Repeated Moral Hazard under Habit Formation

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Version: February 14, 2009

(First Version: January 29, 2008)

Abstract

This paper explores the effect of habit formation on principal-agent problems. Even though habits increase the agent's willingness to save for any given allocation, we find a striking difference to the time-separable Rogerson (1985) model: At optimal contracts, the agent's marginal benefit of saving does *not* in general exceed his marginal cost. The paper shows how this finding depends on the correlation between the agent's marginal valuation of the (risk-free) bond and the wage scheme. As a consequence, we see that optimal contracts feature a positive marginal utility of saving if habit and consumption are complements.

Keywords: repeated moral hazard, habit formation, intertemporal wedge, optimal taxation

JEL Classification: D82, E21, H21

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1 Introduction

The traditional paradigm in economic theory is to assume that only *absolute* levels of consumption matter for a person's well-being, or utility. In particular, it is usually assumed that a person's current utility depends solely on the current level of consumption, but not on the personal consumption history. A growing line of the literature has argued that this way of describing and predicting economic behavior might be incorrect. Prominent examples are Ryder and Heal (1973), Abel (1990), Constantinides (1990), and Campbell and Cochrane (1999). The central hypothesis of these authors is that individuals form habits in the sense that they evaluate their current consumption level relative to a historical reference point.

While habit formation has already been extensively studied in a variety of economic fields, its impact on principal-agent problems has not been explored so far. This is somewhat surprising, since habituation seems to be especially important in employment contexts. Clark (1999), for instance, finds that job satisfaction is strongly positively correlated with recent changes in pay, but not with levels of pay. Grund and Sliwka (2007) draw a similar conclusion. Moreover, habit formation captures an important result from psychology: Repetition of a stimulus lowers the perception and response to it, as described by Helson (1964). This general observation is highly relevant for economic applications, as the review by Frederick and Loewenstein (1999) shows.

The present paper introduces habit formation into the repeated moral hazard model of Rogerson (1985). Rogerson's seminal insight is that optimal contracts satisfy the so-called Inverse Euler equation. This equation states that the agent's inverse marginal utility of consumption is a martingale. The present paper shows how habit formation changes the characterization of intertemporal optimality: For any optimal contract, the expected marginal costs of increasing the agent's utility must still be the same in each period. However, these costs now include effects of current pay on future preferences, so that the martingale property for inverse marginal utilities does not generalize.

The most important finding is that optimal allocations will not necessarily leave the agent with a wish to save (in risk-free bonds), contrary to the time-separable framework. We see that the agent will remain with a wish to save (borrow) if and only if his marginal valuation of bonds is negatively (positively) correlated with his inverse marginal utility of consumption in the next period. Since the inverse marginal utility of consumption is monotonic in wages, the negated correlation measures how well bonds hedge against income risk. The finding thus shows that the agent's marginal utility of saving will be positive if and only if the hedging value of bonds is positive. Note that this hedging value can be interpreted as the marginal incentive cost of bonds, or equivalently as the difference between the social marginal cost of bonds and the agent's individual marginal cost.

The sign of the correlation between the agent's marginal valuation of bonds and his inverse marginal utility of consumption depends on the habit effect of saving. When consumption and habit are complements, then the marginal utility of reducing the habit level is nonincreasing in consumption. Therefore, the habit effect of saving is nonpositively correlated with the inverse marginal utility of consumption. Since the marginal payoff of bonds is decreasing in consumption, the overall correlation will be negative. However, when consumption and habit are substitutes, the marginal utility of reducing the habit level is nondecreasing in consumption. This might outweigh the wealth effect of saving and make the correlation between the marginal valuation of bonds and the inverse marginal utility of consumption positive.

The two most commonly used specifications of habit formation are discussed in detail. For subtractive habits (e.g. Constantinides 1990), consumption and habit are complements. Hence, the agent is savings-constrained. The only qualitative difference to the time-separable model is the increased intertemporal slope of optimal compensation schemes. For multiplicative habits (e.g. Abel 1990), consumption and habit are substitutes if the coefficient of relative risk aversion is smaller than unity. The paper shows that in this case the agent is borrowing-constrained if the importance of habits is sufficiently large.

In a work that I became aware of after the completion of this paper, Grochulski and Kocherlakota (2008) also study a moral hazard environment with preferences that are not time-separable. Their paper focusses on the implementation of optimal allocations by a social security system, an important step that the current paper ignores. Grochulski and Kocherlakota discuss the possibility that the agent might be borrowing-constrained in an example, but do not identify the exact conditions under which this will happen. Moreover, their argument for borrowing constraints rests on the fact that they have two initial periods of borrowing and saving without any incentive problems. The present paper characterizes saving and borrowing constraints in a model where periods are symmetric and identifies the key role of the covariance between the agent's valuation of the bond and his inverse marginal utility of consumption.

The paper can also be seen as a complement to the recent literature on effort persistence, which extends the Rogerson (1985) framework by allowing for a technology that is not time-separable. Ogawa (2004), Mukoyama and Sahin (2005), and Kwon (2006) all show that a persistent effect of effort on future outcomes tends to make wages less responsive to performances in early periods. At the extreme, compensation may depend on the outcome of the final period only. Mukoyama and Sahin (2005) show that effort persistence does not change the Inverse Euler equation. Therefore, effort persistence has no effect on the intertemporal distribution of wages and does not help in overcoming the prediction that wages decrease over time for many generic utility functions.

The paper proceeds as follows: Section 2 describes the setup of the model. Section 3.1 derives the Euler equation for the principal. Section 3.2 studies saving and borrowing constraints included in optimal contracts. In Sections 4.1 and 4.2, the subtractive and the multiplicative formulation of habit formation are explored. Section 5 concludes.

2 Model

The relationship between Principal (P) and Agent (A) lasts for two periods. In each period, A exerts a hidden effort $e' \in \mathcal{E}$, which generates a stochastic output $x \in \{x_1, \dots, x_n\}$. The effort set $\mathcal{E}$ may be discrete or continuous. The output is distributed with positive probability weights $(p_1(e'), \dots, p_n(e'))$. P observes outputs, but not A's effort choices.

A (long-term) **contract** is a tuple (w, e) consisting of $n+n^2$ wages, $w = ((w_i)_{i=1}^n, (w_{ij})_{i,j=1}^n)$, and $n+1$ effort levels, $e = (e_0, (e_i)_{i=1}^n)$. e_0 is the prescribed effort for period 1, e_i the prescribed effort for period 2 given that x_i has occurred in period 1; w_i is the wage paid in period 1, w_{ij} the wage paid in period 2 given that outputs (x_i, x_j) have occurred. P offers a contract at the beginning of the first period. A's outside option delivers a utility of $\underline{U}$.

Preferences are as follows. P maximizes expected profits, calculated as

$$\sum_{i,j=1}^{n} p_i(e_0)p_j(e_i)\Big(x_i - w_i + \alpha(x_j - w_{ij})\Big), \tag{1}$$

where $\alpha \in (0, 1]$ is her discount factor. P can save and borrow at the (risk-free) interest rate r, therefore $\alpha = 1/(1+r)$.

