An Economic Model of the Stages of Addictive Behavior

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ABSTRACT

The aim of this research is to build a realistic model of addictive behavior by assuming that agents have bounded rationality. They make consumption decisions for the present period, taking into account the present and future losses induced by such consumption, as well as the development of a tolerance effect of the addictive product. However, agents do not take into account the reinforcement effect. This behavior triggers losses of self-control that provoke exaggerated consumption of the addictive good. The consumption pattern that is found here corresponds to the one defined in the stages of change theory. The model also shows that fear policies cause a more progressive and effective abstinence than price increases in addiction of preserving agents’ budgets. It is argued that fear policies should be explored more deeply and accompanied by attainable measures that help people to quit their addictive consumption, and avoid negative effects such as denial.

JEL Classification: D00, I10.

Keywords: addiction; bounded rationality; cognitive biases; consumption choice.

1. Introduction

Addictive behavior refers to a repeated consumption of a given good that is amplified by the past consumptions of it. Unlike an ordinary habit, the consumption of an addictive good involves the development of tolerance and reinforcement effects that respectively involve a decrease in the welfare received from the consumption of a given amount of the good, and a tendency to increase the quantities consumed over time. The paper focuses on addictions involving substance consumption such as cigarettes, alcohol or illegal drugs (by opposition to behavioral addictions). Their consumption involves immediate and certain rewards, but also uncertain future losses which vary from one individual to another and cover health, social and economic issues.

A large range of addictive behaviors has been observed across individuals who are able to show attitudes of denial toward their addiction, as well as a consciousness of negative effects which coexists with their desire to maintain the addictive habit, or even a desire to quit it without planning to do so. Furthermore, when agents try to get rid of their addiction, they often endure relapses before succeeding. In psychology, Prochaska and his colleagues (DiClemente et al., 1991; Prochaska et al., 1994, 1992; Prochaska and DiClemente, 1983) have found that addictive behavior progresses through five stages, namely the stages of...
change (including relapses and recoveries). In contrast, economic models continue to consider that preferences and addictive behavior are fixed over time.

Indeed, economists have modeled an individual who decides to consume an addictive good for pleasure first, but who is then constrained by the tolerance and reinforcement effects. These effects are triggered by the growth of an addictive stock that corresponds to the actualized stock of past addictive good consumptions. The individual decides to stop smoking due to an external event (Becker and Murphy, 1988; Gruber and Köszegi, 2001) or an endogenous parameter like age (Suranovic et al., 1999), or like weight-gain associated with the consequences of the addiction (Goldbaum 2000). Thus, this individual never experiences impulsive consumption due to a loss of self-control that causes very low welfare and arouses regrets. Consequently when he makes the decision to abstain, he usually succeeds. However, in the real world, consumers that report their desire to quit their addictive consumption without succeeding are far from being exceptional. Moreover, these models do not explain how the individual modifies his environment in order to facilitate abstention.

On the premise that the individual does not have infinite calculation capacities, the paper aims to construct a model of addictive and harmful consumption choice based on the assumption of bounded rationality (Simon, 1972). For this purpose, Suranovic et al.’s (1999) static decision setting is used, as well as their utility function structure that is additively made of a benefit function, of a loss function and of an adjustment cost function. However, the components of this utility function are reinterpreted: the benefit function only corresponds to immediate rewards and social approval or disapproval of the agent’s behavior is moved to the loss function that covers health as well as present and future social losses, induced by the actual addictive consumption. As for the adjustment cost function, it still represents the individual’s withdrawal effects for each amount of addictive product consumed, and still depends on the history of addictive consumption.

Four further assumptions are made. First, on the premise that the individuals have two decision making modes (Bernheim and Rangel, 2004; Loewenstein, 2000), it is considered here that agents have two sets of preferences which can be activated in each period of time: the cold mode (the rational one), and a hot mode (the impulsive one). In this paper, the chances of entering into the hot mode, which reflects a loss of self-control, depend positively on the degree of withdrawal effects the agent feels at the level of consumption chosen. Second, individuals are prone to the phenomenon of a Cold-to-Hot Empathy Gap (Loewenstein, 2005): when making consumption decisions in the cold mode, they tend to overestimate their capacity to resist to impulses that emerge when in withdrawal, even if they have “already experienced intense craving states hundreds or thousands of time” (Loewenstein, 2005). This assumption implies that decisions taken in the cold mode are likely to intensify the chances of entering into a hot mode in the present period, but also in future periods since they raise the addictive stock. Formally, agents take into account losses of welfare induced by withdrawal effects (tolerance), but ignore their incidence on the activation of the hot mode (reinforcement) acting as if the hot mode did not exist. Third, in this paper, these perceived losses are considered to be directly linked to the level of fear since individuals...
adapt themselves by using cognitive strategies (Witte, 1992) all things being equal. For instance, smokers often use denial or agreeing with received ideas about their addictive consumption in order to protect themselves from fear (Beck et al., 2012). Consequently, the losses induced by the fear of death do not depend on agents’ age as in Suranovic et al. (1999). Thus, preferences variations mainly rest on the evolution of the adjustment cost function that depends on the addictive stock responsible for the decision to quit when agents’ welfare becomes smaller than they would have received if they had never started to consume the addictive product. Finally, it is assumed that individuals have several quitting strategies at their disposal, including: as in Bernheim and Rangel (2004), an avoidance strategy which consists in avoiding the cues that trigger the hot mode, and a rehabilitation strategy in which agents make a pre-commitment in the cold mode that prevents them from any consumption during the time period. The paper shows that the first strategy implies a gradual abstention, whereas the second leads to a cold turkey.

These additional specifications to the Suranovic et al.’s (1999) model make it possible to identify a succession of addictive behaviors corresponding to the stages of change pattern (Prochaska et al., 1994). It allows the effectiveness of public health policies on the modification of agents’ behavior to be studied, according to the stage in which they are placed instead of considering that behavior is homogeneous across individuals and over time. The research shows that, in order to abstain from the addictive consumption, long run regrets are essential since they prevent agents from returning to their old habits when the withdrawal effects have disappeared after a continuous abstention. The study of the model shows that an increase in the price of the addictive good has the same effect as an increase in the loss function but the latter does not involve a budget reduction. Moreover, if the effects of these shocks are not homogenous according to the stage in which agents are placed, they accelerate the transition to the next stage. Thus the effects are not necessarily visible. In addition, when this price increase triggers a decision to abstain using the avoidance strategy, individuals decrease their addictive consumption in a more progressive manner than when a price rise increases their chances of abstaining successfully. This is interesting because this loss function can be affected by public policies such as informative fear campaigns, or denormalization strategies. Nevertheless, increasing the loss function slope has limitations since an increase in fear is easier to internalize than a price increase. The solution given by Witte (1992) would be to propose credible alternatives to abstain from addictive consumption, in order to reinforce agents’ self-efficacy in protecting themselves from the danger of the addictive product and thus prevent them from using ineffective strategies in order to protect themselves from the fear of danger. More precisely, self-efficacy is strengthened by the accessibility of quitting strategies (i.e. the cost of avoidance and rehabilitation strategies).

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2 Of course, the amount of fear about the negative effects of consumption can also increase according to some specific events (like health problem, a birth or a death among family and friends, etc.), or consequently an effective prevention campaign.

3 Denormalization strategies refer to laws or public campaigns aimed at changing social norms. For smoking, it includes laws prohibiting smoking in public places in this category that oblige smokers to smoke in specific areas, as well as campaigns that stigmatize smokers (as the NHS TV spot “If you smoke, you stink” in 2005).
2. The Theoretical Framework

2.1. Economic models of addiction

The traditional economic literature considers that consumers’ preferences are exogenous and that behavior is stable over time. In other words, in a given context, with given income, prices and goods, consumers always make the same decision regardless of the period of time. Thus, an individual who has started to consume drugs because of a preference for them continues endlessly to consume for the same unchanged reason. The evidence of habit formation generated by a repeated consumption (Spinnewyn, 1981), has led economists to build a framework in which preferences evolve over time without any external intervention. More precisely, an individual has a preference for the goods to which he is the most exposed (Bowles, 2009; Zajonc, 1968).

In the rational addiction theory, Becker and his colleagues (Becker et al., 1994; Becker and Murphy, 1988) introduce a form of endogenous preferences via a consumption stock leading the agent to increase consumption of addictive product. However, they suppose the number of life periods is infinite, which implies that a desire to quit is the consequence of an exogenous shock (such as a price increase). In this framework, failures to quit are explained by the phenomenon of time inconsistency (Gruber and Köszegi, 2004, 2001) which refers to a form of strong preference for the present: in each period of time, the agent plans to abstain from the addictive consumption in the next one. In the case of cigarette smoking, Suranovic et al. (1999) show that by introducing a finite number of life periods, the preferences for cigarettes change according to the remaining lifetime. This makes it possible to explain why some people stop smoking without any external intervention. Similarly, Goldbaum (2000) explains the intention of quitting addictive consumption by the increase of the weight placed on health consequences as the agent grows older, whereas Carbone et al. (2005) analyses the evolution of the consumer's beliefs about his characteristics and those of the products.

