence to strict diet and physical exercise, thereby increasing his consumption and weight. On the other hand, medical treatment has a welfare cost, which tends to decrease consumption and weight. The balance between each of these forces is at the heart of the diabetic consumption and weight cycle. One important consequence of this cycle is that labour supply will also present fluctuations.


