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Linda Hirt-Schierbaum and Maryna Ivets[1]

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Abstract

In this paper we develop a theoretical model concerning self-control, motivation and commitment. The model, based on Gul and Pesendorfer (2001), studies a two-period decision problem of an agent who faces a given menu and might experience temptation in the second period. In this case, the agent is tempted by a choice that is, from an ex ante normative point of view, inferior and has to exercise self-control to resist temptation. A random, time-variant degree of motivation is introduced to influence his cost of self-control. We introduce an investment-payoff combination as a commitment device that can help the agent pre-commit to his normative choice before he faces temptation. Depending on how accurately the agents predict their future self-control costs we distinguish between sophisticated and (partially) naive agents. The theoretical results show that our mechanism can help agents to commit successfully, and also can explain why certain agents with a preference for commitment might fail – behavior that is usually attributed to a preference reversal. This commitment failure is associated with underestimation of future self-control costs.

JEL-Code: D01, D11, D84

Keywords: Self-Control; temptation model; motivation; heuristic bias; naiveté; sophistication; commitment device; health behavior

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*1 Linda Hirt-Schierbaum, RGS Econ and TU Dortmund; Maryna Ivets, RGS Econ, CINCH, and UDE .**– We thank Wolfgang Leininger for support, helpful comments and discussions. Special thanks go to Friederike Blönnigen, Markus Fels and Dominik Maxara for extensive discussion and helpful comments. We thank Daniel Avdic, Marcel Düllmann and Eliane Lambertz for comments on an earlier draft. We also would like to thank the participants at various seminars and conferences for their constructive comments and suggestions. All remaining errors are ours. Financial support by the RGS Econ and German Ministry of Education (BMBF grant number 01 EH1602A) and the RAG Stiftung is gratefully acknowledged.**- All correspondence to: Linda Hirt-Schierbaum, TU Dortmund, Germany, e-mail: linda.hirt@tu-dortmund.de*

1 Introduction

In order to find working strategies or incentivize certain healthy behaviors, it is fundamental to understand what exactly is driving such behaviors. Poor, unhealthy diets and lack of exercise are common examples of a much larger class of problems: *self-control problems*. Sooner or later, almost everyone is confronted with choices that enforce the use of self-control. Students must study for good grades, overweight people should lose weight to improve health, and everyone generally should adopt healthy diets and exercise to improve health and longevity. The core challenge that unites these issues is that reaching a desired goal might be gratifying but getting there is costly.

Research in psychology suggests that self-control issues are closely related to a lack of (extrinsic) motivation. When a task is not performed for its own sake but one performs a task in order to reach a certain goal (e.g. exercise to lose weight), self-control has to be exerted in order to reach this goal (e.g. Ryan and Deci, 2000).

The saying "the spirit is willing but the flesh is weak"[1] describes perfectly why people fail when facing self-control problems. For the most part, people know what the rationally optimal choice is; they are just too weak to make it. It also describes how people are torn between two forces. These forces can be best described by desire (the flesh) and reason (the spirit). Neurologists have even shown that these two opposing forces might be caused by different parts of the brain working against each other (Braver *et al.*, 1995).

In a preferences over menus approach Gul and Pesendorfer (2001) (henceforth GP) introduce a model of self-control (SC) that covers these findings. Their so-called *temptation preferences* represent what agents are tempted by (desire), and *commitment preferences* represent what agents know is best for them (the rational part of the self). They find that agents reveal a preference for commitment when they exclude the tempting item from a menu before they choose from that menu.

We adapt GP's basic model such that an agent faces a *given* menu and his *perceived* cost of SC depends on his (random) motivation, which leads to stochastic SC costs. Additionally, we allow agents to experience heuristic bias when predicting their (future) degree of motivation – and thus their perceived SC costs. This bias can be either positive or negative (e.g. *under- or overestimating* (future) SC costs, respectively). Finally, we cover the fact that agents might have a preference for commitment as they know they might succumb to temptation when facing it[2] and, therefore, offer an alternative commitment mechanism in order to enable agents' commitment to their normative intentions.

[1] Which goes back to *Matthew Ch.26:41, King James Bible.*

[2] Evidence on the demand for commitment has been observed in the field and found in several lab-experiments as well. An overview of commitment devices and the demand for them can be found in Bryan *et al.* (2010).

Working from GP we introduce a two-period decision problem. Here, in period one (*before* facing temptation) an agent anticipates the period two choice and chooses a period one investment which will yield a payoff that is paid at the end of period two in case of successful commitment. In the beginning of period two the agent chooses a lottery (consumption) depending on his motivation, the given investment and his discounted expected payoff.

This adaptation of GP's model can be interpreted in various ways. For example, an agent might buy sporting gear and feel pressured to exercise because he invested money. The exercise will pay off with a changed physique and endorphins rushing through the body, making the agent feel good. The investment could also be interpreted as a wager or could be a real wager, in case when the agent bets on himself. If he reaches his pre-specified extrinsically motivated goal, he receives a payoff (at the end of period two).

This is exactly the idea behind Lusher (2016), Pact (2017), WayBetter (2017) and Woerner (2018). While Lusher (2016) introduces self-betting as a commitment device to raise students' GPAs, Woerner (2018) applies it to increase gym attendance. The other two give players an incentive to make health-improving choices, not only in the short term but also in the long run.[3]

The remainder of the paper is organized as follows. Section 2 gives a brief overview of related literature and discusses the contribution of this paper. Section 3 introduces GP's basic model, where Subsections 3.1 and 3.2 introduce our notion of motivation (constant and random, respectively) into their model and compare it to the basic version. Section 4 introduces our model, starting with the most basic version with a constant degree of motivation. Subsection 4.2 extends the basic version and introduces a changing degree of motivation as a random variable. Section 5 discusses policy relevance and application possibilities in different areas, and Section 6 concludes.

2 Placement in Existing Literature

In this section we provide a broad overview of the related literature and discuss our contribution.

2.1 Self-Control and Commitment in Economic Theory

SC is generally defined as an ability to manage one's impulses, emotions, and behaviors to achieve long-term goals. Thus, SC problems arise whenever an agent is tempted by a choice that, from a normative ex ante perspective, would be considered inferior and the agent might in hindsight consider it regrettable if he acts on his impulse and succumbs to temptation.

[3]For example. WayBetter introduced *DietBet* in 2011, where players bet on the percentage of body-weight they lose in a certain amount of time. In the follow-up empirical application paper we use data from *DietBet* to test the conclusions of our theoretical model. For more information see Hirt-Schierbaum and Ivets (2020).

SC issues are inevitably connected with a demand for commitment. Whenever agents are sophisticated enough to realize they have a SC problem and are potentially not strong enough to resist temptation, they have an incentive to commit to their normatively-preferred choice *before* they face temptation. By using the notion of *commitment devices* in the text we follow Bryan *et al.* (2010) and refer to *self-commitment devices*, i.e. agents use such devices to alter their *own* behavior by making certain choices more expensive (economically or psychologically using hard- or soft-commitments, respectively) and do not have any strategic purpose with respect to others.

SC problems are usually seen as a symptom of preference reversals or time inconsistency.[4] *(Quasi-) hyperbolic discounting* (Strotz, 1955; Phelps and Pollak, 1968; Laibson, 1997; O'Donoghue and Rabin, 1999)[5] is the workhorse model that is widely used in neoclassical economic theory to explain these behavioral inconsistencies, e.g. with respect to weight loss, exercising, saving and procrastination when studying, etc. (see e.g. O'Donoghue and Rabin, 1999; Ikeda *et al.*, 2010; Ruhm, 2012; Lusher, 2016; Woerner, 2018, to name a few).

Models of motivation often use hyperbolic discounting and mostly cover principal-agent models and repeated games (e.g. Falk *et al.*, 1999; Benabou and Tirole, 2003). However, neither of these models captures an individual's internal struggle between what he knows would be the best rational choice and what he wants, what is tempting him. Moreover, neither of these models includes the development of motivation over time. Additionally, although the use of (quasi-) hyperbolic discounting is very popular in SC literature, the model has some shortcomings and has been previously criticized (e.g. Mulligan, 1996; Fernandez-Villaverde and Mukherji, 2002; Rubinstein, 2003; Andersen *et al.*, 2014; Janssens *et al.*, 2017).

Benabou and Tirole (2003) assume a positive short-term and a negative long-term effect of extrinsic incentives. However, it has been shown that the impact of incentives varies among motivation types. For example, monetary incentives can increase extrinsic motivation and decrease intrinsic[6] motivation since there is a shift from inherent satisfaction to being satisfied by the extrinsic reward (Deci, 1971). Since self-control problems do not arise when people are intrinsically motivated, we assume that agents are extrinsically motivated. Therefore, we don't have to worry about a negative effect of extrinsic incentives here.

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[4]In a model with present bias an agent changes his preferences inconsistently between two different time points. For instance, an agent might decide to commit to his optimal and rationally-preferred choice today (e.g. to exercise and eat healthy), come tomorrow, the agent might change his mind and not follow through with his commitment. Therefore, an extensive body of literature is dedicated to various commitment devices that can help people reconcile this present bias.

[5]Which goes back to the psychological research on animal and human behavior by Ainslie (1992).

[6]A task is considered intrinsically motivated when it is performed for its own sake, not to reach a certain target (e.g. exercise for the fun of it, not to lose weight or gain muscle).

Relatively recently, GP were the ones to formulate an alternative choice-theoretic model covering temptation and SC. They define temptation in terms of a preference for commitment. More specifically, GP model an agent whose decisions depend on two preferences: his so-called commitment and temptation preferences. Additionally, an agent's decisions are highly dependent on his SC costs. GP's model is formalized as a two-staged preferences over menus approach. In a 'temptation-neutral' first stage, the agent chooses a menu of lotteries which he will face in the second period. In period two, the agent chooses a lottery from the previously chosen menu. GP claim that an agent with commitment preferences chooses a menu that from his ex ante perspective is less tempting to reduce the future SC costs (this can be interpreted as a self- commitment strategy). A menu is perceived as tempting if an element from the menu tempts the agent. Here, GP assume that only the most tempting item of a menu tempts the agent. For example, if we take a literal *menu* {No Dessert, Fruit, Ice Cream} and consider an agent who is on a diet, *No dessert* would be the normatively-preferred choice, but he is tempted by the *Ice Cream*. He might end up eating *Fruit*, as the best compromise between the two. In that case he has to exert SC in order to forgo the *Ice Cream*. According to GP an agent with commitment preferences would prefer to exclude *Ice Cream* from the menu before he faces the menu.[7] In that case he would only face the menu {No Dessert, Fruit} and would not have to face the same SC costs as before.