While these models explain why and when individuals decide to get rid of their addiction, they do not take into account the cases of failed quitting attempts, as well as relapses years after having quit the addictive behavior. It will be shown that this is due to the omission of important parameters related to human cognitive biases.

2.2. The bounded rationality assumption

In this paper, it is assumed that individuals have bounded rationality (Simon, 1972): the agent does not have the cognitive abilities required to process all the available information in order to make perfectly rational decisions. He reasons according to perceptions of his own characteristics (which do not necessarily correspond to the individual’s objective characteristics). Moreover, the agent is neither able to perfectly anticipate all future incomes, nor all the future prices of goods and his future discounted utilities. As for the consequences of addiction, the individual infers the future by using as little information as possible: the consumer is a “cognitive miser” (Fiske and Taylor, 1991) choosing costless cognitive actions in order to reach a satisfactory welfare instead of the optimal one (Simon, 1972, 1957). The individual’s limited calculation capacities imply a static decision setting in which at each period of time he decides on present consumption by maximizing benefits that are gradually affected by the development of tolerance, and by taking into account the present and future perceived negative effects of present consumption. This hypothesis is compatible with
Suranovic et al.’s (1999) utility function structure which is additively composed of a benefit function, a loss function and an adjustment cost function. However, due to additional assumptions made above, the adjustment cost component will have different implications in the individual behavior.

2.3. The presence of two modes of reasoning

As Bernheim and Rangel (2004), this paper considers that two “modes” exist. In those modes, the individual has two independent sets of preferences (Loewenstein, 2000): the cold mode in which he behaves as rationally as his cognitive abilities permit and, the hot mode in which the agent makes impulsive decisions. The latter can be activated during a given period of time if the agent is in a state of craving. Thus, it is assumed that preferences can also vary in the short run (within a period of time). This coexistence of two modes of reasoning reflects the idea of multiple “Selves” according to which the consumer acts differently depending on the context (Davis, 2010; Selten, 2001). More precisely, at the beginning of each period, the agent is always in the cold mode and makes consumption decisions by maximizing perceived welfare, taking into account current benefits, as well as the future losses of actual consumptions. If the amount of the addictive good is sufficient to satisfy the addictive need, i.e. if withdrawal effects are null or marginal, the agent stays in the cold mode and carries out his consumption plans. However, if the amount of the addictive good chosen is too low, the individual has to bear withdrawal effects that can trigger the hot mode in which he only seeks to minimize those withdrawal effects by responding to immediate impulses (consumption of addictive product) without any consideration for the future. The greater the withdrawal effects, the higher the probability of entering into the hot mode. These withdrawal effects that drive agents in the hot mode depend on a combination of the physical addiction for the product (relying on agents’ addictive consumption history) and of a psychological dependence expressed by environmental cues whose presence arouses the desire to behave addictively. These cues are for instance products that the individual considers complementary to addictive consumption (coffee, alcohol in case of smoking) or objects suggesting the consumption (a computer for an addiction to the Internet). Individuals are gradually sensitized to them through the consumption of the addictive product via the classical conditioning phenomenon (Lazev et al., 1999). Indeed, taking drugs causes a decrease in the willpower to resist vices (Bechara, 2005; McClure et al., 2004). This is due to the fact that addictive substances interfere with an important class of processes that the brain uses to anticipate the short term pleasure, leading to impulses that thwart the role of cognitive control area by creating exaggerated expectations of pleasure and therefore the violent urge for consumption (Bernheim and Rangel, 2004). Unlike Bernheim and Rangel (2004), in this paper the

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4 Here, the variation of preferences is considered as exogenous since the two modes correspond to different contexts in which the agents take different decisions. As is explained further in the paper, endogenous preference evolution only concerns the cold mode and the log run (few periods of time).

5 In the case of smoking, the classical conditioning process is a learning technique in which a conditioned stimulus (here the environmental cues) is paired with an unconditioned stimulus (cigarette) and repeated, the individual shows a conditioned response (smoking) to the conditioned stimuli when presented alone. This conditional response was initially an unconditioned response to the unconditioned stimulus (when the smoker faces the environmental cues, it triggers a desire to smoke), see Pavlov (1960).
probability of entering into the hot mode does not only depend on the addiction to the product. Instead, it is also linked to the amount of addictive product chosen (the consumer does not simply decide between consuming or not).

An individual who has already experienced these two states of the world should make decisions in order to maximize expected welfare, i.e. by taking into account the welfare in both modes associated with the probabilities of entering into the hot mode that depends on the level of addiction and on the amount of the addictive good chosen. However, it will be shown here that even if the agent is conscious of the existence of the two modes, he is not able to take into account the existence of the hot mode when making decisions in the cold mode.

2.4. The Cold-to-Hot Empathy Gap

The individual overestimates his ability to resist to impulses (i.e. self-control), because of the difficulty of remembering short-term craving when making a decision in the cold mode (Thaler et al., 1997). As a result, the agent tends to expose himself to environmental cues instead of protecting himself from them (Sayette et al., 2008). In doing so, the agent increases his chances of entering into the hot mode since he makes a decision about consumptions by maximizing welfare without taking into account the actual chances to carrying out these consumption plans. This lack of empathy for future selves (Kahneman and Thaler, 2006; Loewenstein and Schkade, 1999; Read et al., 1999) is commonly called the Cold-to-Hot Empathy Gap (Loewenstein, 2005). Due to this Empathy Gap, it is assumed that when the individual chooses the optimal consumption point, he takes into account the negative impact of past consumption on present welfare provided by present consumption (tolerance effect), but omits to consider their potential action on the activation of the hot mode (the reinforcement effect).

By entering into the hot mode, the agent consumes more of the addictive product and increases the level of addiction more than by staying in the cold mode. Thus, by losing self-control in the present, the individual increases the chances of losing self-control in the future.

2.5. A cognitive adaptation to fear: the Extended Parallel Model

In Suranovic et al.’s (1999) point of view, the loss function variations depend on the evolution of the fear from the death that depends on the agent’s age. Here it is assumed that the function is more complex. First, fear is has not necessarily a proportional relation with the perceived danger to which it is associated. Indeed, according to the Extended Parallel Model (Witte, 1992) in a situation of danger, the subject can either put in place strategies to control the danger (stop smoking or drinking alcohol), or develop strategies to control the fear (by minimizing or denying the danger, or by agreeing with received ideas about smoking or drinking alcohol). Although the latter involves biased and inadequate responses, it has been widely observed (Peretti-Watel et al., 2007). Thus, for a low and a high level of perceived danger:

- if they are too low, the individual does not react;
- if they are perceived as high and if the individual perceives that he is competent to respond to it, he executes actions to control the danger;
- if they are perceived as high and the individual perceives that he is not competent to respond to it, he executes actions to control the fear of danger.

The type of response depends on severity and susceptibility of the danger:
danger, the agent’s fear would be similar if he does not feel competent to protect himself from it. Moreover, as Suranovic et al. (1999) take into account the social disapprobation of smoking in the benefit function, the social issues are here a part of the loss function. The more the individual cares about social disapprobation, the more this will have an impact on the agent’s loss function by increasing its slope. Thus, this function reflects a mix of fear form negative health effects and social disapproval. It should be noted that the agent’s perception of what people think that he should do is taken into account (Fishbein and Ajzen, 2011). For convenience, it is assumed that the fear function only varies exogenously, according to external events (a death, a birth or a disease) or public intervention (as a phobic health campaign or a denormalization campaign like smoking bans). These effects due to exogenous factors are studied in Section 5.

2.6. In search for quitting strategies: commitment and re-commitment

Successive losses of self-control and their consecutive regrets can lead the individual into situations in which consuming the addictive good becomes less attractive than the initial situation of abstention. But because of the rise of the addictive stock formed by actualized past and present addictive consumption that intensifies withdrawal effects, he cannot just make the decision of abstain in order to return to this initial situation of abstention. This provokes long run regrets that lead the agent to look for strategies that could help to abstain from the addictive consumption. Two types of strategies have been put forward by Bénabou and Tirole (2004), and are used as a reference here.

The first concerns a commitment or personal rules that include avoidance strategies. This method is often used in behavioral therapies in order to learn which signals the consumer has to avoid by adopting a new lifestyle and new interests. Therapies which establish alternative cutoff rituals or cures are included in this category. Such therapies are potentially effective because of an aspect of commitment called “self-reputation”. This represents the reputation that the individual creates in his mind knowing that breaking the engagement today (i.e. yielding to the addiction) will also mean yielding tomorrow. Here, the cost of such strategies is not seen as monetary but induces a decrease of welfare: the individual adopts a less attractive lifestyle, and so does not enjoy consumption as before. Avoiding consuming products associated with the consumption of the addictive good (coffee or alcohol in case of smoking, going to pubs in case of alcoholism) are examples of commitment strategies. This strategy corresponds to what Bernheim and Rangel (2004) call the avoidance strategy (in opposition to exposure): when an individual resorts to it, he diminishes the probability of entering the hot mode, but the temptation still exits. Indeed, weakening temptations permits gradual abstention. However, this strategy does not necessarily allow addictive consumption to be cut off immediately. Thus the individual has to adopt it during successive periods of time before completely abstaining. It is assumed that the more he perseveres in this strategy, the more the effects of environmental cues are weakened. But if the agent relaxes his efforts at any one moment, then the environmental cues effect will go back to their initial level.