A maximizes expected utility, which is additively separable into consumption utility and effort disutility. A can neither save nor borrow. Hence, consumption equals wage in each period. The novel feature of this paper is that A forms consumption habits. Consumption utility in period 2 is hence history dependent. A maximizes utility

$$\sum_{i,j=1}^{n} p_i(e_0)p_j(e_i)\Big(u_1(w_i) - v(e_0) + \beta(u_2(w_{ij}, w_i) - v(e_i))\Big) \tag{2}$$

over effort plans. $\beta \in (0,1]$ is his discount factor. u_1 is C^2, increasing and strictly concave; u_2 is C^2, increasing and strictly concave in its first argument, and nonincreasing in its second argument. Moreover, for each $c_2 > 0$, $\lim_{c_1 \to 0} (u'(c_1) + \beta \partial_{c_1} u_2(c_2, c_1)) = \infty$.

To facilitate notation set $U(c_1, c_2) := u_1(c_1) + \beta u_2(c_2, c_1)$. U is called **time-separable** if u_2 does not depend on c_1. The time-separable case has been studied by Rogerson (1985).

3 General results on intertemporal optimality

Definition. A contract (w, e) is **optimal** if it maximizes expected profits subject to incentive compatibility and individual rationality, i.e., if it solves

$$\max_{(w,e)} \quad \sum_{i,j} p_i(e_0)p_j(e_i)\Big(x_i - w_i + \alpha(x_j - w_{ij})\Big) \tag{3}$$

s.t.

$$e \in \operatorname*{argmax}_{(e_0', (e_i'))} \sum_{i,j} p_i(e_0')p_j(e_i')\Big(u_1(w_i) - v(e_0') + \beta(u_2(w_{ij}, w_i) - v(e_i'))\Big) \tag{IC}$$

$$\sum_{i,j} p_i(e_0)p_j(e_i)\Big(u_1(w_i) - v(e_0) + \beta(u_2(w_{ij}, w_i) - v(e_i))\Big) \geq \underline{U}. \tag{PC}$$

3.1 Optimal division of rewards

The advantage of the long-term relationship is that the principal obtains more flexibility in incentivizing the agent. Rewards for good date 1 performance need not be given immediately, but can also be embedded into date 2 wages (which then makes these wages dependent on the first period output). If at least one of the parties is risk-averse, as in the model considered here, then it is clearly beneficial to make use of this ability.

This has an important influence on the shape of optimal contracts.

Proposition 1. *Let* (w, e) *be an optimal contract. Then for all* $i = 1, \ldots, n$

$$\frac{\alpha}{\beta} \sum_j \frac{p_j(e_i)}{\partial_{c_2} u_2(w_{ij}, w_i)} = \frac{1}{u_1'(w_i)} \left(1 - \alpha \sum_j p_j(e_i) \frac{\partial_{c_1} u_2(w_{ij}, w_i)}{\partial_{c_2} u_2(w_{ij}, w_i)} \right). \tag{4}$$

Proof. The proof is a simple extension of the argument in Rogerson (1985). Let $\phi(\cdot)$ be the inverse of $u_1(\cdot)$ and $\psi(\cdot, c_1)$ be the inverse of $u_2(\cdot, c_1)$. For $\epsilon \in \mathbb{R}$, construct a wage scheme $w(\epsilon)$ from w as follows. Along the x_i branch (for some fixed i), increase date 1 utility by ϵ, and reduce date 2 utility by ϵ/β. Leave the other branches unchanged. Formally, set

$$w_k(\epsilon) := \begin{cases} w_k & \text{for } k \neq i, \\ \phi(u_1(w_i) + \epsilon) & \text{for } k = i, \end{cases} \tag{5}$$

$$w_{kj}(\epsilon) := \begin{cases} w_{kj} & \text{for } k \neq i, \\ \psi(u_2(w_{ij}, w_i) - \epsilon/\beta, w_i(\epsilon)) & \text{for } k = i. \end{cases} \tag{6}$$

The incentive and participation constraints under $w(\epsilon)$ and $w = w(0)$ coincide. Hence, a necessary condition for optimality of (w, e) is that expected wage payments are minimal at $\epsilon = 0$. That is, $\epsilon = 0$ must minimize

$$\phi(u_1(w_i) + \epsilon) + \alpha \sum_j p_j(e_i) \psi(u_2(w_{ij}, w_i) - \epsilon/\beta, w_i(\epsilon)), \tag{7}$$

which implies

$$0 = \frac{1}{u_1'(w_i)} + \alpha \sum_j p_j(e_i) \left(-\frac{1}{\beta\, \partial_{c_2} u_2(w_{ij}, w_i)} - \frac{\partial_{c_1} u_2(w_{ij}, w_i)}{u_1'(w_i)\, \partial_{c_2} u_2(w_{ij}, w_i)} \right). \tag{8}$$

Equivalently,

$$\frac{\alpha}{\beta} \sum_j \frac{p_j(e_i)}{\partial_{c_2} u_2(w_{ij}, w_i)} = \frac{1}{u_1'(w_i)} \left(1 - \alpha \sum_j p_j(e_i) \frac{\partial_{c_1} u_2(w_{ij}, w_i)}{\partial_{c_2} u_2(w_{ij}, w_i)} \right). \tag{9}$$

□

Equation (4) means that rewards for period 1 performance are divided optimally over time:

Dropping arguments and using shorthand notation $E_i[\,\cdot\,]$ for expectations with respect to the distribution $(p_j(e_i))_j$, the cost of increasing u_2 by ϵ/β is approximately equal to

$$\alpha\frac{\epsilon}{\beta}E_i\Big[\frac{1}{\partial_{c_2}u_2}\Big]. \tag{10}$$

The cost of increasing u_1 by ϵ while keeping u_2 constant is approximately equal to

$$\frac{\epsilon}{u_1'}-\alpha\frac{\epsilon}{u_1'}E_i\Big[\frac{\partial_{c_1}u_2}{\partial_{c_2}u_2}\Big], \tag{11}$$

where the first term denotes the increase of period 1 consumption required to raise u_1 by ϵ, and the second term stands for the increase of period 2 consumption required to keep u_2 at the former level. Proposition 1 thus states that within each branch $(w_i,(w_{ij})_j)$ of an optimal contract these two costs are the same.

If U is time-separable, with $u_1=u_2=u$, (4) collapses to

$$\frac{1}{u'(w_i)}=\frac{\alpha}{\beta}\sum_j p_j(e_i)\frac{1}{u'(w_{ij})}. \tag{12}$$

This well-known result from Rogerson (1985) is often called the Inverse Euler equation. We have seen above that this relation between inverse marginal utilities does not generalize to preferences with habit formation. However, the Inverse Euler equation is not to be interpreted in terms of A's marginal utility, but in terms of P's marginal costs of rewarding A. In this sense, equations (4) and (12) are Euler equations for the *principal*, both stating that the marginal costs of rewards are the same for both periods.

3.2 Saving and borrowing constraints

This section uses the Euler equation (4) to examine what A would do if he could save and borrow at the same rate as P. The (risk-free) interest rate for saving and borrowing is r, the interest factor is denoted $R=1+r$. The output realization of period 1, x_i, is fixed throughout this section. Hence all expectations and covariances are calculated with respect to the distribution $(p_j(e_i))_j$, and are denoted $E_i[\,\cdot\,]$ and $\text{cov}_i(\,\cdot\,,\,\cdot\,)$ to signal the conditioning on period 1 information.

