AN ECONOMIC MODEL OF THE STAGES OF ADDICTIVE CONSUMPTION
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The aim of this research is to build a model of addictive consumption by taking into account consumers’ growing loss of self-control, as well as their lack of empathy for their future selves. Such model reveals that individuals follow a given consumption pattern composed of five stages, and thereby, that stable addictive consumption level does not exist outside of abstention. It permits to explain how consumers modify their environment in order to get rid of their addiction, and why some of them find it difficult to successfully abstain. The analysis of the model shows that they do not uniformly react to public policies according to the stage in which they are placed. I argue that public forces can reduce addictive consumption through three mechanisms: the first one is to act on the prices. The second consists in increasing consumer’s perceived loss induced by the consumption. Finally, collectivity can nudge the agents in order to help them to make optimal decisions and reinforce their personal willpower.

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1. INTRODUCTION
Addiction refers to a specific consumption pattern that involves tolerance and reinforcement effects, as well as self-control issues, when the substance is not taken in a sufficient amount (American Psychiatric Association, 2014). This paper focuses on addictions involving substance consumption such as cigarettes, alcohol or illegal drugs (by opposition to behavioral addictions as sport, video games or gambling). The specificity of substance use is to provide immediate and certain rewards, but also uncertain future losses which cover health, social and economic issues.

In economics, most of models explaining addiction derive from Becker and Murphy (1988) theory of rational addiction (TRA) where consumption of an addictive good induces the development of a stock of past consumptions, i.e. an addiction stock. The latter has a negative impact on the amount of utility derived from current consumption: in order to get the same amount of utility than previously, the individual has to increase his consumption of addictive good (phenomenon knew as tolerance effect). Moreover, this stock increases the marginal utility of the present addictive consumption: present consumption increases future consumption (reinforcement effect). In this framework, an individual decides to stop his addictive consumption due to an external event like taxes increase (Gordon and Sun, 2015; Gruber and Köszegi, 2001), or due to an endogenous parameter like a growing concern about the consequences of the addiction as the consumer ages (Goldbaum, 2000), or like his beliefs about the product characteristics (Carbone et al., 2005; Caulkins et al., 2012). However, the
TRA ignores the phenomenon of loss of self-control over consumption: since it involves the consumption of amounts that do not correspond to the agent’s decision, such a behavior is not considered as rational. Thus, in the TRA setting, when consumer makes the decision to abstain, he usually succeeds; leaving repeated quitting failures experimented by a part of individuals unexplained. Moreover, these models do not consider agent’s capacity to modify his environment in order to facilitate abstention.

To explain those phenomena, the present paper proposes to build a simple model based on two existing frameworks. The first is Suranovic et al. (1999) model which introduces increasing withdrawal costs that explains tolerance and reinforcement. However, the authors do not go so far as to include loss of self-control effect and thus do not explain quitting failures. The second comes from Bernheim and Rangel (2004) researches. Inspired from researches in psychology, the authors introduce the loss of self-control effect that the consumer can manage by resorting to quitting strategies. Nevertheless, the model puts aside the tolerance effect, by limiting the addictive consumption decision to a binary choice between consuming one single unit or abstention. By linking loss of self-control to withdrawal costs, the present paper permits to keep the advantages of those models, and to overcome their weaknesses. The consumption pattern that is found, shows many similarities with the stage of change path identified in the transtheoretical model commonly used in therapies to treat addiction (Abel and O’Brien, 2014; Connors et al., 2013; Prochaska and Velicer, 1997). In other words, individuals adopt a specific behavior according to the stage in which they are placed, thereby reacting differently to prevention policies that need to be adapted.

After having exposed the theoretical framework used in section 2, the model is built in section 3. The study of the individual consumption pattern in section 4 permits to identify a succession of addictive behaviors corresponding to the stages of change pattern. In section 5, the impact of different public policies is studied. and the section 6 gathers concluding remarks.

2. THEORETICAL FRAMEWORK
2.1. Related literature
In models deriving from the TAR, individual decides to consume an increasing amount of an addictive product as long as it provides him more utility than if he abstains. When he makes the decision to stop his consumption, he does not suffer from any withdrawal effect that could lead him to loose self-control and consume the addictive product anyway. However, loss of self control phenomenon is a criterion for addiction and substance abuse disorders pointed by the DSM-5. Indeed, endowing the agent with a perfect rationality prevents him from such biases in his decisions. Thus, the TAR provides an analysis of addiction development, and of the conditions of a

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2 DSM criteria referring to loss of self-control are “Taking the substance in larger amounts or for longer than they [consumers] meant to”, “wanting to cut down or stop using the substance but not managing to” and “Cravings and urges to use the substance”.

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decision to quit the consumption, but does not explain why some individuals do not manage to modify their behavior despite external shocks as price increases or health problems.

Withdrawal costs are at the core of Suranovic et al. (1999) model. By recognizing that the individuals do not have the required infinite calculation capacities to maximize their welfare on all their future periods of life, the authors assume that consumers have a bounded rationality in the sense of Simon (1972). In a static decision setting, and, with a finite number of living periods, the agent maximizes a utility function which is additively composed of a benefit function, a loss function and an adjustment cost function. Benefit function refers to the agent’s welfare that derives from the present consumptions of addictive goods. Loss function represents anticipated and actualized future (negative) effects of present consumption (i.e. the reduction of lifetime expectancy). Thus, the value of loss function is increasing with the amount consumed, and over time with the upcoming last period of life. Adjustment cost function refers to quitting costs, i.e. withdrawal effects borne by the consumer. The latter are decreasing in an interval spreading between zero consumption and its habitual level which depends on the addiction stock. Below the habitual level, the agent is in withdrawal which lowers his welfare. Above the habitual level, withdrawal effects are null. However, consuming an amount of addictive good equal or above the habitual level raises the adjustment cost function in the next period through an increase of the addiction stock. Consequently, the habitual level increase in the following period. Depending on the adjustment cost function shape, which relies on personal characteristics, the agent quits his consumption progressively, by “cold turkey”, or after several attempts. Nevertheless, Suranovic et al. (1999) do not explain those aborted attempts. It is due to their assumption that the sole impact of withdrawal costs is to decrease the consumer’s utility: even when they are high, withdrawal effects do not trigger any uncontrolled consumption.

In this perspective, Loewenstein (2000) provides some interesting elements: he proposes a simple decision model that takes into account the emotions experienced by the individual when he makes a consumption decision. Indeed, some goods are associated to visceral effects which appear when their consumption is too low and which “motivate” the agent to engage in a specific behavior. Thus, he can experiment two independent sets of preferences: the cold mode, in which he makes his decisions by maximizing his utility, and a hot mode in which his preferences are biased toward the good associated to visceral effects. The latter corresponds to a state of craving in which agent makes impulsive consumption decisions. This dual-process in decision making retains a particular attention in neuroeconomics and behavioral economics (Brocas and Carrillo, 2014). In addition of being activated alternatively, those modes are hermetic to each other (Yang et al., 2012): when the individual finds himself in one mode, he cannot take into account the parameters of the other mode even if he experienced this state many times. In other words, he overestimates his ability to resist to impulses - i.e. self-control - (Myrseth and Wollbrant, 2013) because of the difficulty of remembering short-term craving when making a decision in the cold mode (Weinstein et al., 2004; Liu et al., 2014). Alternatively, in the hot mode, he forgets the decisions made in the cold mode. This lack of empathy for future selves (Badger et al., 2007; Kahneman and Thaler, 2006) is commonly called the hot-cold empathy gap (Fisher and Rangel, 2013; Kang and Camerer, 2013).
Bernheim and Rangel (2004) adapted Loewenstein's (2000) model to the context of addictive good consumption. At each period of time, a consumer placed in the cold mode makes a choice to consume zero or one unit of the addictive good. If he decides to abstain, there is a risk of entering into the hot mode in which he always consumes the product. This risk is positively linked to his addiction stock. Thus, the authors associate the level of visceral effects - renamed “environmental cues” - to past consumptions. The individual can manage those mode switches by attempting to control his own behavior by adopting two strategies. One one hand, he can avoid environmental cues and diminish the probability of entering into the hot mode. On the other hand, he can decide to suppress the possibility of consuming the addictive good by entering in a rehabilitation cure.

