ISSN 0265-8003

SELF-CONTROL, MODERATE CONSUMPTION AND CRAVING

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Discussion Paper No. 2017
November 1998

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CEPR Discussion Paper No. 2017

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ABSTRACT

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We analyse the consumption strategy of a dynamically inconsistent individual for goods that provide an immediate benefit and a delayed cost. The agent has incomplete information on the cost inherent to each unit of consumption and partially learns this value anytime he consumes. We show that, by fear of overconsuming indefinitely, the agent may (optimally) decide to abstain after some periods, even in cases where moderate consumption always dominates abstention. This provides a rationale for why dieters, former smokers, or gamblers stick to strict personal rules of behaviour, such as total abstention, without invoking standard addiction arguments. We also study how urges modify the strategy of the agent and analyse some policy implications. Last, applications of this theory to other issues such as self-knowledge, willpower and habit formation are discussed.

JEL Classification: A12, D83, D90
Keywords: hyperbolic discounting, learning, self-knowledge, moderate consumption, craving

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*This paper is produced as part of a CEPR research network on *The Economic Analysis of Political Institutions: Coalition Building and Constitutional Design*, funded by the European Commission under the Training and Mobility of Researchers Programme (contract No. ERBFMRXCT960028). The author thanks M Castanheira, M Dewatripont, J Miron, J Tirole, P Weil and participants at ULB's Behavioural Economics workshop, Milan and EEA98 (Berlin) for comments. He is specially indebted to Isabelle Brocas for endless discussions. All errors are the author's own.

Submitted 28 September 1998

NON-TECHNICAL SUMMARY

There is substantial evidence in Psychology and Economics that individuals discount short-term events at a higher rate than long-term events. This has been identified as a major cause of self-control problems. It implies that agents tend to overconsume goods that provide an immediate reward but exert a delayed negative externality on welfare, like snacks (which spoil the pleasure of dinner) or chocolate during a diet. Similarly, they do not take basic precautions in their sexual activity, gamble in casinos more than what they can afford, and cut down the fraction of current income saved. All these behaviours are followed, to a greater or lesser extent, by a state of *ex-post* regret.

The purpose of this study is to relate the problem of self-control to casual observation which suggests that, in the type of activities previously mentioned, moderation is much more infrequent than both abstention and excesses. Several theories provide partial explanations for this observation. One could argue that moderation is not desirable. This is not convincing, however, given that some individuals who abstain openly state that moderate 'consumption', if feasible, would be optimal. An alternative explanation is that, although suboptimal, radical abstention serves as a focal point or rule of thumb more likely to be followed than the loosely defined concept of moderation. This argument is intuitively very appealing, but it does not explain why it should be easier to commit to 'zero' rather than to 'two' (cigarettes). Last, one might simply state that moderation is not sustainable in the long run if the good is physically addictive. In our view, at low levels of consumption, physical addiction does not play a crucial role and that is why our theory will leave this issue aside.

The present work takes a different route. It shows that full abstention can be the result of a rational decision process even in situations where a strategy of moderate consumption strictly dominates abstention from the viewpoint of the agent at any date. This conclusion rests on three building blocks. First, the individual has time inconsistent preferences. Second, there is imperfect information about the personal net utility of consuming the good and learning through consumption. And third, the information revealed under moderate consumption is substantially higher than under full abstention.

The intuition for our result is as follows. As long as there is consumption, the agent learns extensively about the value of the delayed cost, i.e. to which extent the negative externality imposed by current consumption affects his future welfare. Learning can be harmful to him because of his time inconsistent preferences, however. For instance, the agent may fall into a state of beliefs where he wishes high consumption at the present date and moderation afterwards but, due to his inability to commit, ends up overconsuming in every period. When the expected intertemporal pay-off under continual excesses is smaller than under sustained abstention, the agent prefers not to consume. Moreover, abstention is the agent's only way to decrease learning radically, and therefore his only possible commitment strategy to avoid sinful temptations in the future. To sum up, we not only prove convergence to abstention but, more importantly, persistence whenever this state is reached as the agent's optimal self-commitment device. Naturally, excesses in every period is always another equilibrium strategy: if the agent anticipates that he will consume at every future date independently of his present behaviour, then he has no incentives to abstain in the current period. Yet, we show that whenever abstention is sustainable, it yields a higher welfare than overconsumption from the perspective of the agent at every date.

In a second step, we introduce the possibility of urges, defined as random positive shocks in the net utility of current consumption. We show that, for some beliefs about the externality, there exist two possible strategies: unconditional abstention and abstention except under an urge. When both strategies coexist, the agent is better off if he refrains from consuming under craving.

Last, the paper develops several other applications of this theory to issues related to psychology and economics. These include habit formation, willpower, and self-knowledge.

1 Introduction

In modern behavioral economics, the empirical observation that individuals discount short-term events at a higher rate than long-term events is identified as one of the major causes of self-control problems.[1] If an agent (hereafter referred to as "he") overweights current events, i.e. exhibits a "salience/impatience" for payoffs in the near future relative to more distant ones, then optimal contingent plans at some date are no longer optimal when reconsidered some periods later. More precisely, the agent tends to *overconsume* goods that provide an immediate reward but exert a delayed negative externality on welfare, like snacks (which spoil the pleasure of dinner) or chocolate during a diet. Similarly, he stays up too late every night watching uninteresting TV programs. More important, he does not take basic precautions in his sexual activity, gambles in casinos more than what he can afford, and cuts down the fraction of current income saved. All these behaviors are followed, to a greater or lesser extent, by a state of ex post regret.

The most obvious way to solve self-control problems is to credibly commit at some point in time to a path of future actions.[2] However, note that welfare from the perspective of the agent at some date is in conflict with his welfare at another date. This raises the question of whether individuals have the right (both ethical and legal) to commit to a pre-specified stream of actions and go against their future will.[3] Still, such commitments are often not possible or enforceable in practice.

The purpose of this study is to relate the problem of self-control under no commitment to casual observation which suggests that, in the type of activities previously mentioned, *moderation is much more infrequent than both abstention and excesses.* Note that this is true for goods that are "physically addictive": many people report their incapacity to smoke a couple of cigarettes a day. However, it *also includes* goods which are not: some people are simply unable to eat one piece of chocolate and still go on with the diet, to play roulette in a controlled way, or even to fall in the temptation of an extramarital adventure only in exceptional occasions.[4]

[1] Naturally, it is not the unique. For example, Loewenstein (1996) argues that agents are often out of control due to 'visceral factors' such as emotions (anger, sadness, fear), drives (hunger, sex, curiosity) and other somatic influences (pain, sleepiness).

[2] One of the most striking examples of commitment is the case of an inveterate gambler who can (and sometimes do) sign a contract forcing casinos to forbid him the admission.

[3] See Parfit (1982) or Schelling (1984) for a discussion of this point.

[4] One might argue that this second type of activities are also subject to addiction, not physical but

Several theories provide partial explanations for this observation. For instance, one could argue that, in those activities, even moderation is harmful. However, this is not convincing given that some individuals who abstain openly state that moderate 'consumption', *if feasible*, would be desirable. An alternative explanation suggested often is that, although suboptimal, radical abstention serves as a focal point, rule of thumb or "bright line" more likely to be followed than the loosely defined concept of moderation. In Elster's (1989) words: *"The trick is to put oneself in a frame of mind in which one violation of the rule allows one to predict rule violations on all later occasions. [...] By setting up this domino effect, I raise the stakes"* [p.49].[5] This argument is intuitively very appealing, but it does not explain why it should be easier to commit to 'zero' rather than to 'one' (piece of chocolate) or to 'two' (cigarettes).[6] We agree that personal rules may provide a partial explanation and, as Schelling (1992) points out: *"Zero is specially attractive, [...] it may be easier to quit alcohol or tobacco with a zero resolution"* [p.175]. Still, they can hardly account for the whole problem. Last, one might simply state that moderation is not sustainable in the long run if the good is physically addictive (i.e. if past consumption raises the marginal utility of current consumption). This would imply that the addictive properties of a couple of cigarettes a day are sufficiently powerful so as to hook individuals. In our view, at low levels of consumption, physical addiction does not play a crucial role and that is why our theory will leave this issue aside. In any case, this argument would not explain abstention in activities such as gambling, adultery or small lapses during diets.

The present work takes a very different route. It shows that full abstention can be the result of a rational decision process even in situations where a strategy of moderate consumption strictly dominates abstention from the viewpoint of the agent at any date. This conclusion rests on three building blocks. First, we suppose that the

of another kind. We certainly think that it is the case (specially for gambling). However, as long as we do not have a robust theory of addiction, we should be reluctant to simply define as "addictive" the activities where the agent is unable to moderate his behavior. Otherwise, explaining no moderation becomes a tautology.

[5]Similarly, Ainslie (1992) argues that: *"Alcoholics find that they cannot engage in 'controlled drinking'... [and] can only hope never to be lured across the bright line between some drinking and no drinking"* [p.169]. Using another controversial but interesting example, he conjectures that *"[nations'] very history of failing to avert the escalation of wars, added to the new threat of nuclear destruction, may have deterred them from venturing beyond the bright line between some war and no war at all"* [p.169].

[6]In fact, for some individuals, a focal point that turns out to be quite successful is to smoke one cigarette after lunch and one after dinner, while having coffee.

agent has dynamically inconsistent preferences and cannot, at any date, commit to the decisions that will be taken in the future. Second, the agent has imperfect information about his personal net utility of consumption and partially learns this value anytime he consumes. And third, the information revealed under moderate consumption is substantially higher than under full abstention. Or, stated more formally, learning is a steeply increasing and concave function of the amount consumed.