I call A **savings-constrained/borrowing-constrained** if the marginal utility of saving,

$$\beta \sum_j p_j(e_i) \left[R\partial_{c_2} u_2(w_{ij}, w_i) - \partial_{c_1} u_2(w_{ij}, w_i)\right] - u_1'(w_i), \tag{13}$$

is positive/negative. The marginal utility of saving is often referred to as the intertemporal wedge and has the following representation.

Proposition 2. *At an optimal contract, conditional on period 1 output x_i, A's marginal utility of saving equals*

$$-\frac{\beta}{E_i[1/\partial_{c_2} u_2(w_{ij}, w_i)]} \operatorname{cov}_i \left(R\partial_{c_2} u_2(w_{ij}, w_i) - \partial_{c_1} u_2(w_{ij}, w_i), \frac{1}{\partial_{c_2} u_2(w_{ij}, w_i)} \right). \tag{14}$$

Hence, A is savings-constrained (borrowing-constrained) if and only if

$$\operatorname{cov}_i \left(R\partial_{c_2} u_2(w_{ij}, w_i) - \partial_{c_1} u_2(w_{ij}, w_i), \frac{1}{\partial_{c_2} u_2(w_{ij}, w_i)} \right) < 0 \ (> 0). \tag{15}$$

Proof. Dropping arguments w_i and (w_{ij}, w_i), the marginal utility of saving can be written as

$$\beta E_i[R\partial_{c_2} u_2 - \partial_{c_1} u_2] - u_1'. \tag{16}$$

Rewriting (4) and using $\alpha = 1/R$ shows

$$u_1' = \beta \frac{R - \operatorname{cov}_i(\partial_{c_1} u_2, \frac{1}{\partial_{c_2} u_2})}{E_i[\frac{1}{\partial_{c_2} u_2}]} - \beta E_i[\partial_{c_1} u_2]. \tag{17}$$

Substitute this into (16) to see that the marginal utility of saving equals

$$\beta \frac{\operatorname{cov}_i(\partial_{c_1} u_2, \frac{1}{\partial_{c_2} u_2}) - R}{E_i[\frac{1}{\partial_{c_2} u_2}]} + \beta E_i[R\partial_{c_2} u_2]. \tag{18}$$

Now the result follows from

$$E_i[R\partial_{c_2} u_2] E_i[\frac{1}{\partial_{c_2} u_2}] - R = -\operatorname{cov}_i(R\partial_{c_2} u_2, \frac{1}{\partial_{c_2} u_2}). \tag{19}$$

□

At an optimal contract, the difference between the social marginal benefit and the social marginal cost of saving must be zero (cp. Golosov, Kocherlakota, and Tsyvinski 2003). It is important to note that the social cost of saving differs from the private cost, because saving affects the incentive compatibility constraint. The difference between the social and the private cost can thus be understood as the incentive cost of saving. Since the social marginal utility of saving is zero at an optimal contract, it follows that the agent's marginal utility of saving coincides with the marginal incentive cost.

Following this interpretation, Proposition 2 shows that at an optimal contract the marginal incentive cost of bonds is a multiple of

$$-\operatorname{cov}_i\left(R\partial_{c_2}u_2(w_{ij},w_i)-\partial_{c_1}u_2(w_{ij},w_i),\frac{1}{\partial_{c_2}u_2(w_{ij},w_i)}\right). \tag{20}$$

The first variable in this covariance, $R\partial_{c_2}u_2 - \partial_{c_1}u_2$, is A's marginal valuation of the bond (excluding the cost u_1', which plays no role for the covariance). The second variable, $1/\partial_{c_2}u_2$, is a monotonic function of the second period wage. Therefore, (20) measures the value of bonds as a hedge against bad income realizations. If the hedging value is positive, then holding bonds will reduce the agent's incentive to exert effort and make the incentive cost of saving positive. Analogously, the incentive cost of saving will be negative if the hedging value of bonds is negative.

An alternative representation of the intertemporal wedge can be derived as follows. Suppose that effort is chosen from a real interval, and let the probability weights be differentiable. It is well-known that optimal contracts satisfy

$$\frac{1}{\partial_{c_2}u_2(w_{ij},w_i)}=\lambda_i+\mu_i\frac{p_j'(e_i)}{p_j(e_i)}, \tag{21}$$

where μ_i is the Lagrange multiplier for the second period incentive constraint. Hence, the intertemporal wedge equals

$$IW = -\frac{\beta}{E_i[1/\partial_{c_2}u_2]}\operatorname{cov}_i\left(R\partial_{c_2}u_2-\partial_{c_1}u_2,\frac{1}{\partial_{c_2}u_2}\right) \tag{22}$$

$$= \frac{\mu_i\beta}{\lambda_i}\operatorname{cov}_i\left(R\partial_{c_2}u_2-\partial_{c_1}u_2,-\frac{p_j'}{p_j}\right) \tag{23}$$

The negative likelihood ratio, $-p_j'(e_i)/p_j(e_i)$, indicates whether P has a reason to punish A. The marginal incentive cost of saving is thus a multiple of the covariance of this punishment indicator with the marginal valuation of bonds.[1]

Different from moral hazard problems with time-separable preferences, the marginal utility of saving is not generally positive in the present model. However, Proposition 2 implies that Rogerson's (1985) insight on saving constraints generalizes to preferences with habit formation as follows.

Corollary 3. *Let (w, e) be optimal, and suppose $w_{ij} \neq w_{ij'}$ for some j, j'.*[2] *If the utility of second period consumption, $u_2(c_2, c_1)$, is supermodular, then A is savings-constrained.*

Proof. Supermodularity of u_2 means $\partial_{c_1}\partial_{c_2}u_2 \geq 0$. Thus, $-\partial_{c_1}u_2(w_{ij}, w_i)$ is nonincreasing in w_{ij}. Since $1/\partial_{c_2}u_2(w_{ij}, w_i)$ is increasing in w_{ij}, this implies

$$\mathrm{cov}_i\left(-\partial_{c_1}u_2(w_{ij}, w_i), \frac{1}{\partial_{c_2}u_2(w_{ij}, w_i)}\right) \leq 0. \tag{24}$$

Using

$$\mathrm{cov}_i\left(\partial_{c_2}u_2(w_{ij}, w_i), \frac{1}{\partial_{c_2}u_2(w_{ij}, w_i)}\right) < 0, \tag{25}$$

the statement follows from Proposition 2. □

The supermodularity of u_2 implies that the marginal utility of decreasing the habit level, $-\partial_{c_1}u_2$, is high whenever second period consumption is low. Since the marginal utility generated by the payoff of the bond, $R\partial_{c_2}u_2$, is due to concavity also high whenever second period consumption is low, this implies that the incentive cost of saving is positive. Thus, under supermodularity, the agent's marginal utility of saving is positive at any optimal contract.

Note that if the utility function for period 2 is submodular (consumption and habit are substitutes), then the habit effect and the wealth effect of saving will have opposite signs. If the habit effect is sufficiently large, this will make the covariance in Proposition 2 positive (see Example 2 on page 19). In this case, saving will have a socially beneficial effect on the incentive problem, and hence the agent's marginal utility of saving will be negative at the optimum.