Despite its qualities, this theoretical framework has two weaknesses. First, the decision to consume the addictive good only concerns one unit of it: the individual consumes a constant amount of the addictive good during his whole career with a growing desire to consume it. Thus, only reinforcement effect and loss of self-control are taken into account whereas tolerance disappears from the model. In addition, the agent fully estimates his chances to enter into the hot mode and is able to manage it by maximizing his expected utility function (the sum of the probabilities of staying in the cold mode and of entering into the hot mode, associated to their respective utilities provided by the consumption alternative chosen). Consequently, the model ignores the hot-cold empathy gap phenomenon.

2.2. The paper contribution

This paper proposes a combination of Suranovic et al. (1999), and Bernheim and Rangel (2004) models by linking adjustment cost function to the hot mode activation. The latter does not only depend on the level of addiction to the product, it also relies on the amounts of addictive good chosen: the more the individual decides to consume, the smaller are the chances for the hot mode to activate. In addition, agent’s decisions are influenced by the empathy gap: instead of maximizing his expected welfare (the sum of the “probabilized” utilities in each mode); he only maximizes the welfare of the mode in which he is placed. In other words, when he makes his decisions in the cold mode, he only takes into account the negative impact of withdrawal effects on his current welfare, but omits to consider their potential role on the hot mode activation. It virtually conduces him to choose consumption levels that are too weak, and thus to an increase the likehood of a hot mode activation.

Under this configuration, addiction stock has a double impact on preferences variation through the increase of adjustment cost function. On one hand, it raises the probability of entering into the hot mode for a given desired amount of the addictive good, which results in a preference variation for the rest of the time period. On the other hand, it lowers welfare, leading to a preference variation in the long run.

Indeed, by entering into the hot mode, the agent consumes more of the addictive product than he planned in the cold mode and increases the level of addiction stock in next period. Thus, self-control is worsened by the hot-cold empathy gap.

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3 Consumer always makes his consumptions plans in the cold mode, either because he was already in the cold mode, or because the hot mode consumption of the previous period satisfied his impulses, so he returned to the cold mode.
Successive losses of self-control and the increase of adjustment cost function that derives can entail a situation, called critical level, in which consuming the addictive good becomes less attractive than the initial abstention situation. However, because of the rise of the addiction stock, the agent cannot just make the decision of abstaining in order to return to this virginal state. This impasse provokes an activation of long run regrets.

Some emotions lead people to re-examine their preferences (Lerner et al., 2015; Livet, 2007). Whereas an individual feeling disappointment often explains the negative consequences of his decisions by destiny, the emotion of regret supposes that he admits that the choice he made was wrong (Petit, 2015). Thus, long run regrets lead the agent to look for strategies that could help him to abstain from the addictive consumption, by enhancing their willpower to change. Those strategies are those enumerated by Bernheim and Rangel (2004), and have similar results in terms of abstinence pattern than in Suranovic et al. (1999) work. Their goal is to lower withdrawal effects which makes easier to stay in the cold mode even if the agent reduces his consumption. Avoidance strategy consists in avoiding the environmental cues, whose presence arouses the desire to consume the addictive product by increasing the subjective value of the drug (Hayashi et al., 2013). These cues are for instance products that the individual considers complementary to the consumption of addictive goods (coffee, alcohol in case of smoking) or objects suggesting the consumption (ashtrays full of butts). Consumers are gradually sensitized to them through the consumption of the addictive product via an interaction between the classical conditioning and the conditional learning processes4 (Gipson and Kalivas, 2016; Vredenburg et al., 2015). Here, the cost of avoidance strategy is non-monetary but induces a decrease in welfare since the individual adopts a less attractive lifestyle than before. Weakening temptations permits a gradual abstention; thereby he has to adopt avoidance during successive periods of time before a complete abstention. The second possible quitting strategy is the rehabilitation that consists in removing voluntarily the possibility of consuming the addictive product. It leads to cold turkey abstention. Here, the individual also needs to resort to this strategy for a few periods in order to make the adjustment cost diminish enough before relaxing his efforts. Unlike avoidance, the price of rehabilitation is assumed to be monetary.

It is considered that, as long as long run regrets are activated, agent willpower permits him to remain careful about controlling his consumption: he bears in mind that returning to his old habits (by relaxing his efforts to abstain) will conduct his consumption pattern to the critical level which triggered the decision to abstain. Thus, when comparing an ordinary consumption that maximizes his present welfare with the quitting strategies, he uses this critical level as a benchmark: he acts as if it corresponded to his present maximized welfare and compares it to the actual welfares provided by the quitting strategies. This type of behavior refers to what Elster (2000) calls “Bunching”: the individual can bootstrap himself out of addiction by viewing each consumption of addictive good as a predictor of future

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4 The classical conditional theory consists in learning a new behavior by linking two stimuli together in order to produce a learned response. In case of smoking, environmental cues are linked to cigarette smoking. First, cigarettes are repeatedly consumed in given circumstances. As the smoker learns these associations, the usual environmental smoking setting transform to environmental cues that trigger the desire to consume when the smoker meets them. In instrumental conditioning, the behavior is controlled by its consequences (e.g. relaxation after having smoked a cigarette).
consumptions. In this perspective, what motivates former smokers not to smoke again is the comparison of actual abstention welfare to the welfare that triggered the decision to abstain (they remember cough, and difficulties to breathe that cigarette consumption implied).

However, willpower is a depletable resource (Ozdenoren et al., 2012) that not persists over time as the long run regrets emotion eases. When it happens, the agent compares anew the quitting strategies to the actual welfare provided by addictive consumption. The latter becomes again more attractive than abstention when adjustment costs have sufficiently diminished. Retuning to the former consumption habits will, sooner or later, lead to critical utility that will re-activate long run regrets. Probability of long run regrets disappearance depends on individual characteristics, and decreases at each re-activation: the more the agent experiences the critical utility, the more he will be perseverant in his attempts to remain abstinent: thus, people who relapse after a serious attempt have better chances to succeed in abstention during the next one (Caponnetto and Polosa, 2008; Vangeli et al., 2011). Thus, the ability to self-regulate by using the critical utility benchmark is like a muscle: the more it is exercised, the stronger it becomes (Ozdenoren et al., 2012).

As a result, there are two explanations for a quitting failure. First, even reduced by a quitting strategy, the chances of losing self-control are still present since withdrawal effects are only reduced. Second, there is a risk of long run regret disappearance that leads to a decrease in consumer’s willpower to change, which can result in a return to his former consumption habits.

A model correctly specified should describe a behavioral pattern actually observed in reality from the beginning of the consumption to total abstention. An interesting framework is based on Prochaska and his team thirty years’ studies (Prochaska and DiClemente, 1983; DiClemente et al., 1991; Prochaska et al., 1992, 1994; Norcross et al., 2011): the transtheoretical model. As it will be detailed in section 4, the present model fits very well with this framework which permits a more complete interpretation of it.

