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ABSTRACT

On Rush and Procrastination*

We analyse the decision of individuals with time-inconsistent preferences who undertake irreversible activities yielding either a current cost and a future benefit or a current benefit and a future cost. We first show that, when benefits come earlier than costs, the individual faces a coordination problem with himself that results in multiple, rankable equilibria. Some of these equilibria may exhibit rush, in the sense that the activity is undertaken 'too early' (i.e. with a negative pay-off). Multiplicity explains why individuals succeed or not in avoiding temptations, depending on 'the degree of trust in their future decision'. Second, we prove that competition between agents for the same activity can be beneficial for them both when costs come before and after benefits: it decreases the agents' incentives to procrastinate (i.e. to undertake the activity 'too late') in the former case and to rush in the latter. Last, complementarity of tasks exacerbates the tendency to rush and to procrastinate. Under procrastination, it may even imply that projects that are valuable for all agents are never undertaken.

JEL Classification: A12, D83, D92, Q20
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NON-TECHNICAL SUMMARY

There is an innate human tendency both to delay unpleasant tasks and to succumb to temptations by rushing into pleasant activities. The literature on behavioural economics has shown that the tendency to undertake activities 'too late' (i.e. to procrastinate) or 'too early' (i.e. to rush) may result from the combination of time-inconsistent preferences and a temporal gap between the costs and benefits associated to those actions.

Time-inconsistency (or the individual tendency to overweight current pay-offs relative to future ones) has extensively been documented in Psychology. Its main implication is that the marginal rate of substitution between one unit of consumption at two different dates depends not only on the absolute time interval between these two dates (as in the traditional theory) but also on the date of reference. Building on the time-inconsistent paradigm, the aim of this Paper is to provide a full characterization of the behaviour of a population of time-inconsistent agents engaged in activities yielding either a current cost and a delayed benefit or a current benefit and a delayed cost. We consider situations in which the activities undertaken by those agents are independent, complementary and in competition. We obtain the following results:

First, we show that if undertaking the activity yields a current benefit and an uncertain delayed cost, two equilibria may coexist. Indeed, the individual may either rush (i.e. undertake the activity when the cost is still too high so that it yields a negative expected pay-off) or else be patient and wait until the cost realization is sufficiently small. Rushing is a Pareto-dominated strategy, in the sense that the other equilibrium leads to a higher intertemporal utility from the point of view of the agent at every single period. Individuals are aware of this inefficiency, but undertaking the activity is their only commitment device against a future behaviour more inefficient from the current viewpoint. Stated differently, if at each point in time the individual anticipates that future selves will rush, then he prefers to rush himself so as to (at least) reap the overweighed benefits of undertaking the activity in the current period. To sum up, each individual faces a coordination problem with himself and his behaviour depends on the degree of trust in his future decisions.

Second, we analyse the effects of competition between agents. We assume that at most one agent can benefit from the activity and show that this can be profitable for all parties. More precisely, in a situation where benefits come earlier than costs, competition decreases the incentives of individuals to rush. The reason is simple. Individuals anticipate that rushing is detrimental (see the previous result). If agents compete for the activity, commitment against future

negative pay-offs can be achieved at no cost whenever the rival rushes himself. In other words, competition mitigates the tendency to rush because each individual uses the interpersonal conflict of the rival to his advantage; he tries to ‘let the opponent rush’. When costs come earlier than benefits, agents have a tendency to procrastinate, i.e. to undertake the activity ‘too late’. Again, competition may not be harmful. If only one agent can benefit from the activity, there is a coordination game in which each individual is willing to procrastinate only if the other also does. Overall, under competition the activity may be undertaken sooner than if agents acted independently without implying any welfare loss for them.

Third, we study the effect of complementarity by assuming that individuals enjoy the benefits of their activity whenever both of them have completed their corresponding task. Interestingly, when costs come earlier than benefits, complementarity exacerbates the incentives of agents to procrastinate. Exerting the cost is not anymore sufficient for enjoying the future benefit; each agent is forced to rely on his teammate, but realizes his partner’s natural tendency to procrastinate. As a result, each agent may want to complete the task at each date with a positive but smaller probability than his rival. This case is characterized by the biggest possible inefficiency: in the unique symmetric equilibrium, no agent ever undertakes the task even though it has positive expected value. A similarly important inefficiency arises when benefits come earlier than costs. The presence of spill-overs increases the agent’s benefits derived from the completion of the activity and therefore exacerbates their tendency to rush. In both cases complementarity may reduce the overall welfare of individuals.

Some other results are obtained when agents have to complete several independent activities. For instance, when effort comes earlier than benefits, apparent work overload (i.e. the agent’s tendency to accept too many tasks when these cannot be completed immediately) may not result in welfare losses. We also show that imposing a sequential completion of activities yielding a current benefit and a delayed cost may even be welfare improving. As under competing tasks, imposing a sequential completion may decrease the agent’s incentives to rush.

The relevance and practical implications of all these results for economic issues as diverse as promotions, job search, R&D cooperation, personal temptations, etc. are widely discussed at the end of the Paper.

1 Introduction

There is an innate human tendency both to delay unpleasant tasks and to succumb to temptations by rushing into pleasant activities. On the one hand, procrastination occurs even under the anticipation that, sooner or later, the referee report has to be completed, the family dinner invitation accepted, and the bedroom shelf fixed. On the other hand, "freezing" (in its literal sense) the credit card is sometimes the only way to prevent an impulse buying behavior that leads to unnecessary purchases.

The literature on behavioral economics has shown that the tendency to undertake activities "too late" (procrastination) or "too early" (rush) may result from the combination of time inconsistent preferences and a temporal gap between the costs and benefits associated to those actions. The aim of this research is twofold. First, we explain why similar environments may exhibit different degrees of procrastination or different degrees of rush. Second, we show how interactions between time inconsistent individuals may mitigate or exacerbate such inefficient behaviors. To this purpose, we consider a population of individuals with time inconsistent preferences who can undertake an irreversible activity. The horizon is infinite (or stochastic), so as long as agents choose not to undertake the activity, there is scope for undertaking it the period after. Two different scenarios are considered. In the first one, the activities require a current cost but provide a future benefit. In the second one, the activities yield a current benefit at the expense of a delayed cost. In addition, at each period and before making his decision, each agent learns the realization of an uncertainty parameter that affects the payoffs of the current decision. For both types of scenarios, we analyze situations in which the activities of each individual are independent, complementary and in competition.