Pre-commitment is another alternative to correct the self-control problem. It refers to an intentional deterioration of all the future options that include the consumption of the addictive product. When the pre-commitment is irreversible (Bernheim and Rangel, 2004; Loewenstein et al., 2003; Read et al., 1999), the individual removes the possibility of performing an action.
Isotherapy in case of alcoholism or more generally isolation cure, are examples of pre-commitment strategies. Such a behavior refers to Bernheim and Rangel’s (2004) rehabilitation strategy which drives the probability of consuming the addictive good to zero. This strategy leads to a cold turkey abstention but the individual also needs to resort to this strategy for a few time periods until the adjustment costs would have sufficiently diminished to permit efforts to be relaxed. Unlike commitment, it is assumed that such alternatives require paying a monetary price which diminishes budget.

Individuals choose one of these alternatives depending on the prices and utilities that they can provide. In both cases, the presence of long run regrets is important since they prevent the individual from returning to former habits when the withdrawal effects have diminished sufficiently.

2.7. A psychological perspective of a decision-making model: Stages of Change

During the consumption “career”, the individual does not have constant behavior. In fact, Prochaska and his team (DiClemente et al., 1991; Prochaska et al., 1994, 1992; Prochaska and DiClemente, 1983) have lengthily observed addictive behavior and conclude that it progresses through five typical stages. First, the pre-contemplation stage concerns individuals who are not aware of their addiction problem: denial about the noxiousness of their consumption is often to be observed. The following stage is contemplation in which agents are beginning to consider a change in behavior but remain ambivalent: on one hand, they recognize that their consumption has a negative impact on their lives, and on the other hand, they are afraid of changes. Next is the preparation stage, when agents plan behavior changes in the future without undertaking any concrete actions. In this stage of action, they make a firm and clear decision to change, and make commitments in order to overcome their problem. Finally, the maintenance stage concerns agents that abstain from smoking and continue to act in order to prevent relapses and to consolidate profits that they made during the action stage. The sequence of stages of change can be summarized through the spiral of change, which refers to cycles of progressions and regression through the different stages. Each attempt increases the chances of overcoming the behavioral problem. The persistent functioning of long run regrets could be an explanation of this phenomenon.

This stages of change behavioral pattern seems to provide an interesting framework for the construction of the model because it is compatible with all the elements mentioned in the previous paragraphs. Indeed, the consumer has bounded rationality and does not reason according to the reality but according to his perceptions of it and is subject to cognitive biases. Moreover, these stages of change potentially constitute a pattern of endogenous preference changes in which the consumer can decide to put in place reinforcing self-control strategies in order to stop smoking. The second interesting point is that every agent experiencing an addiction can be associated with a specific stage. Thus, if the model is correctly specified, we should come across this behavioral pattern as we move along the individual smoking career.

By identifying consumers’ stage of change, it should be possible to understand better why health policies are not visibly effective for every type of agent.
3. Building the Model

3.1. The utility function and its components

As the individual is endowed with a bounded rationality, his behavior is studied here within a static model in which the agent chooses to allocate resources between an addictive good and a composite good for the current period. The budget constraint is:

$$I_t = p_{s,t}s_t + p_{y,t}y_t \quad (1a)$$

where $I_t$ represents income in period $t$, $s_t$ the amount of the addictive good, $y_t$, the amount of a normal composite good$^7$ and $p_{s,t}$ and $p_{y,t}$ respectively prices of the addictive good and composite good. For simplicity, let the number of items of $y_t$ be fixed, regardless of the period of time $t$. The agent can neither save nor borrow (spending his entire income in each period). In addition, it is assumed that income and prices are constant through time, so that:

$$I = p_{s}s + p_{y}y \quad (1b)$$

The consumer’s decisions only concern the present period but he takes into account the future loss due to this actual consumption. The current utility function ($u_t$) is considered to be additively composed of a benefit function $B_t(s_t, y_t)$ and a loss function $L_t(s_t)$:

$$u_t(s_t, y_t) = B_t(s_t, y_t) - L_t(s_t) \quad (2a)$$

that represents the benefits of consuming $(s_t, y_t)$ in the absence of dependence to any product consumed. Adding an adjustment costs function $C_t$ (that represents withdrawal effects for each amount of addictive product consumed), provides a total utility function ($U_t$):

$$U_t(s_t, y_t, D_t) = u_t(s_t, y_t) - C_t(s_t, D_t) \quad (3a)$$

which takes into account the individual’s dependence to the addictive good. This utility composition is similar to Suranovic et al.’s (1999), but the specifications here of each element of this function differ.

The benefit function $B_t(s_t, y_t)$ refers to current benefits that the consumer derives from the consumption of $(s_t, y_t)$ and that are directly linked to his preferences. It is modeled by a quadratic function as in Goldbaum (2000):

$$B_t(s_t, y_t) = \alpha_s s_t + \alpha_{ss} s_t^2 / 2 + + \alpha_y y_t + \alpha_{yy} y_t^2 / 2 \quad (4a)$$

where $\alpha_s, \alpha_y, \alpha_{ss}, \alpha_{yy}$ are the parameters.

First, it should be noted that consumption of $s_t$ and $y_t$ has a positive impact on welfare ($\alpha_s, \alpha_y > 0$) but its respective marginal utilities are decreasing ($\alpha_{ss}, \alpha_{yy} < 0$). In addition, the transformation of (1b) means that: $y_t = I_t / p_y - (p_s / p_y)s_t$ so the benefit function can be transformed in order to obtain:

$$B(s_t) = \left[ \alpha_s - \alpha_y \frac{p_s}{p_y} - \alpha_{yy} \frac{l_t}{p_y} \frac{p_s}{p_y} \right] s_t + \left[ \alpha_{ss} + \alpha_{yy} \left( \frac{p_s}{p_y} \right)^2 \right] \frac{l_t}{2} / 2 + \left[ \alpha_y \frac{l_t}{p_y} + \alpha_{yy} \left( \frac{l_t}{p_y} \right)^2 / 2 \right] \quad (4b)$$

this is a bell-shaped curve (See Appendix B.1.). It is also assumed that the satiation level is beyond the consumer budget, so that $\alpha_s > - \alpha_{ss} \frac{l_t}{p_s}$ and $\alpha_y > - \alpha_{yy} \frac{l_t}{p_y}$.

$^7$The composite good is composed of normal goods, i.e. goods that do not generate any future benefits or losses.
The loss function $L_t$ represents the losses caused by actual addictive product consumption. In Suranovic et al. (1999) work, it represents negative health effects that lower life expectancy, but it is also possible to consider negative effects on social disapproval or job career problems. Due to the bounded rationality assumption and the cognitive adaptation to fear (Witte, 1992), it is assumed that, all things being equal (i.e. in the absence of an exogenous shock as a public dissuasion campaign, a birth or a death in the family or personal health problems), the loss function $L(s_t)$ that is linearly-decreasing with $s_t$, remains unchanged from one period to another.

This implies that, whatever the past consumption was, ceteris paribus, the future anticipated losses are constant for a given amount of the addictive product. As for consequences, $u_t(s_t)$ and $U_t(s_t, D_t)$ are assumed to be bell-shaped curves.

Thus, the utility function can be written as:

$$u(s_t) = B(s_t) - L(s_t) \quad (2b)$$

and represents the amount of utility in the absence of addictive effects.

The consumption of the addictive good increases the agent’s benefits but also has an effect on the formation of an addictive stock $D_t$ that depends on all past and current addictive consumption. The literature usually considers that the addictive stock has a constant depreciation rate over time (Carbone et al., 2005):

$$D_t = (1 - \mu_D)D_{t-1} + s_{t-1} \quad (5)$$

With $\mu_D \in ]0,1[$, the fixed stock depreciation rate. This level of the addiction stock determines the level of threshold value $s^h_t$ that represents the minimal amount of the addictive good that the individual needs in order not to suffer withdrawal effects. Due to the reinforcement phenomenon, the consumption of the threshold value in a given period induces an increase of the threshold value in the next one ($s^h_t < s^h_{t+1}$ when $s_t \geq s^h_t > 0$). Since the addiction stock grows from $t$ to $t + 1$ when $s_t > \mu_D D_t$,

$$s^h_t = \mu_D D_t + \epsilon \quad (6)$$

where $\epsilon$ is a reinforcement parameter reflecting the fact that the agent cannot choose to consume a constant amount of an addictive product during his entire addictive consumption career, and tends to increase consumption.