The intuition for our result is as follows. As long as there is consumption, the agent learns extensively about the value of the delayed cost, i.e. to which extent the negative externality imposed by current consumption affects his future welfare. However, learning can be harmful to him because of his time inconsistent preferences. For instance, the agent may fall in a state of beliefs where he wishes high consumption at the present date and moderation afterwards but, due to his inability to commit, ends up overconsuming in every period. When the expected intertemporal payoff under continual excesses is smaller than under sustained abstention, the agent prefers not to consume. Moreover, the abstention strategy is the agent's only way to decrease learning radically, and therefore his only possible commitment strategy to avoid sinful temptations in the future. To sum up, we not only prove *convergence* to abstention but, more importantly, *persistence* whenever this state is reached as the agent's optimal self-commitment device. Naturally, excesses in every period is always another equilibrium strategy: if the agent anticipates that he will consume at every future date independently of his present behavior, then he has no incentives to abstain in the current period. Yet, we show that whenever abstention is sustainable, it yields a higher welfare than overconsumption from the perspective of the agent at every date. In a second step, we introduce the possibility of urges, defined as random positive shocks in the utility of current consumption. We show that there is a class of equilibria where, for some beliefs, the individual optimally stops consuming *unless* he has an urge. The idea is that, if craving is sufficiently important, consumption under an urge is ex ante rational. However, it reinitiates a learning process that, with some probability, will lead him to inefficiently overconsume indefinitely (i.e. to an ex post state of regret). This equilibrium is closely related to Ainslie's (1992) analysis on the relative performance of different rules of behavior. In his view, a personal rule is likely to be self-sustainable if it is objective and self-restrictive enough so that the agent is able to evaluate the benefits of sticking to the rule. At the same time, it has to be somewhat permissive so that it allows occasional departures that avoid strong frustrations. In our model, there exist for some beliefs two sustainable equilibria that differ only in that some urges are satiated in one and not in the other. We show that, in those cases, the equilibrium with unconditional abstention dominates the equilibrium with abstention conditional on no urge. In other words, the expected intertemporal utility at any point in time is greater when the agent is able to refrain from consuming under craving. Last, the paper suggests some policy implications and develops several other applications of this theory to issues related to psychology and economics such as self-perception and habit formation. We want to highlight that, in the whole paper, the rationale for abstention rests on the existence of a trade-off between optimal current consumption and inefficient learning through consumption. Naturally, this arises due to the dynamically inconsistency of preferences. Absent this individual impulsiveness, information would always be beneficial.

Several papers are related to ours. Caillaud, Cohen and Jullien (1996) and Carrillo and Mariotti (1997) offer partial solutions to the problem of self-control when current payoffs are overweighted while Orphanides and Zervos (1995) already note that abstention can be optimal in situations involving physical addiction.

The first work shows that moderation is sustainable over time if the individual can "self-restrain" his choices. More precisely if, for any given strategy, the agent can restrain the set of potential deviations to strategies that will be themselves followed (i.e. those for which he will not have a further incentive to deviate). Although interesting and very innovative, this approach has several peculiarities. First, the "self-restriction" solution departs from standard equilibrium concepts, and the authors do not provide compelling evidence on whether agents follow this reasoning in practice. Second, the mechanism only works in situations involving addiction, which limits its scope of applicability. Last, this theory advocates moderation whereas the situations we try to explain are mostly characterized by either abstention or excesses.

Carrillo and Mariotti (1997) analyze a situation where, as in the present work, the agent has incomplete information about the delayed cost of consumption. In their study, the agent can at any date acquire as much information as he wants. The paper shows that, even if this information acquisition is costless, the individual may prefer to act under self-restricted information. Ignorance mitigates the agent's impulsiveness and therefore enhances his intertemporal welfare. The analysis is compatible with Bayesian rationality and applies to situations with and without addiction. However, the model has also several special features. First, in many applications, this intra-period double decision of (costless and timeless) learning followed by consumption is unnatural; we feel that considering learning through consumption is more realistic (and at the same time easier to work with). Second, the agent faces a discrete choice. This might seem unimportant, but it implies that intertemporal decisions under no commitment are suboptimal only for a subset of beliefs. In our paper, for *any belief*, time inconsistency leads to excessive consumption (if any). Last, just as Caillaud et al. (1996), the paper by Carrillo and Mariotti (1997) does not treat the issue of urges and, more importantly, suggests that self-control problems are reduced precisely by moderating consumption.[7]

Orphanides and Zervos (1995) introduce incomplete information about the propensity for being addicted in Becker and Murphy's (1988) model of rational addiction (with standard exponential discounting). They consider a similar structure of learning through consumption as we do. The paper shows (among other things) that an agent who has the suspicion of having a high propensity for being addicted may prefer to quit radically by fear of learning it too late, i.e. when he is already trapped in over-consumption. As previously noted, we doubt that smoking moderately can lock people in a physical way.[8] In any case, their result can only be applied to drugs and other strongly addictive substances which, as should be clear by now, is not our primary concern.

2 Consumption with time inconsistent preferences

2.1 The basic model

The model has the following characteristics.

[7]In fact, in their basic binary model the agent has the choice only between consuming and not, so 'moderation' cannot be distinguished from 'abstention'. However, as they argue in Section 6.1, under a larger set of alternatives, an agent who stops learning will on average moderate his consumption (rather than fully abstain).

[8]According to the National Household Survey on Drug Abuse (NHSDA, 1995) the percentage of individuals reporting in 1995 past year and past month use of different substances are respectively: LSD: 1.0 and 0.3. Crack: 0.5 and 0.2. Cocaine: 1.7 and 0.7. Marijuana and Hashish: 8.4 and 4.7. Alcohol: 65.4 and 52.2. Cigarettes: 32.0 and 28.8. Note that the ratio between past month and past year consumption is the smallest in substances with strongest addictive power (LSD, crack, cocaine). This suggests that, even for drugs, physical addiction should not be viewed as the unique or most determinant factor to explain persistent consumption.

• Agent: We analyze the decision of a single agent to consume a free good that exerts a negative externality on his future welfare. We call self-t the incarnation of the agent at date t.

• Preferences: The agent exhibits *dynamically inconsistent preferences* in the sense of Strotz (1956). Basically, it implies that the period-to-period rate of discount falls monotonically, so events in the near future are overweighted relative to more distant ones.[9] Formally, we use the discount function introduced first by Phelps and Pollak (1968) where the τ-period discount rate ($\tau \geq 1$) is equal to $\beta\delta^{\tau}$ with $0 < \beta < 1$.[10] Note that $\beta = 1$ is the standard case of time consistent preferences. When $\beta < 1$, incarnations of the agent play a non-cooperative intra-personal game.[11] Naturally, as β becomes smaller, each self is less able to internalize the effects of his current decision on future welfare so the conflict between selves becomes more acute.

• Utility and externality: At period t, self-t decides the amount $x_t\,(\geq 0)$ of the good that he is going to consume. Consumption generates an *instantaneous* utility equal to $u(x_t)$. However, it also exerts a negative externality on future selves, i.e. it procures a *delayed* cost. More specifically, we suppose the following. First, with probability θ each future self bears an externality proportional to the amount consumed at date t. Second, health has a potential for self-regeneration: if the harm at date $t+1$ of x_t units of consumption at t is $c(x_t)$, then at date $t+1+\tau$ the harm is only of $\alpha^{\tau}\, c(x_t)$ with $\alpha \in [0,1]$.[12] For analytical tractability we restrict our attention to a specific class of functional forms.

Assumption 1 *The utility of consumption is in the CARA class of functions and the externality is linear, i.e.:* $u(x) = -\gamma\, e^{-ax} + b$ *and* $c(x) = x$.

Since we are not facing a problem of addiction, decisions at each period are *independent of past or future behavior*. As a result, for the purpose of this work, we can isolate the consumption decision of each incarnation.

[9] See e.g. Ainslie (1975, 1991), Thaler (1981), Prelec (1989), or Loewenstein and Prelec (1992) for a theoretical discussion and empirical support of this theory.

[10] This formulation has subsequently been used among others in Akerlof (1991), Laibson (1996, 1997a, 1997b), O'Donoghue and Rabin (1996), Caillaud et al. (1996) and Carrillo and Mariotti (1997).

[11] Elster (1986) provides a nice collection of papers dealing with multiple self theories of the individual. See also Thaler and Shefrin (1981) for a principal-agent modelling of the individual (planner-doer).

[12] Note that $\alpha = 0$ implies that the externality is exerted only the period after consumption and $\alpha = 1$ implies no self-regeneration.

• Net payoff of each consumption: Denote by $v(x_t;\theta)$ and $w(x_{t+\tau};\theta)$ the net present value of payoffs from self-t's perspective of consuming x_t units of good in the present period t and $x_{t+\tau}$ in period $t+\tau$ respectively, when the probability of exerting the externality is θ and not including the corresponding discount factor.[13]

$$v(x_t;\theta) = u(x_t) - \theta\,\beta\lambda\,x_t \tag{1}$$

$$w(x_{t+\tau};\theta) = u(x_{t+\tau}) - \theta\,\lambda\,x_{t+\tau} \quad \forall\, \tau \geq 1 \tag{2}$$

where $\lambda \equiv \frac{\delta}{1-\delta\alpha}$.

The key issue is that, because of the dynamically inconsistency of preferences, each self does not fully internalize the effect of his consumption decision on the welfare of future selves. In other words, the net payoff of consumption at the current date (given by equation (1)) is different from the discounted net payoff of consumption at a future date (equation (2)). As we show in the next section, this implies that optimal contingent plans from the perspective of self-t are no longer optimal when reconsidered one (or more) periods later.