Psychologists have evidenced that individuals overweight current payoffs relative to future ones. This suggests that the standard exponential discounting used in the economic literature does not account for the observed preferences of individuals over time, and that discount rates are best approximated by hyperbolas.[1] Its main implication is that the marginal rate of substitution between one unit of consumption at two different dates depends not only on the absolute time interval between these two dates but also on the date of reference. From a theoretical perspective, Strotz (1956) and

[1]See Thaler (1981), Benzion, Rapoport and Yagil (1989), Ainslie (1975, 1992), Mazur (1987) and Loewenstein and Prelec (1992) for empirical investigations and theoretical discussions of this phenomenon.

Phelps and Pollak (1968) are the first studies in which individual and social dynamically inconsistent preferences were analyzed, respectively. In this paper, we consider time inconsistent individuals composed of a collection of 'selves' (one per period) who are aware of their intrapersonal conflict. We provide a *full characterization* of the behavior of agents engaged in independent and interdependent tasks when costs come earlier than benefits (Propositions 1 and 2) and also when benefits come earlier than costs (Propositions 3 and 4). Below we give a brief overview of the most unexpected results (not necessarily displayed in chronological order).

First, we show that if undertaking the activity yields a current benefit and an uncertain delayed cost, two equilibria may coexist. Indeed, the individual may either rush (i.e. undertake the activity when the cost is still too high so that it yields a negative expected payoff) or else be patient and wait until the cost realization is sufficiently small (Proposition 3, part (i)). Rushing is a Pareto dominated strategy, in the sense that the other equilibrium leads to a higher intertemporal utility from the point of view of the agent at every single period. Individuals are aware of this inefficiency, but they may still undertake the activity because it is their only commitment device against a future behavior more inefficient from the current viewpoint. Stated differently, if at each point in time the individual anticipates that future selves will rush, then he prefers to rush himself so as to (at least) reap the overweighed benefits of undertaking the activity in the current period. To sum up, each individual faces a coordination problem with himself and his behavior depends on the degree of trust on his future decisions (no future rush implies no incentives for current rush and vice versa).

Second, we analyze the effects of competition between agents. We assume that at most one agent can benefit from the activity, and show that this can be profitable for all parties. More precisely, in a situation where benefits come earlier than costs, competition decreases the incentives of individuals to rush and undertake activities with net losses (Proposition 4, part (i)). The reason is simple. Individuals anticipate that rushing is detrimental. Yet, given the intrapersonal conflict, it is a commitment against future, more inefficient decisions (see the previous result). If agents compete for the activity, commitment against future negative payoffs can be achieved at no cost whenever the rival rushes himself. In other words, competition mitigates the tendency to rush because each individual uses the intrapersonal conflict of the rival to his advantage; he tries to "let the opponent rush". When costs come earlier than benefits, agents have a tendency to procrastinate, i.e. to undertake the activity "too late". Here again, competition may not be harmful. If only one agent can benefit from the activity, there is a coordination game in which each individual is willing to procrastinate only if the other also does. Overall, under competition the activity may be undertaken sooner than if agents acted independently without implying any welfare loss for each of them (Proposition 2, part (i)).

Third, we also study the effect of complementarity by assuming that individuals enjoy the benefits of their activity whenever both of them have completed their corresponding task. Interestingly, when costs come earlier than benefits, complementarity exacerbates the incentives of agents to procrastinate. Exerting the cost is not anymore sufficient for enjoying the future benefit; each agent is forced to rely on his teammate's willingness to exert his own cost but realizes the natural tendency to procrastinate of his partner due to time inconsistency. As a result, in some instances each agent wants to complete the task at each date with a positive but smaller probability than his rival. This case is characterized by the greatest inefficiency: in the unique symmetric equilibrium, no agent ever undertakes the task even though it has positive expected value (Proposition 2, part (ii)). A qualitatively different but similarly important inefficiency arises when benefits come earlier than costs. The presence of spillovers increases the agents benefits derived by the completion of the activity, and therefore exacerbates their tendency to rush (Proposition 4, part (i)). So, in both cases complementarity may reduce the overall welfare of individuals.

Some other results are obtained for the case in which agents have to complete several independent activities. For instance, when effort comes earlier than benefits, apparent work overload (i.e. the agent's tendency to accept too many task when these cannot be completed immediately) may not result in welfare losses. We also show that imposing a sequential completion of activities yielding a current benefit and a delayed cost may even be welfare improving. For the same reasons as under competing tasks, imposing a sequential completion may decrease the agents' incentives to rush. The relevance and practical implications of all these results for economic issues as diverse as promotions, job search, R&D cooperation, personal temptations, etc. are widely discussed at the end of the paper.

Before presenting the model, we would like to mention two papers on decision making when preferences are dynamically inconsistent which are related to ours. O'Donoghue and Rabin (1996) analyze the decision of agents who are aware of their time inconsistency (sophisticated agents) and those who do not anticipate their self-control problem (naive agents). They demonstrate that, in a situation in which costs come earlier than benefits, sophistication mitigates the tendency to procrastinate with respect to naivete. By contrast, when benefits come earlier than costs, sophistication exacerbates the incentives to rush.[2] Brocas and Carrillo (1999a) analyze a finite horizon model in which a 'sophisticated' agent can embark on an irreversible activity with immediate benefits and a delayed cost. Moreover, cost is uncertain and there is some information revelation between periods as long as the activity is not undertaken. The paper shows the existence of a unique equilibrium. If the flow of information is high, there is an expected positive information value of waiting and, in equilibrium, only activities with a positive net present value (NPV) are undertaken. However, if the flow of information is small, the agent's expected information value of waiting is negative. In that case, the agent decides rationally to rush and undertake the activity with negative NPV, only to prevent himself from undertaking it in the future.[3] The result in Proposition 3 can therefore be seen as a generalization of Brocas and Carrillo (1999a) to a stochastic horizon model. As already noted, the added feature of an uncertain horizon is the existence of multiple, Pareto rankable equilibria.

The paper is organized as follows. Section 2 investigates the decision of individuals to undertake activities characterized by a current cost and a delayed benefit. Section 3 analyzes situations in which individuals may embark on activities yielding salient benefits at the expense of delayed costs. Section 4 addresses some applications of our theory and section 5 concludes.

2 A simple model of procrastination

In this section, we study the decision of individuals to undertake an irreversible activity which requires a *current cost* but provides a *future benefit*. Each agent has time inconsistent preferences in the sense of Strotz (1956) so that short term events are discounted relatively more heavily than long term events. For each individual, we call "self-t" his incarnation at date t. For analytical tractability, we use the quasi-hyperbolic discounting introduced by Phelps and Pollak (1968). In their paper, from the perspective of

[2]See also the related paper on procrastination by Akerlof (1991).