The addiction stock and threshold value enter into the composition of the adjustment costs function $C_t$ which is the last element of the total utility function. It represents the discomfort arising when the addictive good consumption is too weak (under the threshold value). Thus we have a positive decreasing function with $s_t$ in the interval $[0,s^h_t]$ and becomes zero for $s_t > s^h_t$:

$$\begin{cases} 
C_t(s_t, D_t) > 0 \text{ if } s_t < s^h_t \\
C_t(s_t, D_t) = 0 \text{ if } s_t \geq s^h_t 
\end{cases} \quad (7a)$$

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8 This equation is equivalent to: $D_t = \sum_{i=1}^{t}(1 - \mu_D)^{t-i}s_{i-1}$

9 Thus we see that addiction disappears gradually after a cessation. If the agent stops smoking during period $j$, the addictive stock in $t$ becomes: $D_t = \sum_{i=j}^{t}(1 - \mu_D)^{t-i}s_{i-1} + \sum_{i=j+1}^{t}(1 - \mu_D)^{t-i} \times 0 = (1 - \mu_D)^{t-j}D_j$.

10 $D_{t+1} > D_t \iff (1 - \mu_D)D_t + s_t > D_t \iff s_t > \mu_D D_t$
reflecting the fact that the lower the amount of addictive consumption, the more withdrawal effects make the agent suffer. Moreover, the tolerance effect is observed because \( C_t \) depends positively on the \( s_t^h \) parameter:

\[
C_t(s_t, D_t) < C_t(s_t, D'_t) \quad \forall D_t < D'_t \implies s_t^h < s_t^h' \quad (7b)
\]

Thus, the adjustment cost function takes into account both of the addiction characteristics that are reinforced and tolerance (Becker and Murphy, 1988).

It should be noted that for simplicity of presentation, it is assumed that \( C_t \) slope (which partly depends on environmental cues) does not vary with the amount of addictive stock \( D_t \):

\[
\frac{\partial C_t(s_t, D_t)}{\partial s_t} = \frac{\partial C_t(s_t, D'_t)}{\partial s_t} \quad (7c)
\]

Thus, the total utility function can be written as:

\[
U_t(s_t, D_t) = B(s_t) - L(s_t) - C_t(s_t, D_t) \quad (3b)
\]

Moreover, the relationship between \( U_t(s_t, D_t) \) and \( u_t(s_t) \) is:

\[
\begin{cases}
U_t(s_t, D_t) < u(s_t) & \forall s_t < s_t^h \\
U_t(s_t, D_t) = u(s_t) & \forall s_t \geq s_t^h
\end{cases} \quad (8)
\]

3.2. Consumption choice

Each period is composed of two phases: in the first one, the agent is in the cold mode and plans consumption. Then, in the second phase, he consumes either according to plans (if still in the cold mode), or by consuming more than planned (if in the hot mode). Entering into the hot mode can occur with the probability \( \theta_{C_t} \), which positively depends on the withdrawal costs present for the amount of addictive good determined by the consumption plans. Thus, \( \theta_{C_t} \) increases with \( D_t \) and decreases with \( s_t \). Moreover when \( C_t(s_t, D_t) = 0 \), then \( \theta_{C_t} = 0 \).

If the agent were perfectly rational, he would maximize his expected total utility:

\[
E(U_t(s_t, D_t)) = (1 - \theta_{C_t})U_t(s_t, D_t) + \theta_{C_t}U_t(s_t^h, D_t) \quad (9)
\]

where \( U_t(s_t, D_t) \) corresponds to the total utility if the agent stays in the cold mode while \( U_t(s_t^h, D_t) \) is the total utility received at the point corresponding to:

\[
\begin{cases}
\max U_t(s_t, D_t) \\
\text{s.t } C_t(s_t, D_t) = 0
\end{cases} \quad (10)
\]

that is to say if he enters into the hot mode.

This implies taking into account all values of \( U_t(s_t, D_t) \) and of \( \theta_{C_t} \) for every couple \((s_t, D_t)\), representing a considerable amount of information and requiring complex calculations. Indeed, an increase of \( s_t < s_t^h \) (staying below \( s_t^h \)) has:

- a negative impact on \( C_t(s_t, D_t) \);
- a positive impact on \( U_t(s_t, D_t) \) if \( \frac{\partial u(s_t)}{\partial s_t} > \frac{\partial C_t(s_t, D_t)}{\partial s_t} \) (if the marginal utility of consuming the addictive product exceeds the marginal cost);
- a negative impact on \( U_t(s_t, D_t) \) if \( \frac{\partial u(s_t)}{\partial s_t} < \frac{\partial C_t(s_t, D_t)}{\partial s_t} \); and
- provokes a decrease of \( \theta_{C_t} \) and thus an increase of \((1 - \theta_{C_t})\) (i.e. the chances of staying in the cold mode).

However, due to the Cold-to-hot Empathy gap, the perceived expected utility corresponds to the maximum value of the agent’s total utility:
\[
\max [U_t(s_t, D_t)] = \max [B(s_t) - L(s_t) - C_t(s_t, D_t)]
\] (11a)

In other words, the agent takes into account the discomfort and pain of positive withdrawal effects, but is also aware of that the possibility exists of entering into the hot mode in which he consumes \(s_t^h\), but acts as if it could not occur, i.e. as if the \(\theta_{C_t} = 0\).

4. The Model Working

Detail of the model functioning is given here by assuming that income and prices are constant over time, so the benefit function remains unchanged \((B(s_t), \forall t)\). As for consequences, the utility function does not vary over time \((u(s_t), \forall t)\), whereas the adjustment cost function \(C_t(s_t, D_t)\) and thus the total utility function \(U_t(s_t, D_t)\) varies from one period to another, depending on the stock \(D_t\) variations.

As defined in 3.1, this adjustment costs function is assumed to be linear and has a fixed slope whatever the period \(t\). For a given amount of the addictive good, the function rises from one period to another if the addictive consumption is greater or equal to the threshold value (and decreases in the other cases). These assumptions allow a pattern of addictive behaviors to be identified, and which corresponds to the pattern in the stages of change theory.

4.1. Pre-contemplation (see Fig.1.A.)

The stage of pre-contemplation is characterized by the presence of small adjustment costs (they have not yet developed) and thus a small threshold value. The individual chooses to consume the amount of addictive product \(s^*\) that maximizes total utility \(U_t\) and which is higher than \(s_t^h\). As for consequences, adjustment costs are null at this point: \(C_t(s^* \geq s_t^h, D_t) = 0\) (see (7b)), so \(U_t(s_t, D_t) = u(s_t)\) (see equation (8)) and this consumption point also maximizes \(u(s_t)\) whatever the period \(t\). Since adjustment costs are null, he always stays in the cold mode.

Such consumption raises the next period threshold value and consequently adjustment costs function at each point \(s_t\) (this refers to reinforcement). As long as \(s^* > s_t^h\), that is to say, as long as adjustment costs have not developed enough, the individual chooses to consume this fixed amount which yields a constant total utility \(U_t(s^*, D_t)\). The agent has no reason to be aware of the existence of adjustment costs since he has never experienced them. As for the consequences, there is also no reason to consider consumption as a problem or to consider oneself as dependent on the addictive product. This kind of behavior lasts as long as \(s_t^h \in [0, s^*]\).

4.2. Contemplation (see Fig.1.B.)

When adjustment costs develop to become \(s_t^h > s^*\), the agent enters into the contemplation stage. As long as \(\frac{\partial u(s_t)}{\partial s_t} > \frac{\partial C_t(s_t, D_t)}{\partial s_t} > 0\) (i.e. as long as marginal utility exceeds marginal costs), the total utility function \(U_t(s_t, D_t)\) has a positive slope on \(s_t \in [0, s_t^h]\) even when \(u(s_t)\) function decreases on \([s^*; s_t^h]\) interval. As for the consequences, the maximization of \(U_t\) function means that \(U_t(s_t^h, D_t) = u(s_t^h) < u(s^*)\), i.e. the agent’s welfare is smaller than during pre-contemplation. By consuming \(s_t^h\), the adjustment costs function increases in the next period and the optimal amount becomes \(s_{t+1}^h > s_t^h\) and \(U_t(s_{t+1}^h, D_{t+1}) < U_t(s_t^h, D_t)\).
The agent is aware of the development of a tolerance for the addictive good since his welfare decreases from one period to another, even if he increases consumption levels. However, the agent is not ready to change habits, and continues to consume the amount of addictive good that maximizes his total utility function which remains higher than if he had never started to consume the product \( u(0) < U_t(s_t^h, D_t) \). The agent has not yet suffered from dependence because he is not yet in a position of having to bear positive cost adjustments in order to maximize welfare. In addiction, he has not yet experienced the hot mode. During this stage, the agent increases the consumption of the addictive good to the point \( s_t^h = \bar{s} \) where 
\[
\frac{\partial u(\bar{s})}{\partial s_t} = \frac{\partial C_t(s_t, D_t)}{\partial s_t} \text{ (it is assumed this point is constant over time since } C_t \text{ slope and that the } u \text{ function remains constant).}
\]