Contrary to the hyperbolic discounting, GP's approach is consistent with revealed preferences and offers the possibility of costly SC by making the disutility a function of the choice set. GP are the first to formulate a model like this. It has been widely discussed and various adaptations have been proposed since (e.g. Noor, 2007; Dekel *et al.*, 2009; Chatterjee and Krishna, 2009; Stovall, 2010; Noor and Takeoka, 2010, 2015). Furthermore, Gul and Pesendorfer (2004) introduce a dynamic infinite horizon version of the model which has been adapted by Epstein *et al.* (2008) and Noor (2011).

What all of these papers have in common is the underlying assumption that an agent has preferences over menus and can *choose a menu* in one period and then makes choices from the chosen menu in another period. This is a useful starting point for a choice-theoretic model that covers SC problems in this fashion. However, we claim that this assumption is problematic. Although in some situations it might be possible for an agent to deliberately choose a menu according to his preferences, in most situations he has to face a *given* menu.

There are many applications where the choice of a less tempting menu as a commitment strategy is not possible. One example is the application discussed in Hirt-Schierbaum and Ivets (2020) – dieting. For instance, an agent can decide to only buy healthy food in the supermarket or to throw away all of the junk

[7] For example, by throwing away the ice cream he has at home, or going to a restaurant where ice cream is not on the dessert menu.

food he has at home to prevent poor eating choices. However, buying healthy food is itself a choice from a much larger menu, namely the supermarket stock. He can hardly choose a supermarket that only sells healthy food (even in organic supermarkets unhealthy foods like chocolate, ice-cream, wine and crisps are available). Additionally, the agent still has to walk through the streets and could be tempted to buy sweets or ice cream, or stop at a fast food restaurant. In these situations he faces a *given* menu which might include highly-tempting alternatives. Hence, he has to face a much larger cost of SC than in situations where he can simply choose a less tempting menu. In this case the agent might have a preference for commitment as he knows his SC is not strong enough to resist temptation, but he cannot necessarily choose the least tempting menu. Then the agent might want to give himself other incentives to behave the way he prefers normatively, i.e. he utilizes another commitment mechanism.

The availability of various commitment devices in the market (e.g. SEED - *Save, Earn, Enjoy Deposits* (Ashraf *et al.*, 2006); CARES - *Commitment Action to Reduce and End Smoking* (Giné *et al.*, 2010); SMT - *Save More Tomorrow* (Thaler and Benartzi, 2004), WayBetter, Pact and `StickK.com`) and the high demand for them indicate that there is a need for external commitment devices that is not covered by the GP approach.

Examples of such devices are the much discussed *carrots* and *sticks*. Carrots are pre-defined rewards that are disbursed after an agent succeeded to reach a pre-defined target. Sticks are pre-defined penalties that are executed after an agent failed to reach a pre-defined target.

A *commitment contract*, similar to a stick, punishes failure. The crucial difference is that agents put their own money on the line in case they do not reach a pre-specified target. Agents have to pay their share before they take action and are reimbursed if they succeed to reach their goal. However, evidence shows that these contracts often only increase desired behavior to a small margin and have low take up rates (Giné *et al.*, 2010).

Alternatively, a *self-bet* mechanism has been suggested as a commitment device. It combines the elements of both, a carrot and a stick. In a self-bet an agent places a wager on his future normatively-preferred behavior. If he commits and follows through with his intentions, he receives a payoff (e.g. a share of the total pot in parimutuel betting) or, in case of failure, he forfeits the wager (similar to a commitment contract).

Lusher (2016) and Woerner (2018) test self-bet mechanisms as commitment devices in experimental settings and find promising results. Both studies look at parimutuel bets where winners share the total amount wagered. In case of Lusher (2016), the bets are not matched and applied in the context of education; while Woerner (2018) looks at matched[8] bets with respect to gym attendance.[9] Hirt-Schierbaum and Ivets (2020) add to this literature by analyzing

[8]In a matched bet a social planner matches players on their ability levels, so everyone has the same chance of winning.

[9]A study by Burger and Lynham (2010) examines self-bets in a not parimutuel set up and uses data from UK bookmaker William Hill from 1993 to 2006 to analyze a real-world weight-

data from DietBet, an online weight-loss program that offers parimutuel self-betting, with respect to hypotheses that are drawn from the theoretical results of this paper.

2.2 Heuristic Bias

Some previous empirical studies have documented surprising facts about human behavior that cannot be easily reconciled with standard neoclassical economic theory. For example, Oster *et al.* (2013) document that very few individuals who are at risk of developing Huntington disease – a hereditary neurodegenerative disorder – get tested, given low testing costs and the predictive power of the test; and that untested individuals behave in a overly optimistic way.[10] The paper highlights the importance of accounting for uncertain individuals' subjective perceptions and beliefs in their decision-making and suggests that theoretical approaches need to accommodate for this in order to better explain the observed empirical results.

Della Vigna and Malmendier (2006) in their seminal paper look at the context where people are prone to experience SC problems – exercising – and document that individuals tend to overpay for their gym memberships given their attendance, and would be better off by paying per visit. This observed consumer behavior is difficult to reconcile with standard preference and beliefs, and they suggest that people overestimate their future SC or future efficiency. Therefore, a theoretical framework that incorporates this overoptimism might be more appropriate than the standard model of rational consumer to explain such behavior.

There is also an ample cognitive research literature on the less rational side of decision-making. For example, people often overestimate their abilities, positive traits and attributes, and the degree to which they control outcomes. The more controllable these outcomes are through their future actions, the greater the overestimation (see, e.g. Alloy and Abramson, 1979; Taylor and Brown, 1988; Metcalfe, 1998).

To the best of our knowledge, this is the first study that introduces self-perception heuristic bias[11] into the SC framework that allows agents to have biased beliefs about their own SC abilities – with implications for their commitment success. More specifically, in the current study we introduce a novel theoretical framework that allows for these cognitive biases in human judgement. This framework can shed light on documented behaviors that sometimes can

loss betting market. The results show that only 20% of bettors won their bets. However the sample size is rather small (51 observations) and therefore provides only limited insight into the mechanism.

[10]Similar behavior is also observed for HIV testing and various cancer screening.

[11]Heuristic biases are cognitive biases that stem from relying on judgemental heuristics. They can lead to errors in beliefs, predictions and estimations of subjective probabilities of uncertain events.

be considered irrational.[12] In the following we rely on the general idea about human judgement under uncertainty discussed in the seminal work of Tversky and Kahneman (1974) and introduce a heuristic bias into our model – specifically, the bias in agents' self-perception of their own SC abilities.

Various heuristic biases are well-documented in the mind science research. The idea is that normal psychological processes can lead to systematic errors in judging one's own abilities. This can influence subsequent behaviors in a manner inconsistent with a rational individual's behavior.[13] We achieve this by allowing agents' to have beliefs about their motivation and by introducing uncertainty in our decision-theoretic model via a stochastic random shock to agents' motivation that influences their future SC costs. This allows us to distinguish between different agents' types based on their self-awareness. As a result, the helpfulness of the suggested commitment mechanism depends on *how accurately* the agents predict their motivation and this shock and, by extension, their (future) SC costs.

2.3 Our Contribution

In this study we introduce a model that is based on the underlying idea of GP, but offers an alternative cost-efficient commitment strategy which has proven to be effective in experimental settings. We assume the menu an agent faces to be *given* and introduce an investment-payoff combination that allows an agent to commit to a normatively-preferred choice before facing temptation.

Moreover, we introduce a notion of motivation that influences agents' SC costs, and we incorporate the uncertainty by allowing the degree of motivation to change and, thus, also influence agents' future SC costs. Based on *how accurately* the agents predict their (future) SC costs, we introduce a heuristic bias into the model and define different agent types. Additionally, we analyze possible problems arising with self-commitment with regard to this bias. This provides an alternative explanation for behavior that is usually understood as a preference reversal and also for potential failure of commitment.

It is well-known that people can experience preference reversals if a decision's consequences are far in the future compared to immediate consequences

[12]Standard economic theory usually assumes that people have unlimited mental and cognitive capacity in their decision-making, however in reality many decisions are made using simple heuristics: decision-making shortcuts, automated thinking or mental rule of thumb. Most of the time these mental shortcuts allow us to make decisions quickly and accurately, however, they can also lead to systematic errors in judgment.

[13]In the current context we focus on the heuristic bias that is applied to the perception of one's *own* abilities. However, more generally, it could refer to many other areas, e.g. self-assessment of one's abilities or attributes relative to other people (e.g. believing that you are healthier relative to a reference group); estimating accuracy or precision of one's knowledge or information (e.g. be overly certain that your perceived health is your true health); estimating probabilities of various outcomes (e.g. probability of having a certain disease) or likelihoods of uncertain events (e.g. underestimation of time needed to find a new job by unemployed; predicting own longevity); and perception of others (e.g. racial bias).

(e.g. Thaler, 1981; Benzion *et al.*, 1989; Ainslie and Haslam, 1992). However, we can also observe people changing behavior from one day to another or even within hours or minutes. This might not necessarily be based on a reversal of the underlying preferences, but in certain situations something else – here the degree of motivation might have changed.

Our model offers an alternative explanation for observed consumer behavior where hyperbolic discounting fails.[14] Also, contrary to assumptions in hyperbolic discounting, we allow motivation to change in both directions, whereas in the standard $\beta - \delta -$model the possibility that an agent will act more rationally tomorrow than he did today is usually excluded.

3 Gul and Pesendorfer (2001) - Model and Adaptations

As we are adapting GP, we will first give a brief introduction to their model. Next, we will introduce the notion of motivation into their model and analyze the implications this has on the agent's choice.

GP model an agent with SC problems and analyze a two-period decision problem. In the first period the agent chooses a set of lotteries which constitutes feasible choices in period two. In the second period the agent chooses consumption, i.e. a single lottery. GP operate on a compact metric space (Z, d), where Z is the set of all prizes and Δ is the set of all measures on the Borel σ-algebra of Z, endowed with the weak topology; d is the metric on Z. $\mathcal{A}$ is the set of compact subsets of Δ and the preference relation $\succsim$ is a subset of $\mathcal{A} \times \mathcal{A}$. GP base their model on standard axioms of utility theory (Preference Relation, Strong Continuity and Independence) extended by their fundamental axiom, *Set Betweenness* (SB).

GP assume that agents can be tempted by irrelevant alternatives and temptation is utility decreasing. Furthermore, they assume that only the most tempting option available affects the agent's utility.