[3]See also Carrillo and Mariotti (1997), Carrillo (1998), and Brocas and Carrillo (1999b) for other situations in which information can be harmful if preferences are dynamically inconsistent.

self-t, period $t+s$ is discounted at a rate $\beta\delta^s$ with $\delta < 1$ and $\beta \in (0,1)$.[4] For simplicity, we assume that undertaking the activity in period t has an immediate cost e at date t and a delayed benefit π at date $t+1$.[5] As stated in the introduction, this is meant to capture the idea that completing a report or seeking for a job requires time and effort but, in the long run, it also provides some satisfaction.

In this setting, self-t prefers to do the activity at date t rather than never if:

$$-e + \beta\delta\,\pi > 0 \;\Leftrightarrow\; e < \overline{e} \equiv \beta\delta\,\pi \tag{1}$$

Similarly, self-t prefers to do the activity at date $t+1$ rather than at date t if:

$$-e + \beta\delta\,\pi < -\beta\delta\, e + \beta\delta^2\,\pi \;\Leftrightarrow\; e > \underline{e} \equiv \beta\delta\,\pi\,\frac{1-\delta}{1-\beta\delta} \tag{2}$$

We will assume that both (1) and (2) hold simultaneously. This is possible only because of the dynamic inconsistent nature of preferences ($\beta < 1$).

Assumption 1 $e \in (\underline{e}, \overline{e})$. **(A1)**

We will investigate two scenarios. In the first one, agents undertake independent activities, so that the payoff of each individual is not affected by the decision of others. In the second, we will analyze the incentives of each agent to complete his activity (or task) when his expected payoff is affected by the decision of the other agents. Our first result is a characterization of the behavior of agents when each of them may undertake either one or several independent tasks.

Proposition 1 *(Procrastination under independent tasks).*

(i) *When each agent can undertake one task, there exists one and only one symmetric subgame perfect equilibrium in which the agents complete the task at each date with probability* $\lambda^* \in (0,1)$.

(ii) *When each agent can undertake* n *independent and identical tasks, there is no loss in welfare if the agent cannot perform more than one task per period, as long as* $n \leq 1/\lambda^* + 1$.

[4]Naturally, $\beta = 1$ is the standard case with time consistent preferences. As β decreases, the intrapersonal conflict of preferences becomes more important. This modeling has subsequently been used in most of the previously mentioned papers and also in Caillaud et. al. (1996) and Laibson (1996, 1997).

[5]There is no loss of generality by assuming that costs and benefits are deterministic, stationary and with a lag of exactly one period.

Proof. Part (i). Suppose that each agent undertakes the project with probability λ at each date. Given **(A1)**, $\lambda \in \{0,1\}$ cannot be an equilibrium. Anticipating that each self-t ($t \geq 1$) undertakes the activity with probability λ, self-0 is indifferent between doing the task and not if and only if:

$$\begin{aligned} -e + \beta\delta\,\pi &= \lambda(-\beta\delta\, e + \beta\delta^2\,\pi) + (1-\lambda)\lambda(-\beta\delta^2\, e + \beta\delta^3\,\pi) + ... \\ &= (-e + \delta\,\pi)\frac{\lambda\beta\delta}{1-\delta(1-\lambda)} \end{aligned}$$

rearranging terms, we get $\lambda^* = \dfrac{1-\delta}{\delta(1-\beta)}\left(\dfrac{\beta\delta\,\pi}{e} - 1\right) \in (0,1)$.

Part (ii) consists in two steps.

Step 1. Suppose that the agent cannot complete more than one task per period. In addition suppose that $n-1$ projects have been achieved at date τ_n. Self-τ_n anticipates that each future self $(\tau_n+1, \tau_n+2, ...)$ will undertake the last task with probability λ_1. Then, self-τ_n is indifferent between completing it in the current period and not if:

$$\begin{aligned} -e + \beta\delta\,\pi &= \lambda_1(-\beta\delta\, e + \beta\delta^2\,\pi) + (1-\lambda_1)\lambda_1(-\beta\delta^2\, e + \beta\delta^3\,\pi) + ... \\ &= (-e + \delta\,\pi)\frac{\lambda_1\beta\delta}{1-\delta(1-\lambda_1)} \end{aligned}$$

Therefore $\lambda_1 = \lambda^*$. By the same reasoning, if $n-2$ tasks have been completed at date τ_{n-1}, self-τ_{n-1} anticipates that all subsequent selves will complete the next to last task with probability λ_2 before completing the last task with probability λ_1. Then, self-τ_{n-1} is indifferent between undertaking the task in the current period and not if:

$$\begin{aligned} -e + \beta\delta\,\pi + \lambda_1(-\beta\delta\, e + \beta\delta^2\,\pi) + (1-\lambda_1)\lambda_1(-\beta\delta^2\, e + \beta\delta^3\,\pi) + ... = \\ \lambda_2\Big[(-\beta\delta\, e + \beta\delta^2\,\pi) + \lambda_1(-\beta\delta^2\, e + \beta\delta^3\,\pi) + ...\Big] + \\ (1-\lambda_2)\lambda_2\Big[(-\beta\delta^2\, e + \beta\delta^3\,\pi) + \lambda_1(-\beta\delta^3\, e + \beta\delta^4\,\pi) + ...\Big] + ... \end{aligned}$$

Which can be rewritten as:

$$2(-e + \beta\delta\,\pi) = (-e + \delta\,\pi)\frac{\lambda_2\beta\delta}{1-\delta(1-\lambda_2)} + [-e + \beta\delta\,\pi]\frac{\lambda_2\delta}{1-\delta(1-\lambda_2)}$$

Recursively, when $n-k$ tasks have been already implemented, the $(n-k+1)^{\text{th}}$ one is completed with probability λ_k that is solution of:

$$k(-e + \beta\delta\,\pi) = (-e + \delta\,\pi)\frac{\lambda_k\beta\delta}{1-\delta(1-\lambda_k)} + (k-1)[-e + \beta\delta\,\pi]\frac{\lambda_k\delta}{1-\delta(1-\lambda_k)} \qquad \text{(B1)}$$