4.3. Preparation (see Fig.1.C.)

The preparation stage corresponds to situations where \( s_t^h \) is such as 
\[
\frac{\partial u(s_t^h)}{\partial s_t} < \frac{\partial C_t(s_t^h, D_t)}{\partial s_t} \text{ (i.e. when } s_t^h > \bar{s} \text{). Thus } U_t \text{ admits a maximum in } \bar{s}, \text{ decreases in } s_t > \bar{s}, \text{ and equals the utility function for } s_t > s_t^h. \text{ By choosing to consume } \bar{s}, \text{ the agent knows that he will feel withdrawal effects (since } C_t(\bar{s}, D_t) > 0 \text{ for } \bar{s} < s_t^h \text{) that will eventually lead to the hot mode. But the Cold-to-Hot Empathy Gap leads the agent to choose this amount rather than maximizing expected total utility given by (9). If the agent falls into the hot mode, then he consumes } s_t^h \text{ (see (10)), perceiving a lower welfare. This amount does not fit to his consumption plans and is associated with a smaller level of welfare than if he stays in the cold mode. Therefore, hot mode consumption raises short term regrets (uniquely for the present period because of the Empathy Gap effect). By consuming } s_t^h, \text{ the threshold value grows in the next period } (s_{t+1}^h > s_t^h) \text{ and the adjustment costs associated with } \bar{s} \text{ increase } (C_t(\bar{s}, D_{t+1}) > C_t(\bar{s}, D_t)). \text{ Consequently, the more the agent enters into hot mode, the more difficult it becomes for him to consume the desired amount (i.e. to maintain control over consumptions). Thus, the agent becomes aware of his dependence problem to the addictive good, but does not yet act to manage it. However, if he succeeds in consuming the chosen quantity } \bar{s} \text{ by staying in the cold mode, then the adjustment costs will decrease in the next period (since } \bar{s} < s_t^h).\]

According to the success or failure of maintaining the cold mode, the agent’s consumption may stabilize around \( \bar{s} \) or tend to rise, so this preparation stage may last a long time. Some events, like a disease, additional information about the product toxicity or job loss may modify the loss function slope (transitorily or permanently) and precipitate the consumer into the action stage (this point is discussed in Section 5). This behavior (choosing consumption of \( \bar{s} \)) is maintained until the adjustment costs becomes such that \( U_t(\bar{s}) = u(0) \): i.e. when the amount of welfare the agent would have received if he had never started to consume the addictive product is greater than the actual total utility. This critical utility imprints itself in the individual memory that causes the appearance of long run regrets.

4.4. Action (see Fig.1.D.)

These long run regrets cause addicts to look for strategies to end addiction that were ignored in previous stages. Thus, the agent compares the welfare that could be achieved by adopting different quitting strategies to the critical utility.
It is assumed that as long as long run regrets are activated, the individual focuses on the critical utility when considering the exposure lifestyle. For instance, as long as regrets of having attained a critical amount of cigarettes consumed are activated, the individual remains careful about controlling cigarette consumption: the agent bears in mind that returning to this lifestyle, and consumption pattern will lead to the critical utility $U_t(\tilde{s}) = u(0)$ which triggered the action stage. Thus, when comparing the exposure lifestyle with the quitting strategies, he takes into account this critical utility as if it were the present total utility and compares it to the actual total utilities given by the quitting strategies at the agent’s disposal. For instance, a former smoker compares the welfare given by chewing gum to the welfare that triggered the decision to abstain from smoking when considering consuming cigarettes.

If long run regrets are not persistent enough, the agent will again compare the quitting strategies to his present utility. As soon as the adjustment cost will decrease enough to make renewed consumption of the addictive good more attractive than abstention, the individual will relax his efforts and return to this consumption. For example, an individual allow himself to smoke at evening parties after having stopped smoking in the past if the regrets about former cigarette consumption as being uncontrollable are forgotten. Thus, the agent will regress to a previous stage (depending on how much the adjustment costs have decreased). Sooner or later, he will be confronted again to the critical utility that will activate long run regrets, which will be more persistent than previously.

These long run regrets are expressed through a stock that is activated at each passing through the critical utility. The more it is activated, the more it becomes persistent.

The action stage corresponds to the attempts to change addictive behavior in order to get rid of the addictive behavior and once the individual succeeds in abstaining, he enters the maintenance stage. Quitting strategies, that are inspired by Bernheim and Rangel (2004) work, are described in the following sub-sections.

4.4.1. Spontaneous quitting or consumption reduction (exposure strategy E)

In the exposure lifestyle $E$, the individual faces usual environmental cues and does not bear extra costs. Deciding to progressively decrease the amount, or to going cold turkey would be irrational since the welfare associated do not maximize the total utility. In order to abstain from the addictive good consumption, the agent needs to put in place a specific strategy.

4.4.2. Commitment: avoidance strategy A (see Appendix B.2)

When smoking becomes less appealing than initial abstention, the agent also has the opportunity of lowering the effects of environmental cues by adopting avoidance strategy $A$. It consists in adjusting the environment by avoiding some places and/or some specific situations in order to weaken temptation. On the one hand, the effect of the agent’s level of withdrawal diminishes whatever the level $s_t$ of consumption, but on the other hand, it makes the environment less enjoyable. In other words, the agent accepts to pay a non-monetary price $p^A > 0$ that diminishes his benefit function which becomes $B^A(s_t) = B(s_t) - p^A$. In fact, this is equivalent to committing not to consume some goods that are complementary to the addictive ones. For instance, an individual who enjoyed smoking with a pint of beer will avoid the consumption of this product in order to lower the temptation of smoking. Consequently the utility function decreases: $u^A(s_t) = u(s_t) - p^A$. As compensation, the
adjustment costs function becomes $C_t(s_t, D_t)/m$, where $m > 1$ corresponds to lower sensitivity to environmental cues. Thus, the adjustment cost function slope decreases but $s_t^h$ remains unchanged. The agent will suffer less than in the exposure strategy if he consumes a given amount of the addictive product, but just the amount of addictive good necessary to minimize adjustment costs $s_t^h$ (this refers to the physical addiction). The total utility maximization becomes:

$$\max[U_t^A(s_t, D_t)] = \max[x[B_t(s_t) - p_A - L(s_t) - C_t(s_t, D_t)/m]]$$

Such a strategy is chosen when the reduction of the slope of the adjustment cost function sufficiently compensates the loss in the utility function. In these circumstances, the maximum point of the total utility function yields higher welfare than in case of exposure, and corresponds to a lower amount of the addictive product $s_t^A < s_t$, if long run regrets are activated (see Appendix B.2). Moreover, commitment is effective if the adjustment cost reduction is sufficiently large to obtain $C_t(\tilde{s}_t^E, D_t) > C_t(s_t^A, D_t)/m$ and therefore diminish the chances of entering into the hot mode ($\theta_t^E > \theta_t^A/m$) (see Graph A.1)). Thus, it provides possibilities to the agent of sticking to his plan of consuming $\tilde{s}_t^A$.

The avoidance strategy takes place over a few periods. If the individual perseveres in the avoidance strategy, his sensitivity to the environmental cues will progressively decrease. For this reason, it is considered here that the value of $m$ increases at each re-use of the avoidance strategy. Nevertheless, $m$ returns to its initial value if there is an interruption (if the avoidance strategy is abandoned and then readopted whatever the disruption period). Consequently, in each period, when the individual chooses the avoidance strategy, the optimal amount of the addictive product diminishes, as does the slope of the adjustment cost function ($p^A$ being constant).

When long run regrets are persistent enough, the optimal amount of addictive good tends to correspond to $s^*$, that is $u^A(s_t)$ maximum when the threshold value has sufficiently diminished to become $s_t^h \leq s^*$. As he reaches this point, the individual is aware that if he continues to maximize $U_t^A(s_t, D_t)$, then the adjustment cost will increase again. With long regrets still activated, the agent compares the anticipated future avoidance utility if he does nothing, and the different utilities that could obtain by abstaining: $U_t^A(0, D_t), U_t^B(0, D_t), U_t^R(0, D_t)$. The agent then chooses the most advantageous. If he succeeds in abstaining, the agent passes into the maintenance stage.

4.4.3. Pre-commitment: rehabilitation strategy $R$ (see Appendix B.3)

Another option for the agent is to make a pre-commitment not to consume the addictive product during the period by deliberately degrading the utility of the behavioral options that include the addictive behavior. When he opts for this lifestyle (the rehabilitation $R$), the individual ensures himself of abstaining completely without any risk of failing. The agents pays a price $p_R > 0$ to make the adjustment costs null at $s_t = 0$ (it remains the same for the other values of $s_t$):

$$\begin{cases} C_t(s_t, D_t) = 0, s_t = \{0\} \cup [s_t^h, +\infty[ \quad \text{(7d)} \end{cases}$$

to make the probability of entering into the hot mode zero in $s_t = 0$: $\theta_t^R = 0$. The agent’s budget becomes $I_t - p_R$ (so the benefit function becomes $B^R(s_t)$), and total utility becomes
discontinuous: the total utility equals the utility \( s_t = 0: B^R(s_t) - L(s_t) \), and is equal to \( B^R(s_t) - L(s_t) - C_t(s_t, D_t) \) for \( s_t > 0 \). Thus, at the zero consumption point, we have:

\[
\max U_t^R(s_t, D_t) = U_t^R(0, D_t) = u^R(0) \quad (11c)
\]

The commitment strategy is chosen directly when \( U_t^R(0, D_t) > \max \left( U_t^A(s_t, D_t) \right) \). To be advantageous, the decrease of utility in \( s_t = 0 \) induced by the payment of the price \( p_R \) must be low enough to provide a greater utility amount than the maximum total utility in case of avoidance.