Definition 1 (Tempting Good). y is *tempting* if $\{x\} \succ \{y\}$ and $\{x\} \succ \{x, y\} \succsim \{y\}$.

We can distinguish two different cases, $\{x\} \succ \{x, y\} \succ \{y\}$ and $\{x\} \succ \{x, y\} \sim \{y\}$. The first relation $\{x\} \succ \{x, y\}$ implies adding y to the menu leaves the agent worse off. The first case $\{x\} \succ \{x, y\} \succ \{y\}$ indicates that he chooses x from $\{x, y\}$, i.e. he exercises costly SC and does not consume the tempting good y. The second case $\{x\} \succ \{x, y\} \sim \{y\}$ implies that the agent chooses y from $\{x, y\}$, i.e. he succumbs to temptation. The characterizing condition for self-control preferences is then defined by this notion of temptation and builds the basis of GP's model:

[14] With Della Vigna and Malmendier (2006) providing one of the prominent examples.

Axiom 1 (Set Betweenness (GP)). $A \succsim B$ implies $A \succsim A \cup B \succsim B$.

Here B represents the tempting menu, i.e. the most tempting element in B is more tempting than the most tempting element in A. Note that the standard case of the rational consumer is also implied: $A \sim A \cup B \succsim B$.

Based on Set Betweenness GP can prove the existence of the utility function representing SCP:

$$U(A) := \max_{x \in A} u(x) + v(x) - \max_{y \in A} v(y). \tag{1}$$

Where u and v are von Neumann-Morgenstern utility functions over lotteries. u is the utility U assigns to singletons, i.e. $u(x) = U(\{x\})$, and it represents the agent's preference for commitment. Therefore, GP refer to $u(x)$ as the *commitment utility* of the choice x. The utility function v represents the temptation ranking ($v(x)$ is referred to as *temptation utility*).

The term $\max_{y \in A} v(y) - v(x)$ can be interpreted as the SC cost of choosing x, the difference in temptation utility between the most tempting option available and the actual period two choice. The disutility then depends on the choice menu and the actions taken in period two. Unlike the standard rational consumer who maximizes u and does not suffer from temptation, the agent with SCP maximizes $u + v$, i.e. tries to find the best compromise between temptation and commitment.

3.1 GP with Constant Degree of Motivation

Now that we have an understanding of what the basic GP model looks like, we introduce the *degree of motivation* $\delta \in (0, 1)$ into this model. GP do not consider any notion of motivation in their model. As it is a main part of our model, we introduce our notion of motivation into their model to see how it influences their model and its outcomes.

For simplicity, first assume δ to be constant over time and assume the agent has full knowledge of δ. A period one agent anticipates period two choices correctly. The model then changes to

$$U_\delta(A) := \max_{x \in A} \left[u(x) - (\frac{1}{\delta} - 1)(\max_{y \in A} v(y) - v(x)) \right] \tag{2}$$

Depending on the value of δ the additional term can either increase ($\delta < \frac{1}{2}$), decreases ($\delta > \frac{1}{2}$) or not change ($\delta = \frac{1}{2}$) the *perceived cost of SC* ($\frac{1}{\delta} -$

$1)(\max_{y\in A} v(y) - v(x))$.[15] Apart from that it does not change the agent's choice since it does not alter the preference order.

This case is then a special case of the model introduced by Noor and Takeoka (2015). To introduce menu dependence into their model, they extend the utility function by an increasing function $\psi(\cdot) > 0$:
$U_{NT}(A) := \max_{x\in A}\left[u(x) - \psi(\max_{y\in A} v(y))(\max_{y\in A} v(y) - v(x))\right]$. They note that their model reduces to GP's model when ψ is constant, which is the case here.

3.2 GP with Random Degree of Motivation

More interesting is the case when $\delta \in (0,1]$ is assumed to be random. Note that we can rewrite the utility from (2) to

$$U_\delta(A) := \max_{x\in A}\left[(2-\frac{1}{\delta})u(x) + (\frac{1}{\delta}-1)\left(u(x)+v(x)-\max_{y\in A} v(y)\right)\right] \tag{3}$$

since $u(\cdot)$ is assumed to be linear. Then, if $\delta \in [\frac{1}{2}, 1]$ and with $\rho = (\frac{1}{\delta}-1)$ this reduces to the model introduced by Chatterjee and Krishna (2009) and can thus be interpreted in terms of their dual self approach: with probability $(1-\rho)$ the rational self makes the second period choice and chooses $u(x)$. With probability ρ a tempted alter ego appears and makes the second period decision based on $(u(x)+v(x)-\max_{y\in A} v(y))$. For more details see Chatterjee and Krishna (2009).

If $\delta \in (0, \frac{1}{2})$, this interpretation does not hold as this includes $(\frac{1}{\delta}-1) \notin [0,1]$. In that case we stick to the representation of U_δ as illustrated in (2). Here, the motivation is a simple weight on the cost of SC. As long as we assume sophistication, the agent in period one can foresee his motivation in period two. Hence, $\delta \in (0, \frac{1}{2})$ makes him succumb to temptation easier, compared to the default model without motivation.

4 Model

In the following we first introduce a simplified version of our model which is closer to GP. Afterward, we modify the model to incorporate a changing (random) degree of motivation.

[15] For the sake of comparability we will maintain to call $\max_{y\in A} v(y) - v(x)$ the *cost of SC* and will use the term *perceived cost of SC* for the cost of SC dependent on the degree of motivation $((\frac{1}{\delta}-1)(\max_{y\in A} v(y) - v(x)))$.

4.1 Basic Model

We introduce a simple two-period decision problem. We stick to the menus over lotteries approach as used by GP. This facilitates comparability of the models.

4.1.1 Preliminaries

We face a two-period decision problem. In the first period the agent anticipates period two choices given a set of lotteries $A \in \mathcal{A}$ and chooses an investment-payoff combination (w, p_w) from a given set of combinations $\mathcal{W}^2 \subset \mathbb{R}^2_+$. If he chooses an investment-payoff combination $(w, p_w) \neq (0,0)$, i.e. he chooses to commit his future self, he has to pay an effort cost $k \geq 0$ in period two. This cost is independent of the actual size of the investment and payoff. Following GP we operate on a compact metric space (Z, d), where Z is the set of all prizes. Let the set of all lotteries, Δ, be the set of all measures on the Borel-σ-algebra of Z, endowed with the weak topology; d the metric on Z. Let $\mathcal{A}$ be the set of compact subsets of Δ. The period $t = 2$ investment w from a given compact set of investments $[0, e]$, where $e > 0$ is a constant given endowment that cannot be used for consumption. The investment leads to a binary payoff $p_2 \in \{p_w, 0\}$ depending on the amount of w and the agent's period $t = 2$ choice. The payoff is paid at the end of period two after the choice has been made. In case the period two choice does not coincide with the ex ante optimal choice (which was preferred in $t = 1$), the payoff will be zero, and $p_w \geq w$ otherwise. Here p_w describes the short-run benefit. In the first period, i.e. before the actual choice of consumption is made, the agent is not tempted by any item and does not have to carry any cost of SC. In period $t = 2$ the agent chooses a lottery $x \in A$ (i.e. consumption) from a given set of lotteries $A \in \mathcal{A}$, possibly facing a temptation.

The binary relation $\succsim$ is a subset of $\mathcal{W}^2 \times \mathcal{W}^2$. Given a menu $A \in \mathcal{A}$, the real valued function $U_A : \mathcal{W}^2 \to \mathbb{R}$ represents the first period preference relation $\succsim$ when $(w, p_w) \succsim (w', p_{w'})$ if and only if $U_A(w, p_w) \geq U_A(w', p_{w'})$. For convenience we write wp instead of (w, p_w).

The utility is dependent on the degree of extrinsic motivation $\delta \in (0,1)$. For now assume δ is constant over time. An agent can then use his investment to alter the perceived period two cost of SC. Following GP we assume that an agent is only tempted by the most tempting item in the menu $A \in \mathcal{A}$. We part from GP in that we assume that the agent *cannot* influence which menu he will face. If an agent has a preference for commitment, he has an incentive to commit to a choice before he actually has to face temptation. That is, he commits to a period two choice in period one.

4.1.2 Period One Choices

Before we define the details of the model, we start with some basic terminology:

Definition 2 (Self-Commitment Mechanism)**.** An agent who uses a *self-commitment mechanism* utilizes an instrument, a *commitment device*, to modify his own behavior in a normatively-preferred fashion.

Definition 3 (Investment-Payoff Combination)**.** An *investment-payoff combination* is a self-commitment device, where an investment is made before the action is taken. After the action is taken a pre-defined payoff – at least the size of the investment – is rewarded if the pre-defined goal is reached. The investment is lost in case of failure.

Definition 4 (Investment-Payoff Mechanism)**.** An *investment-payoff mechanism* is a self-commitment mechanism, that utilizes an investment-payoff combination as commitment device.

For convenience, we use the terms "investment" or "investing" synonymous to "investment-payoff" or "investing given payoff p_w", respectively, from here on.

If $00 := (0, p_0) = (0, 0)$ stands for not investing, i.e. no commitment, then:

Definition 5 (Preference for Commitment at a given Menu)**.** The preference $\succsim$ has a *preference for commitment at a given Menu $A \in \mathcal{A}$* if there exists $wp \succ 00$ for a $w > 0$ whenever he faces A.

The preference $\succsim$ has a *preference for commitment* if $\succsim$ has a preference for commitment at some $A \in \mathcal{A}$.

Thus, an agent has a preference for commitment at a given menu whenever he prefers to take action in order to change his future behavior over not choosing a commitment.

Period one utility is given by:

$$U_A(wp) = \begin{cases} u(x) & \text{, if } A = \{x\} \\ \max\limits_{x \in A} \left(u(x) - (\frac{1}{\delta} - 1)(\max\limits_{y \in A} v(y) - v(x)) + s(-w + \lambda p_2(x) - k) \right) & \text{, if } |A| \geq 2 \end{cases} \quad (4)$$

Let u, v be von Neumann-Morgenstern utilities as introduced by GP. They defined u as the agent's commitment utility, since in their basic model $U(\{x\}) = u(x)$ describes the utility the agent would receive if he committed to menu $\{x\}$ in period one. We set the menu as given. Hence, here u describes rather the agent's normative preferences and will be called *normative utility*, accordingly. Then, v describes the agent's *temptation utility* and the difference $\max_{y \in A} v(y) - v(x)$ describes the SC cost.