Let $g_k(\lambda) = \dfrac{\lambda}{k(1-\delta)+\lambda\delta}$. It is decreasing in k and increasing in λ. Moreover $g_k(0) = 0$ for all k, $g_1(1) = 1$ and $\lim_{k\to+\infty} g_k(\lambda) = 0$. From (B1), if λ_k is an interior solution, it satisfies:

$$\frac{-e+\beta\delta\,\pi}{\beta\delta[-e+\delta\,\pi]} = g_k(\lambda_k)$$

Given **(A1)**, an interior solution for λ_k exists if and only if $\frac{-e+\beta\delta\,\pi}{\beta\delta[-e+\delta\,\pi]} < g_k(1)$. So, if we denote by $\tilde{n}$ the largest integer such that $\frac{-e+\beta\delta\,\pi}{\beta\delta[-e+\delta\,\pi]} < g_{\tilde{n}}(1)$, then $\lambda_k \in (0,1)$ for all $k \leq \tilde{n}$ and $\lambda_k = 1$ for all $k > \tilde{n}$. Moreover, $\lambda_k = k \times \lambda^*$ for all $k \leq \tilde{n}$, so $\tilde{n}$ is the largest integer below $1/\lambda^*$. Overall, when $n \leq \tilde{n}$, the intertemporal welfare from the perspective of self-0 is:

$$\begin{aligned} U(n) &= \lambda_n(-e+\beta\delta\,\pi) + \lambda_n[(n-1)(-e+\beta\delta\,\pi)] + (1-\lambda_n)[n(-e+\beta\delta\,\pi)] \\ &= n[-e+\beta\delta\,\pi] \end{aligned}$$

However, when $n = \tilde{n} + m$ with $m > 0$, the agent completes the m first projects with probability 1 at each period and the $\tilde{n}$ subsequent tasks with probabilities $\lambda_{\tilde{n}} > \lambda_{\tilde{n}-1} > \ldots > \lambda_1$. Then, the intertemporal welfare from the perspective of self-0 is:

$$U(n^* + m) = -e + \beta\delta\,\pi + \delta^{m-1}\tilde{n}[-e+\beta\delta\,\pi] + \beta\delta[-e+\delta\,\pi]\frac{1-\delta^{m-1}}{1-\delta}$$

Note that $U(\tilde{n}+m)$ is increasing in m. Besides, $U(\tilde{n}+1) = (\tilde{n}+1)[-e+\beta\delta\,\pi]$ and $U(\tilde{n}+m) < (\tilde{n}+m)[-e+\beta\delta\,\pi]$ for all $m > 1$.

Step 2. Suppose now that the agent can complete several tasks at the same period. Since projects are identical and independent, he undertakes each of them with probability λ^* at each period. In that case, the intertemporal welfare from the perspective of self-0 is $n[-e+\beta\delta\,\pi]$. Therefore, when $n \leq \tilde{n}+1 = n^*$, there is no loss of welfare from the perspective of self-0 to complete the tasks sequentially. □

First, under time inconsistent preferences and a unique project, it may occur that each self wants the task to be completed but, at the same time, prefers to delegate its realization to a future incarnation. In that case, and given the natural tendency to procrastinate, the only symmetric strategy for each self is to undertake the activity at each period with some probability. This provides an explanation to the common observation of different delays in completing unpleasant (but otherwise similar) tasks. Naturally, this setting is formally equivalent to a situation in which the agent has to undertake several identical tasks. Our theory says that even if there are no increasing marginal costs, the agent will undertake only a fraction of the tasks at each date (rather than all or none). From the definition of λ^*, note that $\frac{\partial \lambda^*(\cdot)}{\partial \beta} > 0$: procrastination is more likely when the intra-personal conflict of preferences is more acute. More interestingly, $\frac{\partial \lambda^*(\cdot)}{\partial e} < 0$, $\frac{\partial \lambda^*(\cdot)}{\partial \pi} > 0$, and $\left[\frac{\partial \lambda^*(\cdot)}{\partial e} + \beta\delta \frac{\partial \lambda^*(\cdot)}{\partial \pi}\right] < 0$. The task is more likely to be delayed the higher the cost and the smaller the benefit. Furthermore, it will be also left for the future when, keeping the current net benefit $(\beta\delta\,\pi - e)$ constant, the stakes e and π are increased. Since the present payoffs are overweighed, an increase in the stakes raises the net payoff of undertaking the task in the future relative to the present. So, contrary to common wisdom, our theory predicts that procrastination is more likely to occur if the activity is important. It is therefore not correct to neglect the problem of self-control on the grounds that it mainly affects decision making in situations of limited importance.

Second, when each agent has to undertake several projects, the timing of completion affects the incentives to procrastinate. Indeed, if the agent can decide to complete any task at any period then, by the assumption of independence, the decision to pursue a given task does not affect the decision to undertake others. In that situation, each self undertakes each activity at each period with the same probability λ^* as if he had to complete only that task. By contrast, when the agent is forced to undertake the different projects *sequentially*, completing a given project makes possible the completion of future ones. As a consequence, in the case of sequential tasks there is an option value of undertaking the current activity. This option value is an increasing function of the number of remaining tasks, and it affects negatively the agent's incentives to procrastinate. In other words, the higher the number of future projects to be done is, the higher the benefit of completing a given task, and so the higher the probability of effectively undertaking it.[6] Besides, when the number of remaining projects is sufficiently large, the current task is completed immediately. The interesting feature is that the agent may not suffer a welfare loss due to the impossibility of undertaking projects simultaneously. This is counterintuitive. One could think that introducing a constraint on the timing of completing tasks should affect negatively self-0's welfare, as it is the case under time consistent preferences. However, as described above, when the agent is forced to complete the projects sequentially he revises upwards the

[6] As stated formally in the proof of Proposition 1, the m^{th} task will be undertaken with probability λ_{n-m+1} where $\lambda_i = \min\{i\,\lambda^*, 1\}\ \forall\, i \in \{1, ..., n\}$.

probabilities of undertaking each task. As long as all these probabilities (or all but one of them) remain strictly below one, the present self is by construction currently indifferent between undertaking the activity and not. In this case, the constraint only increases the speed of completing the earliest projects (i.e. it refrains the agent from excessive procrastination) without affecting the overall welfare. By contrast, if self-0 wants to undertake with probability one at least two tasks (which occurs whenever $n > 1/\lambda^* + 1$, see footnote 6) then imposing a sequential realization has the effect of suboptimally delaying the completion of (at least) the second one. This in turn has a negative impact on the welfare of the individual. The result suggests that apparent work overload (i.e. the agent's tendency to accept too many tasks which then are not completed immediately) may not be welfare damaging. It can simply be a commitment device to overcome a natural tendency to procrastinate.