• Intertemporal Continuation Utility (ICU): Denote by $V^t(\cdot)$ the net present value of payoffs from self-t's perspective and *gross of the externality due to past consumption.*

$$V^t(\{x_{t+\tau}\}_{\tau=0}^{\infty};\theta) = v(x_t;\theta) + \beta\sum_{\tau=1}^{\infty}\delta^{\tau}\,w(x_{t+\tau};\theta) \tag{3}$$

$$= \left[u(x_t) + \beta\sum_{\tau=1}^{\infty}\delta^{\tau}\,u(x_{t+\tau})\right] - \theta\,\beta\lambda\left[x_t + \sum_{\tau=1}^{\infty}\delta^{\tau}\,x_{t+\tau}\right] \tag{4}$$

• Intertemporal Net Utility (INU): Similarly, denote by $W^t(\cdot)$ the net present value of payoffs from self-t's perspective and *including the externality due to past consumption.*

$$W^t(\{x_i\}_{i=0}^{\infty};\theta) = V^t(\{x_i\}_{i=t}^{\infty};\theta) - \theta\left[1+\alpha\,\beta\lambda\right]\sum_{k=0}^{t-1}\alpha^{t-1-k}\,x_k \quad \forall\, t\geq 1 \tag{5}$$

Once again, note that for each self, the externality due to past consumption is just a sunk cost which therefore does not affect his consumption decision. Furthermore, self-0 does not carry over any past externality, so $V^0(\cdot) \equiv W^0(\cdot)$.

[13]It should be clear that $v(\cdot)$ *is not* self-t's utility (instantaneous or intertemporal) because it includes neither the negative effect of consumption by previous selves nor the discounted utility due to future consumption. By abuse of language we will from now on refer to θ as the probability of suffering the externality or simply as the externality itself.

2.2 Consumption under full commitment and no commitment

The purpose of this work is to analyze the agent's behavior when (i) there is incomplete information about the probability of bearing the externality θ and (ii) consumption is informative, i.e. it partially reveals the value of this parameter. However, as a benchmark, we first study the case where θ is fixed and known. We are also interested in the agent's decision when, at each period, *moderate consumption strictly dominates abstention.* In order to better focus on this case, let us introduce the following assumption.

Assumption 2 $\left.\dfrac{\partial v(x;\theta)}{\partial x}\right|_{x=0} > 0$ *and* $\left.\dfrac{\partial w(x;\theta)}{\partial x}\right|_{x=0} > 0 \quad \forall \theta, \beta$. *Given Assumption 1, and equations (1) and (2) this is ensured with the condition* $\gamma a > \lambda$.

Note that the net current payoff of abstention is $v(0;\theta) = b - \gamma$ which needs not to be positive. Our last piece of notation deals with the units of good consumed in equilibrium. Denote by $x^*(\theta)$ and $x^{**}(\theta)$ the optimal number of units that each self desires to consume in the current period and at future dates respectively.

$$x^*(\theta) = \arg\max_x v(x;\theta) \qquad \text{and} \qquad x^{**}(\theta) = \arg\max_x w(x;\theta) \tag{6}$$

Our first objective is to characterize the agent's optimal consumption path. Naturally, this will crucially depend on whether some incarnation has the ability to impose his desired future stream of actions to subsequent selves or not. As in Phelps and Pollak (1968) and most subsequent works, we are going to focus on Markov Perfect Equilibria.[14] We have.

Lemma 1 (i) *If θ is known and self-0 can commit to the level of consumption of all future selves, there is a unique equilibrium where consumption is characterized by:*

$$x_0 = x^*(\theta) \qquad \text{and} \qquad x_\tau = x^{**}(\theta) \quad \forall\, \tau \geq 1$$

(ii) *If θ is known and no self can commit to the level of consumption of future selves, there is a unique Markov Perfect Equilibrium where consumption is characterized by:*

$$x_t = x^*(\theta) \quad \forall\, t \geq 0$$

[14] We refer the reader to Maskin and Tirole (1996) for a thoughtful discussion of this equilibrium concept.

Proof: immediate given equations (1), (2), (3) and (6). □

Given (1) and (2), notice that $x^*(\theta) > x^{**}(\theta)$. That is, a dynamically inconsistent individual desires a high level of consumption in the current period and moderation thereafter. However, because of his inability to commit to a given consumption path, the agent ends up *overconsuming* from the perspective of every incarnation. This is graphically represented in Figure 1.[15]

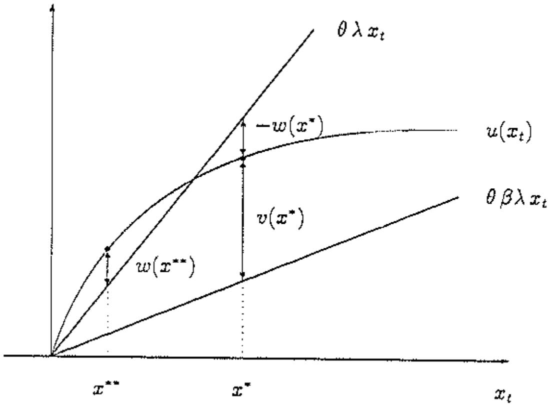

Figure 1

Last, denote by $\hat{V}(\theta)$ the ICU obtained in equilibrium by a given self when he can commit to the future levels of consumption. Similarly, $V(\theta)$ is the ICU from the perspective of any self when no one can commit to future consumption and V^{abst} is the ICU (or equivalently INU) of abstaining at every period.

$$\hat{V}(\theta) = v(x^*(\theta);\theta) + \beta \sum_{\tau=1}^{\infty} \delta^{\tau}\, w(x^{**}(\theta);\theta) \tag{7}$$

$$V(\theta) = v(x^*(\theta);\theta) + \beta \sum_{\tau=1}^{\infty} \delta^{\tau}\, w(x^*(\theta);\theta) \tag{8}$$

$$V^{abst} = v(0;\theta) + \beta \sum_{\tau=1}^{\infty} \delta^{\tau}\, w(0;\theta) \equiv \left(1 + \beta\frac{\delta}{1-\delta}\right) u(0) \tag{9}$$

[15]In the figure, it is assumed w.l.o.g. that $b = \gamma$ so that $u(0) = 0$.

Using (7), (8) and (9) it is possible to provide a full characterization of self-t's ICU under no commitment and full commitment.

Lemma 2 (*i*) $\hat{V}(\theta) > V(\theta) \quad \forall\, \theta,\, \beta,\, \delta.$

(*ii*) $\hat{V}'(\theta) < 0$ and $V'(\theta) < 0 \quad \forall\, \beta,\, \delta.$

(*iii*) $\hat{V}(\theta) > V^{\text{abst}} \quad \forall\, \theta,\, \beta,\, \delta.$

(*iv*) If $\delta > 1/2$, there exists $\underline{\beta}$, $\overline{\beta}$, $\bar{\gamma}$ and $\theta^*(\beta, \gamma)$ such that for all $\beta \in [\underline{\beta}, \overline{\beta}]$ and for all $\gamma \in [\lambda/a, \bar{\gamma}]$ then $V(\theta^*) = V^{\text{abst}}$, with $\theta^* \in (0, 1)$.

<u>Proof</u>: see Appendix A1. □

This result can be interpreted as follows. Given the conflict of interests between selves, each of them would be strictly better-off by being able to select the whole consumption path (part (*i*)). ICU under no commitment is negatively affected by an increase in the externality both because the net payoff of current consumption diminishes, i.e. $\frac{\partial v(x^*(\theta);\theta)}{\partial \theta} < 0$ and because future actions are "more suboptimal", i.e. $\frac{\partial w(x^*(\theta);\theta)}{\partial \theta} < 0$ (part (*ii*)).[16] By Assumption 2, moderate consumption strictly dominates abstention. Therefore, under commitment, the agent at *every period* consumes a positive amount of good and gets a strictly higher utility than if he abstains at some date (part (*iii*)).

The most interesting point, which is also the basis of this paper, is that under no commitment the ICU of a given self may be *strictly smaller* than the ICU of an individual who abstains at every period (part (*iv*) combined with (*ii*)). In other words, for some values of the time inconsistency parameter β, the positive effect of optimal current consumption ($v(x^*)$ in Figure 1) can be offset by the negative effect of over-consumption at every future date ($w(x^*)$ in Figure 1) if the externality θ is sufficiently important. Note that this occurs only for values of β strictly between 0 and 1. The idea is that when β decreases two countervailing forces are at work. On the one hand, each self internalizes less the welfare of previous selves. That is, the gap between the level of consumption chosen by the current self x^* and the level desired by the previous

[16] $v(x^*(\theta);\theta)$ and $w(x^{**}(\theta);\theta)$ decreasing in θ are just a consequence of the envelope theorem. By contrast, some specific conditions (naturally satisfied by the CARA class of utility functions and linear costs) are required on $u(\cdot)$ and $c(\cdot)$ to ensure that $w(x^*(\theta);\theta)$ is also decreasing in θ. The exact condition can be found in Appendix A1.

ones x^{**} increases, so decisions are more suboptimal from the perspective of previous incarnations. But, on the other hand, each self puts a lower weight on the future and therefore is less concerned about what may occur at those dates. In particular, as $\beta \to 0$, each self's ICU is only determined by his present consumption and therefore cannot be smaller than under abstention. Note also that, by the same reasoning, if $\delta < 1/2$ the future has a small value from the perspective of each self and once again the ICU depends mainly on current consumption. Last, as $\beta \to 1$ the self-control problem vanishes and abstention never dominates consumption.

Note that each self desires the same amount of consumption from next period on (i.e., under commitment at date t, $x_\tau = x^{**}\ \forall \tau > t$). This is the only particularity of our simple modelling of time inconsistency. In a more sophisticated version of hyperbolic discounting, the agent could be willing to revise not only his current consumption but also the consumption planned for the future. However, the qualitative results would remain unchanged: each incarnation's inability to internalize future welfare or, stated differently, the salience of immediate payoffs relative to distant ones inevitably leads to a systematic overconsumption.