[1] Measuring the hedging value of bonds as in (20) has the advantage that the formula can be applied to any specification of technology. In addition, there is no necessity to show that the Lagrange multiplier is positive.

[2] The case with $w_{ij} = w_{ij'}$ for all j, j' is not interesting. It corresponds to the implementation of minimal effort.

An entirely distinct reason for a negative intertemporal wedge is explored by Albanesi (2006), who studies the moral hazard problem of entrepreneurial activity. Entrepreneurial capital changes the effectiveness of the incentive scheme in two opposing ways in her model. In addition to the standard negative wealth effect, there is a positive effect because the return to entrepreneurial capital depends on the entrepreneur's effort. If the second effect dominates, then entrepreneurial capital will have a negative hedging value, and thus the entrepreneur's marginal utility of increasing entrepreneurial capital will be negative at the optimum.

The next section studies two functional forms of habit formation. For subtractive habits, consumption and habit are complements. For multiplicative habits, consumption and habit can be substitutes. In this case, the agent will be borrowing constrained if the importance of habit formation is sufficiently large compared to the agent's risk aversion.

4 Subtractive and multiplicative habits

In this section, I explore the two most commonly used models of habit formation, the subtractive and the multiplicative specification. Among many others, Constantinides (1990), Lahiri and Puhakka (1998), and Campbell and Cochrane (1999) model habit formation in a subtractive way. Prominent examples of the multiplicative approach are Abel (1990) and Carroll, Overland, and Weil (1997, 2000).

4.1 Subtractive habits

Let $u : \mathbb{R}_+ \to \mathbb{R}$ be C^2, increasing, strictly concave, $\lim_{c\to 0} u'(c) = \infty$, $\gamma \in [0, 1]$. Set

$$\begin{aligned} u_1(c_1) &:= u(c_1), \\ u_2(c_2, c_1) &:= u(\tilde{c}_2), \quad \tilde{c}_2 := c_2 - \gamma c_1. \end{aligned} \tag{26}$$

Equivalently, $\tilde{c}_2 = (1-\gamma)c_2 + \gamma(c_2 - c_1)$, i.e., **effective consumption** in period 2 is a weighted average of nominal consumption per se and nominal consumption minus the habit level. The parameter γ controls the intensity of habits: The higher the value of γ, the more the agent cares about how period 2 consumption relates to period 1 consumption.

Since P's objective function is linear in wages, the subtractive formulation of habits affects the contracting problem in a simple way. Except for a factor $(1 + \alpha\gamma)$ attached to date 1 wages, P faces a standard repeated moral hazard problem with time-separable preferences, as the following proposition shows.

Proposition 4. *Let A's preferences be given by* (26)*. Then the contracting problem is equivalent to a contracting problem with time-separable utility in which P attaches a factor* $(1+\alpha\gamma)$ *to wages paid at date 1.*

Proof. P's problem is

$$\max_{(w,e)} \sum_{i,j} p_i(e_0)p_j(e_i)\Big(x_i - w_i + \alpha(x_j - w_{ij})\Big)$$

s.t.

$$e \in \operatorname*{argmax}_{(e_0',(e_i'))} \sum_{i,j} p_i(e_0')p_j(e_i')\Big(u(w_i) - v(e_0') + \beta(u(w_{ij} - \gamma w_i) - v(e_i'))\Big)$$

$$\sum_{i,j} p_i(e_0)p_j(e_i)\Big(u(w_i) - v(e_0) + \beta(u(w_{ij} - \gamma w_i) - v(e_i))\Big) \geq \underline{U}.$$

Substituting $\tilde{w}_{ij} = w_{ij} - \gamma w_i$, this can be rewritten as

$$\max_{((w_i,\tilde{w}_{ij}),e)} \sum_{i,j} p_i(e_0)p_j(e_i)\Big(x_i - (1+\alpha\gamma)w_i + \alpha(x_j - \tilde{w}_{ij})\Big)$$

s.t.

$$e \in \operatorname*{argmax}_{(e_0',(e_i'))} \sum_{i,j} p_i(e_0')p_j(e_i')\Big(u(w_i) - v(e_0') + \beta(u(\tilde{w}_{ij}) - v(e_i'))\Big)$$

$$\sum_{i,j} p_i(e_0)p_j(e_i)\Big(u(w_i) - v(e_0) + \beta(u(\tilde{w}_{ij}) - v(e_i))\Big) \geq \underline{U},$$

which concludes the proof. □

This result shows that subtractive habits increase the costs associated with wages paid in the first period. In addition to the direct cost, there is now also a cost due to the formation of habits: If the habit parameter γ is positive, then wages paid in period 1 have a negative effect on the agent's utility in period 2. The principal has to account for this effect in her optimization problem, which generates the aforementioned factor.

Subtractive habits do not change Rogerson's (1985) result that A will remain with a wish to save, as the next proposition shows.

Proposition 5. *Let (w, e) be an optimal contract, and suppose that for each i there exist j, j' such that $w_{ij} \neq w_{ij'}$. Then A is savings-constrained.*

Proof. Note $\partial_{c_1}\partial_{c_2}u_2(w_{ij}, w_i) = -\gamma u''(c_2 - \gamma c_1) \geq 0$. Hence the statement follows from Corollary 3.[3] □

Since for the subtractive specification consumption and habit are complements, the wealth effect and the habit effect of saving go the same direction. Both effects imply that the intertemporal wedge is positive, as argued in Section 3.2.

The remainder of this section discusses the comparative statics of optimal wage profiles in the habit parameter.

Under time-separable utility, the intertemporal slope of wages is determined by the curvature of inverse marginal utility, as Rogerson (1985) has shown. If inverse marginal utility is strictly convex, then expected compensation would be decreasing over time, which is opposite to empirical findings. The convexity requirement is satisfied in many generic cases, for instance for CRRA utility with a coefficient of relative risk aversion larger than one.

If the agent forms habits, then the intertemporal slope of wages does not solely depend on the curvature of inverse marginal utility, but also on the intensity of habits. For logarithmic utility, the functional relation between the slope of wages and the habit intensity γ is particularly simple.

Example 1. Let $u(c) = \log(c)$, $\alpha = \beta$. The condition for intertemporal optimality of rewards takes the form

$$\sum_j p_j(e_i)\frac{1}{u'(\tilde{w}_{ij})} = \frac{1}{u'(w_i)}(1 + \alpha\gamma), \tag{27}$$

which implies

$$\frac{\sum_j p_j(e_i)w_{ij}}{w_i} = 1 + (1 + \alpha)\gamma. \tag{28}$$

Thus, expected wages are exactly constant over time if the agent does not form habits. If he does, expected wages are increasing over time. Moreover, the ratio between expected wages

[3] The reader may wonder why the analogy of the contracting problem to a model with time-separable utility does not immediately imply that A is savings-constrained. However, due to the extra factor $(1 + \alpha\gamma)$ in that model, it only follows that A is savings-constrained with respect to the interest factor $(1 + \alpha\gamma)R$.

paid in period 2 and period 1 is increasing in the habit parameter γ.