2.3. Interpreting the results through a psychological perspective: the stages of change

Transtheoretical model describes behavioral change by five typical stages that follow each other in a defined order. This pattern applies in various contexts of problematic behavior (Prochaska et al., 1994) among which addictions (Abel and O’Brien, 2014, p. 2012; Connors et al., 2013).

First, in pre-contemplation stage, agents are not aware of their addiction problem, and express denial about the noxiousness of the product consumption. It is commonly observed when consumers have not yet developed an addiction for the product, and have stable consumptions. Individuals in this stage refuse to modify their behavior in the long run.

In the following stage, contemplation, agents are beginning to consider a change in their behavior but remain ambivalent: on one hand, they recognize that it has a negative impact on their lives, and on the other hand, they are afraid of changing. Usually, individuals reporting a desire to modify their behavior in the long run (one year for instance), but who do not plan to do it within the six months, are associated to this stage.

Next stage is preparation, when behavior becomes problematic, due to self-control losses. Although, they plan behavior changes in the future, agents don’t undertake any
concrete actions. Typically, literature considers that individuals who plan to change their addictive behavior within the six months are in the preparation stage.

In the action stage, agents make a firm and clear decision to change, and make commitments in order to overcome their problem. This stage includes individuals who started to modify their behavior (diminishing their addictive good consumption), or who modified their behavior for less than six months.

Finally, the maintenance stage concerns agents that succeeded in modifying their behavior but who continue to act in order to prevent relapses and to consolidate the benefits they gained during the action stage. Those who quitted their addictive consumption for more than six months, belong to this stage.

The sequence of stages of change can be summarized through the spiral of change, which refers to cycles of progressions and regression in behavioral change. Each attempt to change increases the chances of overcoming the behavioral problem (that corresponds to the idea of the increase in regrets persistence at each of their apparition).

What is interesting with the transtheoretical model, as well as in the framework proposed in the present paper, is that every consumer can be associated to a specific stage. Consequently, it is possible to predict how he will behave in the future. It permits to study the effects of different types of health policies according the stage in which the agents are in order to identify which one is the more effective at which stage.

3. BUILDING THE MODEL
3.1. Individual’s welfare

At time $t$, the consumer, chooses to allocate his resources between an addictive good $s_t$ and a composite good $y_t$. It is assumed that he can neither save nor borrow, and that income $(I)$ and prices $(p_s, p_y)$ are constant over time. Moreover, it is supposed that satiation level is beyond budget. The addictive good consumption induces the development of an addiction stock $S_t$ that affects future welfare. As in the previous studies (Becker and Murphy, 1988; Carbone et al., 2005), a simple investment function is considered:

$$S_t = S_{t-1}(1 - \mu_s) + s_{t-1}$$  \hspace{1cm} (1)

where $\mu_s$ is a fixed discount rate. Addiction stock is positively related to the habitual level of consumption $s^h_t$ that represents the minimal amount of the addictive good that the individual needs in order not to suffer withdrawal effects. It is assumed that if the agent consumes an amount higher than or equal to this habitual level, then the addiction stock increases in the next period ($S_{t+1} > S_t$ and $s^h_{t+1} > s^h_t$ if $S_t \geq s^h_t$), whereas if the amount consumed is smaller, the addiction stock decreases.

As in Suranovic et al. (1999) model, consumption at period $t$ generates effects that are represented by a benefit function $B_t$, a loss function $L_t$, and an adjustment cost function $C_t$.

Benefit function refers to current benefits that the consumer derives from the consumption of $(s_t, y_t)$ at $t$, and is assumed to be the same in the cold mode and in the hot

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5 The composite good is composed of normal goods i.e. goods that do not generate any future benefits or losses.
mode. As in Goldbaum (2000), a quadratic function is used to model it. Since it has been assumed that income and prices are fixed, the parameters are rearranged by replacing \( y_t \) by \( \frac{I}{p_y} ps \) to obtain a function \( B(s_t) \) only depending on \( s_t \) (see Appendix B.1.).

Loss function represents the discounted value of the future negative effects of present consumption such as health effects, social disapproval, or job problems. It is assumed that, within a period of time, the loss function is linearly-increasing with \( s_t \), and is null for \( s_t = 0 \). Exogenous shocks (as a public dissuasion campaign, personal health problems, a birth or a death in the family) are likely to modify \( L(s_t) \) slope (see section 6.2.).

Adjustment cost function \( C_t \) represents the discomfort arising when the addictive good consumption is too weak (lower than the habitual level), \textit{i.e.} withdrawal effects. Accordingly, \( C_t \) depends on the amount of addictive good consumed \( S_t \), and on the habitual level of consumption \( S_t^h \) through the addiction, stock \( S_t \). The function is positive or null in \( s_t = 0, and decreases with \( s_t \) in the interval \([0, S_t^h]\) to become zero in \( s_t > S_t^h \):

\[
\begin{cases}
  C(s_t, S_t) > 0 & \text{if } s_t < S_t^h \\
  C(s_t, S_t) = 0 & \text{if } s_t \geq S_t^h
\end{cases}
\] (2)

For simplicity of presentation, it is assumed that \( C_t \) slope remains constant whatever the amount of addiction stock \( \left(\frac{\partial C(s_t, S_t)}{\partial s_t} = \frac{\partial C(s_t, S_t)}{\partial s_t}\right)^6 \).

In the present model, there are two representations of welfare. The first is utility function that represents agent’s welfare in the absence of addiction development:

\[
u(s_t) = B(s_t) - L(s_t)
\] (3a)

The second representation, total utility function, takes into account this phenomenon through the inclusion of \( C_t \):

\[
U(s_t, S_t) = B(s_t) - L(s_t) - C(s_t, S_t)
\] (3b)

Such a specification permits the consumer to assess his opportunity cost of having entered into the addictive good consumption. To do so, he uses \( u(0) \) as a benchmark that he compares to his actual welfare \( U(s_t, S_t) \).

\( B(s_t) \) is a bell-shaped curve (see Appendix B.2.), and the functions \( L(s_t) \) and \( C(s_t, S_t) \) are linear. Thereby \( u \) and \( U_t \) are also bell-shaped curves.

The contribution of the present model is to consider that if \( C_t = 0 \), then the consumer always remains in the cold mode, whereas if withdrawal effects appear (\textit{i.e.} if \( C_t > 0 \)), then a risk of entering into the hot mode arises (see section 4.). Consequently to (2), the following relationship between \( U_t(s_t, S_t) \) and \( u_t(s_t) \) is derived:

\footnote{It is assumed that the absolute value of the adjustment cost function slope depends on the consumer’s profile (an exogenous parameter that contains personal sensitivity to environmental cues). If it is small, a given reduction in the addictive good consumption will have a small impact on his welfare (it will not hurt so much the consumer), referring to a weak addiction. At the opposite, a higher absolute slope refers to an individual that may develop strong addiction: a small decrease in consumption generates huge withdrawal effects.}
Thus, the higher $C_t$ at a given level of $s_t$, the lower $U_t$ will be (tolerance effect), and the more the agent will be induced to consume in order to remain as close as he can of $u$ function (reinforcement effect). Thus, adjustment cost function takes into account both of the addiction aspects defined by (Becker and Murphy, 1988).

3.2. Consumption choice

Each time period is composed of two phases: in the first one, the agent in the cold mode plans his consumption by maximizing his total utility:

$$\max U_t(s_t, s_t) \quad (5a)$$

Entering into the hot mode occurs with the probability $\theta_{c_t}$, which positively depends on the level of withdrawal effects at the consumption level planned in the first phase. Thus, $\theta_{c_t}$ increases with $S_t$ and decreases as $s_t$ increases. Moreover when $C_t(s_t, S_t) = 0$, then $\theta_{c_t} = 0$.