Here, $\arg\max_{y \in A} v(y)$ is the most tempting alternative in a given menu A and the agent is assumed to suffer from not choosing this alternative. The *perceived cost of SC* $(\frac{1}{\delta} - 1)(\max_{y \in A} v(y) - v(x))$ is influenced by the degree of extrinsic motivation $\delta \in (0, 1)$, which can either increase or decrease the perceived SC cost. The underlying idea is that depending on the agent's motivation the burden of resisting temptation weighs heavier or lighter. Note, that $\frac{1}{\delta} > 1$ for all $\delta \in (0, 1)$. The extreme cases of $\delta = 0$ and $\delta = 1$ are not considered. In the first case, the agent does not have a preference for commitment and will succumb to temptation in any situation. In the latter case, the agent does not face SC problems and, thus, would not have to pay any SC cost, does not have a preference for commitment and would never succumb to temptation.

Let the utility $s : \mathbb{R} \to \mathbb{R}$ be *well behaved*, i.e. it is defined, strictly monotonic, and twice continuously differentiable. With $s(-w) < 0$ for all $w > 0$ and $s(0) = 0$, defined over the investment w, the effort cost k and period two payoff p_2, which will be paid at the end of the period, and is discounted by $\lambda \in [0, 1]$. s is upwardly sloped, i.e. $s'(x) > 0$. For simplicity and its explanatory value we first consider the case of risk neutrality that serves as a baseline. Then, we introduce a more realistic assumption of *loss aversion*, i.e. losses loom larger than gains (Tversky and Kahneman, 1991).

We model s as a (asymmetric) sigmoid function[16] with reference point $s(0) = 0$, i.e. $s'(0) = 0$, $s''(0) = 0$ and $s'''(0) \neq 0$. The idea of utilities over investments following this characteristic s-shaped curve goes back to Kahnemann and Tversky (1979, 1992) and their findings that people tend to prefer avoiding losses more than obtaining gains of the same size, possibly twice as much.

As for now, since we assume δ to be constant its introduction only influences the value of the cost of SC. Thus, the only difference here, compared to GP, is that the agent cannot choose a menu but must find another way to commit to a less tempting but normatively-preferred choice. If the investment is chosen efficiently, it will have the effect that it cancels out the temptation by eliminating the cost of SC. As Peysakhovich (2014) points out: if a tempting item cannot be removed physically, a commitment technology can only be optimal if it removes the temptation from that item, as it will lead to exertion of (costly) SC otherwise, which has not been an optimal choice in the first place.

Note, that $p_w \geq 0$ describes a (potentially monetary) direct payoff from the investment. Define $x^M := \arg\max_{x \in A} (u(x) + v(x))$ and $y^M := \arg\max_{y \in A} v(y)$.

Assume that the agent's period two choice is $x_2^* \in A$, then

$$p_2(x) = \begin{cases} 0 & \text{if } x_2^* = y^M \neq x^M, \\ p_w & \text{if } x_2^* = x^M. \end{cases}$$

[16]The term "sigmoid function" is oftentimes used for the special case of the logistic function $(\frac{1}{e^{-x}+1})$. We do not make this restriction. Further examples of sigmoid functions are the arctangent ($arctan(x)$), the hyperbolic tangent ($tanh(x)$) and the Gauss error function ($\frac{2}{\pi} \int_0^x e^{-t^2} dt$).

In the following, w.l.o.g. assume that $|A| \geq 2$. Since if A is a singleton there is no SC problem and the choice is uninteresting.

It is important to note that endowment, investment, commitment costs and payoff can but do not necessarily have to be monetary. It might even be that endowment, investment and costs are monetary, but payoff is not. Therefore, all of the mentioned are measured in utility units. The endowment is not included in the utility function, as it does not influence the decision/consumption problem under the given assumptions, other than it restrains w. Since we are only considering a two-period model, it also does not influence future choices. Intuitively, if we think of the investment as a self-bet, then one, for example, could invest essentially anything from his own reputation, honor, time to money.

More specifically, whenever $|A| \geq 2$ and $x^M \neq y^M$, the agent faces a singleton or binary choice in period two. The underlying assumption is that the agent is tempted by the most tempting item in the menu but in the absence of temptation wants to commit to choosing the consumption that maximizes the combination of normative and temptation utility and utility from his investment ($u(x) + v(x) + s(-w + \lambda p_2(x) - k)$). Due to its definition $x^M = \arg\max p_2(x) = \arg\max s(-w + \lambda p_2(x) - k)$, for given w, p_2, k. Then, his choice reduces to maximizing $u(x) + v(x)$. Thus, we only have to consider the choice between x^M and y^M in period two, as all other alternatives are irrelevant and do not influence the cost of SC. The agent must solve the period two decision problem in period one already, anticipating his future choices. He then makes his period one choice such that his period one utility is maximized subject to his anticipated future behavior. As mentioned before, in this basic version of the model we assume δ to be constant.

Assuming risk neutrality towards the investment ($s(w) = w$), the payoff p_w needs to exceed a certain threshold in order for the agent to resist temptation in the second period:

$$p_w \geq \frac{u(y^M) - u(x^M) + (\frac{1}{\delta} - 1)(v(y^M) - v(x^M))}{\lambda} \tag{5}$$

The threshold depends negatively on the degree of motivation δ and the discount factor λ. Intuitively, the less motivated the agent is, the higher his incentive to choose against temptation has to be. The less he weighs future benefits, the higher they have to be to change his choice.

Note, that – in the light of interpreting the investment-payoff combination as a self-bet – Equation 5 suggests that period two agent's choice is dependent on the possible payoff from the bet and independent of the investment. However, this impression comes from our simplifying assumption that the agent chooses an investment-payoff combination.

Considering the underlying payoff structure of a typical bet, there are various possibilities how the payoff is defined and when the actual size of the payoff is revealed. For example, two parties could bet over tangible assets in which case the size of the reward is known from the beginning. The reward could also be a share of an actual monetary pot that is split between winners (e.g. the parimutuel betting setup) – as discussed in Hirt-Schierbaum and Ivets (2020). In this case the size of the payoff is revealed at the end of the second period and the payoff is defined as $p_w = \frac{Nw}{G}$, with N being the number of players and $G \leq N$ – the number of winners.

If we do not assume risk neutrality towards the investment, the requirement for resisting temptation with $wp \neq 00$ in period two is given by:

$$s(\lambda p_w - w - k) - s(-w - k) \geq u(y^M) - u(x^M) + (\frac{1}{\delta} - 1)(v(y^M) - v(x^M)) \quad (6)$$

From this inequality we can draw the following conclusion:

Proposition 1.

(a) For a loss-averse agent, with $\lambda \in (0,1)$ and $k \geq 0$ an investment-payoff combination, wp_w, with $\lambda p_w - w - k \geq 0$ is more effective as a commitment device than a *stick* of the same size as the investment w.

(b) For a loss-averse agent, with $\lambda \in (0,1)$ and $w > k \geq 0$ an investment-payoff combination, wp_w, with $\lambda p_w - w - k \geq k$ is more effective as a commitment device than a *carrot* of the same size as the payoff p_w.

Proof.

(a) A *stick* is a penalty that has to be paid after failing to reach a pre-defined goal. If an agent decides to use a stick, $\kappa \geq 0$, as a commitment device, his utility in cases of success or failure will be given by:

$$U_A(\kappa) = \begin{cases} u(x^M) - (\frac{1}{\delta} - 1)(v(y^M) - v(x^M)) + s(-k) & ;\ x_2^* = x^M \\ u(y^M) + s(-\lambda\kappa - k) & ;\ x_2^* = y^M \neq x^M \end{cases}$$

Thus, he will resist temptation in period two, whenever

$$\begin{aligned} & u(x^M) - (\tfrac{1}{\delta} - 1)(v(y^M) - v(x^M)) + s(-k) \geq u(y^M) + s(-\lambda\kappa - k) \\ \Leftrightarrow \quad & s(-k) - s(-\lambda\kappa - k) \geq u(y^M) - u(x^M) + (\tfrac{1}{\delta} - 1)(v(y^M) - v(x^M)). \end{aligned}$$

For $\kappa = w$ and $\lambda \in (0,1)$: $s(\lambda p_w - w - k) \geq 0 > s(-k)$ and $-s(-w - k) > -s(-\lambda\kappa - k) = -s(-\lambda w - k)$ and thus $s(\lambda p_w - w - k) - s(-w - k) > s(-k) - s(-\lambda\kappa - k)$. Using inequality (6) this yields that an investment of the same size as the stick can compensate for a higher cost of SC, due to the facts that i) it is paid at the beginning of period two and thus not discounted and ii) the additional payoff in case of success offers an even higher incentive to resist temptation.

(b) A *carrot* is a reward that is paid after successful resistance to temptation. If the agent chooses a carrot, $c \geq 0$, as a commitment device, his utility in cases of success or failure will be given by:

$$U_A(c) = \begin{cases} u(x^M) - (\frac{1}{\delta} - 1)(v(y^M) - v(x^M)) + s(\lambda c - k) & ;\ x_2^* = x^M \\ u(y^M) + s(-k) & ;\ x_2^* = y^M \neq x^M \end{cases}$$

Analogously to before, the agent will resist temptation in period two whenever

$$s(\lambda c - k) - s(-k) \geq u(y^M) - u(x^M) + (\frac{1}{\delta} - 1)(v(y^M) - v(x^M)).$$

As in (a) we need to show that whenever the above equation is satisfied for $c = p_w$ it is also satisfied for wp and

$$s(\lambda p_w - w - k) - s(-k - w) > s(\lambda p_w - k) - s(-k). \tag{7}$$

Recall that $s(-w) < 0$ for $w > 0$, $s(0) = 0$, $s'(0) = 0$, $s''(0) = 0$, $s'''(0) \neq 0$ and $s'(w) > 0$ for $w \neq 0$ and $s''(w) < 0$ for $w > 0$, $s''(w) > 0$ for $w < 0$. Hence, for $w > 0$ the slope decreases with increasing w and for $w < 0$ it increases with increasing w. Furthermore, s might be symmetrical ($s(-w) = -s(w)$), but most likely is not. As Kahnemann and Tversky (1992) have shown it is more likely that $s(-w) < -s(w)$.[17] This implies that a change of the same amount in the positive and negative of the function has stronger effects in the negative.

Measure the distance between any two points a, b with the absolute difference $d(a, b) = |b - a|$. We know that $d(\lambda p_w - w - k, 0) \geq k$ and $d(-k, 0) = k$. Given the slope and curvature of s this implies $d(s(\lambda p_w - w - k), s(\lambda p_w - k)) < d(-s(-k), -s(-w-k))$. This means, addition of the investment $-w$ decreases the value of s in case of success compared to the carrot, where no investment has to be taken, as $s(\lambda p_w - w - k) < s(\lambda p_w - k)$. Note that these are the first addends on either side of (7). But the decrease in s in the positive is not as strong as in the negative part of s: $-s(-k) < -s(-w-k)$ (the second addends on either side of (7)). Thus the loss aversion that comes with the investment outweighs the smaller net payoff that comes with it, compared to the carrot, where the agent only receives the payoff but does not have to invest.