In this example, expected compensation was increasing over time for any positive habit intensity γ. More generally, no matter what utility function is chosen, expected compensation will increase over time if the habit intensity is sufficiently large, as the following proposition shows.

Proposition 6. *Let $\gamma = 1$. If (w, e) is an optimal contract, then $w_{ij} > w_i$ for all i, j.*

Proof. For $\gamma = 1$, period 2 utility takes the form $u_2(w_{ij}, w_i) = u(w_{ij} - w_i)$. Therefore, the statement follows immediately from the assumption $u'(0) = \infty$. □

The ratio between expected wages paid at date 2 and date 1 was a monotonic function of the habit parameter γ in the above example. This result can be generalized. However, for non-logarithmic utility, the condition for intertemporal optimality of rewards cannot be solved for wages. The shape of wages can only be studied if one includes the incentive and participation constraint in the analysis. To keep things tractable, I study the simplest possible case: no discounting, $\alpha = \beta = 1$; two effort levels, $\mathcal{E} = \{l, h\}$; and two outputs, $\{x_L, x_H\}$, $x_L < x_H$. Probability distributions satisfy $p_H(l) < p_H(h)$, and effort costs are $v(l) = 0$, $v(h) = v > 0$. Set $v' := v/(p_H(h) - p_H(l))$. Suppose P wants to implement effort h in both periods (i.e., $x_H - x_L$ is sufficiently large).

I call w an **optimal wage scheme** if (w, e), with effort vector $e = (h, h, h)$, is an optimal contract. Optimal wage schemes are characterized as follows:

$$\frac{1+\gamma}{u'(w_H)} - p_H(h)\frac{1}{u'(w_{HH} - \gamma w_H)} - (1 - p_H(h))\frac{1}{u'(w_{HL} - \gamma w_H)} = 0 \tag{29}$$

$$\frac{1+\gamma}{u'(w_L)} - p_H(h)\frac{1}{u'(w_{LH} - \gamma w_L)} - (1 - p_H(h))\frac{1}{u'(w_{LL} - \gamma w_L)} = 0 \tag{30}$$

$$u(w_{HH} - \gamma w_H) - u(w_{HL} - \gamma w_H) - v' = 0 \tag{31}$$

$$u(w_{LH} - \gamma w_L) - u(w_{LL} - \gamma w_L) - v' = 0 \tag{32}$$

$$u(w_H) + u(w_{HL} - \gamma w_H) + 2v'p_H(l) - v' - \underline{U} = 0 \tag{33}$$

$$u(w_L) + u(w_{LL} - \gamma w_L) + 2v'p_H(l) - \underline{U} = 0. \tag{34}$$

Here, (29),(30) are the intertemporal optimality conditions, (31),(32) ensure incentive compatibility of second period effort, (33),(34) ensure incentive compatibility of first period effort, and together with (31),(32) also imply that the participation constraint is satisfied.

This system of six equations can be separated into two subsystems with three equations each—one system determining w_H, w_{HL}, w_{HH}, and one determining w_L, w_{LL}, w_{LH}. The comparative statics in the habit parameter γ are as follows.

Proposition 7. *Let w be the optimal wage scheme in the two-effort two-output model described above. Then for each i, j, the ratio w_{ij}/w_i is increasing in γ.*

Proof. Let $i = H$. (The case $i = L$ is exactly analogous.) Applying the implicit function theorem to the system of equations (29),(31),(33) yields

$$\begin{aligned}
\frac{\partial w_H}{\partial \gamma} &= -\frac{1}{D} u'(w_H) u'(\tilde{w}_{HL})^3 u'(\tilde{w}_{HH})^3 \\
\frac{\partial w_{HH}}{\partial \gamma} &= w_H + \frac{1}{D} u'(w_H) u'(\tilde{w}_{HL})^3 u'(\tilde{w}_{HH})^2 [u'(w_H) - \gamma u'(\tilde{w}_{HH})] \\
\frac{\partial w_{HL}}{\partial \gamma} &= w_H + \frac{1}{D} u'(w_H) u'(\tilde{w}_{HL})^2 u'(\tilde{w}_{HH})^3 [u'(w_H) - \gamma u'(\tilde{w}_{HL})],
\end{aligned}$$

where

$$\begin{aligned}
D = {} & (-1 + p_H(h)) u'(w_H)^3 u'(\tilde{w}_{HH})^3 u''(\tilde{w}_{HL}) \\
& - u'(\tilde{w}_{HL})^3 [(1+\gamma) u'(\tilde{w}_{HH})^3 u''(w_H) + p_H(h) u'(w_H)^3 u''(\tilde{w}_{HH})] \\
& > 0.
\end{aligned}$$

Hence, the expression $\frac{\partial w_{HH}}{\partial \gamma} w_H - w_{HH} \frac{\partial w_H}{\partial \gamma}$ is equal to

$$w_H^2 + \frac{1}{D} u'(w_H) u'(\tilde{w}_{HL})^3 u'(\tilde{w}_{HH})^2 \left[w_H u'(w_H) + (w_{HH} - \gamma w_H) u'(\tilde{w}_{HH}) \right],$$

which is larger than zero. This shows that the ratio w_{HH}/w_H is increasing in γ. Monotonicity of w_{HL}/w_H can be seen analogously. □

The intuition underlying Proposition 7 is straightforward. If A's habit intensity increases, he requires a higher compensation for the "comparison effects" generated by date 1 wages. This makes wages paid at date 1 more costly relative to wages paid at date 2, hence P substitutes.

4.2 Multiplicative habits

Let $u : \mathbb{R}_+ \to \mathbb{R}$ be C^2, increasing, strictly concave, $\lim_{c\to 0} u'(c) = \infty$, $\gamma \in [0,1]$, $b \geq 0$. Set

$$\begin{aligned} u_1(c_1) &:= u(c_1), \\ u_2(c_2, c_1) &:= u(\hat{c}_2), \quad \hat{c}_2 := c_2/(b+c_1)^\gamma. \end{aligned} \tag{35}$$

Effective consumption in period 2 can be rewritten $\hat{c}_2 = c_2^{1-\gamma}(c_2/(b+c_1))^\gamma$. That is, effective consumption is a Cobb-Douglas aggregate of nominal consumption per se and nominal consumption relative to the habit level $(b+c_1)$. The parameter γ is the weight attached to the latter term. For an agent with a higher value of γ, the comparison between date 2 consumption and date 1 consumption thus gets more important in this sense.

The introduction of b in the habit term is a technical necessity for this specification. Note that for $b = 0$ one obtains

$$u'(c_1) + \beta \partial_{c_1} u_2(c_2, c_1) = u'(c_1) - \beta\gamma c_1^{-\gamma-1} c_2 u'(\hat{c}_2). \tag{36}$$

Hence, in this case the assumption $u'(0) = \infty$ is no longer sufficient for the condition

$$\forall c_2 > 0 \quad \lim_{c_1 \to 0} \big(u'(c_1) + \beta \partial_{c_1} u_2(c_2, c_1)\big) = \infty, \tag{37}$$

which is needed to make sure that solutions are interior. In fact, for certain utility functions the marginal utilities in (37) might even converge to $-\infty$ for all $c_2 > 0$, implying non-existence of a solution. The following lemma shows that for $b > 0$ the problem does not arise. It also shows that a positive b is not required for CRRA utility with a risk aversion coefficient larger than one.