If the agent were perfectly rational, he would maximize his expected total utility\(^7\). However, due to the hot-cold empathy gap, when in the cold mode, he does not take into account his hot mode preferences and estimates $\theta_{c_t}$ to be null. Doing so, he only maximizes his total utility (5a) according his current preferences. Thus, hot-cold empathy gap induces an increase of the chances to enter into the hot mode.

In the second phase, he consumes either according to his plans if still in the cold mode, or by consuming more than planned if in the hot mode. Indeed, in the hot mode, his preferences are biased toward the urge of minimizing withdrawal effects. His addictive consumption level $s^h_t$, results from:

$$\begin{cases}
\max U_t(s_t, S_t) \\
st \quad C_t(s_t, S_t) = 0
\end{cases} \quad (5b)$$

A hot mode triggering leads to an increase of adjustment cost function in next time period (through an increase of the addiction stock and the habitual level of consumption), that negatively impacts the total utility function on the interval $[0, s^h_{t+1}]$. In other words, for a given level of addictive good consumed in $t$, if the agent enters into hot mode, it will be more difficult for him to stay in the cold mode in $t + 1$.

If he attains the critical level $U^c(s_t, S_t) < u(0)$, that is to say, if the maximization of his total utility function provides him a lower satisfaction than if he never started to consume the addictive product, then he suffers long run regrets: he would like to get rid of his addictive consumption but he cannot since if he tries to lower his consumption, he will almost automatically enter into the hot mode due to high $\theta_{c_t}$. As for consequences, he looks for a strategy that will help him to return to his initial utility level $u(0)$, by acting on $C_t$ function.

\(^7\) $E(U_t(s_t, s_t)) = (1 - \theta_{c_t})U_t(s_t, s_t) + \theta_{c_t}U_t(s^h_t; S_t)$, where $U_t(s_t, s_t)$ corresponds to the total utility when the agent stays in the cold mode while $U_t(s^h_t; S_t)$ is the total utility received in the hot mode.
4. THE MODEL WORKING

Since income and prices are assumed to be constant over time, then \( B_t, L_t \) and thus \( u_t \) have a fixed value for a given amount of addictive good whatever \( t \). Although, \( C_t \) and thus \( U_t \) vary from one period to another for a given amount of addictive good, depending on \( S_t \) variations. As defined in Section 3.1., \( C_t \) has a fixed slope over time. These assumptions allow a pattern of addictive behaviors to be identified, and which is composed of five distinct stages.

4.1. Precontemplation stage: a misperception of the addiction development (see Fig.1.A.)

**Proposition 1**: \( U_t \) admits a constant maximum in \( s^* > s^h_t \), when \( \frac{\partial u(s^h_t)}{\partial s_t} > 0 \).

**Proof**: \( u_t \) admits a maximum at \( s^* \left( \frac{\partial u(s^*)}{\partial s_t} = 0 \right) \). When \( s^* > s^h_t, C(s^*, S_t) = 0 \) (see (2)), thus \( U(s^*, S_t) = u(s^*) \) (see (4)). The welfare provided by the consumption of \( s^* \) corresponds to the maximal welfare attainable in the absence of addiction effects. Moreover, \( s^* > s^h_t \) \( \Rightarrow S_t < S_{t+1} \Rightarrow C(s_t, S_t) \leq C(s_{t+1}, S_{t+1}) \) and \( s^h_t < s^h_{t+1} \) whatever \( s_t = s_{t+1} \). If \( s^* > s^h_{t+1} \) \( \Rightarrow C(s^*, S_t) = 0 \) \( \Rightarrow U(s^*, S_{t+1}) = u(s^*) \). The amount consumed, and the associated welfare remains unchanged from \( t \) to \( t + 1 \).

**Implication**: when the individual enters into the consumption of an addictive product, his adjustment costs are negligible. As long as adjustment costs have not developed enough, he chooses to consume this fixed amount \( s^* \) which provides a constant welfare \( U(s^*, S_t) = u(s^*) \). Moreover, since withdrawal effects are null at this consumption point, he always stays in the cold mode. His welfare is equivalent what he would get in the absence of addiction development. Thus, the agent has no reason to be aware of the existence of adjustment cost since he has never experienced them. There is also no reason to consider consumption as a problem or to consider oneself as dependent on the addictive product.

Consequently, the model predicts a temporary stable consumption \( s^* \) as long as \( \frac{\partial u(s_t^h)}{\partial s_t} > 0 \), i.e. as long as \( s^* > s^h_t \). This stability is only temporary since the adjustment costs grow.

4.2. Contemplation stage: an increase in consumption (see Fig.1.B.)

**Proposition 2**: when \( s^* < s^h_t, U_t \) admits a maximum in \( s^h_t \) as long as \( 0 > \frac{\partial u(s^h_t)}{\partial s_t} > \frac{\partial C_t(s^h_t, S_t)}{\partial s_t} \).

**Proof**: \( U(s_t, S_t) = u(s_t) - C(s_t, S_t) \Rightarrow \frac{\partial u(s_t, S_t)}{\partial s_t} = \frac{\partial u(s_t)}{\partial s_t} - \frac{\partial C_t(s_t, S_t)}{\partial s_t} \).

If \( \frac{\partial u(s^h_t)}{\partial s_t} > \frac{\partial C_t(s^h_t, S_t)}{\partial s_t} \) thus \( \frac{\partial u(s^h_t, S_t)}{\partial s_t} > 0 \) in \( s_t < s^h_t \) and \( \frac{\partial C_t(s^h_t, S_t)}{\partial s_t} < 0 \) in \( s_t \geq s^h_t \) (since \( U_t = u_t \) for \( s_t \geq s^h_t \)) and \( \frac{\partial u(s^h_t)}{\partial s_t} < 0 \) for \( s_t > s^* \). Thus \( U_t \) admits a maximum in \( s^h_t \).

As long as marginal utility exceeds marginal costs (i.e. \( \frac{\partial u(s_t)}{\partial s_t} > \frac{\partial C_t(s_t, S_t)}{\partial s_t} \)), \( U(s_t, S_t) \) has a positive slope on \( s_t \in [0; s^h_t] \) - even when \( u(s_t) \) decreases on \( [s^*; s^h_t] \) interval - and a
negative slope for \( s_t > s^h_t \) where \( U(s_t, s_t) = u(s_t) \). Thus \( s^h_t \) is the optimal consumption point here, which is higher than in the contemplation stage \( (s^* < s^h_t) \), and which is associated to a smaller welfare: \( U(s^h_t, s_t) = u(s^h_t) < u(s^*) \). In addition, consuming \( s^h_t \) makes \( S_t \) and \( C(s^h_t, S_t) \) increase in the next period and the optimal amount of the addictive good to become \( s^h_t < s^h_{t+1} \) and \( U(s^h_t, S_t) > U(s^h_{t+1}, S_{t+1}) \).

Implication: the agent is aware of the development of a tolerance and reinforcement effect for the addictive good since his welfare decreases from one period to another, as his consumption increases. However, he is not ready to change his habits, and continues to consume \( s^h_t \), providing him a higher welfare than if he had never started to consume the addictive product \( (U(s^h_t, S_t) > u(0)) \). He has not yet suffered from withdrawal effects since his optimal consumption point corresponds to null adjustment cost. Thus, he does not experience the hot mode yet. During this stage, there is no stable consumption level: it increases until to the point \( s^h_t = \bar{s} \) where \( \frac{\partial U(s)}{\partial s_t} = \frac{\partial C(\bar{s}, S_t)}{\partial s_t} \).