3 Learning through consumption

In the previous section we have shown that, under no commitment, the agent's ICU is a decreasing function of the externality θ. Our objective is to investigate the potential incentives of the agent to refrain from consuming, even though moderate consumption strictly dominates abstention at every period and from the perspective of every self (Assumption 2). In order to analyze this issue, we assume that the agent cannot, at any date, impose his decisions to future incarnations. Besides, we focus on the interesting case where, if the true externality θ is sufficiently high, the agent's ICU is strictly smaller than under abstention. These assumptions are summarized below and will be maintained throughout the paper.

Assumption 3 *No self can commit to the actions that will be taken at future dates.*

Assumption 4 $\delta > 1/2$, $\gamma \in (\lambda/a, \bar{\gamma})$ *and* $\beta \in (\underline{\beta}, \overline{\beta})$ *so that there exists a value* $\theta^* \in (0, 1)$ *such that* $V(\theta^*) = V^{\text{abst}}$.

We now analyze the agent's consumption decision when there is incomplete information about the value of the externality and there is a possibility of learning through consumption.

3.1 The learning process

Suppose that, at date 0, the agent only knows the prior probability distribution π_0 where θ is drawn.[17] For simplicity, we will assume that θ has a full support continuous density $f(\theta)$, i.e. $f(\theta) > 0$ for all $\theta \in [0,1]$.

As a benchmark, consider the situation where consumption is uninformative. In this case, the individual behaves at every period according to the prior expected value of the externality $E_{\pi_0}[\theta]$. More specifically, following the argument developed in Lemma 1 part (ii), the agent's consumption x^* at every period is given by

$$x^*(E_{\pi_0}[\theta]) = \arg\max_x \; E_{\pi_0}[v(x;\theta)] \tag{10}$$

By contrast, when each period of consumption allows the agent to learn about the value of the externality, the optimal level of consumption is revised from period to period.

Learning is modelled in its simplest form. We suppose that the probability of exerting the externality is a random variable θ of unknown value. If there is consumption at date t, two events are possible. With fixed (but unknown) probability θ, the individual learns at the beginning of $t+1$ that consumption at t had indeed a negative impact on his future welfare. We denote this event by $z_t = 1$. Conversely, with probability $1-\theta$ the agent learns that consumption did not affect his future welfare. We denote it by $z_t = 0$. After each observation $z_t \in \{0,1\}$, the distribution π_t of the externality is revised in a Bayesian way. In particular, we have: $E_{\pi_t}[\theta|z_t = 0] < E_{\pi_t}[\theta] < E_{\pi_t}[\theta|z_t = 1]$. For expositional ease we suppose the following:

(i) If at some date the agent does not consume, he exerts no externality on future welfare. As a result, there is no learning about θ either (and hence, no updating).

(ii) The accuracy of information about the externality (captured by z_t) is the same for any (strictly positive) level of consumption.

[17] Naturally, the analysis below would be the same if we rather assumed imperfect information on the benefit of consumption.

(iii) There is perfect correlation between the externalities imposed by each consumption. Formally, it means that consumption x_t at date t exerts with probability θ an externality on *all* future selves (equal to $\alpha^{\tau-(t+1)}x_t$ for all $\tau \geq t+1$) and with probability $1-\theta$ *no* externality at all.[18]

Remark.

The assumptions stated in parts (i) and (ii) may seem unrealistic for several reasons. First, if exogenous information may randomly arise independently of the agent's behavior, some learning (and updating) will take place even under abstention. Second, if each unit consumed marginally affects welfare (say, with probability θ), then the informational content of an observation $z_t(x_t)$ is an increasing function of the amount consumed. Last, the learning gap between no consumption and some consumption only makes sense in a discrete consumption framework. However, including these considerations in our setting *would not affect our results.* In fact, the basic property that matters for our theory is that learning at each period is a non decreasing and sufficiently concave function of the amount consumed. Or, stated differently, that abstention decreases substantially the individual's capacity to learn about the externality. Imposing no learning under abstention (part (i)) and fixed learning for any positive consumption (part (ii)) is simply the easiest way of capturing this property.[19]

We can now turn to analyze the agent's decision problem.

3.2 Agent's consumption/abstention strategy

If the probability distribution of θ at date t is π_t and self-t decides not to abstain, we know that the number of units consumed will be given by

$$x^*(E_{\pi_t}[\theta]) = \arg\max_x E_{\pi_t}[v(x;\theta)] \tag{11}$$

The question we raise is the following: given that consumption automatically implies learning about the externality, is it always in the interest of the agent to consume independently of π or can he decide at some point to abstain? Our first result is not surprising.

[18] This implies in particular that the whole effect of each consumption is learned after a one period lag. Recall however that this does not influence next period's decision since, at that point, the externality has become a sunk cost.

[19] As we will see later on, each incarnation will face a trade-off between costly learning and optimal consumption. Therefore, when we loosely speak of "concavity" in the informational content of an observation, it is always relative to the concavity of the utility function $u(\cdot)$.

Proposition 1 *There always exists an MPE where the agent consumes at every period.*

Proof: see Appendix A2. □

If self-t anticipates that all future incarnations (self-$t+1$, self-$t+2$, and so on) are going to consume independently of his present behavior, then consuming in the current period has two net benefits. First, there is the net expected payoff of optimal present consumption $E\left[v(x^*(E[\theta]);\theta)\right]$ which, by Assumption 2, is positive. Second, future incarnations will inherit a more accurate information about the externality (due to the observation of z_t). Each self benefits from this increase in the quality of future information. The reason is that, even if future expected consumption is "excessive" from the current perspective, this consumption gap is fixed. So, if an information z_t about θ improves the decision at $t+1$ for self-$t+1$, this extra piece of news is also beneficial from the perspective of previous selves. These two considerations do not depend on the posterior probability distribution π so the same reasoning holds for selves $t-1$, $t-2$, etc. As a result, the agent consuming in every period is an equilibrium. Note that, because of the agent's time inconsistency, this systematic overconsumption may be undesirable compared to total abstention if the true value of the externality θ is greater than θ^* (see Lemma 2 part (iv)).

However, this is not the unique equilibrium of the game. In order to compare other possible equilibria with the one already described, it is useful to introduce the following definition.

Definition 1 *Suppose there exist two MPEs denoted M_1 and M_2. We say that M_1 Pareto dominates M_2 with respect to INU if and only if*

$$E_{\pi_t}[W^t|M_1] \geq E_{\pi_t}[W^t|M_2] \quad \forall t,\ \pi_t$$

with at least one strict inequality.

Recall that, from the definition of INU in Section 2.1, $W^t(\cdot)$ corresponds to the intertemporal *welfare* from self-t's perspective. The next proposition characterizes the other type of equilibria that may emerge in this game.

Proposition 2 (i) *(Existence) There exists a family of MPEs, each of them being characterized by a set of posterior distributions of θ such that the agent abstains from consuming.*

(ii) (Pareto dominance) Each of these MPEs Pareto dominates with respect to INU the MPE with consumption in every period described in Proposition 1.

Proof: see Appendix A3. □

In order to better understand the intuition behind this result, suppose that one single consumption informs the agent *perfectly* about the value of the externality. If self-0 consumes, all future selves will know θ and, according to Lemma 1 part (*ii*), they will also consume. The expected benefit in this case, denoted $E_{\pi_0}[\tilde{V}(\theta)]$, is bounded above by $E_{\pi_0}[V(\theta)]$ (which is the expected ICU if not only future but also the current consumption decision $x^*(\theta)$ is taken knowing the true θ).[20] By abstaining at every period, the agent's payoff is V^{abst}. If $E_{\pi_0}[\theta] > \theta^*$ and $\text{Var}_{\pi_0}[\theta]$ is "sufficiently small" then, given Assumption 4, self-0's net payoff of consuming is smaller than if all selves abstain. As a result, he is better-off by abstaining *provided that future selves stick to the same strategy.* Naturally, self-1 prefers a fortiori to abstain since his reasoning is the same with respect to self-2, and so on. This argument easily extends to the case where each consumption reveals partial information and also to equilibria where the agent first consumes during a number of periods and then abstains forever. Note that $E_{\pi_t}[\theta] > \theta^*$ is a *necessary* condition for the agent to prefer abstention from date t on. Otherwise, his expected ICU under consumption, even if it is not fully efficient, at least it strictly dominates the ICU under abstention. However, this condition *is not sufficient*; if at this point the variance is sufficiently large, the agent may still want to consume in every period, because he realizes that with high probability the true externality lies well below θ^*. Note also that abstention is valuable only insofar as it is followed by every future incarnation: no self is willing to abstain if, for the same beliefs, his immediate successor is going to reinitiate consumption. Therefore, there is a problem of coordination in the region of posterior beliefs where abstention takes place. This immediately gives rise to multiple equilibria.

The Pareto dominance property is also intuitive. If the agent (optimally) refrains from consuming after date t, the INU of every self between 0 and $t-1$ increases since future abstention avoids inefficient overconsumption from their perspective (recall that if $E_{\pi_t}[\theta] > \theta^*$ then, necessarily, $E_{\pi_t}[w(x^*(\theta), \theta)] < 0$). Moreover, by definition, any self.

[20] Formally, $E_{\pi_0}[V(\theta)] = E_{\pi_0}\left[v(x^*(\theta);\theta) + \beta\sum_{\tau=1}^{\infty} w(x^*(\theta);\theta)\right]$

$$\geq E_{\pi_0}\left[v(x^*(E_{\pi_0}[\theta]);\theta) + \beta\sum_{\tau=1}^{\infty} w(x^*(\theta);\theta)\right] = E_{\pi_0}[\tilde{V}(\theta)].$$

after date t sticks to abstention only if consumption reinitiates a learning process that leads to an expected ICU smaller than under abstention. Therefore, the very existence of an equilibrium with abstention implies that it dominates also from the perspective of all the selves who abstain a strategy of consumption, otherwise they would deviate.[21] From Definition 1, note that our criterion of Pareto dominance is very strong since it applies for *every incarnation* of the agent and for *any path* of the learning process. Furthermore, we analyze dominance with respect to INU, i.e. including the externality due to past consumption. This result also holds if we consider Pareto dominance with respect to ICU (see the previous footnote).