Lemma 8. *Either of the following conditions is sufficient for* (37)*:*

(i) $b > 0$, $u'(0) = \infty$,

(ii) $b \geq 0$, $u(c) = \frac{1}{1-\rho} c^{1-\rho}, \rho > 1$,

(iii) $b \geq 0$, $u(c) = \log(c)$.

Proof. Note

$$u'(c_1) + \beta\partial_{c_1} u_2(c_2, c_1) = u'(c_1) - \beta\gamma(b + c_1)^{-\gamma-1} c_2 u'(\tilde{c}_2). \tag{38}$$

If b is positive, this converges to $u'(0) - \beta\gamma c_2 u'(c_2/b^\gamma)/b^{1+\gamma}$, which shows that (i) suffices. If $b = 0$, and $u'(c) = c^{-\rho}$, the expression above can be rewritten as

$$c_1^{-\rho} - \beta\gamma c_1^{-\gamma-1} c_2 \left(\frac{c_2}{c_1^\gamma}\right)^{-\rho}, \tag{39}$$

which is the same as

$$c_1^{-\rho}\left(1 - \beta\gamma c_2^{1-\rho} c_1^{-1-\gamma+\gamma\rho+\rho}\right). \tag{40}$$

Since $-1 - \gamma + \gamma\rho + \rho \geq 0$ is equivalent to $\rho \geq 1$, (ii) and (iii) are each sufficient. □

In what follows, I always assume that one of the conditions of Lemma 8 is valid. It is understood that assuming $b > 0$ does not change the intuition behind the specification at all. The assumption merely makes sure that driving consumption in period 1 to zero does not lead to habit effects that generate arbitrarily high utility levels in period 2.[4]

The multiplicative formulation of habits involves a second important problem. In contrast to the subtractive formulation, the marginal rate of substitution between current and future consumption does not generally decrease in the parameter γ. Thus, the number of marginal date 2 consumption units the agent requires in exchange for one marginal date 1 consumption unit might *increase* with γ. This goes against the intuition underlying habit formation, as for instance Wendner (2003) has argued. Hence, the parameter γ is not always a sensible measure of the importance of habits for this specification.

For certain parameter ranges, e.g., CRRA utility with $\rho > 1$, $b+c_1 > 1$, or $\rho < 1$, $b+c_1 < 1$, this problem does not arise.[5] But the comparative statics in the habit parameter γ prove still intractable. Even for the first best solution the sign of the derivative of w_2/w_1 with respect to γ cannot be determined.[6] Yet, at least for all the two-effort two-output examples I have

[4]Alternatively, one could achieve this by defining effective consumption for instance as $\hat{c}_2 := c_2/(\alpha\bar{c} + (1-\alpha)c_1)^\gamma$, with $\bar{c} > 0$ being exogenous. In this case, A's habit level would be a weighted average of last period's consumption and of a variable that may represent things like older consumption levels or consumption levels of a third party. However, the difference between the two approaches seems to be negligible, so I stick to definition (35) for simplicity.

[5] For CRRA utility, the marginal rate of substitution between current and future consumption is $\partial_{c_1} U(c_1, c_2)/\partial_{c_2} U(c_1, c_2) = \beta c_1^{-\rho} c_2^{\rho} \exp(-\gamma(\rho - 1)\log(b + c_1)) - \gamma c_2(b + c_1)^{-1}$.

[6]Consider for example the two-effort two-output model with CRRA utility, $\rho > 1$, $b = 0$. One can use the implicit function theorem to show that the sign of the derivative of w_2^{FB}/w_1^{FB} with respect to γ is nonnegative

numerically studied, the comparative statics of the optimal contract were well-behaved as long as the contract fell into one of the two ranges specified above. One such example is depicted at the end of this section.

The next proposition is the main result of this section. It shows that multiplicative habits change the fundamental insight of Rogerson's (1985) time-separable model: The agent does not generally remain with a wish to save.

Proposition 9. *Let A's preferences be given by* (35)*, let* (w, e) *be an optimal contract and suppose that for each* i *there exist* j, j' *such that* $w_{ij} \neq w_{ij'}$*. Then the following holds true.*
(i) A is not savings-constrained in general.
(ii) A is savings-constrained if A's coefficient of relative risk-aversion, $\rho^r(\hat{c}_2) = -\hat{c}_2 \frac{u''(\hat{c}_2)}{u'(\hat{c}_2)}$*, is bounded below by 1.*

Proof. (i) See Example 2.
(ii) The assumption $\rho^r \geq 1$ implies $-u'(\hat{w}_{ij}) - \hat{w}_{ij} u''(\hat{w}_{ij}) \geq 0$ for all $\hat{w}_{ij}$. Hence,

$$-\gamma(b + w_i)^{-1-\gamma} u'(w_{ij}(b + w_i)^{-\gamma}) - (b + w_i)^{-1-2\gamma} w_{ij} u''(w_{ij}(b + w_i)^{-\gamma}) \geq 0 \qquad (41)$$

for all w_i, w_{ij}. This is equivalent to $\partial_{c_1}\partial_{c_2} u_2 \geq 0$. Hence, A is savings-constrained by Corollary 3. □

The reason why the agent's marginal utility of saving is not always positive has already been pointed out at the end of Section 3.2: While in the time-separable model A's valuation of the bond is always negatively correlated with P's desire to reward, this is no longer the case for the model with multiplicative habits. If consumption and habit are substitutes, which happens exactly when the coefficient of relative risk aversion is smaller than one, then the correlation

if and only if

$$\frac{w_1^{2\rho} w_2^2(-1+\gamma) - w_1^{2+2\gamma}\hat{w}_2^{2\rho}(-1+\rho)\log(w_1) - w_1^{1+\gamma+\rho} w_2 \hat{w}_2^{\rho}(1 + (-1+\rho)\log(w1))}{w_1^{2\rho} w_2^2(-1+\gamma)\gamma + w_1^{2+2\gamma}\hat{w}_2^{2\rho}\rho + w_1^{1+\gamma+\rho} w_2 \hat{w}_2^{\rho}(-2\gamma+\rho)} \geq 0.$$

Under the assumption $w_1 > 1$, which guarantees that the marginal rate of substitution does not change counter-intuitively in γ, the numerator is negative. Concerning the denominator, this assumption does not give a result, though. There is one negative term, one positive term, and one term that depends on the sign of $(-2\gamma + \rho)$. An assessment of the relative sizes of these terms seems impossible, since they depend on the exact value of the endogenous variables. Therefore, the sign of the derivative remains indeterminate.

may be positive. In this case, the hidden social cost of saving will be negative and A's individual marginal benefit of saving will be smaller than his individual marginal cost.

To prove the first part of Proposition 9, I now study an example in which the coefficient of relative risk aversion is smaller than one. Note that with multiplicative habits optimal contracts can only be solved numerically (except for logarithmic utility).

Example 2. Consider the two-effort two-output problem. The optimal wage scheme can be characterized by a system of equations analogous to the system (29)–(34) for subtractive habits. Assume $\beta = \alpha = \frac{1}{R} = 1$, $u(c) = \frac{1}{1-\rho}c^{1-\rho}$, $\rho = 0.4$, $b = 0.3$, $v = 0.1$, $p_H(l) = 0.25$, $p_H(h) = 0.5$, $\underline{U} = 2$.