An individual who has opted for an avoidance strategy in a first step, can also choose the commitment strategy when \( s^A = s^B \) if \( U_t^A(0, D_t) < U_t^R(0, D_t) \).

Choosing commitment, the consumer totally abstains (see Graph A.2) and directly enters into the maintenance stage.

4.4.4. Choice between the different strategies

The choice between the strategies \( E, A, \) and \( R \) involves taking into account two parameters. First, the price: paying an amount \( p^A \) or \( p^R \) is equivalent to a decrease in utility, whatever the value of \( s_t \). The more costly the alternatives, the more the total utility function will be reduced and thus its maximum. The second parameter is the maximum total utility value achievable: the counterpart of the price paid must compensate the losses in utility.

It is also important to note that if the quitting strategies available do not provide the agent a higher utility than the critical one, then the agent is forced to experience them as long as he does not find an alternative. Therefore, the reduction in utility has sometimes to decrease beyond the critical level. In such cases, the abstention process becomes more longer and difficult if the avoidance strategy is chosen.

The price of rehabilitation is uniform whereas the cost of avoidance and the effects on the slope of adjustment cost function will vary from an individual to another. Indeed some individuals face more environmental cues than others, especially when peers have the same addictive habits. Individuals who were used to drinking beer and smoking cigarettes together but who do not specifically enjoy drinking beer alone will experience a small \( p_A \). If drinking beer is particularly pleasant when going out with friends, the cost \( p_A \) will be large. In both cases, the agent’s \( m \) will depend on the complementary strength between the two products. If the avoidance costs are too high (for an individual with friends who smoke, it could lead to sacrificing social life), or if \( m \) does not diminish enough (if the psychological addiction is not so high or marginal compared to the costs of avoidance), then a rehabilitation strategy seems to be a better alternative.

4.5. Maintenance

The maintenance stage corresponds to a phase in which the individual maintains his efforts not to fall into the spiral of changes. The stage ends when he relaxes efforts and abstains with success (i.e. when he chooses the exposure lifestyle and abstains from consuming the addictive good \( s_t = 0 \)). However, in some cases, this stage can last the rest of a lifetime.

The individual continues to compare the welfare given by adopting each of the three lifestyles. Therefore, the persistence of long run regrets is still essential in not succumbing to the temptation of getting a bigger but temporary welfare by consuming the addictive product.
again. At a certain point, exposure can become the most attractive abstention strategy. It corresponds to the phase when the abstinent person reduces addiction-fighting efforts because he considers that the level of addiction has diminished sufficiently. The lower the cost of commitment and pre-commitment, the higher the return to exposure. Moreover, the adjustment cost at this moment will be smaller, and the chances of the individual succeeding in abstention will be greater. If nicotine patches are expensive, the agent will certainly decide to stop using them earlier, maybe when the withdrawal effects have not diminished sufficiently, and so risk entering the hot mode.

We can see that if the individual does not express any specific motivation to abstain from smoking, and is just looking for utility maximization, the avoidance and the rehabilitation strategies will just help him from diminishing his consumption until the exposure lifestyle again becomes more appealing than entering the spiral of changes. Other things being equal, long run regrets are a driving force creating this specific motivation. But the costs borne by the individual when he chooses the avoidance strategy or rehabilitation are also important since they determine when the agent feels ready to relax his efforts.
Fig. 1. Utility function, Adjustment Costs function and Total Utility function in the pre-contemplation, contemplation, preparation and action stages. Note: In the pre-contemplation stage, the individual consumes the amount $s^*$ as long as the threshold value is smaller. The total utility received is constant. When $s_t^b = s^*$, he enters the contemplation stage in which optimal consumption is $s_t^b$. During this stage, consumption increases and total utility decreases. The stage begins at the consumption point 1 and ends at the consumption point 2 when the marginal utility equals the marginal cost. In the preparation stage, the maximization of total utility yields the same amount: i.e. the amount at which marginal utility equals marginal costs. It corresponds to positive adjustment costs. Thus, the more the agent enters into the hot mode (point a), the higher these adjustment costs, and the smaller total utility is. In this preparation stage, the individual’s consumption plans move between points 2 and 3. When the total utility becomes lower than if the agent had never started smoking (the point b), he enters into the action stage.
5. Studying and Interpreting the Model

5.1. An increase in the price of the addictive product (see Appendix B.4)

An increase in the price of the addictive good has a negative effect on the benefit function and thus on the utility function \( u^s(s_t) \) for \( s_t > 0 \). This negative effect grows with the amount of the addictive good \( s_t \) since the \( u^s(s_t) \) slope decreases more than \( u(s_t) \). We can deduce that the \( u^s(s_t) \) curve reaches its maximum for a lower amount of the addictive good than before the price increase. Moreover that maximum corresponds to a lower amount of utility.

If the agent is in the pre-contemplation stage, then a moderate increase in the price of the addictive good will decrease its consumption until the new optimal point \( s_t^{**} > s_t^h \). If the price increase is substantial, and the new optimal point becomes \( s_t^{**} = s_t^h \), then the individual passes into the contemplation stage and consumes the amount \( s_t^h \). If the agent is initially in the contemplation stage, a moderate increase in the addictive good’s price has no effect on him if \( \frac{\partial C(s_t)}{\partial s_t} > \frac{\partial u'(s_t)}{\partial s_t} \) in \( s_t^h \) point. If the increase is sufficiently large to give \( \frac{\partial C(s_t)}{\partial s_t} < \frac{\partial u'(s_t)}{\partial s_t} \) in \( s_t^h \) point, then the individual passes in the preparation stage and consumes a smaller amount of the addictive good associated with a lower utility and positive adjustment costs. If initially in the preparation stage, his consumption will diminish and be associated with a smaller amount of total utility and trigger the hot mode with greater probability. Moreover, if he attains the critical level of utility that is smaller than that of the abstaining-agent \( u(0) \), then the agent enters in the action stage. Thus, the agent enters in the action stage with lower adjustments costs than without the price increase. This makes quitting smoking easier.

Accordingly, a given increase of the addictive good’s price will have different consequences depending on the stage in which the agent is. Moreover, reductions in the amounts of the addictive good consumed that are induced by the price increase in the pre-contemplation stage and preparation are only temporary because the individual continues to progress through the different stages of change (by increasing his consumption). Nevertheless this price increase accelerates passing into the action stage, which is done with smaller adjustment costs making the abstention from smoking easier. In other words, the visibility of an increase in the price of an addictive good is not immediate but should diminish the duration of the smoking career ceteris paribus.

5.2. An increase in the loss function (see Appendix B.5.)

A prevention campaign that arouses fear about the negative health or social effects of consuming the addictive product has a direct effect on the loss function here, by increasing its slope.

Whatever the stage of change in which the individual is placed, an increase of the loss function does not generate a decrease in the utility (and total utility) function at the zero consumption point.

Since it decreases the slope of the utility function, the latter becomes null earlier and equalizes the slope of the adjustment cost function for a smaller amount of addictive good. Moreover the utility function becomes smaller for every \( s_t > 0 \), so the total utility function equalizes the abstaining-agent’s utility for a lower amount of the addictive good and a lower value of adjustment costs function. The optimal addictive consumption leads to less welfare.
The passing from one stage to another is done earlier, at smaller adjustment costs. This makes the attempts of abstention more effective when the agent enters into the action stage.

The slope of the loss function may increase in case of a prevention policy which aims at increasing addicts’ fears or promoting the benefits of a healthy life. It principally depends on the importance placed on the judgments of others, but concerns about health are also significant (an athlete will be more concerned by this parameter for instance). Even if the duration of these effects may generate debate, we can observe that the effects in terms of the addictive good’s consumption are similar to those of an increase in the addictive good’s price (but without a decrease in the budget). As for the consequences of fear-invoking policies or healthy life propaganda, these seem to be credible alternatives to taxes that deserve to be studied specifically. Nevertheless, invoking fear has limits: if the fear aroused is too intense, the agent will use cognitive strategies in order to diminish such fear, instead of looking for ways to protect himself from the dangers of addiction. One solution would be to propose credible strategies permitting control of such dangers; i.e. helping the agent to quit addictive consumption in order to enhance self-efficacy. Another kind of prevention raising the loss function involves denormalization policies aimed at modifying norms: in feeling rejected by peers, an individual could then change behavior. This technique has led to debate, since stigmatization may lead agents who cannot easily modify their behavior to reinforce their dangerous behavior (Peretti-Watel, 2010). Therefore, it appears necessary to study the characteristics required to make a prevention campaign more efficient since a lasting increase of the loss function slope provides interesting results about the individual’s behavior. Studies psychology should provide interesting avenues to be explored further.