To sum up, Proposition 2 provides a rationale for abstention in situations where positive but moderate consumption would always be a superior strategy. We show that inefficient overconsumption due to time inconsistency can only be avoided if all incarnations are able to coordinate on a different pre-specified strategy. However, we do not *impose* the 'complete abstention' strategy arguing that this rule acts better than any other as a focal point (as Ainslie (1992), Elster (1989) and Schelling (1992) implicitly do and which may be partially true but still seems rather ad hoc). Instead, we claim that when a given self decides to abstain, learning about the externality ceases, and no future self has an interest in reinitiating it. Hence, abstention endogenously becomes a basin of attraction due to its learning properties. This explains both *convergence to* and *persistence of* no consumption.

Remarks:

• We want to insist in the fact that Proposition 2 holds even if there is some learning under abstention. As explained above, our result relies on the trade-off between net utility of current consumption and potential inefficiency of future consumption caused by learning. As a result, insofar as consumption substantially increases the amount of information revealed, "abstention in every period" can (and will) be a sustainable and Pareto superior strategy.

• By contrast, it is easy to see that we do need concavity of the learning curve to sustain abstention. Imagine a good such that there is no learning when the amount consumed is $x \leq \underline{x}$ where $\underline{x} \in (0; x^{**}(1))$. In that case, abstention will never occur in equilibrium since it is always strictly dominated by $\underline{x}$ units consumed at each period.

[21] After date $t+1$, every self has a second benefit of coordinating in an equilibrium with abstention: they avoid *inheriting* the externality due to each consumption after t. Note that this is the only benefit that affects their INU and not their ICU.

• Obviously, the type of strategies described in Proposition 2 cannot be labelled as being "optimal": by construction, moderate consumption at every period would enhance the agent's welfare from the perspective of every self. Still, and contrary to moderation, the second best solutions proposed here are dynamically sustainable.

• This equilibrium predicts that individuals who decide to abstain will minimize the chances of being exposed to new information about the externality. In particular, they will try to avoid both the people and the situations where this consumption is likely to play an important role, a behavior commonly seen in practice. (For instance, inveterate gamblers do not go out for dinner to a casino and former smokers avoid smoking areas).

• A related point is that two populations starting with the same prior but having different realizations of the incomplete information parameter in the first periods may end up with a very different pattern of behavior (abstention and excesses). Moreover, given that abstainers want to minimize their exposition to new information, two sub-cultures may develop in parallel only as a consequence of slight differences in the initial conditions.

• Suppose that the externality can be decomposed in two components: a (known) common factor and a random, idiosyncratic factor that can be revised and updated through personal consumption. When the relative importance of the common effect in determining the absolute magnitude of the externality is large, the idiosyncratic factor plays little role. In this case, abstention will be either rarely a sustainable strategy (if the common effect is small so that the absolute externality is very likely to be also small) or possible from the outset (if the common effect is big). By contrast, when the relative importance of the idiosyncratic factor is big, the agent may at some point abstain. However, it will take him a large number of periods before doing it (until the variance of the posterior about this factor is "sufficiently small").

• A related remark is that, ceteris paribus, in this theory "old agents" are more likely to abstain than young ones: on average, their updated value of the externality is more precise. However, we do not want to stress this conclusion because, in our view, several other considerations not included in this analysis (such as inertia or "switching cost" increasing with age, expected lifetime horizon decreasing with age, etc) will greatly influence their decision.

4 Urges and the control of craving

Individuals commonly state that, on specific occasions, an irresistible "force" persuades them to deviate from the strategy of no consumption. Those stimuli may be of two different natures: internal impulses (e.g. craving when the agent is addicted to a good) or external factors (e.g. an invitation to a party when the agent is on a diet). The first type of stimuli is more problematic because it entails a greater difficulty in evaluating *objectively* whether an urge was really present. Stated differently, under internal impulses, the agent is tempted to cheat on himself and *subjectively* evaluate every occasion as a special circumstance so that immediate gratifications are always satiated. Naturally, this leads to an endless process of inefficient deviations from the optimal strategy. More interestingly, even under objective assessment of urges, casual observation suggests that if an agent sticking to a strict no consumption strategy allows himself some degree of freedom (by making the rule more flexible), he is inclined to restart a process of inefficient overconsumption. This is particularly the case with addictive goods. For instance, several people impute their failure to stop smoking to the illusion of being able both to smoke only in social events and to control craving. It is also common wisdom that the most powerful recommendation of 'Anonymous Alcoholics' is never to fall in the temptation of having "just this drink". Still, it also applies to other problems of self-control like in the case of a former gambler who decides to play cards because he is having dinner in a casino, or a dieter who does not forgo Thanksgiving meal because of its sentimental value.

In this section, we explore within our framework a particular effect of urges on the behavior of agents. We model urges in the simplest form: at each period and with (exogenous) probability p the agent receives a positive shock on the benefit derived by current consumption. Formally, the instantaneous utility under craving becomes: $u^c(x) = b - \gamma e^{-a'x}$ with $a' > a$.[22] Besides, we rule out any intra-personal problem of information transmission and assume that each incarnation knows perfectly whether

[22]This modelling is far from capturing all the aspects of craving. For example, in our view, the probability of a new urge is increasing in the number of past urges that have been satiated. Moreover, the instantaneous utility under abstention is smaller in periods of urges than in normal circumstances. Last, one would think that under craving the agent consumes more ($x^*(\theta;a')$ greater than $x^*(\theta;a)$) whereas in our model consumption can go both ways. These considerations could easily be included but they do not constitute the main purpose of the present analysis, so we prefer to leave them aside and focus simply on the property $u^c(x) > u(x)\ \forall\, x > 0$.

past selves acted under an urge or not. Denote by $V^c(\theta)$ the analogue of the function $V(\theta)$ to the case of consumption with possibility of urges. As in Section 3, we focus on the interesting situation where abstention may dominate inefficient overconsumption. To this purpose we introduce the analogue of Assumption 4.

Assumption 5 *a' and p are such that for given values of β, δ and γ, there exists a value $\theta^{**} \in (0,1)$ such that $V^c(\theta^{**}) = V^{\mathbf{abst}}$.*

Given our new setting, the following proposition is immediate.

Proposition 3 *(i) There exists a family of MPEs, each of them being characterized by a set of posterior distributions of θ such that the agent abstains conditionally on not having an urge.*

(ii) There also exists a family of MPEs, each of them being characterized by a set of posterior distributions of θ such that the agent unconditionally abstains.

Proof: see Appendix A4. □

This result is not surprising and, in some sense, it is a consequence of the way we have modelled craving. Urges being identifiable, we have been able to focus on the informational aspect of consumption. Part (*i*) shows that consumption in periods of urges can be rational even though, as the previous examples suggest, it may drive the agent to an endless state of overconsumption. The idea is simple. By consuming when an urge flows in, the agent reinitiates the learning process about the externality. This might be ex ante desirable if craving is sufficiently important and the chances that the individual abstains in the near future (or realizes that consumption is in fact harmless) are relatively high. However, with some probability, it will be ex post inefficient: once learning is restarted, inefficient consumption may take place for a long period (or even indefinitely). Those cases are characterized by an ex post state of regret. Naturally, the presence of urges makes more difficult for the agent to succeed in abstaining. Nevertheless, as it is shown in part (*ii*), commitment to unconditional abstention (i.e. even under urges) is still possible for some states of beliefs.

More interestingly, the strategy described in part (*i*) has the flavor of a *personal rule* of the type 'abstention only if beliefs about the negative externality are above a given value and there is no urge'. This rule is, on the one hand, rigid and objective enough to avoid the temptation of *subjectively* relabelling each opportunity as a "special occasion" (it depends solely on the state of beliefs). On the other hand, it is also sufficiently flexible so as to serve short run interests in truly special circumstances (such as urges) and therefore avoid strong frustrations. We can notice that this equilibrium is in fact closely related to Ainslie's (1992, ch.5) informal discussion on the types of personal rules that are more likely to be self-sustainable and, at the same time, succeed in mitigating (at least partially) self-control problems. In his words:

> *"A person who tries to indulge [his vices] in a controlled way according to rules for prudence often will find loopholes that will lead him beyond prudence into behavior for which he will be caught and blamed"* [p.170].

But at the same time:

> *"If a person sticks to a rigid schedule, he cannot take advantage of big opportunities offered by the environment if they also represent any kind of small lapse"* [p.177].[23]

Ainslie insists in the problem (not considered here) motivated by contingencies that are ex post profitable but ex ante unforeseen. In those instances, deviating from the rule is optimal but it opens the door to a subjective downward revision of which future unforeseen contingencies will be considered as profitable. Still, the existence of different types of equilibria (where objective and predictable urges may and may not be satiated) raises an interesting question: is it true, as Ainslie claims, that lenient rules (i.e. those which are somewhat permissive) outperform the rigid ones? Our formal framework allows us to provide an answer.

Proposition 4 (*i*) *For some beliefs, there does not exist any MPE characterized by unconditional abstention while there exist MPEs characterized by either consumption or abstention conditional on not having an urge.*

(*ii*) *However, suppose that M_a and M_b are two MPEs that differ only in that, for some beliefs, some urges are satiated in M_a but not in M_b. Then, M_b Pareto dominates M_a with respect to INU.*

[23] Similarly, Schelling (1992) states that *"rules seem to work better if they are unambiguous"* but also *"self-imposed rules have to deal with exceptions, like the glass of champagne at somebody's wedding"* [p.175]. See also Ainslie (1987) for a discussion of different kinds of personal rules employed in practice by individuals.