In the remaining of the section, we consider the second scenario. Namely, we investigate situations in which projects are interdependent so that the payoff of each agent is affected by the decision of other individuals. First, we concentrate on the case in which two agents pursue *competing* tasks (or projects). To keep the analysis simple, we suppose that each agent has the possibility to undertake his own project and reap the entire benefit π only if the other agent has not undertaken his own one in a previous period. Besides, if both agents do the task in the same period, they both get the benefit π.[7] Natural examples are investment in R&D and competition for a promotion within a firm. In these cases, it is only valuable to be the first in obtaining an innovation or proposing a clever idea. Second, we analyze the case in which two individuals embark in *complementary* projects. Then, each agent enjoys the benefit of the joint activity when both of them have sunk the cost. The situations we have in mind are cooperative R&D projects and team production in which two firms or individuals exert a complementary effort to obtain a joint innovation or product of value π. In this setup, we can state our next result.

Proposition 2 *(Procrastination under interdependent tasks). There exist two cutoff efforts e^* and e^{**} that determine the stable, symmetric equilibria of the game.*

(i) *When agents pursue competing tasks, agents complete the task in the first period with probability 1 if $e \in [\underline{e}, e^*)$ and with probability $p \in \{\mu, 1\}$ at each period (where*

[7] An alternative modeling would be to assume that when both agents do the task in the same period each one gets $\pi/2$. The results would be essentially the same, but the calculations are more intricate. Note also that the extension to more than two agents is trivial.

$\mu > \lambda^*$) if $e \in [e^*, \overline{e}]$.

(ii) *When agents pursue complementary tasks then, as long as nobody has undertaken his own task, agents complete them with probability γ ($< \lambda^*$) at each period if $e \in [\underline{e}, e^{**})$ and with probability 0 if $e \in [e^{**}, \overline{e}]$. Moreover, for some values of β and δ then $e^{**} = \underline{e}$, i.e. never completing the task is the only symmetric equilibrium.*

Proof. Part (i). Suppose that agent 2 undertakes the activity at each date with probability p. Besides, self-0 of agent 1 anticipates that each of his future selves $t \geq 1$ will undertake the activity with probability q. Self-0 is then indifferent between doing the task in the current period and not if:

$$\begin{aligned} -e + \beta\delta\,\pi &= (1-p)q(-\beta\delta\, e + \beta\delta^2\,\pi) + (1-p)^2(1-q)q(-\beta\delta^2\, e + \beta\delta^3\,\pi) + ... \\ &= (-e + \delta\,\pi)\frac{\beta\delta(1-p)q}{1-\delta(1-p)(1-q)} \end{aligned}$$

which can be rewritten as:

$$q = f(p) \equiv \frac{1-\delta(1-p)}{\delta(1-p)}\,\Pi \qquad \text{where } \Pi = \frac{1}{1-\beta}\left(\frac{\beta\delta\,\pi}{e} - 1\right)$$

Note that $f(0) = \lambda^* \in (0,1)$. Besides, $\lim_{p\to 1} f(p) = +\infty$, $f'(p) = \frac{1}{\delta(1-p)^2}\Pi > 0$ and $f''(p) > 0$.

- If $\Pi > \delta$, then $f'(0) > 1$. Given $f''(p) > 0$, we have $f(p) > p$ for all p. In that case, in the unique symmetric equilibrium both agents do the task at the first date.
- If $\Pi < \delta$, then $f'(0) < 1$. Denote $\hat{p}$ the value such that $f'(\hat{p}) = 1$. We have:

$$\frac{1}{\delta(1-\hat{p})^2}\,\Pi = 1 \;\Leftrightarrow\; \hat{p} = 1 - \sqrt{\Pi/\delta}$$

After some manipulations, we get:

$$f(\hat{p}) > \hat{p} \;\Leftrightarrow\; (1+\Pi)^2\delta < 4\Pi$$

Given $\Pi < \delta$, this is true if $\Pi > \Pi^* = \frac{2-\delta-2\sqrt{1-\delta}}{\delta}$ (where $\Pi^* \in (0,\delta)$).

Overall, when $e < e^* = \frac{\beta\delta^2\,\pi}{(1-\beta)(2-\delta-2\sqrt{1-\delta})+\delta}$ (where $e^* \in (\underline{e}, \overline{e})$) so that $\Pi > \Pi^*$, then $\hat{p} < f(\hat{p})$. Hence, $f(p) > p$ for all p and, just as before, both agents do the task in the first period.

Last, when $e \in [e^*, \overline{e})$ so that $\Pi \in (0, \Pi^*)$, then there are two cutoffs (μ, μ') such that $\mu = f(\mu)$ and $\mu' = f(\mu')$ with $\mu < \mu'$. If $p \in [0,\mu) \cup (\mu', 1]$, then $f(p) > p$ and if

$p \in (\mu, \mu')$ then $f(p) < p$. The same reasoning holds for the other agent ($p = f(q)$). Hence, in that case, both agents doing the task at each date with probability $p \in \{\mu, 1\}$ are the two stable symmetric equilibria of this game.[8] Note also that $\lambda^* = f(0) < \mu$ since $f'(p) > 0$.

Part (ii). When one agent has already completed his own project, the other is in the same situation as in Proposition 1, part (i). Therefore, each self undertakes the project with probability λ^*. Suppose that agent 2 completes the task with probability q (< 1) at each period as long as no task has been already achieved. Self-0 of agent 1 anticipates that each of his future incarnations will undertake the activity with probability λ before agent 2 completes his task (and with probability λ^* afterwards). Then, he is indifferent between completing it today and not if and only if:

$$-e + \beta\delta q\,\pi + \beta\delta^2 \frac{(1-q)\lambda^*\,\pi}{1-\delta(1-\lambda^*)} = q(-e + \beta\delta\,\pi) +$$

$$\beta\delta \frac{(1-q)q\lambda[-e+\delta\,\pi]}{1-\delta(1-\lambda)(1-q)} + \beta\delta \frac{-e(1-q)^2\lambda}{1-\delta(1-\lambda)(1-q)} + \tag{B2}$$

$$\frac{\lambda^*\beta\delta^3\,\pi}{1-\delta(1-\lambda^*)}\frac{(1-q)^2\lambda}{1-\delta(1-\lambda)(1-q)} + \frac{\lambda^*[-e+\delta\,\pi]\beta\delta^2}{1-\delta(1-\lambda^*)}\frac{(1-q)(1-\lambda)q}{1-\delta(1-\lambda)(1-q)}$$