5.3. Rehabilitation price variations (see Appendix B.6.)

The higher the price required to benefit from the rehabilitation strategy, the lower the utility the zero addictive consumption point is. Moreover, the marginal effect of such an increase diminishes. Consequently, a given decrease of this price will have a stronger effect if the price is already low. If the price decreases enough, the individual who previously opted for the avoidance strategy, will opt for the rehabilitation strategy which permits direct entry into the maintenance stage, without any risk of losing control.

It also has an important implication on the final success of abstention since the agent relaxes his efforts in the maintenance stage when abstention in the exposure lifestyle provides more welfare than abstention in the avoidance or rehabilitation strategy. Thus, if the price of rehabilitation is low, the agent will let up on his efforts latter, i.e. when withdrawal effects are smaller, and probability of entering the hot mode is smaller.

5.4. Comparison between the effects of a price increase and an increase in the loss function (see Appendix B.7)

Both prevention techniques have a speed-up effect on the successions of stages of change, and both permit entry into the action stage with lower adjustment costs, which facilitate the attempts of quitting. The difference between the two measures is the fact that a price increase of an addictive good affects the agent’s utility through the benefit function, whereas an increase of loss function directly decreases it without modifying its slope.
Although it is difficult to compare the effects of these two types of variations (since fear and budget reduction do not belong to the same dimension), it is possible to compare the situations when they trigger the action stage, that is to say when \(\max U_0^L(s_t, D_t) = u(0)\) (for a given adjustment cost function). Since we have \(\frac{\partial^2 u^L(s_t)}{\partial s_t^2} < \frac{\partial^2 u^R(s_t)}{\partial s_t^2}\) (see Appendix B.4 and B.6), we can deduce that the maximization of \(U_0^L(s_t, D_t)\) leads to a smaller consumption of the addictive good than the maximization of \(U_0^L(s_t, D_t)\), but corresponds to higher adjustment costs. If the rehabilitation strategy is more appealing, the utility obtained \(u^{sR}(0)\) or \(u^{LR}(0)\) is the same since \(u(0) = u^s(0) = u^L(0)\). However, if the avoidance strategy is chosen, the new optimal consumption point will correspond to a lower amount of the addictive good in the case of a price increase, and thus to higher adjustment costs. Consequently, the chances of succeeding in the attempt of reducing the addictive good consumption are smaller. Consequently, when an increase in fear leads to the action stage, the individual that chooses the avoidance strategy stops smoking more slowly than in the case of a price increase, and is less subject to suffering from withdrawal effects, so the chances of success are greater.

**Conclusions**

This research models addictive behavior throughout the consumption “career”, by bringing together changes in endogenous preferences, bounded rationality and stages of change behavioral pattern. These have so far been largely examined separately but not together.

In the model presented here, the role of the adjustment cost function is central since it explains the non-linear rise of addictive good’s consumption, for instance during the smoking career, as well as the individual’s decision to quit addictive consumption, when the welfare procured becomes lower than what the agent would have perceived if he had never engaged in such consumption. Adjustment costs also explain why the individual can consume more than he had planned to, and why he cannot stop smoking without resorting to help strategies. This research has also explained how these strategies work and permit the agent to abstain gradually (using the avoidance strategy) or in one go (using the rehabilitation strategy). The choice of one of these strategies depends on the individual’s characteristics.

Long run regrets play a key role in the decision to quit and the individual’s perseverance in maintaining new, healthier habits. There have an essential factor that prevents the individual from returning to consuming the addictive good, once the product’s physical effects have disappeared (in opposition to psychological ones). The persistence of long run regrets or not explains the individual’s successes or failures in abstaining.

The research here finds that health policies, especially price increases, do not have homogeneous effects on all agents according to the stage in which they are: consumers in pre-contemplation and preparation stages reduce their consumption of the addictive good when its price increases. But in the contemplation stage (which occurs between pre-contemplation and preparation), consumption levels remain unchanged. This result hides the fact that a price increase brings the agent closer of the next stage and is likely to explain why some agents are not directly impacted.
The second main result is that increases of the loss function (via fear policies, the promotion of a healthy life or by changing social norms) have similar effects in terms of the consumption of the addictive good than price increases. But the former do not cut the agent’s consumer budget. If the effects on the loss function are durable, then a detailed study would be essential because of the controversies that taxation causes (Evans et al., 1999; Evans and Farrelly, 1998; Godefroy, 2004; Gruber and Mullainathan, 2005; O’Donoghue and Rabin, 2006). Moreover, an increase of fear is more susceptible to lead the agent to reduce consumption of the addictive good (via an increase of the loss function) than a price increase, if the agent chooses the avoidance strategy to stop smoking.

Thus, it is necessary to discuss the possibilities of increasing fear from the negative health effects of taking drugs especially in the smoking case, as well as the costs of such campaigns compared to a price increase. Indeed, a message that generates intensive fear can be rejected by cognitive rationalization (the agent tries to control the fear instead of the associated danger), as has been shown in the literature (Gallopol, 2005; Witte, 1992). Thus, an effective fear campaign should be accompanied by the suggestion of effective strategies to avoid such dangers, and must convince individuals that these strategies can work. As for the consequences, the incidence of the individual’s willpower on his own beliefs seems to be a key point to study.

Finally, we must consider measures that tend to modify social norms. It could be an interesting alternative to fear campaigns, since it would let to the agent less margin to control his loss function. Indeed, individuals are concerned by social issues and the theory of reasoned action Ajzen and Fishbein (1980) postulate that one motor of the intention to act is based on subjective norms: i.e. the individual’s beliefs about what people think that he should do or not. Some studies have illustrated this point by observing that smoking bans at work or in public places could be linked to smoking bans in private places, including home (Borland et al., 1991; Fong et al., 2006; Pursell et al., 2007) in order to further reduce the environmental cues of addiction.
The utility maximization in exposure corresponds to point 4 on Fig.A.1. It indicates long run regrets since the amount of welfare is smaller than what the agent would have received if he had never started addictive consumption (point b on Fig. A.1). By choosing the avoidance strategy, the utility function decreases (from $u$ to $u'$). However, the slope of the adjustment cost function decreases ($C_t$ function becomes $C_t'$), and transforms the total utility function ($U_t$ to $U_t'$). The agent’s optimal point corresponds to a smaller amount of the addictive good, and to greater welfare (point 5 on Fig.A.1). It should be noted that if the agent enters into the hot mode, this will correspond to point a on Fig.A.1. in exposure, and to the point a’ on Fig.A.1. in avoidance (the latter corresponds to lower welfare but the chances of being affected by it are lower).

The rehabilitation strategy permits the agent to move from point 4 to point 5 (Fig.A.2.). Note that the higher the cost of rehabilitation, the greater the difference between the welfare that the individual would have received if he had never started consuming (point b on Fig.A.2), and the actual welfare experienced (point 5 on Fig.A.2.).
Appendix B. Demonstrations

Demonstration B.1. \( B_t(s_t) \) shape

\[
\frac{\partial B(s_t)}{\partial s_t} = \alpha_s - \alpha_y \frac{p_y}{p_y} + \alpha_y \frac{l_t}{p_y} s_t + \left[ \alpha_{ss} + \alpha_{yy} \left( \frac{p_x}{p_y} \right)^2 \right] s_t \text{ with } \alpha_s - \alpha_y \frac{p_y}{p_y} - \alpha_{yy} \frac{l_t}{p_y} > 0 \text{ and } \left[ \alpha_{ss} + \alpha_{yy} \left( \frac{p_x}{p_y} \right)^2 \right] s_t < 0.
\]

Condition: \( \alpha_s > \frac{p_y}{p_y} \left( \alpha_y + \alpha_{yy} \frac{l_t}{p_y} \right) \) preference for the addictive product must be important enough and the price ratio \( p_x/p_y \) must be sufficiently low.

The function \( B_t(s_t) \) increases for \( s_t < \frac{\alpha_s - \alpha_y \frac{p_y}{p_y} - \alpha_{yy} \frac{l_t}{p_y}}{\alpha_{ss} + \alpha_{yy} \left( \frac{p_x}{p_y} \right)^2} \) and then decreases.

\[
\frac{\partial^2 B(s_t)}{\partial s_t^2} = \left[ \alpha_{ss} + \alpha_{yy} \left( \frac{p_x}{p_y} \right)^2 \right] < 0: \text{ the benefit function is represented by a bell shaped curve.}
\]

Demonstration B.2. Avoidance strategy

Maximization of \( U^A(s_t, D_t) \)

The optimal addictive consumption point corresponds to the point where the slope of \( C_t(s_t, D_t)/m \) equals the slope of \( u^A(s_t) \). Since the slope of \( u^A(s_t) \) equals the slope of \( u^E(s_t) \), and the slope of \( C_t(s_t, D_t)/m \) is smaller than the slope of \( C_t(s_t, D_t) \), then the optimal amount of the addictive product will be smaller in avoidance strategy.