Proof: see Appendix A5. □

Part (i) simply states that if the instantaneous utility under craving is very important, no equilibrium where urges are deterred will exist. In this case, complete abstention is not a credible alternative. So, as Ainslie proposes, the best the agent can do is to abstain as long as his desires for current consumption are mild and hope not to suffer from an urge that inevitably reinitiates consumption (and learning).

However, this is not to say that flexibility is always preferable. Indeed, part (ii) shows that an inflexible rule, *whenever sustainable*, yields always a greater welfare for the individual than a more permissive one. The intuition for this result is similar to the Pareto dominance property stated in Proposition 2. An equilibrium where urges are not satisfied exists only if, even under craving, a deviation from the situation advocating abstention leads on average to an ICU smaller than if no current or future incarnation ever consumes. Therefore, whenever both equilibria coexist, deterring urges must necessarily be a dominant strategy.

5 Information and social intervention

The main lesson derived from Propositions 1 and 2 is that, in activities subject to self-control problems, uncertainty may improve the welfare of individuals. This can have powerful policy implications. For instance, it has long been argued that the efficiency of an institution is related to its capacity to provide *objective* and *stable* criteria for the evaluation of actions taken by citizens. This paper proposes a new approach to the value of information. It goes against the previous argument and states that, in some cases, a government may have incentives to design institutions that deliberately keep agents uninformed (or more exactly uncertain) about the costs and benefits of their actions. To better understand the implications of our theory, we focus on one particular example where, according to our model, the standard efficiency arguments in defense of a given institution may in fact be counter-beneficial for the welfare of individuals.[24]

The debate between the relative advantages of common law and statute law has captured a great deal of attention of scholars in Law and Economics. In this comparison, a law is *assumed* to be more efficient if it contains a clearly defined system

[24]We thank Isabelle Brocas for suggesting this example.

of rewards and penalties for each possible action. Let us cite two examples. In his well-known book, Posner (1977) claims that the common law is far more efficient than the statute law because, among other things, judges render their decisions based on more objective criteria. Similarly, Heiner (1986) argues that *stare decisis* (reasoning by analogy with past decisions) has become a primary mode of decision in common law. Among the reasons for this choice is the idea that "people's desire for security and stability may lead them to prefer legal precedent over other, less predictable means of resolving disputes" [p229]. Note that, in order to prove efficiency, the authors simply try to show why a particular law results in less subjective judgements. Clearly, objectivity has the advantage of being more difficult to manipulate. However, suppose that (i) offenses are subject to self-control problems (the "benefit" is immediate while the cost, if any, is delayed) and (ii) by engaging repeatedly in those activities agents learn about their cost. Then, our model suggests that an institution which remains deliberately vague about the penalties imposed in case of conviction may help in the self-commitment of individuals to abstain from undertaking such actions.

We do not want to push our argument too far because we are aware that many other factors influence the efficiency of a law. Still, people tend to believe that information is always desirable and that governments should design policies that keep citizens as informed as possible about the payoffs of every activity. This presumption needs not to be always true, and problems of self-control are surely not the unique reason for it.[25]

6 Other applications

The theory developed in Section 3 may partially account for some puzzles in social psychology and economics. The purpose of this section is to propose other interpretations of our model.

6.1 Learning about personal preferences

Most individuals have at some point experienced the temptation of undertaking one of the so-called "immoral" activities such as, adultery, compulsive lying, cheating on exams, etc. The common characteristic in this type of actions is an instantaneous

[25]Rabin (1995) has an interesting analysis of an agent who acts subject to a moral rule. He finds that making more information available may harm the moral conduct of agents. By contrast, making available information unavoidable improves their conduct.

state of pleasure followed by a sustained period of regret, shame or even self-deception. The main reason commonly argued for not succumbing is the intrinsic moral cost of those acts (possibly combined with the social and/or legal sanctions). In our view, this explanation is certainly valid but does not account for all the aspects of the problem. Given that individuals are unable to evaluate accurately their personal net utility derived by these actions, there is another complementary reason for not surrendering that follows the lines of the model previously presented.

Imagine an agent willing to have a love affair under the current special circumstances and given his evaluation of how a one-shot deviation from loyalty may affect his stable sentimental relation. This person is also aware that, if adultery becomes the norm rather than the exception, in the long run it will ruin his stable relationship almost with certainty. Under dynamically inconsistent preferences, the agent may be afraid of learning that the pleasure of an adventure is large enough so that he will inevitably fall in adultery at every occasion (special or not) but still low enough so that unconditional loyalty is preferable from an intertemporal viewpoint. In this case, the agent might decide to abstain from any sexual adventure and keep incomplete information about the pleasure of infidelity. Note that loyalty is a sustainable strategy only if there is incomplete information and learning through "acting" as in the consumption model previously analyzed.[26]

There are several other cases where imperfect self-knowledge is related to a fear of learning something that could lead to inefficient repeated actions. For example, some individuals are reluctant to learn the pleasure of risk exposure (both in hazardous sports or in trivial activities such as stealing gadgets from a department store). Others, deliberately ignore the value of holidays because it entails the risk of losing the previous hard working attitude. Last, some individuals keep a distant attitude to avoid close personal relations that, at some point, may imply suffering.

[26]Naturally, there are several specificities about the problem of infidelity that are not considered. For example, given that the stable relationship is shared with someone, adultery has definitely an uncertain payoff (probability of being caught, reaction of the partner, etc). However, the cost can also be manipulated (e.g. by lying).

6.2 Habit formation

Closely related to the previous point, is the well known issue in Industrial Organization of habit formation.[27] Consider a consumer who has the choice between a standard quality and a luxury good. Suppose that he has imperfect knowledge about his valuation of the quality upgrade and that each consumption partially reveals this information. For example, an individual who is used to fly in economy class, to drive a compact car or to use wire-link communications does not know the value he attaches to fly in business class, to drive a luxury car or to use mobile communications. Under time inconsistent preferences, the agent may not want to try the luxury good, even if there is an option value of enjoying it substantially. The reason is that if the consumer likes the luxury good only moderately, he will be trapped in an inefficient behavior from an intertemporal perspective: each self will consume high quality and sacrifice future wealth.

Naturally, this consideration also affects the optimal behavior of the firm offering such products, which now internalizes the possibility of "getting the consumer hooked" to high quality. For example, according to this theory, an airline company should find more profitable to offer business class upgrades rather than free economy tickets as frequent flyer awards. Similarly, introductory pricing and free test before purchase should be relatively more frequent for goods where the agent learns rapidly his taste for quality (flying first class) than for goods where learning is more gradual (driving a luxury vehicle).

6.3 Self-perception and willpower

Individuals have imperfect knowledge about some of the personal characteristics that affect their behavior. For example, agents typically do not know accurately how strong they are in resisting different sorts of temptations. If we are willing to accept this hypothesis, it is clear that each action is self-informative in the sense that it allows the agent to update the beliefs about his own personality. The logic of our model can be applied to this situation and provide some interesting insights.

Consider for example the issue of willpower. In special occasions, a person might be willing to stay up late at night at the cost of feeling miserable the next morning.

[27] We thank Jean Tirole for suggesting this application and the corresponding examples.

Still, that agent may decide to go to bed early only because of the fear that a negative signal about his willpower can drive him to the conclusion that in every future occasion (important or not) he will inevitably surrender to the temptation of staying awake. Once again, this is directly related to the following observation made by Ainslie (1992): *"The will is created by the perception of impulse-related choices as precedents for similar choices in the future. This perception generates the same pattern of incentives that operate in a repeated prisoner's-dilemma game"* [p.161]. Hence, the focal attitude of never giving up is suboptimal from the current self's perspective but, at least, it proves superior to the opposite potential state of succumbing indefinitely and regretting most of the time. Naturally, the same reasoning applies to other personal rules frequently employed by individuals such as never being late for an appointment, staying a minimum number of hours in the office, or never watching TV after dinner.

As it should be clear by now, in this application there is incomplete information about the agent's willpower rather than the externality level. Therefore, every action is informative about the agent's weakness of will (it will be revised upwards if the agent falls in the temptation and downwards if he does not) so the analysis conducted in Section 3 does not fit perfectly to this case. Still, for some beliefs, "every gain on the wrong side undoes the effect of many conquests on the right". In those cases, it will definitely be desirable to avoid some temptations only because of their potential signalling value about the will.

Last, note that actions may inform agents about several other traits of their personality besides willpower.[28] We do not pretend that the fear of (inefficiently) learning about some personal characteristics affects crucially all the agents' actions. Still, our theory may partially explain the apparently irrational tendency to self-justification as well as the pervasive bias in the agents' self-evaluation or self-esteem.

7 Conclusion

The purpose of this paper has been to explore why individuals do not moderate the consumption of goods subject to self-control problems. We have studied the consumption strategy of a dynamically inconsistent agent who has incomplete information about his

[28] This claim is at the core of the well-known "Self-perception theory" in social psychology. We refer the reader to Bem (1972) for a comprehensive survey of this theory and to Aronson (1995, ch.5) for a criticism of it, as well as a brief overview of subsequent related trends in dissonance theory.

net payoff of each unit consumed, and who updates this value after each consumption. We have shown that, even if moderate consumption always dominates abstention, the agent may (optimally) decide not to consume at any period. The reason is simple. Under time inconsistent preferences, moderation is not possible: each self either abstains or consumes an excessive amount (from the perspective of other selves). In some cases, abstention is preferable to overconsumption, but only as long as all selves stick to the same behavior. Given that under abstention there is no learning about the value of consuming, if some self prefers to abstain provided that future selves abstain, those future selves also choose a fortiori not to consume. So, radical abstention is a sustainable strategy. We have also analyzed the effect of urges in shaping the behavior of the agent. Last, we have discussed some policy implications and suggested other applications of this theory in particular to issues such as self-knowledge, willpower or habit formation.