4.3. Preparation stage: losses of self-control (see Fig.1.C.)

Proposition 3: when \( \bar{s} < s^h_t \), \( U(s^h_t, S_t) \) admits a maximum in \( s_t = \bar{s} \), then the consumer is likely to experience the hot mode.

Proof: \( \bar{s} \) represents a point such as:
- when \( s^h_t \leq \bar{s} \), \( C(\bar{s}, S_t) = 0 \) thus \( \frac{\partial U(\bar{s})}{\partial s_t} < \frac{C(\bar{s}, S_t)}{s_t} < 0 \)
- when \( s^h_t > \bar{s} \), \( C(\bar{s}, S_t) > 0 \) thus \( 0 > \frac{\partial U(\bar{s})}{\partial s_t} = \frac{C(\bar{s}, S_t)}{s_t} \)

Thus, for \( \bar{s} < s^h_t \), there is \( \frac{\partial U(s^h_t, S_t)}{\partial s_t} > 0 \) in \( s_t < \bar{s} \) and \( \frac{\partial U(s^h_t, S_t)}{\partial s_t} < 0 \) in \( s_t > \bar{s} \).

When \( \bar{s} < s^h_t \), then \( U_t \) increases in \( s_t < \bar{s} \) and decreases in \( s_t > \bar{s} \), (equaling the utility function for \( s_t = s^h_t \) ). \( U_t \) admits a maximum in \( \bar{s} \), but this amount corresponds to positive adjustment cost \( (C(\bar{s}, S_t) > 0 \) in \( \bar{s} < s^h_t \)).

The agent sticks to his decision and consumes \( \bar{s} \) with the probability \( (1 - \theta_\bar{s}) \) which implies \( s^h_t > s^h_{t+1} \) \( \Rightarrow \theta_\bar{s} > \theta_{\bar{s}+1} \) and \( U(\bar{s}, S_t) < U(\bar{s}, S_{t+1}) \). Otherwise, he enters into the hot mode and consumes \( s^h_t \) implying \( s^h_t < s^h_{t+1} \) \( \Rightarrow \theta_\bar{s} < \theta_{\bar{s}+1} \) and \( U_t(\bar{s}, S_t) > U_{t+1}(\bar{s}, S_{t+1}) \). Thus, the more he enters into hot mode, the more difficult it becomes for him to consume the desired amount \( \bar{s} \). By losing his self-control, he becomes aware of his dependence problem to the addictive good, but does not yet act to manage it.

Implication: according to his successes or failures to stay in the cold mode, the agent’s consumption stabilizes around \( \bar{s} \) or tends to rise, so this stage may last a long time. This behavior (choosing consumption of \( \bar{s} \)) is maintained as long as his welfare \( U_t(\bar{s}, S_t) \) remains higher than \( u(0) \). Consequently, there is no stable level of consumption in this stage: the agent always plan to consume \( \bar{s} \), but depending on the hot mode triggering, his effective consumption is \( \bar{s} \) or \( s^h_t \) (the latter vary at each period of time).
4.4. Action stage: attempts to get rid of the addictive consumption (see Fig.1.D.)

The agent attains a critical level of total utility $U^c(s_t, S_t) < u(0)$ when the amount of welfare he would have received if he had never started to consume the addictive product becomes greater than his actual total utility. This stage corresponds to the consumer’s attempts to change addictive behavior in order to get rid of the addictive behavior by resorting to quitting strategies. Once the individual succeeds in abstaining, he passes to the next phase.

4.4.1. Spontaneous quitting or consumption reduction (exposition strategy $E$)

In the exposition lifestyle $E$, the individual faces usual environmental cues and does not bear extra costs. Try to diminish progressively the amounts consumed, or to go cold turkey would be irrational since the welfare associated, would not corresponds to total utility maximization. In order to quit his addiction, the agent needs to put in place a specific strategy.

4.4.2. Commitment: avoidance strategy $A$ (see Appendix B.3)

When consuming the addictive product becomes less appealing than initial abstention, the agent also has the opportunity to lower the effects of environmental cues by adopting avoidance strategy $A$.

Proposition 4: if the agent chooses the avoidance strategy, his optimal addictive consumption will decrease to a fixed level $\bar{s}^A$, as $U^A$ will increase from one period to another until $\bar{s}^A = s^h_t$.

Proof: the agent accepts to pay a non-monetary price $p_A > 0$ such as $B^A(s_t) = B(s_t) - p_A \Rightarrow u^A(s_t) = u(s_t) - p_A$. As compensation, the adjustment cost function becomes $(s_t, S_t)/m$, where $m > 1$ corresponds to the diminution of sensitivity to environmental cues.

Since $C(s_t, S_t)/m < C(s_t, S_t) \Rightarrow \theta c_t/m < \theta c_t$ for a given $s_t$ and $\frac{\partial C(s_t, S_t)/m}{\partial s_t} > \frac{\partial C(s_t, S_t)}{\partial s_t} > 0$ but

$$\frac{\partial B^A(s_t)}{\partial s_t} = \frac{\partial B^E(s_t)}{\partial s_t} \Rightarrow \frac{\partial u^A(s_t)}{\partial s_t} = \frac{\partial u^E(s_t)}{\partial s_t} \forall s_t.$$ Thus $\bar{s}^A < \bar{s}$. As avoidance strategy diminishes the adjustment cost slope, it does not have any impact on $s^h_t$ (which refers to a physical need).

Avoidance strategy is effective if the adjustment cost reduction is sufficiently large to obtain $C(s_t, S_t)/m < C(s^\theta, S_t)$, providing more chance of sticking to his consumption plans (see Graph A.1.). However, if $m$ is too low, the diminution of adjustment cost slope can be insufficient to permit the agent to stay in the cold mode.

If long run regrets are strong enough, avoidance is chosen when $\max U^A > \max U^c$. If the agent does not feel long run regrets, the strategy can be chosen as long as $\max U^A > \max U$.

Implication: the avoidance strategy takes place over a few periods. In a given period of time, if the individual remains in the cold mode, he consumes $\bar{s}^A < s^h_t$, thus $S_t$ and $s^h_t$ decrease in the next period. The agent perseveres in the avoidance strategy until $\bar{s}^A = s^h_t$. As he reaches
this point, he is aware that if he continues to maximize $U_t^A(s_t, S_t)$, then the adjustment cost will increase again to reach $U_t^A(\bar{s}_t, S_t) < u(0)$.

With active long regrets, he anticipates this situation and uses it as a benchmark when in compares consumption in the avoidance strategy with alternatives involving an abstention due to the “bunching” phenomenon (Elster, 2000): $U_t(0, S_t), U_t^A(0, S_t), U_t^R(0, S_t)$. The agent then chooses the most advantageous. If he succeeds in abstaining, he passes into the next stage. Thus, the choice is made between consuming the addictive product today and on latter occasions; and abstaining today and on latter occasions.

4.4.3. Pre-commitment: rehabilitation strategy R (see Appendix B.4)

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 alternatives that involve a consumption.

**Proposition 5**: if the agent chooses the rehabilitation strategy, his addictive consumption will immediately fall to zero, as his welfare will rise.

**Proof**: the agent pays a price $p_R > 0$ to make the adjustment cost null at $s_t = 0$ (it remains the same for the other values of $s_t$): $C(0, S_t) = 0 \Rightarrow \theta_{c_t}^R = 0$.