Table 1 depicts the optimal wage scheme for different values of the habit parameter γ. Figures 1 and 2 display wages graphically. We see that first period wages w_i decrease in the habit parameter γ, whereas second period effective wages $\hat{w}_{ij}$ increase in γ.

Figure 3 shows A's marginal utility of saving, evaluated at the optimal contract, for each output realization of period 1, $i \in \{L, H\}$. For $\gamma = 0$, preferences are time-separable, and thus the marginal utility of saving is positive. The marginal utility of saving declines in γ, and eventually becomes negative. Hence, there is a cutoff value of γ (depending on i), below of which A has the wish to save at the optimal contract, and above of which A has the wish to borrow. Define γ^* as the lower of the two respective cutoff values. In summary, we have the following.

Observation 1. A's marginal utility of saving decreases in γ and can become negative (Figure 3).

The intuition is as follows. Set $h := b + c_1$. The covariance of the marginal habit effect of buying the bond, $-\partial_{c_1} u_2(w_{ij}, w_i) = \gamma h^{\gamma(\rho-1)-1} w_{ij}^{1-\rho}$, and the second period wage w_{ij} is positive and increasing in γ. If γ is sufficiently large, then this will outweigh the negative covariance between the marginal payoff of the bond, $\partial_{c_2} u_2(w_{ij}, w_i) = h^{\gamma(\rho-1)} w_{ij}^{-\rho}$, and the second period wage. In this case, A's valuation of the bond will be positively correlated with the second period wage, hence the hedging value of saving will be negative.

The size of the covariance between the bond's marginal payoff and the second period wage depends crucially on A's risk aversion. The above discussion points out that the habit effect of buying bonds will dominate the wealth effect if the coefficient ρ of relative risk aversion is small.

γ	w_H	$\hat{w}_{HH}$	$\hat{w}_{HL}$	w_L	$\hat{w}_{LH}$	$\hat{w}_{LL}$
0	0.57615	0.75031	0.42881	0.42444	0.58109	0.29632
0.1	0.50713	0.83061	0.49353	0.36826	0.63594	0.34152
0.2	0.40427	0.96563	0.60437	0.29368	0.72352	0.41315
0.3	0.24524	1.22542	0.82304	0.19830	0.87988	0.53872
0.4	0.10551	1.54966	1.10302	0.10978	1.09680	0.71313
0.5	0.05256	1.72965	1.26090	0.06041	1.24748	0.83940
0.6	0.03091	1.82740	1.34723	0.03648	1.33626	0.91567
0.7	0.02001	1.88827	1.40119	0.02380	1.39268	0.96471
0.8	0.01377	1.92978	1.43806	0.01638	1.43138	0.99855
0.9	0.00988	1.95983	1.46479	0.01171	1.45945	1.02320
1	0.00730	1.98254	1.48501	0.00861	1.48068	1.04189