Before concluding, we would like to insist in some questions for future research that have been raised throughout the paper. First, urges are modelled in an extremely stylized way. In our view, the type of urges that are more pervasive and, at the same time, more difficult to deal with are internal impulses. It would be interesting to study how and why craving acts in the motivational state of the individual so that he subjectively reevaluates the costs and benefits of consumption (on this point, see Loewenstein, 1996). Second, the value of ignorance (in the form of not acquiring free information) has extensively been recognized in economics (see e.g. Crémer, 1995). It is therefore not surprising that an individual with internally conflicting interests may also find desirable to keep imperfect knowledge about himself. Issues related to self-esteem, or more generally to self-perception, could and should be analyzed under this light. Last, it should be possible to determine empirically which goods are more likely to be subject to habit formation. This in turn would provide compelling evidence on whether time inconsistency is a determinant factor in the agents' decision making.

Appendix

Before proceeding to the formal proofs, let us introduce some notations. We call

- $\sigma_t \in \{0, 1\}$: self-t's current consumption decision, where 0 means "abstention" and 1 means "consumption".
- $z_t \in \{0, 1\}$: observation of the random variable θ at date t (of course *conditional on* $\sigma_t = 1$), where 0 means "no effect of consumption on future welfare" and 1 means "negative effect of consumption on future welfare".
- $s_t = \sum_{i=0}^{t-1} \sigma_i$: number of periods in which the agent has consumed before date t.
- $k_t = \sum_{i=0}^{t-1} z_i$: number of periods in which the agent has consumed before date t and consumption affected welfare negatively (naturally, $s_t - k_t$ is the number of periods in which consumption did not affect welfare).
- π_{s_t}: probability distribution of θ when the agent has consumed s_t times.
- π_{s_t,k_t}: probability distribution of θ when the agent has consumed s_t times being negatively affected k_t times.

Last, we will use indifferently $E_{\pi_{s_t+1}}[\theta]$ and $E_{\pi_{s_t}}[\theta|z_t]$ to denote the expectation of θ at date $t+1$ given that self-t has consumed.

A1. Proof of Lemma 2

First of all note that, given our specific functional form, (6) can be rewritten as

$$u'(x^*) = \theta\,\beta\lambda \;\Rightarrow\; x^*(\theta) = \frac{1}{a}\ln\left(\frac{\gamma\, a}{\theta\,\beta\lambda}\right) \tag{1'}$$

(i) is obvious given Lemma 1. The first part of (ii) is simply a consequence of the envelope theorem and the fact that

$$\frac{\partial v(x^*(\theta);\theta)}{\partial\theta} = -\beta\lambda\, x^*(\theta) \quad \text{and} \quad \frac{\partial w(x^{**}(\theta);\theta)}{\partial\theta} = -\lambda\, x^{**}(\theta)$$

In the general formulation with $u(x)$ and $c(x)$, $V'(\theta)$ is

$$\begin{aligned} V'(\theta) &= \frac{\partial v(x^*(\theta);\theta)}{\partial\theta} + \beta\sum_{\tau=1}^{+\infty}\delta^\tau\left[\frac{\partial w(x^*(\theta);\theta)}{\partial\theta} + \frac{\partial w(x^*(\theta);\theta)}{\partial x^*}\frac{\partial x^*(\theta)}{\partial\theta}\right] \\ &= -\beta\lambda\frac{1}{1-\delta}\left[c(x^*(\theta)) + \delta\,\theta(1-\beta)\,c'(x^*(\theta))\frac{\partial x^*(\theta)}{\partial\theta}\right] \end{aligned}$$

For CARA utilities and linear costs, it becomes

$$V'(\theta) = -\frac{1}{1-\delta}\frac{\beta\lambda}{a}\left[\ln\left(\frac{\gamma\, a}{\theta\,\beta\lambda}\right) - \delta(1-\beta)\right] \tag{2'}$$

It is easy to see that if $\gamma\, a > \lambda$ then $V'(\theta) < 0$. Part (*iii*) is just a direct consequence of Assumption 2.

Last, call $f(\beta, n) = V(1;\beta, n) - V^{\text{abst}}(\beta, n)$ where $n = \gamma\, a/\lambda$. Since $V(\theta;\beta,n)$ is decreasing in θ for all β and n (> 1), in order to prove part (*iv*) it is sufficient to show that if $\beta \in [\underline{\beta}, \overline{\beta}]$ and $n \in [1, \bar{n}]$ then $f(\beta, n) < 0$. We have

$$\begin{aligned} f(\beta, n) &= \left(1+\beta\frac{\delta}{1-\delta}\right)\left[b - \frac{\beta\gamma}{n}\right] - \beta\lambda\frac{1}{1-\delta}\left[\frac{\ln\left(\frac{n}{\beta}\right)}{a}\right] - \left(1+\beta\frac{\delta}{1-\delta}\right)(b-\gamma) \\ &= \frac{\gamma}{1-\delta}\left[(1-\delta(1-\beta))\left[1-\frac{\beta}{n}\right] - \frac{\beta}{n}\ln\left(\frac{n}{\beta}\right)\right] \end{aligned} \tag{3'}$$

$$\frac{\partial f(\beta,n)}{\partial\beta} \propto \delta\left(1-\frac{\beta}{n}\right) - \frac{1}{n}\left[\ln\left(\frac{n}{\beta}\right) - \delta(1-\beta)\right] \tag{4'}$$

$$\frac{\partial f(\beta,n)}{\partial n} \propto \ln\left(\frac{n}{\beta}\right) - \delta(1-\beta) \tag{5'}$$

$$\frac{\partial^2 f(\beta,n)}{\partial\beta^2} \propto \frac{1}{\beta} - 2\delta \tag{6'}$$

(*a*) $\lim_{\beta\to 0} f(\beta, n) > 0$.

(*b*) From (5′), we can check that $\dfrac{\partial f(\beta,n)}{\partial n} > 0$ for all $n > 1$. Moreover, $f(1,1) = 0$ so $f(1,n) > 0$ for all $n > 1$.

(*c*) From (6′), $\dfrac{\partial^2 f(\beta,n)}{\partial\beta^2} > 0 \;\Leftrightarrow\; 2\beta\delta < 1$. Hence, if $\delta < 1/2$ then $f(\beta,n)$ is convex in β in the whole interval. Similarly, if $\delta > 1/2$ then $f(\beta, n)$ is first convex and then concave.

(*d*) $\left.\dfrac{\partial f(1,n)}{\partial n}\right|_{n=1} = 0$.

Combining all these results we have:

• If $\delta < 1/2$, $f(\beta,n)$ is convex in β. By (*a*), (*b*) and (*d*), $f(\beta, n) > 0$ for all β and $n > 1$.

• If $\delta > 1/2$ then, given (*c*) and (*d*), there is one value β^* such that if $\beta \in (\beta^*, 1)$, then $f(\beta,1) < 0$ and if $\beta \in [0, \beta^*)$ then $f(\beta, 1) > 0$.

Last, by (*b*), if n increases, the interval $[\underline{\beta}, \overline{\beta}]$ in which $f(\beta,n) < 0$ (where $\underline{\beta} > \beta^*$ and $\overline{\beta} < 1$) shrinks and for n sufficiently high it vanishes. □

A2. Proof of Proposition 1

Denote by $V_t^{**}(\cdot)$ and $V_t^{*}(\cdot)$ self-t's ICU if he currently consumes and abstains respectively, anticipating that from next period on, every self is going to consume.

$$E_{\pi_{s_t}}\left[V_t^{**}(\theta)\right] = E_{\pi_{s_t}}\left[v(x^*(E_{\pi_{s_t}}[\theta]),\theta) + \beta \sum_{\tau=1}^{+\infty} \delta^\tau w(x^*(E_{\pi_{s_t+\tau}}[\theta]),\theta)\right] \qquad (7')$$

$$E_{\pi_{s_t}}\left[V_t^{*}(\theta)\right] = E_{\pi_{s_t}}\left[0 + \beta \sum_{\tau=1}^{+\infty} \delta^\tau w(x^*(E_{\pi_{s_t+\tau-1}}[\theta]),\theta)\right] \qquad (8')$$

By Assumption 2, $E_{\pi_{s_t}}\left[v(x^*(E_{\pi_{s_t}}[\theta]),\theta)\right] > 0$. In order to prove the proposition, it is therefore sufficient to show that

$$E_{\pi_{s_t}}\left[w(x^*(E_{\pi_{s_t+\tau}}[\theta]),\theta) - w(x^*(E_{\pi_{s_t+\tau-1}}[\theta]),\theta)\right] > 0 \qquad \forall \tau \geq 1$$

We proceed in two steps.

Step 1. $E_{\pi_{s_t}}\left[v(x^*(E_{\pi_{s_t+1}}[\theta]),\theta) - v(x^*(E_{\pi_{s_t}}[\theta]),\theta)\right] > 0$.
By the law of iterated expectations, then for $y \in \{s_t, s_t+1\}$:

$$E_{\pi_{s_t}}\left[v(x^*(E_{\pi_y}[\theta]),\theta)\right] = E\left[E_{\pi_{s_t}}\left[v(x^*(E_{\pi_y}[\theta]),\theta) \;\middle|\; z_t\right]\right]$$

Given that $E_{\pi_{s_t+1}}[\theta] = E_{\pi_{s_t}}[\theta|z_t]$ and $x^*(E_{\pi_{s_t+1}}[\theta]) = \arg\max_x E_{\pi_{s_t}}[v(x,\theta)\,|\,z_t]$, then

$$E_{\pi_{s_t}}\left[v(x^*(E_{\pi_{s_t}}[\theta\,|\,z_t=0]),\theta) \;\middle|\; z_t = 0\right] > E_{\pi_{s_t}}\left[v(x^*(E_{\pi_{s_t}}[\theta]),\theta) \;\middle|\; z_t = 0\right]$$

Naturally, the same reasoning holds for $z_t = 1$ which proves Step 1.