Since we look for a symmetric equilibrium, suppose that $q = \lambda$. Then, after some calculations, the expression reduces to:

$$-e[1-\delta(1-\lambda)^2] = \left[(1-\lambda)\lambda\delta[-e+\beta\delta\pi] + \lambda\beta\delta[-e+\lambda\delta\,\pi] - \frac{\lambda^*\beta\delta}{1-\delta(1-\lambda^*)}\pi\delta[1-\delta(1-\lambda)]\right]$$

The potential solution γ satisfies:

$$\frac{\gamma\beta\delta}{1-\delta(1-\gamma)} = \left[\frac{\lambda^*\beta\delta^2\,\pi}{1-\delta(1-\lambda^*)} - e\right]\frac{1}{-e+\delta\,\pi}$$

which, using the definition of λ^*, can be rewritten as:

$$\gamma = \frac{1-\delta}{\delta(1-\beta)}\left[\frac{\beta\delta^2\,\pi^2}{-e(e-2\delta\pi)} - 1\right] < \lambda^*$$

Note that

$$\frac{\beta\delta^2\,\pi^2}{e(2\delta\pi - e)} > 1 \;\Leftrightarrow\; (1-\beta) < g(e) \equiv \left(1 - \frac{e}{\delta\pi}\right)^2$$

[8] Both agents completing the task with probability μ' is also a symmetric equilibrium, although unstable.

Besides, $g'(e) < 0$, $g(\overline{e}) < (1-\beta)$ and $g(\underline{e}) > (1-\beta)$ if and only if $1 - 2\delta + \beta\delta^2 < 0$.

Last, note that by equation (B2) if self-0 of agent 1 anticipates $q = 0$ for agent 2 and $\lambda = 0$ for all his future selves, then he undertakes the task in the current period with probability 1 if $g(e) > (1-\beta)$ and with probability 0 if $g(e) < (1-\beta)$.

Combining all these results, we end up with two cases:

$*$ When $1 - 2\delta + \beta\delta^2 < 0$ (i.e. when $\delta > \frac{1}{1+\sqrt{1-\beta}}$), there exists a solution $e^{**} \in (\underline{e}, \overline{e})$ such that $(1-\beta) = g(e^{**})$. For all $e \in [\underline{e}, e^{**})$, $g(e) > (1-\beta)$ so that undertaking the first task with probability $\gamma \in (0,1)$ is the unique stable, symmetric equilibrium. For all $e \in [e^{**}, \overline{e}]$, $g(e) \leq (1-\beta)$ so that undertaking the first task with probability 0 is the unique stable, symmetric equilibrium.

$*$ When $1 - 2\delta + \beta\delta^2 \geq 0$, then $g(e) \leq (1-\beta)$ for all $e \in [\underline{e}, \overline{e}]$ so that undertaking the first task with probability 0 is the unique, symmetric equilibrium. □

When agents seek for competing projects, the tendency to procrastinate is affected not only by the anticipation of future behavior, but also by the tendency to procrastinate of the other agent. Given that doing the task is desirable, if the cost of effort is sufficiently low ($e < e^*$) each agent prefers to do the task immediately, fearing his opponent's behavior and the possibility of not reaping any benefit. More surprisingly, for intermediate values of effort ($e \in (e^*, \overline{e})$) time inconsistency introduces a coordination problem: each agent is willing to delay the completion of the project but only as long as the other agent does the same. As a result, there is a multiplicity of equilibria each of them characterized by the probability of the task being realized at each date. By construction, all (symmetric) equilibria yield the same expected payoff to each agent ($\beta\delta\,\pi - e$). In other words, under competition, projects are on average undertaken sooner than under independent tasks since each period of procrastination increases the chances of not getting any profit, but this does not imply any welfare loss for the individuals.

When projects are complements, the analysis changes. If one agent has already undertaken his own project, each self of the team mate completes his project with probability λ^*. This is the case because the agent faces the same decision as under independent projects (see Proposition 1 part (i)). However, complementarity of projects increases the agents' incentives to delay the task: exerting effort is not anymore sufficient to enjoy the benefit at the following period, so there is an extra incentive to procrastinate. As a result, the probability of completing the task is at most γ ($< \lambda^*$).

The most striking feature of the equilibrium under cooperation, is the welfare loss implied by the possibility that agents *never* undertake tasks yielding net profits. This may happen because of two reasons. First, a trivial one. If e is close enough to $\overline{e}$, then the project is valuable only if both undertake it in the current period (formally, $-\overline{e} + \beta\delta^2\,\pi < 0$). However, each of them has incentives to procrastinate and wait until the other has incurred the cost (i.e. $-\overline{e} + \beta\delta\,\pi \equiv 0 < \beta\delta[-\overline{e} + \delta\,\pi]$). This free-riding problem results in an inefficiency because nobody ever is willing to take the first step.[9] Second and more surprising, if $\delta < \frac{1}{1+\sqrt{1-\beta}}$, then the free-riding problem arises *for all* e satisfying **(A1)**, so that the only symmetric equilibrium is to never undertake the task. Basically, for any given probability that the team mate undertakes the project, the agent is willing to complete it himself with a positive, but always smaller probability. Again this leads to an inefficient, unique symmetric equilibrium in which, because of a coordination problem, tasks with deterministic positive net value remain unfulfilled forever. Notice that as long as δ is not too close to 1, this inefficiency arises even if the intra personal conflict is very small (i.e. even if β is close to 1).

The general conclusion of this section is that by considering the individual as a collection of "selves" with conflicting goals, we implicitly introduce strategic considerations in his decisions. As stated in Propositions 1 and 2, different degrees of procrastination can then be observed in similar environments. Naturally, the importance of the strategic behavior is intensified when several agents, each of them with a taste for immediate gratification, interact. Contrary to standard results, work overload and competition between agents may not be detrimental for each individual (it just decreases the tendency to procrastinate) while complementarity of tasks may be harmful.

3 A simple model of rush

We now turn to analyze a situation in which time inconsistent agents can undertake an irreversible activity that yields a *current benefit* at the expense of a *delayed cost.* More precisely and by symmetry with the previous section, if self-t undertakes the activity, he enjoys a benefit x at date t and pays a cost c at date $t+1$. As already noted, one can think of credit facilities for consumer purchases as an example of the situations we have in mind. The most notable difference with the previous setup is the assumption

[9] Note that, in this case, there is not even an *asymmetric* equilibrium in which the task is completed with positive probability.

that the cost incurred is now a random variable drawn from a common knowledge distribution with c.d.f. $F(c)$. At each period t and before making his decision, self-t learns the realization c_t of the cost to be paid at $t+1$. In the credit buying example, it captures the idea that the opportunity cost of a purchase varies from period to period. Furthermore, we make the following assumption.