His budget becomes $1 \cdot p_R$, so the benefit function becomes $B^R(s_t)$, and total utility becomes discontinuous: it is equal to $B^R(0) - L(0) > U_t(s_t, S_t) > B^R(s_t) - L(s_t) - C_t(s_t, S_t)$, for all $s_t > 0$.

**Implication**: after having made the pre-commitment, a positive consumption of the addictive lead to a lower welfare than no consumption. To be chosen, the decrease of utility in $s_t = 0$ (induced by the payment of the price $p_R$), must be low enough. Adopting rehabilitation strategy makes the consumer totally abstain (see Graph A.2) and directly enter into the next stage.

4.4.4 Choice between the different strategies

The choice between the strategies $E, A,$ and $R$ requires taking into account two parameters. First, the price: paying $p_R$ or $p_A$ is equivalent to a decrease in utility, whatever the value of $s_t$. The more expensive the alternatives are, the more the total utility function will be reduced and thus its maximum. However $p_A$ and $p_R$ do not impact $u(s_t)$ in the same way: $p_A$ refers to an indirect payment (and is directly subtracted from the utility function), and $p_R$ to a direct one (that impacts the budget and then the utility function). The second parameter that the agent takes into account is the maximum total utility value achievable: the counterpart for 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 he is forced to adopt the exposition lifestyle as long as he does not find a more advantageous alternative: he waits for a diminution in the quitting strategies costs, or waits to have a welfare low enough – thus below the critical utility – to make those strategies attractive.
The price of rehabilitation $p_R$ is uniform across the agents, whereas the cost of avoidance $p_A$ and its effects $m$ on the slope of adjustment cost function vary from an individual to another. Indeed some individuals face more environmental cues than others, especially when their peers have the same addictive habits. For instance, a smoker used to smoke cigarettes while on the coffee break with colleagues but who do not specifically enjoy the coffee break alone, will experience a small $p_A$ of avoiding coffee breaks, but if the coffee break is an important moment of socialization in the agent’s office, the cost $p_A$ will be large. In both cases, $m$ will be an exogenous parameter (willpower). If the avoidance costs are too high, or if $m$ is too small, then a rehabilitation strategy seems to be a better alternative.

4.5. The last stage: maintaining efforts to stay abstinent

A successful abstention during one period does not mean that the individual has got rid of his consumption. Indeed, he has to maintain his efforts in order to ensure that he will not relapse and return to his old habits.

The individual continues to compare the welfare provided in each of the three alternatives for a null amount of addictive product consumed. Therefore, the persistence of long run regrets is still essential not to succumb to the temptation of getting a bigger but temporary welfare by consuming the addictive product again. This phase lasts as long as $U_t^A(0,S_t) > U_t^E(0,S_t)$ if he has chosen avoidance strategy, and as long as $U_t^E(0) > U_t^E(0,S_t)$, if he has chosen rehabilitation. This situation is brought to an end when $U_t^E(0,S_t)$ becomes the optimal choice, i.e. when the costs of quitting strategies (constant) overcompensate their effects, the agent relaxes his efforts.

This abstention stage is the only one in which the individual tends to a stable level of addictive consumption: the more he remains in this stage, the higher the probability of succeeding in the abstention.

If the individual does not express any specific motivation to abstain from addictive consumption, and is just looking for utility maximization, the avoidance and the rehabilitation strategies will just help him to diminish his consumption until the exposition lifestyle becomes anew more appealing. All things being equal, long run regrets are a driving force improving this specific motivation, the willpower. 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 cost function and Total Utility function in first four stages. Note: In pre-contemplation stage, the individual consumes the amount $s^*$ as long as $s_H$ is smaller. The total utility received is constant. When $s^H = s^*$, he enters contemplation stage in which optimal consumption is $s^H$. During this stage, consumption increases and total utility decrease. The stage begins at the consumption point 1 and ends at the consumption point 2 when the marginal utility equals the marginal cost. In preparation stage, the maximization of total utility always provides the same optimal amount where which marginal utility equals marginal costs. It corresponds to positive adjustment cost. Moreover, if the agent enters into the hot mode, he consumes $s_H > \bar{s}$ (point a). During this stage, the individual’s consumption plans move between points 2 and 3 as the adjustment costs grow consequently to successive hot mode activations. When the total utility becomes lower than if the agent had never started smoking (the point b), he enters into action stage.
5. STUDYING AND INTERPRETING THE MODEL: IMPLICATIONS FOR PUBLIC POLICIES

5.1. An increase in the price of the addictive product (see Appendix B.5)

An increase in the price of the addictive good has a negative effect on benefit function and thus on utility function becoming $u^s(s_t) < u(s_t)$ for $s_t > 0$. Moreover, the maximal value of $u^s(s_t)$ is smaller than before the price increase $\left(\frac{\partial u^s(s_t)}{\partial s_t} < \frac{\partial u(s_t)}{\partial s_t}\right)$ and corresponds to a lower amount of addictive good.

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 $s^{*s} > s^* > s^h$. If the price increase is substantial, and the new optimal point becomes $s^{*s} = s^h < s^*$, then the individual enters into the contemplation stage and consumes the amount $s^h_t$. If the agent is initially in the contemplation stage, a moderate increase in the addictive good’s price has no effect on him if $\frac{\partial c(s^h_t, s_t)}{\partial s_t} > \frac{\partial u'(s^h_t)}{\partial s_t}$. If the increase is sufficiently large to give $\frac{\partial c(s^h_t, s_t)}{\partial s_t} < \frac{\partial u'(s^h_t)}{\partial s_t}$, then the individual passes in the preparation stage and consumes a smaller amount of the addictive good associated with a lower utility and but higher adjustment cost. He also diminishes the amounts consumed if initially in the preparation stage. If he attains the critical level of utility that is smaller than an initial abstention utility $u(0)$, then the agent enters into the action stage. This action stage entrance occurs earlier, and with lower adjustments costs than without any price increase. This makes quitting smoking easier.

Here, quitting costs have a non linear effect on the demand responsiveness whereas for Suranovic et al. (1999) demand becomes unresponsive when quitting costs develop. Indeed, a given increase of the addictive good’s price will have different immediate consequences depending on the stage in which the agent is placed. Although the effects are not immediately visible, an increase in the addictive product price diminishes the duration of the addictive consumption career ceteris paribus. Of course a drastic price increase would eliminate consumption, but its feasibility is controversial (it would be equivalent to a prohibition and induce a black market appearance).

5.2. Variation in the price of rehabilitation strategy (see Appendix B.6.)

The lower the price required to benefit from the rehabilitation strategy, the higher the utility to the zero addictive consumption point is. Moreover, a given decrease in rehabilitation price will have a stronger effect if the price is already low (marginal effect of a given price variation diminishes when the price increases). If the price decreases enough, the individual who previously opted for the avoidance strategy, will opt for the rehabilitation strategy which permits to enter immediately into the maintenance stage, without any risk of losing control.

It also has an important implication on the final success in abstention. Indeed, agent relaxes his efforts in the maintenance stage when abstention in the exposition lifestyle provides more welfare than abstention in the avoidance or rehabilitation strategy. Thus, the lower the price for the alternative, the latter the agent will relax his efforts in maintenance stage, the smaller will be the adjustment cost, the greater will be the chances of success in
abstention. For instance, 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.