Step 2. $E_{\pi_{s_t}}\left[w(x^*(E_{\pi_{s_t+1}}[\theta]),\theta) - w(x^*(E_{\pi_{s_t}}[\theta]),\theta)\right] > 0$.
From (1′), we have that in our specific formulation:

$$v(x^*(E[\theta]),\theta) = b - E[\theta]\frac{\beta\lambda}{a} - \theta\frac{\beta\lambda}{a}\ln\left(\frac{\gamma a}{E[\theta]\,\beta\lambda}\right)$$

$$w(x^*(E[\theta]),\theta) = b - E[\theta]\frac{\beta\lambda}{a} - \theta\frac{\lambda}{a}\ln\left(\frac{\gamma a}{E[\theta]\,\beta\lambda}\right)$$

So, in our particular case, Step 1 proves that

$$E_{\pi_{s_t}}\left[\theta\,\ln\left(E_{\pi_{s_t}}[\theta\,|\,z]\right)\right] > E_{\pi_{s_t}}\left[\theta\,\ln\left(E_{\pi_{s_t}}[\theta]\right)\right]$$

which is the same condition needed to prove Step 2. The proof is completed by noting that the same argument applies to all $\tau > 1$. □

A3. Proof of Proposition 2

Given that θ is the only payoff relevant variable, a pure Markov strategy for self-t σ_t is contingent only on the information relevant for the distribution of θ, namely s_t the number of past periods of consumption, and k_t the number of observations $z_\tau = 1$ $(0 \leq \tau \leq t-1)$ given $\sigma_\tau = 1$.

(i) Consider the following strategy for self-t:

$$\sigma_t = \begin{cases} 0 & \text{if } s_t = T \text{ and } k_t = K \\ 1 & \text{otherwise} \end{cases}$$

According to this strategy, selves 0 to $T-1$ and also all future selves if $k_T \neq K$ consume with probability 1. Using the previous proof, it is easy to show that these selves have no interest in deviating.

Now, assume that $k_T = K$. If self-T conforms to the prescribed strategy and abstains, his ICU is V^{abst}. If he deviates, consumption will be reinitiated so his ICU is

$$V_{\pi_{T,K}} = E_{\pi_{T,K}}\left[v(x^*(E_{\pi_{T,K}}[\theta]),\theta) + \beta \sum_{\tau=1}^{+\infty} \delta^\tau\, w(x^*(E_{\pi_{T+\tau}}[\theta]),\theta)\right] \tag{9'}$$

Note that $V_{\pi_{T,K}} < E_{\pi_{T,K}}[V(\theta)]$. Hence, for K and T such that $E_{\pi_{T,K}}[V(\theta)] < V(\theta^*)$ then $V_{\pi_{T,K}} < V^{\text{abst}}$. From equation (2′), we have $V''(\theta) > 0$ so, by Jensen's inequality, $E[V(\theta)] > V(E[\theta])$. As a result, $E_{\pi_{T,K}}[\theta] > \theta^*$ is a necessary but not sufficient condition for abstention being sustainable. More specifically, the smaller the variance $\text{Var}_{\pi_{T,K}}[\theta]$, the more likely (T,K) forms a sustainable equilibrium with no consumption.

Naturally, if T abstains, no future self reinitiates consumption. This proves only the existence of a particular class of MPEs. Obviously, other types of MPEs may follow different patterns.

(ii) Trivial. Given the absence of learning under no consumption, any strategy specifying that self-t abstains for a pair (T,K) implies also abstention for selves $t+1$, $t+2$, etc. By construction of the equilibrium with abstention, $E_{\pi_{T,K}}[W^t] < W_t^{\text{abst}}$ where W_t^{abst} denotes self-t's INU when every self after t abstains. Moreover, $E_{\pi_{T,K}}[W^{t+\tau+1}] < E_{\pi_{T,K}}[W^{t+\tau}]$ since each self inherits the negative externality due to past consumption. Last, when $E_{\pi_{T,K}}[\theta] > \theta^*$ we have $E_{\pi_{T,K}}[w(x^*(\theta),\theta)] < 0$ so every self between 0 and $t-1$ also benefit from future abstention. □

A4. Proof of Proposition 3

Call $\phi_t \in \{0,1\}$ the realization of the event "no urge at date t" ($\phi_t = 0$) which occurs with probability $1-p$ and "urge at date t" ($\phi_t = 1$) which occurs with probability p. Naturally, a Markov strategy for self-t σ_t is now contingent on s_t, k_t and ϕ_t.

(i) The construction of the proof is similar to the previous one. Call $v^c(\cdot)$ and $w^c(\cdot)$ the analogue of $v(\cdot)$ and $w(\cdot)$ when there is an urge at the period considered. Take the following strategy for self-t:

$$\sigma'_t = \begin{cases} 0 & \text{if } s_t = T,\ k_t = K \text{ and } \phi_t = 0 \\ 1 & \text{otherwise} \end{cases}$$

Again, consumption takes place for selves 0 to $T-1$ and for future selves when $k_T \neq K$ or, when for some $m \geq 0$, $k_{T+m} = K$ and $\phi_{T+m} = 1$.

Suppose that $k_T = K$ and $\phi_T = 0$. If self-T conforms to the prescribed strategy and abstains (knowing that consumption will be reinitiated after the first urge), his ICU is

$$V^{0,\text{abst}}_{\pi_{T,K}} = \left[1 + \beta\frac{\delta(1-p)}{1-\delta(1-p)}\right] u(0) + \beta\frac{\delta p}{1-\delta(1-p)} E_{\pi_{T,K}}\Big[w^c(x^*(E_{\pi_{T,K}}[\theta]),\theta) + \sum_{\tau=2}^{+\infty}\delta^{\tau-1}\left(p\, w^c(x^*(E_{\pi_{T+\tau-1}}[\theta]),\theta) + (1-p)\, w(x^*(E_{\pi_{T+\tau-1}}[\theta]),\theta)\right)\Big] \tag{10'}$$

If he deviates, consumption is automatically reinitiated and his ICU is

$$V^{0,\text{cons}}_{\pi_{T,K}} = E_{\pi_{T,K}}\Big[v(x^*(E_{\pi_{T,K}}[\theta]),\theta) + \beta\sum_{\tau=1}^{+\infty}\delta^{\tau}\left(p\, w^c(x^*(E_{\pi_{T+\tau}}[\theta]),\theta) + (1-p)\, w(x^*(E_{\pi_{T+\tau}}[\theta]),\theta)\right)\Big] \tag{11'}$$

Suppose now that $k_T = K$ and $\phi_T = 1$. If the agent consumes, his ICU is

$$V^{1,\text{cons}}_{\pi_{T,K}} = E_{\pi_{T,K}}\Big[v^c(x^*(E_{\pi_{T,K}}[\theta]),\theta) + \beta\sum_{\tau=1}^{+\infty}\delta^{\tau}\left(p\, w^c(x^*(E_{\pi_{T+\tau}}[\theta]),\theta) + (1-p)\, w(x^*(E_{\pi_{T+\tau}}[\theta]),\theta)\right)\Big] \tag{12'}$$

If he deviates and abstains, then consumption is reinitiated only after the first urge, i.e.: $V^{1,\text{abst}}_{\pi_{T,K}} = V^{0,\text{abst}}_{\pi_{T,K}}$.

Note that $\lim_{p\to 0} V^{0,\text{abst}}_{\pi_{T,K}} = V^{\text{abst}}$. Given Assumption 5 and following the same reasoning as in the previous proof, if $\text{Var}_{\pi_{T,K}}[\theta] \to 0$ there exists a posterior distribution of θ such that

$$V^{0,\text{cons}}_{\pi_{T,K}} < V^{0,\text{abst}}_{\pi_{T,K}} = V^{1,\text{abst}}_{\pi_{T,K}} < V^{1,\text{cons}}_{\pi_{T,K}} \tag{13'}$$

in which case σ_t' is an equilibrium strategy.

This is not the most interesting equilibrium since after the first urge during abstention the agent is "trapped" in overconsumption forever. However, using a recursive argument it is easy to show the sustainability of equilibria where at *several consecutive periods* the agent abstains unless there is an urge.

(ii) Given that $V_{\pi_{T,K}}^{0,\text{cons}} < V_{\pi_{T,K}}^{1,\text{cons}}$, if we further have

$$V_{\pi_{T,K}}^{1,\text{cons}} < V^{\text{abst}} \tag{14'}$$

then the strategy

$$\sigma_t'' = \begin{cases} 0 & \text{if } s_t = T,\ k_t = K \text{ and } \phi_t \in \{0,1\} \\ 1 & \text{otherwise} \end{cases}$$

is also an equilibrium of this game. □

A5. Proof of Proposition 4

(i) Trivial. Note that $v^c(x^*(E[\theta]),\theta) > v(x^*(E[\theta]),\theta)$. So for some pairs (T,K), $V_{\pi_{T,K}}^{0,\text{cons}} < V^{\text{abst}} < V_{\pi_{T,K}}^{1,\text{cons}}$ and the proof follows.

(ii) The reasoning is very similar to part (ii) of Appendix A3. Consider two MPEs M_1 and M_2 identical except that when $s_t = T$, $k_t = K$ and $\phi_t = 1$, then $\sigma_{t,M_1} = 1$ whereas $\sigma_{t,M_2} = 0$. Call $\tilde{V}_{\pi_{T,K}}^1$ self-T's ICU in this case when he plays the equilibrium M_1. The condition for M_2 being also an equilibrium is that $\tilde{V}_{\pi_{T,K}}^1 < V^{\text{abst}}$. Hence, self-$T$'s INU is greater under M_2. As previously, by construction, every self before and after T also prefer the equilibrium M_2.

□

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