□

In broad terms, an investment-payoff combination can be regarded as a combination of a carrot and a stick. While carrots and sticks reward good behavior and punish bad behavior, respectively, an investment-payoff combina-

[17] They approximated $s(-w) = -2s(w)$, which implies $s'(-w) = 2s'(w)$.

tion does both. What Proposition 1 suggests is that a smaller investment is needed to have the same binding effect as a stick of a certain size and a lower payoff is needed compared to the payoff of a carrot.

Given condition (6), period one agent has to make a decision which combination to choose from the set of given investment-payoff combinations $\mathcal{W}$. However, an investment-payoff combination that induces resistance is only welfare enhancing if

$$\begin{aligned} & u(x^M) - (\tfrac{1}{\delta} - 1)(v(y^M) - v(x^M)) + s(\lambda p_w - w - k) \geq u(y^M) \\ \Leftrightarrow \quad & s(\lambda p_w - w - k) \geq u(y^M) - u(x^M) + (\tfrac{1}{\delta} - 1)(v(y^M) - v(x^M)). \end{aligned} \tag{8}$$

Definition 6 (Efficient Investment-Payoff)**.** An investment-payoff combination is *efficient* whenever it induces equality in (8).

Definition 6 says that an investment-payoff combination is *efficient* whenever it makes the agent indifferent between both choices, x^M with investment and y^M without investment. Given that, without the investment the utility maximizing choice would have been y^M and the investment successfully changes this choice.

4.1.3 Period Two Choices

We described the optimal behavior for the utility maximizing agent in period one. There, he evaluates investment-payoff combinations in anticipation of his period two behavior when facing a given set of lotteries. Now, we need to consider his period two choices.

In period two the agent chooses a lottery x from the given set of lotteries A, with regard to the possible payoff. Hence, we follow GP in defining the period two preference relation as a conditional preference, depending on the first period choice. Let $\succsim^2$ denote the extended period two preference relation over lotteries $x \in A$ for a given set of lotteries $A \in \mathcal{A}$ and a chosen investment-payoff combination $wp \in \mathcal{W}^2$. The preference relation $\succsim^2$ is defined on the set $\mathcal{S}_A = \{((w, p_w), x) \in \mathcal{W}^2 \times \Delta : x \in A\}$. Then, choice $x \in A$ is preferred over $y \in A$, given period one choice wp, $(wp, x) \succsim^2 (wp, y)$, if and only if there exists a utility function $U_A^2 : \Delta \to \mathbb{R}$ such that $U_A^2(wp, x) \geq U_A^2(wp, y)$.

Let the utility function that is faced by period two agent be defined by

$$U_A^2(wp, x) := u(x) - (\frac{1}{\delta} - 1)(\max_{y \in A} v(y) - v(x)) + s(\lambda p_2(x) - w - k). \tag{9}$$

Then, the choice correspondence can be defined as:

$$\mathcal{C}_A^2(wp, \succsim^2) := \left\{ x \in A : (wp, x) \succsim^2 (wp, y) \; \forall y \in A \right\}. \tag{10}$$

Definition 7. Say an investment-payoff combination $wp \in \mathcal{W}$ *implements resisting* temptation if $\arg\max_{x\in A} U_A^2(00, x) = y^M$ and $\arg\max_{x\in A} U_A^2(wp, x) = x^M$. Let $\mathcal{W}^R$ be the set of investment-payoff combinations that implements resisting.

Note, that this is the case whenever condition (6) is satisfied with investment, but would not be satisfied without investment, hence:

$$\mathcal{W}^R = \left\{ wp \in \mathcal{W}^2 \setminus \{00\} \, |U_A^2(wp, x^M) \geq U_A^2(wp, y^M), y^M := \arg\max_{x\in A} U_A^2(00, x) \right\}.$$

Definition 8. The set of *efficient* investment-payoff combinations is defined by

$$\mathcal{W}^E = \left\{ wp \in \mathcal{W}^R | U_A^2(wp, x^M) = U_A^2(00, y^M), y^M := \arg\max_{x\in A} U_A^2(00, x) \right\}.$$

Observe that $\mathcal{W}^E \subset \mathcal{W}^R$.

Definition 9. The set of *optimal* investment-payoff combinations is defined by

$$\mathcal{W}^* := \left\{ wp \in \mathcal{W}^2 | U_A^2(wp, x_2^*) \geq U_A^2(\widetilde{wp}, \widetilde{x_2}^*) \right\}$$

for any $\widetilde{wp} \in \mathcal{W}^2$.

Note, that optimal investment-payoff combinations are not necessarily efficient, and resistance inducing investments are not necessarily optimal.

Corollary 1. For any value of $\lambda \in [0, 1]$ there exists an open set $(\underline{wp}, \overline{wp})$ such that $wp \in (\underline{wp}, \overline{wp})$ implements resisting, but does not improve welfare over $wp = 00$.

Proof.

This is clearly the case for all investment-payoff combinations wp that satisfy (6), but not $U_A^2(wp, x^M) \geq U_A^2(00, y^M)$. The inequality is equivalent to $s(\lambda p_w - w - k) \geq u(y^M) - u(x^M) + (\frac{1}{\delta} - 1)(v(y^M) - v(x^M))$. Note that the right-hand side is equal to the one in (6) and the left-hand side is one of the addends on the left-hand side of (6). Thus, whenever this inequality is satisfied condition (6) is satisfied as well, but not vice versa. □

In the following we introduce the heuristic bias into the model. More specifically, period one agent solves the expected utility maximization problem given his belief about his motivation, $\hat{\delta}$.

An agent is considered *rational* if he is fully motivated and is aware of it ($\delta = \hat{\delta} = 1$). A rational agent does not face SC problems since he does not experience SC costs. Note that we excluded the case of $\delta = 1$ from our analysis earlier. An agent is *sophisticated* if he is not fully motivated and assesses his true motivation ($\delta = \hat{\delta} < 1$). We deviate from O'Donoghue and Rabin (2001) in that we use the term *partially naive* for an agent that is aware of his SC problem but cannot asses his true motivation. O'Donoghue and Rabin (2001) introduced this term to describe a special case which we call *optimistic*. An agent is *optimistic* if he knows he is not fully motivated but *overestimates* his true motivation ($\delta < \hat{\delta} < 1$).[18] We then introduce another special case of partial naiveté, *pessimism*. A *pessimistic* agent is aware of his SC problem but *underestimates* his true motivation ($\hat{\delta} < \delta < 1$).[19] We can measure the degree of naiveté by $|\hat{\delta} - \delta|$. A *naive* agent is not aware that he is not fully motivated, thus he does not know he has a SC problem ($\delta < \hat{\delta} = 1$).

Period one agent first solves period two agent's problem, subject to his belief:

$$\max_{x \in A} \hat{U}_A^2(wp, x) := \max_{x \in A} u(x) - (\frac{1}{\hat{\delta}} - 1)(\max_{y \in A} v(y) - v(x)) + s(\lambda p_2(x) - w - k). \tag{11}$$

He then solves Equation 8 for $\hat{\delta}$:

$$u(y^M) - u(x^M) + (\frac{1}{\hat{\delta}} - 1)(v(y^M) - v(x^M)) \leq s(\lambda p_w - w - k). \tag{$\hat{8}$}$$

Depending on his type (sophisticated, (partially) naive), his commitment will then either be successful or a failure. Given the choice function of the period two agent we can conclude the following about the optimal choices in period one:

(1) If $C_A^2(00, \succsim^2) := \{x^M\} = \{y^M\}$, there is no SC problem in the absence of commitment ($wp = 00$) and therefore no incentive to commit. Period one agent faces the following choice problem, which is independent of his motivation:

$$\max_{wp \in \mathcal{W}^2} U_A(wp) = \max_{wp \in \mathcal{W}^2} u(x^M) + s(-w + \lambda p_w - k) \text{ s.t. } w \leq e$$

Note that this decision problem allows the agent to invest even though he has no incentive to commit. In fact his decision problem reduces to:

$$\max_{wp \in \mathcal{W}^2} s(-w + \lambda p_w - k)$$

[18] This would, for example, correspond to the overconfidence bias – human tendency to overestimate their positive attributes – that has been widely documented by empirical evidence. For example, people tend to think that they are healthier, better drivers, more financially secure than they actually are or compared to the median individual (e.g. Weinstein, 1980; Svenson, 1981; Weinstein, 1982; Groeger and Grande, 1996; Walton and McKeown, 2001; Robb *et al.*, 2004). For a brief overview of this literature see Sandroni and Squintani (2004).

[19] This, in its turn, corresponds to an underconfidence bias occasionally observed in the empirical literature, e.g. in depressed individuals (see, e.g. Stone *et al.*, 2001; Fu *et al.*, 2012).

Intuitively, the agent has the opportunity to make a safe investment, if his anticipated net payoff is higher than the effort cost.

(2) If $\mathcal{C}^2_A(00, \succsim^2) := \{x^M\} \neq \{y^M\}$ and there exists at least one $wp \in \mathcal{W}$ with $w \leq e$ such that $s(-w-k+\lambda p_w) > 0$, there is no need for commitment, but the agent can reduce his cost of SC when he commits to his choice in advance.

(3) If $\mathcal{C}^2_A(00, \succsim^2) := \{y^M\} \neq \{x^M\}$ and there exists at least one $wp \in \mathcal{W}^E$ with $w \leq e$ such that $\mathcal{C}^2_A(wp, \succsim^2) := \{x^M\} \neq \{y^M\}$, i.e. in the absence of commitment he would succumb to temptation, but there exists an investment-payoff combination that is efficient, then:

$$\max_{wp \in \mathcal{W}^2} \hat{U}_A(wp) = \max_{wp \in \mathcal{W}^2} u(x^M) - (\tfrac{1}{\hat{\delta}} - 1)(v(y^M) - v(x^M)) + s(-w + \lambda p_w - k).$$

This is the most interesting case and the only case where the agent uses the commitment to alter his behavior. In this case the agent will invest whenever condition ($\hat{8}$) is met and choose the utility maximizing investment-payoff combination for his believed degree of motivation.