5.3. **An increase in the loss function (see Appendix B.7.)**

An increase in the loss function slope can occur when fear from the negative consequences of the product consumption increase, as an effect of a prevention policy which aims at raising addicts’ fear or promoting the benefits of a healthy lifestyle. It can also be the result of a disturbing event in the social circle. Whatever the stage of change in which the individual is placed, an increase in the loss function slope has no effect on utility (and total utility) function at the zero consumption point. Since it reduces the slope of the utility function, the latter becomes null earlier $s_t^b < s_t^*$ and equalizes the slope of the adjustment cost function for a smaller amount of addictive good. Moreover, by reducing the value of utility function, the critical level $U_t(s_t^b, S_t) = u(0)$ is attained for a lower $s_t$ and $S_t$, and thus a lower value of $C_t$. The stages succession is accelerated and the decision to stop occurs with smaller adjustment costs. As for consequences, quitting consumption is facilitated. Thus, 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).

The variation in the loss function slope principally depends on the importance placed on the judgments made by others, but concerns about health are also significant (an athlete will be more concerned by this parameter for instance). However, invoking fear has also limits that are defined by the Extended Parallel Process Model (So, 2013; Tannenbaum et al., 2015; Witte and Allen, 2000): if the fear aroused is too intense, the agent will use cognitive strategies in order to diminish such fear - i.e. cognitive rationalization - instead of looking for ways to protect himself from the dangers of an addiction by resorting to behavioral rationalization (Peters et al., 2013). In the present model, it would be represented by a smaller increase in $L$ slope than an increase without cognitive strategies. One solution would be to propose credible strategies permitting to control such dangers, i.e. helping the agent to quit addictive consumption by enhancing self-efficacy. In case of smoking, it has been shown that individuals with a large self-efficacy are more responsive to fear-appeal campaigns (Thompson et al., 2009). The agent accepts the danger presence which is represented by a higher increase in $L$ slope. Another kind of prevention raising the loss function involves denormalization policies that aim at modifying norms: in feeling rejected by peers, an individual could then change behavior. This technique has led to debate, since stigmatization may conduce agents who cannot easily modify their behavior to reinforce their dangerous behavior (Mourre and Gurviez, 2015; 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.

As in Suranovic et al. (1999), it is considered here that a price increase and fear development have a positive effect on consumption reduction. However, it is not necessary immediate and durable. Moreover, the link between the concrete danger and fear is modulated by cognitive mechanisms.
5.4. Reinforcement of the avoidance strategy: willpower and nudges

An increase in $m$ decreases the absolute value of the adjustment costs function slope in the interval $[0, s_1^H]$. Although there is no impact on $u(s)$, $U(s_1, s_2)$ increases in this interval. Moreover, utility function slope equalizes the adjustment cost one for a smaller value of $s_1$, i.e., $\delta^m < \delta$. Not only, the preparation stage occurs earlier, but the consumer gains in welfare. The decrease in the absolute value of the adjustment cost slope permits also a more efficient abstinence since the withdrawal effects are smaller.

Private rules permit to get a significant value for $m$. But public authorities, as well as some collective initiatives can also act in order to increase its value. Those interventions are the so-called nudges (Thaler and Sunstein, 2009), which consist in altering people behavior without forbidding any option. The starting point is that “in many cases, individuals make pretty bad decisions – decisions they would not have made if they had aid full attention and possessed complete information, unlimited cognitive capabilities and complete self-control” (Thaler and Sunstein, 2009, p.6). Thus nudges permit to guarantee agents’ interests by altering their behavior in order to facilitate an optimal decision making. Diet, smoking, drinking are not rational behaviors for everybody and some people would like to be constrained. Here, nudges help the individual to diminish the consequences of urge by putting into place commitment strategies (Lades, 2014). Diminishing the product accessibility, as it has been the case in many countries with smoking bans and alcohol selling restrictions are an efficient way to diminish their consumption (Boes et al., 2015; Goeij et al., 2015).

5.5. Enhance willpower to change

In order to stick to their good resolutions to change, consumers can also develop “private rules” that seem to be the most efficient method to attain their objectives (Elster, 2000). Those private rules can be supported by communities as the website stickk.com which propose to fix an objective (for instance to stop smoking, or go on a diet), to fix a device permitting to control the realization of the objective (for instance to proceed to cotinine test after six months in a given center, or to weigh himself), and to put an amount of money on an account that the agent will only take back if he attains his objective. A similar project has been set in Philippines to diminish smoking: CARES (Committed Action to Reduce End Smoking). Those devices appear have positive effects on behavioral change (Giné et al., 2010; Gneezy et al., 2011).

6. CONCLUSIONS

This research paper models addictive behavior throughout the consumption “career”, by taking as a starting point two models that, taken alone, present a number of limits, but combined, show interesting results. The association of Bernheim and Rangel (2004) losses of self-control to Surananovic et al. (1999) adjustment cost function (representing the withdrawal effects), as well as the inclusion of Loewenstein (2005) empathy gap phenomenon (the lack of empathy for the future selves), permits to find a behavioral pattern that matches with the stages of change described in the transtheoretical model (Prochaska and Velicer, 1997). It is
an interesting result since each addictive product consumer can be placed in one of these five stages, making his future behavior and attitude toward his consumption predictable.

In the model presented here, the role of the adjustment cost function is central since it explains the movements from one stage to another from the initiation to the final abstention. It also explains individual losses of self-control *i.e.* why he can find himself in situations in which he consumes more than he had planned to, and why he cannot abstain without resorting to quitting strategies (avoidance and rehabilitation). Long run regrets also play a key role in the model since their presence explain the individual’s perseverance in maintaining new and healthier habits, after deciding to quit their addictive consumption, even once withdrawal effects have disappeared.

The study of the model parameters permits to find that three kinds of tools can be used by public forces in order to reduce addictive consumption. The first one is prices variation. Although an increase of one addictive good price (directly for legal addictive goods, and indirectly through repressive policies for illegal ones) does not have homogeneous effects on all agents according to the stage in which they are, it brings the agent closer to the next stage. Thereby, the action stage is triggered earlier, for smaller values of the adjustment cost function, making the attempts to abstain more effective. The monetary cost of rehabilitation strategies has also to be discussed. Indeed, a decrease of it should have two effects: first, it incites the agent to choose the rehabilitation strategy instead of the avoidance, making his entrance into the maintenance stage certain. It also delays the when the agent relaxes his efforts to abstain from the addictive consumption, making the chances to relapse smaller.

The second way to reduce addictive consumption is to act on the loss function slope via fear-appeal policies, the promotion of a healthy life or by changing social norms. Effects are similar than in a case of a price increase, but the former do not cut the agent’s budget. It is an interesting result because taxation raises controversies about its inequitable nature toward modest consumers (Evans et al., 1999; Evans and Farrelly, 1998; Godefroy, 2004; Gruber and Mullainathan, 2005; O’Donoghue and Rabin, 2006). Thus, it is necessary to discuss the possibilities of maintaining consumers’ fear of the negative health effects of taking drugs especially in the smoking case. The extended parallel model (Peters et al., 2013; So, 2013; Tannenbaum et al., 2015) suggests that an effective fear campaign should be accompanied by the proposition of credible solutions providing support to an abstention from addictive consumption, that consumers would feel able to put in place reinforcing their self-efficacy. More precisely, self-efficacy is strengthened by the accessibility of quitting strategies (*i.e.* the cost of avoidance and rehabilitation strategies). Unlike fear campaigns, interventions aiming a change in social norms let to the agent few margin for deny process. 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 that correspond to his beliefs about what people think that he should do or not.