Optimal strategy

\[
U^A_t(s_t, D_t) = B(s_t) - p_A - L(s_t) - C_t(s_t, D_t)/m = B(s_t) - L(s_t) - C_t(s_t, D_t) - \left( p_A + \frac{1-m}{m} C_t(s_t, D_t) \right) \text{ where } m > 1.
\]

\[
U^A_t(s_t, D_t) > U^E(s_t, D_t) \iff \left( p_A + \frac{1-m}{m} C_t(s_t, D_t) \right) < 0 \iff C_t(s_t, D_t) > \frac{m}{m-1} p_A
\]

i.e. when the optimal amount of addictive good corresponds to high adjustment costs.

Or when the cost of avoidance is weak or the reduction of adjustment costs function is high (when \( \lim_{m \to +\infty} \frac{m}{m-1} = 1 \)).

Demonstration B.3. Rehabilitation strategy

\[
B^R(0) = \alpha_y \frac{l_t-P_R}{p_y} + \alpha_{yy} \left( \frac{l_t-P_R}{p_y} \right)^2 / 2 = B(0) - \alpha_y \frac{p_R}{p_y} + \alpha_{yy} \left( \frac{-l_t-P_R+P_R}{2p_y^2} \right)
\]

\[
B^R(0) = B(0) - \frac{p_R}{p_y} \left( \alpha_y + \alpha_{yy} \frac{l_t-P_R}{2p_y} \right)
\]

\[
\alpha_y + \alpha_{yy} y_t > 0 \text{ whatever } y_t \leq \frac{l_t}{p_y} \text{ (the budget does not saturate demand)}
\]

Thus \( \alpha_y + \alpha_{yy} \frac{l_t-P_R}{2p_y} > 0 \) since \( \frac{l_t-P_R}{2p_y} < \frac{l_t}{p_y} \)

Thus \( B^R(0) < B(0) \).
Demonstration B.4. Impact of an increase in the price of the addictive good

\[ \frac{\partial B(s_t)}{\partial p_s} = \left( -\alpha_y \frac{1}{p_y} - \alpha_{yy} \frac{1}{p_y^2} \right) s_t + \alpha_{yy} \frac{2 p_s s_t^2}{p_y^2} \]

\[ \frac{\partial^2 B(s_t)}{\partial p_s^2} = -\left( \alpha_y + \alpha_{yy} \frac{1}{p_y} \right) s_t + \alpha_{yy} \frac{2 p_s s_t^2}{p_y^2} \]

Since \( \alpha_y y_t + \alpha_{yy} \frac{y_t^2}{2} > 0 \) whatever \( y_t \leq \frac{l_t}{p_y} \) (true because the budget does not saturate demand), we deduce:

\[ \alpha_y y_t + \alpha_{yy} y_t^2 > 0 \iff \alpha_y + \alpha_{yy} \frac{1}{p_y} > 0 \]

In addition, \( \alpha_{yy} \frac{2 p_s + \Delta s_t}{p_y} < 0 \) so that:

\[ \frac{\partial^2 B(s_t)}{\partial p_s^2} < 0. \]

Thus we have \( B^s(s_t) < B(s_t) \), \( \forall s_t > 0 \) so that an increase in the price of the addictive good has a negative effect on the budget. For an unchanged loss function and adjustment cost functions, the utility and total utility decrease, whatever \( s_t > 0 \). For \( s_t = 0 \), there is no modification since \( B^t(0) = B_t(0) = \left[ \alpha_y \frac{l_t}{p_y} + \alpha_{yy} \frac{(l_t^2)}{2} \right] \).

Moreover,

\[ \frac{\alpha^2 B(s_t)}{\partial s_t \partial p_s} = -\left( \alpha_y + \alpha_{yy} \frac{1}{p_y} \right) \frac{1}{p_y} + \left( \alpha_{ss} + \alpha_{yy} \frac{2}{p_y^2} \right) s_t < 0 \iff \frac{\partial^2 B(s_t)}{\partial s_t \partial p_s} < \frac{\partial^2 B(s_t)}{\partial s_t^2}. \]

An increase in price lowers the Benefit function slope. Since the respective slopes of \( L(s_t) \) and \( C_t(s_t, D_t) \) are constant, this price increase also lowers the slopes of \( u^s(s_t) \) and \( U^s_t(s_t, D_t) \) comparatively to \( u(s_t) \) and \( U_t(s_t, D_t) \). As for the consequences, these functions \( (B^s(s_t), u^s(s_t)) \) and \( U^s_t(s_t, D_t) \) have a lower maximum for a lower amount of the addictive good.

Furthermore,

\[ \frac{\partial^2 B(s_t)}{\partial s_t^2} = \alpha_{yy} \frac{2 p_s}{p_y^2} < 0 \iff \frac{\partial^2 B^s(s_t)}{\partial s_t^2} < 0. \]

The bell shaped curve is preserved but the slope decreases quicker, and this intensifies the effects of a price increase when the amount of the addictive good increases.

Demonstration B.5. Impact of an increase of the loss function

Since \( L_t \) is assumed to be a linearly-increasing function, let \( L_t(s_t) = a s_t \) where \( a \) is the intensity of fear concerning the addictive good’s negative effects.

\[ u^L(s_t) = B(s_t) - L(s_t) \]

\[ \frac{\partial u(s_t)}{\partial a} = -s_t < 0 \]

Thus \( u^L(s_t) < u(s_t) \) \( \forall s_t > 0 \)

An increase of fear lower the utility function whatever \( s_t > 0 \).

Moreover:

\[ \frac{\partial^2 u(s_t)}{\partial s_t \partial a} = -1 \iff \frac{\partial u^L(s_t)}{\partial s_t} < \frac{\partial u(s_t)}{\partial s_t}. \]

This negative effect increases with the amount of the addictive good since the new utility function slope is smaller than the previous one, whatever \( s_t > 0 \).

However, the utility function’s bell shape is preserved since:

\[ \frac{\partial^2 u(s_t)}{\partial s_t^2} = 0 \iff \frac{\partial^2 u^L(s_t)}{\partial s_t^2} = \frac{\partial^2 u(s_t)}{\partial s_t^2}. \]
**Demonstration B.6. The impact of an increase of the rehabilitation price \( p_R \)**

When the individual opts for a rehabilitation strategy, he ensures himself to abstain from consuming the addictive good: \( s_t = 0 \). Thus, the remaining budget is spent on composite good.

\[
B^R(0) = \alpha_y \left( \frac{1 - p_R}{p_y} \right) + \alpha_{yy} \left( \frac{1 - p_R}{p_y} \right)^2 / 2
\]

\[
\frac{\partial B^R(0)}{\partial p_R} = -\frac{\alpha_y}{p_R} + \alpha_{yy} \frac{1 - p_R}{p_y^2} = -\frac{1}{p_y} (\alpha_y + \alpha_{yy}y_t) < 0
\]

since \( \alpha_y + \alpha_{yy}y_t > 0 \) (the budget does not saturate demand).

Paying for a rehabilitation strategy causes a decrease in the utility perceived at the zero point of consumption, compared to the utility the individual would have received if he had never started smoking. The higher the rehabilitation price, the greater the benefits, so that utility is negatively impacted.

Moreover, \( \frac{\partial^2 B^R(0)}{(\partial p_R)^2} = \alpha_{yy} \frac{p_R}{p_y^2} < 0 \), i.e. the higher the rehabilitation price, the less important the impact of a given increase will be.

**Demonstration B.7. Comparison of the avoidance strategy effects following an increase in the price of the addictive good or an increase of the loss function**

In both cases, adoption of the avoidance strategy decreases the utility function but not its slope:

\[
u^A(s_t) < u^S(s_t) \text{ and } \frac{\partial u^A(s_t)}{\partial s_t} = \frac{\partial u^S(s_t)}{\partial s_t}, \quad u^L(s_t) < u^S(s_t) \text{ and } \frac{\partial u^L(s_t)}{\partial s_t} = \frac{\partial u^S(s_t)}{\partial s_t}.
\]

Thus, if \( \frac{\partial u^A(s_t)}{\partial s_t} \) equalizes \( \frac{\partial C(s_t,D^t)}{\partial s_t} \) for a lower \( s_t \) than \( \frac{\partial u^L(s_t)}{\partial s_t} \), it also equalizes \( \frac{\partial C(s_t,D^t)/m}{\partial s_t} \) for a lower \( s_t \) than \( \frac{\partial u^L(s_t)}{\partial s_t} \).

Consequently, \( \frac{\partial u^A(s_t)}{\partial s_t} \) equalizes \( \frac{\partial C(s_t,D^t)/m}{\partial s_t} \) for a lower \( s_t \) value than \( \frac{\partial u^L(s_t)}{\partial s_t} \).

The optimal amount of the addictive good in the avoidance strategy is lower after an increase in the price of the good, rather than after an increase of the loss function. But this corresponds to a higher level of adjustment costs.
References