(4) If $\mathcal{C}^2_A(wp, \succsim^2) := \{y^M\} \neq \{x^M\}$ for all $wp \in \mathcal{W}$ with $w \leq e$ (i.e. $\mathcal{W}^R = \emptyset$), then the choice problem reduces to:

$$\max_{wp \in \mathcal{W}^2} U_A(wp) = \max_{wp \in \mathcal{W}^2} u(y^M) + s(-w-k)$$

In this case the optimal choice in period one is always not to invest, as $s(-w-k) < 0$ for all $w > 0$. Intuitively, the cost of SC is too high to be compensated with any investment-payoff combination from the given set $\mathcal{W}$ and thus the agent should not invest, since that would only decrease his utility.

We will concentrate on the third case, which is the only case where a demand for commitment actually occurs. A rational agent ($\delta = \hat{\delta} = 1$) will not consider to commit to a choice as he does not face SC problems. He will just make the rationally-preferred choice.

Proposition 2 (Investment Effect - Basic Model)**.**

i) An agent who chooses an investment-payoff combination $wp > 00$ has a dominant investment strategy, given his beliefs.

ii) A sophisticated agent uses an investment-payoff mechanism successfully as a commitment device.

iii) An optimistic agent undercommits[20] when choosing his efficient investment-payoff combination. The higher the degree of naiveté, the more severe the undercommitment.

[20]Undercommitment meaning the choice of $wp \notin \mathcal{W}^E$.

iv) A pessimistic agent overcommits[21] when choosing his efficient investment-payoff combination. The higher the degree of naiveté, the more severe the overcommitment.

v) Naive agents fail to consciously use an investment-payoff mechanism as a commitment device. They might however commit successfully by coincidence.

vi) Without an investment-payoff mechanism, an agent with SC problems is more likely to succumb to temptation.

Proof.

i) This holds true, since agents only choose an investment if ($\hat{8}$) is satisfied. Thus, given their beliefs the expected utility with investment will be higher than without.

ii) A sophisticated agent maximizes his true utility, as $\delta = \hat{\delta} < 1$. He will invest whenever equation (8) is met and choose the optimal investment-payoff combination. He will not invest otherwise and therefore uses the investment-payoff mechanism successfully as commitment device.

iii) An optimistic agent solves ($\hat{8}$) with equality when he chooses an efficient investment, but since $1 > \hat{\delta} > \delta > 0$ this leads to:

$$\begin{aligned} s(\lambda p_w - w - k) &= u(y^M) - u(x^M) + (\tfrac{1}{\hat{\delta}} - 1)(v(y^M) - v(x^M)) \\ &< u(y^M) - u(x^M) + (\tfrac{1}{\delta} - 1)(v(y^M) - v(x^M)). \end{aligned}$$

This implies his choice is efficient, given his belief, but is not welfare enhancing, given his true motivation. If furthermore $u(y^M) - u(x^M) + (\frac{1}{\delta} - 1)(v(y^M) - v(x^M)) > s(\lambda p_w - w - k) - s(-w - k)$, his chosen investment does not even induce resistance given his true motivation. The larger the degree of naiveté, $|\delta - \hat{\delta}|$, the larger is the difference between the two right-hand sides above, $u(y^M) - u(x^M) + (\frac{1}{\hat{\delta}} - 1)(v(y^M) - v(x^M))$ and $u(y^M) - u(x^M) + (\frac{1}{\delta} - 1)(v(y^M) - v(x^M))$. And this means the more severe is the undercommitment.

iv) Analogously, a pessimistic agent that invests efficiently solves ($\hat{8}$) for $1 > \delta > \hat{\delta} > 0$ with equality, which leads to:

$$\begin{aligned} s(\lambda p_w - w - k) &= u(y^M) - u(x^M) + (\tfrac{1}{\hat{\delta}} - 1)(v(y^M) - v(x^M)) \\ &> u(y^M) - u(x^M) + (\tfrac{1}{\delta} - 1)(v(y^M) - v(x^M)). \end{aligned}$$

Thus again, his choice is efficient given his belief but not given his true motivation. However, it does induce resisting and also satisfies (8) and is,

[21] Overcommitment meaning the choice of $wp \in \mathcal{W}^R$ such that the inequality in (8) is strict.

therefore, welfare enhancing. But with some (w', p_w'), such that $w' < w$ and/or $p_w' < p_w$, he could have yielded the same commitment result. The higher investment did not alter his behavior in comparison.

v) As naive agents falsely solve the following problem:

$$\max_{wp \in \mathcal{W}^2} u(x^M) + s(\lambda p_w - w - k) \text{ s.t. } s(\lambda p_w - w - k) > 0 \text{ and } w \leq e,$$

they believe they will choose x^M with certainty and will invest when the utility from the net payoff is positive, i.e. when they increase their expected utility by investing, but they cannot spend more than their endowment.

Remember that s is upwardly sloped and has no global maxima. Since k is constant and thus the same for any investment $wp \neq 00$ and $u(x^M)$ is constant, their problem reduces to:

$$\max_{wp \in \mathcal{W}^2} d(\lambda p_w, w) = |\lambda p_w - w| \text{ s.t. } s(\lambda p_w - w - k) > 0 \text{ and } w \leq e.$$

Hence, they maximize the distance between investment and payoff. This might lead them to choose an investment that does induce resistance in period two, since condition (8) demands $s(\lambda p_w - w - k) > u(y^M) - u(x^M) + (\frac{1}{\delta} - 1)(v(y^M) - v(x^M))$, which implies that condition (6) is satisfied as well. A naive agent might not consider either of these conditions but the larger $s(\lambda p_w - w - k)$ the more likely condition (8) is satisfied. And given that a naive agent does maximize this expression, subject to his endowment, the only option where he does not invest successfully is if there does not exist an investment-payoff combination in $\mathcal{W}^2$ with $w \leq e$ that satisfies (8).

However, this is a special case of our model since we assume p_w to be given. If we would assume that the payoff is revealed at the end of period two, results might change. However, it is likely that naifs would overestimate their possible future payoff in that case.

vi) This follows directly from ii)-v).

□

Proposition 2 implies that the use of an investment-payoff mechanism is welfare enhancing for a sophisticated agent. Optimistic agents fail to invest efficiently or even implement resistance and will lose their investment and succumb to temptation. Optimistic agents are those who seem to reveal preference reversals as they act contrary to their previous intentions. Proposition 2 suggests that this is not the case; rather, their behavior is the consequence of their inability to commit successfully. Pessimistic agents, on the other hand, do not invest efficiently as they invest more than is necessary to commit, but they will resist temptation and receive the reward. Naive agents are not aware that they have a SC problem. Thus, they will either choose not to invest (under the belief they have no need to commit) or they will invest (under the belief to receive the payoff with certainty). However, naive agents do not consider SC costs in their calculations – they solve a different problem than their real one. For details see Proof.

The model becomes more sophisticated when we assume motivation to be variable.

4.2 Dynamic Model

Previously, we assumed – just like GP – that the cost of SC does not change over time. We now extend the model to where the degree of motivation is stochastic and ex ante unknown, which in turn means the perceived cost of SC is stochastic. The degree of motivation δ is distributed on $(0, 1)$. Suppose this distribution is well behaved and denote the CDF $F(\cdot)$, with support $\mathrm{supp}(F) = [0, 1]$. The degree of motivation is revealed in the beginning of each period, so that agents know their period one motivation, but not their period two motivation.

The period one utility function is given by

$$\mathbb{E}U_A(wp) := \mathbb{E}\left[\max_{x \in A}\left(u(x) - (\frac{1}{\delta_2} - 1)(v(y^M) - v(x)) + s(-w + \lambda p_2(x) - k)\right)\right] \quad (12)$$

Definitions 6-9 can be adopted from the Basic Model and will not be stated again.

We want to consider different agent types defined in the previous subsection. Due to the randomness of the motivation we need to redefine the terms. Generally, we assume agents' naiveté lies in their *perception* of the shock – subject to heuristic bias.

An agent is considered *rational* if he does not face SC problems: his motivation is constant at $\delta_t = 1,\ t = 1, 2$. An agent is *sophisticated* if he is not fully motivated and is aware that his motivation is exposed to random shocks, but he foresees the shock correctly, $0 < \delta_t = \hat{\delta}_t < 1,\ t = 1, 2$. A *partially naive* agent assesses his current degree of motivation correctly, but is biased with regard to his belief about the shock. An *optimistic* agent is not fully motivated and assumes that tomorrow's motivation will be higher than today's, $1 > \hat{\delta}_2 > \hat{\delta}_1 = \delta_1 > 0$. A *pessimistic* agent is not fully motivated and assumes that tomorrow's motivation will be smaller than today's $0 < \hat{\delta}_2 < \hat{\delta}_1 = \delta_1 < 1$. A *naive* agent is not aware that he has any kind of SC problem and is neither aware of his actual motivation, nor the randomness of it. The different agent types then face different choice problems, given their different beliefs about their future motivation.

4.2.1 Choice Problems

As in the Basic Model discussed above, the period one agent tries to predict his future behavior. In order to make the optimal choice he needs to solve period two's problem first and maximize his expected period two utility, $\mathbb{E}U_A^2(wp, x)$, given his belief about his motivation. The objective in period two is the same as in the Basic Model. Since δ_2 is revealed at the beginning of period two, the choice problem is the same as when faced with a constant δ.

- The *sophisticated* agent knows his current and future motivation and thus maximizes his real period two utility:

$$\max_{x \in A} u(x) - (\frac{1}{\delta_2} - 1)(\max_{y \in A} v(y) - v(x)) + s(-w + \lambda p_2(x) - k). \quad (13)$$

- The *optimistic* agent knows his current motivation but estimates his future motivation to be larger and thus, falsely maximizes the following expected period two utility:

$$\max_{x \in A} \int_{\delta_1}^{1} u(x) - (\frac{1}{\delta_2} - 1)(\max_{y \in A} v(y) - v(x)) + s(-w + \lambda p_2(x) - k) dF(\delta_2). \quad (14)$$

- The *pessimistic* agent knows his current motivation but estimates his future motivation to be smaller, thus falsely maximizes:

$$\max_{x \in A} \int_{0}^{\delta_1} u(x) - (\frac{1}{\delta_2} - 1)(\max_{y \in A} v(y) - v(x)) + s(-w + \lambda p_2(x) - k) dF(\delta_2). \quad (15)$$

- The *naive* agent is not aware of his SC problem, nor of the costs that are attributed to the commitment. He then maximizes:

$$u(x^M) + s(-w + \lambda p_w - k). \quad (16)$$

As stated above, similar to the basic model define $\mathcal{W}^R$ the set of resistance inducing investments ($wp \in \mathcal{W} : \mathbb{E}U_A^2(wp, x^M) \geq \mathbb{E}U_A^2(wp, y^M)$ and $y^M = \arg\max_{x \in A} \mathbb{E}U_A^2(00, x)$) and $\mathcal{W}^E$ the set of efficient investments ($wp \in \mathcal{W}^R$: $\mathbb{E}U_A^2(wp, x^M) = \mathbb{E}U_A^2(00, y^M)$ and $y^M = \arg\max_{x \in A} \mathbb{E}U_A^2(00, x)$).