Table 1: optimal wage scheme for different values of the habit parameter γ

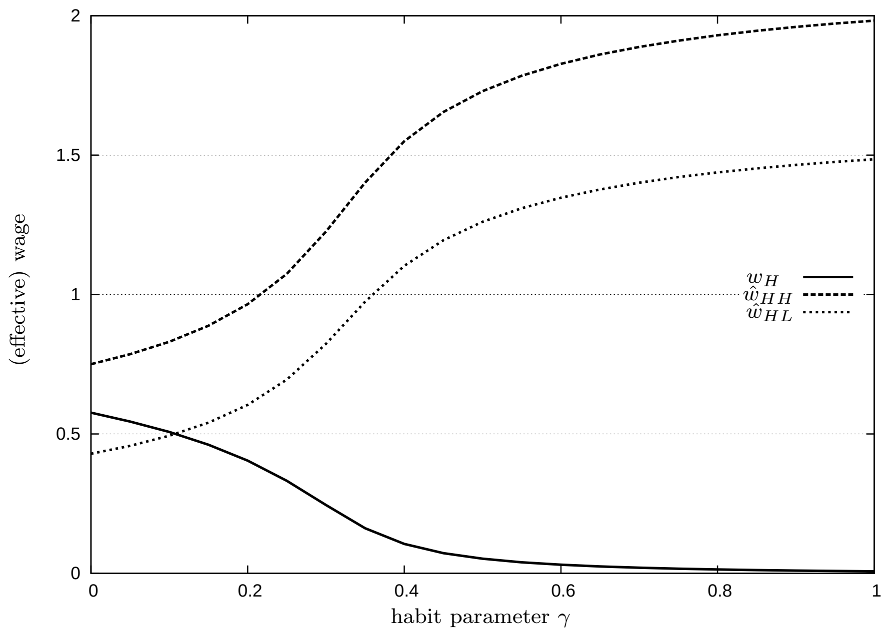

Figure 1: (effective) wages for output realization $i = H$

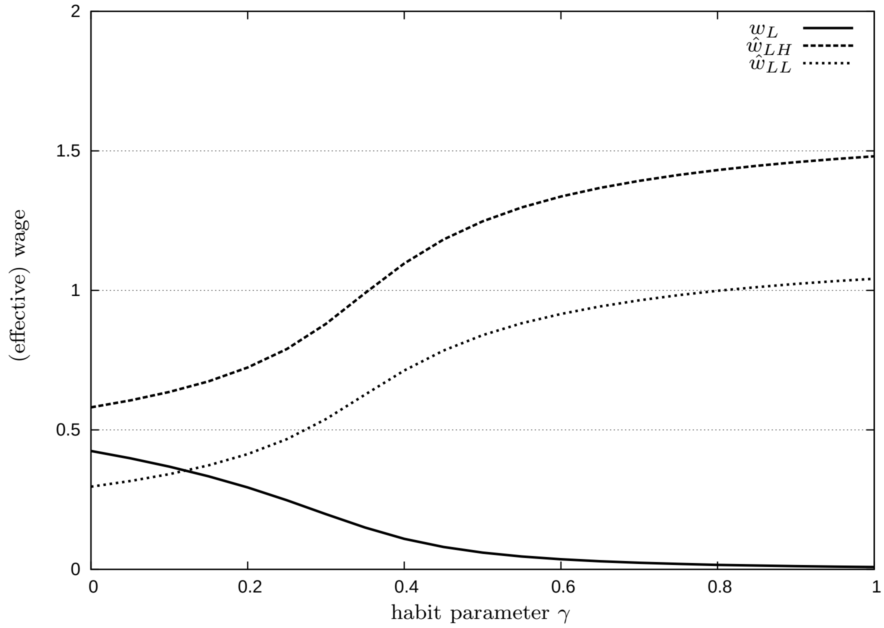

Figure 2: (effective) wages for output realization $i = L$

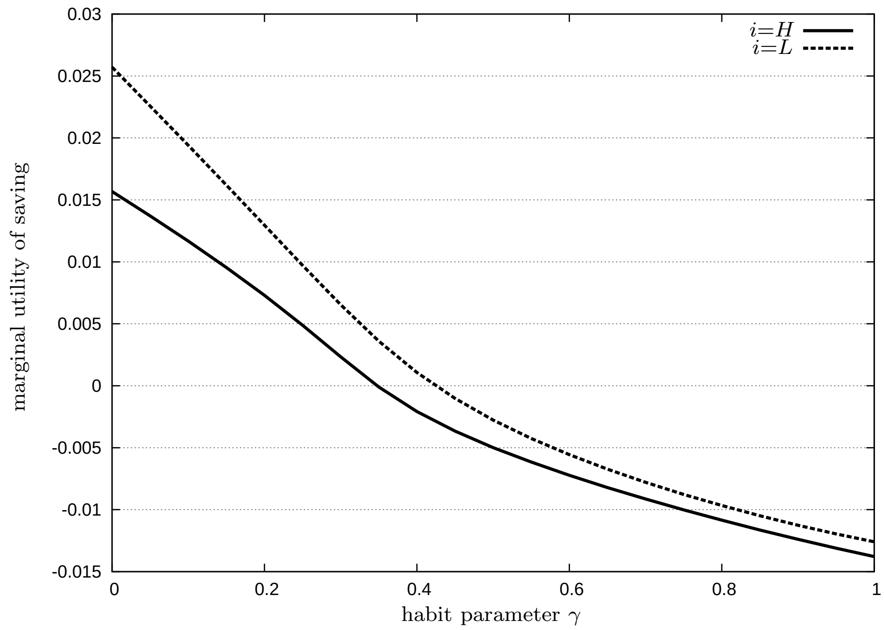

Figure 3: A's marginal utility of saving

This suggests that for small values of ρ, the intertemporal wedge will only be positive under relatively small values of the habit parameter γ. Figure 4 shows the cutoff value γ^*, above of which A is borrowing-constrained for at least one output realization, for varying coefficients ρ of relative risk aversion. Indeed we see the following.

Observation 2. The cutoff value γ^* increases in ρ (Figure 4).

In other words, Figure 4 shows that A is borrowing-constrained if the habit intensity γ is sufficiently large compared to the coefficient ρ of relative risk aversion. We also note the following.

Observation 3. There exist coefficients $\rho < 1$ with $\gamma^* = 1$ (Figure 4).

Hence, the highest possible habit intensity, $\gamma = 1$, does not for all risk aversion coefficients $\rho < 1$ lead to optimal contracts that make the agent borrowing-constrained. By decreasing the size of the constant b, the set of parameters under which the agent becomes borrowing-constrained can be increased, as Figure 5 shows. This seems due to the fact that b has a dampening effect on changes in the habit level: The larger the size of b, the smaller is the relative change of the habit level $h = b + c_1$ given a reduction of consumption c_1 by one unit.

5 Concluding remarks

This paper has studied the effect of habit formation on principal-agent problems. We have seen that when habit and consumption are complements, the optimal contract will be qualitatively similar to the time-separable model, except that consumption will have a stronger tendency to increase over time. When habit and consumption are substitutes, the agent might however remain with a desire to borrow at the optimal contract.

The study of the two-period problem has highlighted how habit formation changes the effect of saving on next period's incentives. There may however be effects on later periods that the current model does not capture. When the agent changes his saving, this might not only affect his habit level for the coming period, but possibly for the entire future—depending on how the habit process is specified. This topic clearly calls for future research.

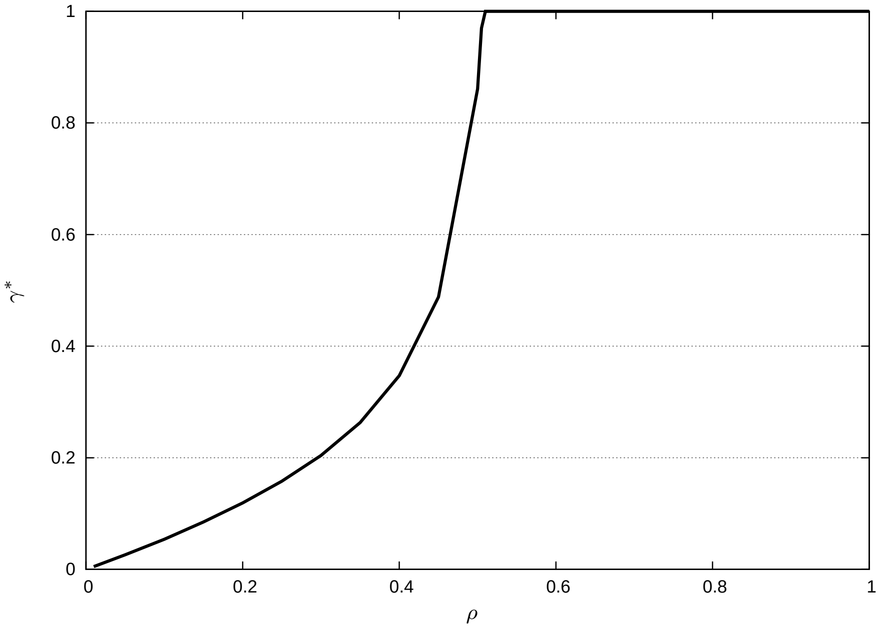

Figure 4: highest value of the habit parameter γ for which A's marginal utility of saving is positive (for varying coefficients ρ of relative risk aversion)

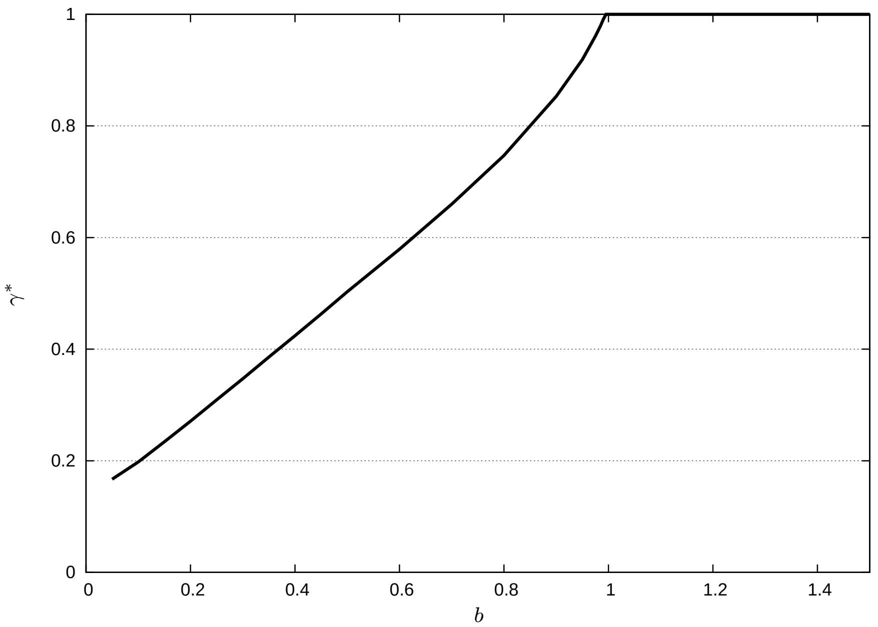

Figure 5: highest value of the habit parameter γ for which A's marginal utility of saving is positive (for varying constants b in the habit term)

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