Assumption 2 c_t i.i.d. $\mathcal{N}(m, 1)$.[10] **(A2)**

We will focus on Markov Perfect Equilibria (MPE) for which the realization of the cost c is the state variable. Assume that self-t anticipates that, from next period on, all future incarnations will undertake the activity if and only if $c_\tau \leq c^*$ ($\tau \geq t+1$). For a current realization c_t, self-t prefers to undertake the activity himself if and only if:

$$\begin{aligned} x - \beta\delta\, c_t \;&\geq\; \beta\delta F(c^*)(x - \delta E[c \,|\, c \leq c^*]) + \beta\delta(1 - F(c^*))F(c^*)(x - \delta E[c \,|\, c \leq c^*]) + ... \\ &\geq\; \beta\delta\, F(c^*)\, \frac{x - \delta E[c \,|\, c \leq c^*]}{1 - \delta(1 - F(c^*))} \end{aligned}$$

Note that the left hand side of the inequality is decreasing in c_t, so an equilibrium strategy must specify a cutoff below which the agent undertakes the activity. Rearranging terms we get:

$$x\left[(1-\delta) + \delta F(c^*)(1-\beta)\right] \;\geq\; \beta\delta\left[c_t(1-\delta) + \delta F(c^*)(c_t - E[c \,|\, c \leq c^*])\right] \tag{3}$$

Overall, from (3) we note that if an MPE exists, it must satisfy:

$$x\left[(1-\delta) + \delta F(c^*)(1-\beta)\right] \;=\; \beta\delta\left[c^*(1-\delta) + \delta F(c^*)(c^* - E[c \,|\, c \leq c^*])\right] \tag{4}$$

In the rest of the section we will refer to MPE c^* as the equilibrium such that each self-t undertakes the activity at t if and only if $c_t \leq c^*$. Furthermore we will denote by $\hat{c}$ the value of the cost such that:

$$x = \beta\delta\, \hat{c}$$

In this framework, we will say that an MPE c^* implies "rush" if $c^* > \hat{c}$, that is if selves may choose to undertake the task with a negative expected payoff ($c \in (\hat{c}, c^*)$). Naturally, an equilibrium never implies rush if and only if $c^* < \hat{c}$.

[10] None of our results change if we rather assume that the uncertainty is on the benefit or both on the cost and the benefit. Setting the variance equal to one is not necessary. However, it simplifies notations considerably.

As in the previous section, we first consider the case in which agents have to complete independent activities so that the payoff of each individual is not affected by the decisions of the other agents. In a second step, we investigate scenarios in which the decision of a given agent affects the payoff of the other individuals. When activities are independent, we get the following result.

Proposition 3 *(Rush under independent tasks).*

(i) *When each agent can undertake one task, there exist at most two stable MPEs* $c^* \in \{c_1^*, c_2^*\}$*. Moreover, it may be that in one MPE the agent rushes* ($c_2^* > \hat{c}$) *and not in the other* ($c_1^* < \hat{c}$)*. Last, for all* c_1^* *and* c_2^* *such that* $c_2^* > c_1^*$*, the ex ante expected welfare from the perspective of all selves is smaller in the MPE* c_2^* *than in the MPE* c_1^**.*

(ii) *When each agent can undertake two independent and identical tasks sequentially, there exist at most two stable MPEs* $\tilde{c} \in \{\tilde{c}_1, \tilde{c}_2\}$ *for completing the first task. Moreover,* $\tilde{c} > c^*$ *if* $c^* < \hat{c}$ *and* $\tilde{c} < c^*$ *if* $c^* > \hat{c}$*.*

Proof. Part (i). From (4) an MPE must satisfy $B(c^*; x) = W(c^*)$ where, using **(A2)**:

$$B(c^*; x) \equiv x\left[(1-\delta) + \delta\,\phi(c^* - m)(1-\beta)\right]$$

$$W(c^*) \equiv \beta\delta\left[c^*(1-\delta) + \delta\,\phi(c^* - m)c^* - \delta\,\phi(c^* - m)m + \delta\,\varphi(c^* - m)\right]$$

with $\varphi(\cdot)$ and $\phi(\cdot)$ being the density and c.d.f. of the standard normal distribution. Note that $B'(c^*; x) > 0$, $B''(c^*; x) > 0$ if $c^* < m$ and $B''(c^*; x) < 0$ if $c^* > m$. Also, $W'(c^*) > 0$ and $W''(c^*) > 0$. Hence, there can be at most three values $c^* \in \{c_1, c_2, c_3\}$ such that $B(c^*; x) = W(c^*)$ where $c_1 < c_2 < c_3$.[11] When this is the case, c_1 and c_3 are stable, whereas c_2 is unstable. Suppose that the parameters are such that one of the equilibria is $c^* = \hat{c} \equiv x/\beta\delta$. This would imply:

$$B(\hat{c}; x) = W(\hat{c}) \;\Leftrightarrow\; \frac{\varphi(x/\beta\delta - m)}{\phi(x/\beta\delta - m)} = m - x/\delta$$

From the properties of the normal distribution, we know that the Mill ratio $\frac{\varphi(y)}{\phi(y)}$ satisfies: $\left(\frac{\varphi(y)}{\phi(y)}\right)' < 0$ and $\frac{\varphi(y)}{\phi(y)} \underset{-\infty}{\sim} -y$. In our case, this implies: $\lim_{m\to+\infty} \frac{\varphi(x/\beta\delta - m)}{\phi(x/\beta\delta - m)} + x/\delta - m < 0$. Hence, there always exists a value m^* (> 0) s.t. $\frac{\varphi(x/\beta\delta - m^*)}{\phi(x/\beta\delta - m^*)} = m^* - x/\delta$. This proves that for a suitably chosen m, $\hat{c}$ can be an MPE.

Now, if x, β and δ are such that:

[11] Note also that, if $\beta = 1$, we have $B'(c^*; x) = 0$. Then, for any distribution, there is one and only one equilibrium value c^* below which the agent undertakes the activity. Furthermore, $x - \delta\, c > 0$ for all $c < c^*$ so that, as it is well known, under time consistency rush never occurs.