The respective sets of expected choice strategies contain the choices each type of period one agent expects his future self to make and can, similar to before, be defined as follows:

$$\mathbb{E}\mathcal{C}^2_A(wp, \succsim^{\mathbb{E}2}) := \left\{x \in A : (wp, x) \succsim^{\mathbb{E}2} (wp, y)\ \forall y \in A\right\}, \tag{17}$$

where $\mathbb{E}2$ stands for the expected period two utility, depending on each agent's type (rational, sophisticate, (partially) naive). Given the expected choice function we can then conclude the following about the optimal choices in period one:

(1*) If $\mathbb{E}\mathcal{C}^2_A(00, \succsim^{\mathbb{E}2}) := \{x^M\} = \{y^M\}$ period one agent faces the following choice problem:

$$\max_{wp \in \mathcal{W}^2} U_A(wp) = \max_{wp \in \mathcal{W}^2} u(x^M) + s(-w + \lambda p_w - k) \text{ s.t. } w \leq e.$$

Note, that this decision problem does not differ from the Basic Model. Again, it allows the agent to invest even though he has no incentive to commit and his decision problem reduces to:

$$\max_{wp \in \mathcal{W}^2} s(-w + \lambda p_w - k).$$

When no commitment is necessary, the effort cost might in many cases be too high to choose this option, though.

(2*) If $\mathbb{E}\mathcal{C}^2_A(00, \succsim^{\mathbb{E}2}) := \{x^M\} \neq \{y^M\}$ and there exists at least one $wp \in \mathcal{W}$ with $w \leq e$ such that $s(-w - k + \lambda p_w) > 0$, there is no need for commitment, but the agent can reduce his cost of SC when he commits to his choice in advance.

(3*) If $\mathbb{E}\mathcal{C}^2_A(00, \succsim^{\mathbb{E}2}) := \{y^M\} \neq \{x^M\}$ and there exists at least one $wp \in \mathcal{W}^E$ with $w \leq e$ such that $\mathbb{E}\mathcal{C}^2_A(wp, \succsim^{\mathbb{E}2}) := \{x^M\} \neq \{y^M\}$, then the discussed types maximize their respective expected utilities as outlined in (13)-(16) over $wp \in \mathcal{W}$.

This is the most interesting case and the only case where the agent has a demand for commitment. We discuss it further below.

(4*) If $\mathbb{E}\mathcal{C}^2_A(wp, \succsim^{\mathbb{E}2}) := \{y^M\} \neq \{x^M\}$ for all $wp \in \mathcal{W}$ with $w \leq e$ (i.e. $\mathcal{W}^R = \emptyset$), then the choice problem reduces to:

$$\max_{wp \in \mathcal{W}^2} U_A(wp) = \max_{wp \in \mathcal{W}^2} u(y^M) + s(-w - k)$$

In this case, as in the non-stochastic model above, the optimal choice in period one is always not to invest, as $s(-w - k) < 0$ for all $w > 0, k \geq 0$.

Now, we look at the third case (3*) more closely. Here is where the major difference between the two models occurs. In the Basic Model we note that the agent would invest whenever condition ($\hat{8}$) is met. And there we can easily predict the mistakes that certain types of agents are going to make, e.g. an optimistic agent in the basic model will undercommit and possibly fail to resist temptation. In the stochastic case this is not as clear. Consider the optimistic agent again: he will not maximize his true expected utility, as he neglects the possibility of a negative shock. But, given that his motivation is exposed to a random shock, there is always a possibility that he will indeed experience a positive shock in which case the commitment that he chose might be efficient or at least induce resistance. The pessimistic agent, on the other hand, neglects the possibility of a positive shock, but, with a small probability, he too might choose an efficient investment given the fact that the shock might indeed be negative. It might even be so severe, that a pessimistic agent undercommits, when he maximizes his expected utility. Thus, whilst in the Basic Model, optimistic agents always fail to enhance welfare and pessimistic agents always succeed to resist temptation and enhance welfare, we cannot claim the same results in case of stochastic motivation.

Proposition 3 (Investment Effect - Dynamic Model)**.**

i) An agent who chooses an investment-payoff combination $wp > 00$ has a dominant investment strategy, given his beliefs.

ii) A sophisticated agent uses an investment-payoff mechanism successfully as a commitment device.

iii) An optimistic agent is more likely to undercommit when choosing an efficient investment-payoff combination, given his belief. The higher the period one motivation the more likely the undercommitment.

iv) A pessimistic agent is more likely to overcommit when choosing an efficient investment-payoff combination, given his belief. The lower the period one motivation the more likely the overcommitment.

v) Naive agents fail to use an investment-payoff mechanism as a commitment device, but might commit successfully by coincidence.

vi) Without an investment-payoff mechanism, an agent with SC problems is more likely to succumb to temptation.

Proof.

i) Similar to i) in Proposition 2, this follows from the fact that agents only invest if ($\hat{8}$) is satisfied for $\hat{\delta}_2$.

ii) Similar to proposition 2 ii) the sophisticated agent solves his true problem. He will only invest if resistance is induced and welfare enhanced.

iii) An optimistic agent that invests efficiently solves ($\hat{8}$) with equality for $\mathbb{E}\hat{\delta}_2$. He believes the distribution F of δ_t lives on $[\delta_1, 1]$ rather than $[0, 1]$. The optimistic agent thus assigns a higher expected value to his motivation than the true expected value ($\mathbb{E}\hat{\delta}_2 > \mathbb{E}\delta_2$). Thus, the efficient investment he makes is less restrictive than the one he would have to make to solve ($\hat{8}$) with equality for $\mathbb{E}\delta_2$. This means his investment will be smaller and thus the likelihood that it induces resistance is smaller as well. Given the fact that δ_2 results from δ_1 due to a random shock, there is still a positive probability that his investment is resistance inducing, but this decreases with increasing values of δ_1, as $[\delta_1, 1]$ gets smaller with increasing δ_1.

iv) A pessimistic agent that invests efficiently solves ($\hat{8}$) with equality for $\mathbb{E}\hat{\delta}_2$. He believes the distribution F of δ_t lives on $[0, \delta_1]$ rather than $[0, 1]$. The pessimistic agent thus assigns a lower expected value to his motivation than the true expected value ($\mathbb{E}\hat{\delta}_2 < \mathbb{E}\delta_2$). Thus, the efficient investment he makes is more restrictive than the one he would have to make to solve ($\hat{8}$) with equality for $\mathbb{E}\delta_2$. This means his investment will be larger and thus the likelihood that it induces resistance is larger as well. Given the fact that δ_2 results from δ_1 due to a random shock, there is still a positive probability that his investment is efficient, but this decreases with decreasing values of δ_1, as $[0, \delta_1]$ gets smaller with decreasing δ_1.

v) As in the basic model, naive agents are not aware that they have a SC problem. They neglect their true motivation and the possibility of external shocks. This type of agent has then the same maximization problem as in the basic model. So either a naive agent does not commit at all or maximizes the net-payoff of the investment, which is the most binding choice he can make, given his endowment. In this case he might unintentionally commit successfully to a choice.

vi) This follows directly from ii)-v).

□

Propositions 2 and 3 give us clear indications of why we tend to observe behavior that is interpreted as a preference reversal in the field. In the light of Weinstein (1980, 1982) and others, it is plausible that a significant share of people are of the optimistic type (i.e. overconfident about their future SC). Given that optimists tend to realize their problem but not the extent of it, and thus are likely to fail in choosing the right commitment, it is not surprising to see a large share of people fail – especially if we consider that pessimistic agents can also fail in the stochastic case.

Additionally, the general overconfidence bias regarding one's SC skills is captured by the optimistic agent in the basic model, but could easily be incorporated in the dynamic model as well.[22] In this case, we would have to assume that partially naive agents are not only naive about the stochastic shock but also about their current motivation. This would yield the same results as above, just with a stronger statement. If an agent, for example, would overestimate his current motivation and additionally expect his motivation to rise the next day, the likelihood of undercommitment would increase.

5 Discussion

The results from our theoretical analysis show that the proposed utilization of an investment-payoff combination is a promising mechanism. It can increase agents' (extrinsic) motivation and help them overcome their SC problems. Contrary to other commitment mechanisms on the market, the suggested investment-payoff mechanism makes use of both agents' loss aversion and their taste for gains. Kahneman *et al.* (1990) suggest that greater potential loss yields greater motivation, and losses are a greater motivator than gains. Potential gains, on the other hand, provide a greater incentive to pick up the mechanism and serve as an additional motivator once the agent has decided to invest. By including both incentives at the same time, we can increase the effect of the commitment mechanism compared to others that only include one of the incentives.

5.1 Policy Relevance

When agents erroneously make choices that are not in their own best interest, policymakers might have an incentive to help them make better decisions. This is especially true when externalities of those choices influence social costs.

A concern about policy interventions is that they impose second-order costs on rational individuals. Hence, research increasingly focuses on minimally interventionist policies, which have little effect on fully rational agents while helping those who make errors (e.g. O'Donoghue and Rabin, 1998; Camerer *et al.*, 2003; Sunstein and Thaler, 2003; Thaler and Sunstein, 2003; Sandroni and Squintani, 2007). A main concern is helping agents make better decisions without limiting their choices.

The proposed policies following this approach include so called "sin taxes" which are instruments to increase prices of *sinful goods*.[23] Although evidence suggests that the introduction of sin taxes reduces purchases of the respective goods (e.g. Gruber and Köszegi, 2001; Jensen and Smed, 2013; Smed *et al.*, 2016; Allcott *et al.*, 2019), they are less effective than expected. Recent work by Schmacker and Smed (2019) shows that it is high-SC consumers who re-

[22]Similarly, the underconfidence bias is captured by the pessimistic agents.