The last tool is self-control and willpower strengthening. Self-control can be strengthened by intensifying the decrease in environmental cues effect that follows the adoption of the avoidance strategy, by diminishing the product accessibility (Boes et al., 2015; Goeij et al., 2015), or by increasing willpower by the help of collective initiatives that extend the duration of the intention of a behavioral change (Giné et al., 2010; Gneezy et al., 2011).
APPENDIX A. GRAPHS

(Fig.A.1.) Selection of avoidance strategy in the action stage. Note: in exposition lifestyle, total utility maximization provides the point 4 on Fig.A.1. The agent suffers long run regrets since the amount of welfare is smaller than what he would have received if he had never started addictive consumption (point b). By choosing avoidance strategy, utility function decreases (from $u$ to $u^A$). However, adjustment cost function slope decreases ($C_t$ function becomes $C_t/m$), and transforms the total utility function ($U_t$ to $U_t^A$). The agent’s optimal point corresponds to a smaller amount of addictive good, and to a greater welfare (point 5). It should be noted that if he enters into the hot mode, it will correspond to point $a$ if in exposition, and to the point $a'$ if in avoidance (the latter corresponds to lower welfare but the chances to suffer $a'$ are smaller than the chances of getting $a$).

(Fig.A.2.) Selection of the rehabilitation strategy in the action stage. Note: Rehabilitation strategy permits the agent to move from point 4 to point 5 on 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), and the actual welfare experienced (point 5).
APPENDIX B. DEMONSTRATIONS

Demonstration B.1. \( B(s_t, y_t) \) transformation into \( B(s_t) \)

\[
B(s_t, y_t) = \alpha_s s_t + \alpha_{ss} s_t^2 / 2 + \alpha_y y_t + \alpha_{yy} y_t^2 / 2
\]

where \( \alpha_s, \alpha_y, \alpha_{ss}, \alpha_{yy} \) are the parameters with \( \alpha_s, \alpha_y > 0 \) and \( \alpha_{ss}, \alpha_{yy} < 0 \).

Budget constraint is \( l = p_x s_t + p_y y_t \) (\( l, p_x \) and \( p_y \) are constant over time). Due to the relation \( y_t = l_t / p_y - (p_x / p_y) s_t \), the benefit function can be transformed in order to obtain:

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

Condition: satiation level is beyond the consumer budget, so that \( \alpha_s > - \alpha_{ss} \frac{l_t}{p_s} \) and \( \alpha_y > - \alpha_{yy} \frac{l_t}{p_y} \).

Demonstration B.2. \( B(s_t) \) shape

\[
\frac{\partial B(s_t)}{\partial s_t} = \alpha_s - \alpha_y \frac{p_x}{p_y} - \alpha_{yy} \frac{l_t}{p_y} + \left[ \alpha_{ss} + \alpha_{yy} \left( \frac{p_x}{p_y} \right)^2 \right] s_t
\]

and

\[
\alpha_{ss} + \alpha_{yy} \left( \frac{p_x}{p_y} \right)^2 s_t < 0.
\]

Condition: \( \alpha_s > \frac{p_x}{p_y} \left( \alpha_y + \alpha_{yy} \frac{l_t}{p_y} \right) \) 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 \( s_t < \frac{\alpha_s - \alpha_y \frac{p_x}{p_y} - \alpha_{yy} \frac{l_t}{p_y}}{\alpha_{ss} + \alpha_{yy} \left( \frac{p_x}{p_y} \right)^2} \) 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.3. Avoidance strategy

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

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

Optimal strategy

\[
U^A(s_t, S_t) = B(s_t) - p_A - L(s_t) \cdot C(s_t, S_t)/m = B(s_t) - L(s_t) \cdot C(s_t, S_t) - \left( p_A + \frac{1-m}{m} C(s_t, S_t) \right)
\]

where \( m > 1 \).

\( U^A(s_t, S_t) > U(s_t, S_t) \) if \( p_A + \frac{1-m}{m} C(s_t, S_t) \) \( < 0 \) \( \Leftrightarrow \) \( C(s_t, S_t) > \frac{m-1}{m} p_A \).
i.e. when adjustment cost function is sufficiently low at the optimal consumption level, or when the cost of avoidance environmental cues \( p_A \) is low, or when adjustment cost are lowered enough, i.e. for large \( m \) (\( \lim_{m \to +\infty} \frac{m}{m-1} = 1 \)).

**Demonstration B.4. Rehabilitation strategy**

\[
B^R(0) = \alpha_y \frac{lt}{p_y} + \alpha_{yy} \left( \frac{lt}{p_y} \right)^2 / 2 = B(0) \alpha_y \frac{p^R}{p_y} + \alpha_{yy} \left( \frac{lt \cdot p^R}{2p^2_y} \right)
\]

\[
B^R(0) = B(0) - \frac{p^R}{p_y} (\alpha_y + \alpha_{yy} \frac{lt}{2p_y})
\]

\( \alpha_y + \alpha_{yy} y_t > 0 \) whatever \( y_t \leq \frac{lt}{p_y} \) (the budget does not saturate demand).

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

Thus \( B^R(0) < B(0) \).

**Demonstration B.5. Impact of an increase the addictive product price**

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

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

Since \( \alpha_y y_t + \alpha_{yy} \frac{p^2_s}{2} > 0 \) whatever \( y_t \leq \frac{lt}{p_y} \) (true because the budget does not saturate demand), the following relationship is deduced:

\( \alpha_y y_t + \alpha_{yy} \frac{p^2_s}{2} > 0 \iff \alpha_y + \alpha_{yy} y_t > 0 \iff \alpha_y + \alpha_{yy} \frac{lt}{p_y} > 0 \)

In addition, \( \alpha_{yy} \frac{p^2_s}{2p_y} < 0 \) so that:

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

Thus \( B^S(s_t) < B(s_t), \forall s_t > 0 \) so 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 \( B^S(0) = B(0) = \left[ \alpha_y \frac{lt}{p_y} + \alpha_{yy} \left( \frac{lt}{p_y} \right)^2 / 2 \right] \).

Moreover,

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

An increase in price lowers the benefit function slope. Since the respective slopes of \( L(s_t) \) and \( C(s_t,s_r) \) are constant, this price increase also lowers the slopes of \( u^S(s_t) \) and \( U^S(s_t,s_r) \) comparatively to \( u(s_t) \) and \( U(s_t,s_r) \). Consequently, these functions \( (B^S(s_t), u^S(s_t) \) and \( U^S(s_t,s_r) \)) have a lower maximum for a lower amount of the addictive good.

Furthermore,

\[
\frac{\partial^2 B(s_t)}{\partial s_t^2} = \alpha_{yy} \frac{2p^2_s}{p^2_y} < 0 \iff \frac{\partial^2 B^S(s_t)}{\partial s_t^2} < \frac{\partial^2 B^S(s_t)}{\partial s_t^2} < 0.
\]
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.6. The impact of an increase of the rehabilitation price \( p_R \)**

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

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

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

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

Paying for rehabilitation causes a decrease in the utility perceived at \( s_t = 0 \), 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 \( \frac{\partial^2 B^R(0)}{(\partial p_R)^2} = \alpha_y p_R \frac{p_R}{p_y^2} < 0 \), i.e. the higher the rehabilitation price, the less important the impact of a given price increase will be.

**Demonstration B.7. Impact of an increase of the loss function**

Since \( L_t \) is assumed to be a linearly-increasing function, let \( L(s_t) = \alpha s_t \) where \( \alpha \) 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, utility function’s bell shape is preserved since:

\[
\frac{\partial^3 u(s_t)}{\partial s_t^2 \partial a} = 0 \iff \frac{\partial^2 u^L(s_t)}{\partial s_t^2} = \frac{\partial^2 u(s_t)}{\partial s_t^2}
\]
REFERENCES