[23]Sinful goods are those that are harmful to consumers' health, when larger amounts are consumed, e.g. cigarettes, sugar and fat.

act most to the introduction of the tax, while low-SC consumers are the ones that are targeted. Also, O'Donoghue and Rabin (2003) find that consumers use avoidance strategies to forego the tax, e.g. by substituting the taxed good. Nevertheless, Schmacker and Smed (2019) note that the introduction of sin taxes might compensate for the social cost burden caused by the erroneous behavior of low-SC agents. Cremer *et al.* (2012) show in a theoretical approach that it might be beneficial to subsidize healthcare expenditures while taxing sin goods. That is, reward good behavior and punish bad behavior at the same time – like we do here. They show that in a dual-self setting, the sin tax that is required to alter behavior has to be smaller when health expenditures can be compensated – which reduces the second-order costs on rational individuals. This finding is in line with Proposition 1.

This is exactly where our proposed mechanism fits in. Similar to the idea of taxing sinful behavior (investment) while subsidizing healthcare expenditures (payoff for good behavior), the investment-payoff mechanism combines the concept of punishing bad behavior while rewarding good behavior. We can easily observe that the investment-payoff mechanism is in line with the minimally interventionist approach. Since it is a *self*-commitment device, rational agents are not affected when the mechanism is introduced on the market.

At the same time, agents need a certain amount of self-awareness in order to realize that they can benefit from using a commitment device in order to counterbalance their lack of SC. Naifs, who lack this self-awareness, might be attracted to invest by the possibility to receive the reward. However, they need an additional intervention by a policymaker to learn about their naiveté.

Additionally, the policymaker should offer a set of investment-payoff combinations rather than a single combination. Otherwise, the commitment by the offered combination might be too weak for overconfident agents; choosing the offered commitment would then be welfare decreasing for this agent type. A higher investment, on the other hand, might repel agents from choosing commitment over no commitment.[24] Since it is especially the naive optimists and naive agents that need support to make the right choices, a policymaker should target them and inform them about their naiveté and the possibility to increase their likelihood of successful commitment through higher investments. Another possibility (and something that should be considered in future research) is the learning effect that agents will experience when they use this tool repeatedly.

A final concern relates to a possible interpretation of the suggested investment-payoff mechanism as an analog to gambling. Gambling's negative connotations might be problematic if this inference is made. Therefore, a policymaker should be careful to use the right framing when introducing the mechanism.

[24]The latter might be the case for pessimistic agents and for agents who lack the financial resources.

5.1.1 Application Areas

In the following, we discuss areas where our proposed mechanism can be applied. It should be noted that after identifying the areas where a policy intervention is needed, we also need to make sure that the prerequisites for our mechanism's utilization are met.

Given the setup of our model, we would suggest utilizing the proposed mechanism for incentivizing a certain behavioral change within a relatively short time frame. An additional reason to stick to short time frames is the agent's discounting of future rewards[25] and the possible depreciation of past investments.

Another important prerequisite for utilization is whether participants' target behaviors or outcomes are easily observable. In the latter case, we suggest the use of proxies which can be input- or output-oriented. It could be argued that input proxies are preferred over the output proxies since individuals can have better control over their inputs. However, the former might not be easily available and might lead to inefficient substitutions.

We suggest the utilization of our mechanism especially in the health sector where a change of personal behavior can have major implications, e.g. smoking, exercising and weight loss. In all of the above, decisions on the personal level add up to a large economic (cost) burden, so policymakers have an incentive to alter behavior. Moreover, behavior changes in these fields lead to instant or fast results.

Specifically, policymakers have a great rationale to intervene when it comes to tobacco smoking. WHO (2020) estimates that smoking tobacco costs households and governments over US$ 1.4 trillion annually in healthcare expenditures and productivity losses. More than 8 million people die every year from tobacco use, inclduing 1.2 million from second-hand smoke (WHO, 2020). Smoking is suspected to cause many diseases, including but not limited to infertility (both in men and women), delays in conceiving, increased risk of various cancer types (e.g. oral, throat, lung, cervix), type two diabetes, stroke and dementia (WHO, 2019). Therefore, the WHO recommends tax increases on tobacco products, directed especially toward young people (WHO, 2003, updated reprint 2004, 2005, Article 6). While our proposed mechanism might not be the right tool to prevent agents, especially young people, from starting to smoke, it could be useful in the fight to help people quit. Smoking cessation can be tracked by cotinin tests, which could be monitored by physicians or insurance companies in a policy-led program.

Another example relates to regular physical exercise. It is long established that exercise has major health benefits and can prevent disease (e.g. Fentem, 1978, 1994) or improve the course of disease (e.g. Scheewe *et al.*, 2012; Wonders *et al.*, 2019). As a result, regular exercise helps reduce healthcare expenditures and productivity losses. For example, in an experimental framework Towne Jr

[25]For an overview of literature and empirical evidence on discounting see Heal (2007)

et al. (2018) find that older adults (age 65 and older) in the intervention group increased their physical activity and ”among those insufficiently active at baseline there was a relative cost savings from baseline to 6 months over and above the estimated cost of the intervention estimated between $143 and $164 per participant”.

Lin *et al.* (2015) find significant positive effects of exercise on cardiorespiratory fitness (CRF) and other cardiometabolic biomarkers. With CRF being a major predictor of mortality, as ”low levels of CRF are associated with a high risk of cardiovascular disease, all-cause mortality, and mortality rates attributable to various cancers” (Ross *et al.*, 2016). Thus, policymakers have a great rationale to incentivize people to exercise more in order to increase health and lower costs. For instance, Myers *et al.* (2018) find significant effects of cardiorespiratory fitness on annual health care costs in veterans, with an annual cost reduction of $4,163 for each higher quartile of fitness.

Although exercising behavior can be difficult to observe, it can be proxied with gym attendance. Moreover, fitness trackers are available at reasonable costs and new generation devices monitor steps, heart rate and sleep, offer automated workout-tracking, GPS (to measure distances) and are water resistant. The Apple Watch Series 5 can even perform an ECG (electrocardiogram) on demand (Johnson, 2020). The data collected by these trackers can be monitored by physicians or insurance companies in a program that utilizes our proposed mechanism. As we noted before, one possible interpretation of our investment-payoff mechanism is the one of a self-bet. A study by Woerner (2018) suggests that matched centralized bets[26] prove effective in increasing gym attendance with an average of 38% more gym attendances in the treatment than in the control group. If the possible payoff would not depend on number of gym attendances but rather on the CRF level, matching would be obsolete, which might lower the workload required when introducing such a program.

In Hirt-Schierbaum and Ivets (2020) we show that the investment-payoff mechanism is also applicable and effective to use as a decentralized bet without matching in a weight-loss framework. According to the WHO, in 2016 more than 1.9 billion adults were overweight, including 650 million obese (WHO, 2016). That amounts to 39% (13% for obesity) of the worldwide population. Comparing the effects of obesity, smoking and problem drinking on medical problems and costs in the U.S. Sturm (2002) finds that obesity is the major cause for type two diabetes, hypertension and asthma. Additionally, his findings indicate that obesity has stronger associations with reduced quality of life, increased healthcare, and medication spending compared to smoking or drinking. The WHO advises policymakers to intervene at the global, regional and local level in order to tackle this global problem (Waxman, 2004). Here, the WHO suggests promoting a healthier lifestyle (exercise and healthy diet) and providing accurate information and nutrition labeling.

[26]In a matched centralized bet a policymaker matches people with similar characteristics, so that grouped participants are equally likely to win the bet.

We suggest that our investment-payoff mechanism can be implemented to help people succeed in weight loss. As the model describes, oftentimes knowledge about what would be considered the right choices is not always enough when SC costs are too high. Here, our suggested commitment mechanism helps agents to follow through with their intentions. Weight loss is easily observable by physicians or, as utilized by the program discussed in Hirt-Schierbaum and Ivets (2020) – DietBet – through photo- or video-verification of the participants on the scale. For policy interventions we would suggest the utilization of a body fat monitor to track the loss of body fat in percent rather than pure weight loss, which could include the loss of muscle mass due to unhealthy weight-loss approaches.

5.1.2 Challenges and Limitations in Application

When it comes to policy implementation of our mechanism, optimal goal setting is crucial. It should be possible to reach a pre-defined goal within a given time frame in a healthy fashion, i.e. not ”lose 10% of bodyweight within 1 month time”. On the other hand, in order to increase participants' health significantly it has to be challenging enough to reach the pre-defined goal, i.e. not ”lose 1% of bodyweight within 1 month time”. Moreover, as stated above, targeted behavior should be observable or traceable and the defined target should be reachable within a relatively short time frame.

Notably, this mechanism is aimed at individuals and tackles their behavior on the personal level. Since our mechanism seems to work better for naive pessimists and sophisticated agents, there is a need for policymakers to educate naive optimists and naive agents about their naiveté. This might be problematic. Findings of Zimmermann (2020) suggest that after failing at a SC task agents may learn about their naiveté, but over time this learning effect is lost. A possible explanation is that negative feedback is recalled with significantly lower accuracy, compared to positive feedback. But he also finds that if the monetary gains are large enough, the agents are willing to uncover unpleasant memories. This means agents need to be offered incentives in order to recall negative feedback in the long run. Thus, policy interventions such as offering information and education will only have short run effects, and will either have to be repeated regularly or policymakers will have to offer incentives for agents to recall that information in the long run.

Another point to keep in mind is that SC problems usually do not disappear after one period of time. This circumstance demands a repeated application of our suggested mechanism or an adapted version of it. Given that optimistic agents might fail to commit successfully, they might refrain from utilizing the mechanism a second time. In this case intervention from the policymaker is required to educate those types of agents about their former mistakes. Therefore, an extension of the model over more than one period should be considered in future work. Here, learning effects and possible habit formation should be considered.

6 Conclusion

Using a theoretical model, we develop an alternative explanation for the behavior that is usually referred to as preference reversal in the literature. We also offer an alternative commitment device: an investment-payoff combination in the form of a self-bet. This mechanism can help people follow through with their normatively-preferred behavior (e.g. weight loss, exercising goals, smoking cessation).

The theoretical model is inspired by Gul and Pesendorfer (2001) and is extended to allow for a random degree of motivation that influences the agents' *perceived cost of self-control*. We also introduce a heuristic bias into the model based on *how accurately* the agents predict their future self-control costs. This allows us to distinguish between different agent types (rational, sophisticated and (partially) naive) and analyze their behavior with respect to the proposed commitment mechanism.

We find that how agents benefit from the mechanism depends on their type, as overestimation of their own self-control might lead them to undercommit. Therefore, a situation where an agent has a preference for commitment, but fails to commit successfully, can alternatively be explained by our model as the overestimation of future motivation and, thus, the underestimation of future self-control costs.

We show that an investment-payoff mechanism can help overcome agents' self-control problems and incentivize (extrinsic) motivation by choosing higher investments/payoffs. Moreover, our mechanism proves to be more efficient than other well-known commitment devices, like carrots and sticks.

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