-a- $x/\beta\delta - x/\delta = \varphi(0)/\phi(0) \;\Rightarrow m^* = x/\beta\delta \;\Rightarrow\; B''(x/\beta\delta) = 0$. Then, $c_2 = x/\beta\delta$, and therefore $c_1 < \hat{c}$ and $c_3 > \hat{c}$.

-b- $x/\beta\delta - x/\delta < \varphi(0)/\phi(0) \;\Rightarrow m^* > x/\beta\delta \;\Rightarrow\; B''(x/\beta\delta) > 0$. Then, $c_1 = x/\beta\delta$, and therefore $c_2 > \hat{c}$ and $c_3 > \hat{c}$.

-c- $x/\beta\delta - x/\delta > \varphi(0)/\phi(0) \;\Rightarrow m^* < x/\beta\delta \;\Rightarrow\; B''(x/\beta\delta) < 0$. Then, $c_3 = x/\beta\delta$, and therefore $c_1 < \hat{c}$ and $c_2 < \hat{c}$.

This proves that, depending on the parameters, the two stable MPEs may imply either rush in one equilibrium (case -a-), or rush in both equilibria (case -b-) or no rush in equilibrium (case -c-). Naturally, the same reasoning can be extended to $m \neq m^*$.

When the different selves coordinate on a given equilibrium c^*, then the welfare from the perspective of self-0 is, by construction of c^*:

$$F(c^*)[x - \beta\delta E[c|c \leq c^*]] + (1 - F(c^*))[x - \beta\delta\, c^*]$$

In the normal case this writes as:

$$x - \beta\delta[c^* + \phi(c^* - m)m - \varphi(c^* - m) - \phi(c^* - m)c^*]$$

which is decreasing in c^* given that $\varphi'(x) = -x\varphi(x)$. Therefore, self-0 is better-off when all his future incarnations coordinate on the smallest stable MPE.

Part (ii). Suppose that each agent must undertake two identical and independent projects. When one task has already been completed, the agent is in the same situation as in (i). Therefore, he undertakes the last project at each period when the cost is below c^*. Anticipating that the MPE for the completion of the last project is c^*, $\tilde{c}$ is an MPE for the completion of the first project if and only if:

$$x - \beta\delta\,\tilde{c} + x - \beta\delta\, c^* = \beta\delta F(\tilde{c})\frac{x - \delta E[c|c \leq \tilde{c}]}{1 - \delta(1 - F(\tilde{c}))} + (x - \beta\delta\, c^*)\frac{F(\tilde{c})\delta}{1 - \delta(1 - F(\tilde{c}))}$$

this can be rewritten as:

$$B(\tilde{c}; x) + (1 - \delta)[x - \beta\delta\, c^*] = W(\tilde{c})$$

By definition of $B(\cdot\,; x)$ and $W(\cdot)$, it comes immediately that $\tilde{c} < c^*$ if $c^* > \hat{c}$ and $\tilde{c} > c^*$ if $c^* < \hat{c}$. □

First of all, we would like to point out that the risk of undertaking a task with net expected losses even if the agent has always the option of never undertaking it (what we identify by "rush" or "haste") is not a new result. In a previous work (Brocas and Carrillo, 1999a), we extensively analyzed this possibility in a related context, also under uncertainty and time inconsistent preferences. We showed that an individual could undertake an activity that yields net losses only as a commitment for not undertaking it in the future, which would lead to expected gains from the perspective of future selves but greater losses from the current perspective. This same mechanism operates in the present environment.

The key novelty of Proposition 3 is the existence of multiple equilibria, each of them with a different, rankable expected profit.[12] As in the context of procrastination, the agent behaves strategically against his future incarnations. However, when benefits come earlier than costs, the individual is tempted to undertake the activity 'too early' (i.e. when the cost is still 'too high'). As a result and unlike in the previous setup, each individual faces a *coordination problem with himself*, that is even when projects are independent. In this strategic intra-personal game, when the current realization of cost is relatively high, each self is willing to avoid rushing into the project only as long as future incarnations do not rush themselves. In other words, *the behavior of the agent will crucially depend on the "degree of trust on his future incarnations"*. It is interesting to note that this anticipation of future conduct may lead to radically different outcomes. Two equilibria may coexist for the same individual, one in which patient, trustful selves obtain always high payoffs ($c_1^* < \hat{c}$), and one in which impatient, distrustful selves may get a negative payoff ($c_2^* > \hat{c}$).[13] In this context, agents may greatly benefit from building some "self-reputation" for being *patient*. As stated in the proposition, patience is valuable independently of whether there is rush or not: when two equilibria coexist it is ex ante optimal for every self to coordinate on the one that specifies the lowest cutoff c^*.

When the agent has to undertake two sequential tasks, his decision to embark on the first one depends on his anticipated future behavior. Naturally, any self who has to decide whether to complete the first project today is better-off if his future incarnations plan not to rush when completing the second one. The interesting result is that anticipating rush in the second task makes the agent less prone to rush in the first

[12]In Brocas and Carrillo (1999a), the equilibrium is unique because the game has a finite horizon.
[13]Naturally, it may also be that both equilibria implies rush or no equilibrium implies rush.

one. Patience is, in that case, the best commitment device to delay as much as possible that future action inefficient from the current viewpoint. Conversely, anticipating no rush in the second task makes the agent more willing to undertake the first one rapidly, and therefore more prone to rush on it. Overall, we get a stronger result than in Proposition 1 part (ii): if $c^* > \hat{c}$ so that selves are likely to rush, imposing the restriction of a sequential completion of tasks is welfare improving from the perspective of self-0. By contrast, under no rush ($c^* < \hat{c}$) agents are strictly better-off by being able to do the tasks simultaneously.

As in the previous section, we now investigate a scenario in which the payoffs of individuals are interdependent. First, we are concerned with situations in which dynamic inconsistent agents compete for projects. One can think of politicians in two neighboring jurisdictions willing to undertake a public project (library, TV station, sports center, etc). This investment yields current benefits in terms of prestige and chances of reelection, and it is financed over time. If duplication of projects is inefficient and the cost is stochastic, the two politicians may engage in a race in which only the first one to make a "sensible" proposal will be allowed to undertake the project in his own jurisdiction. In this situation and by analogy with the case of independent projects, if one politician anticipates that the other will propose the project whenever the cost is $c \leq c_b^*$, then it is in his interest to propose it when $c \leq c_a^*$, where:

$$x - \beta\delta\, c_a^* = \beta\delta\, F(c_a^*)(1 - F(c_b^*)) \frac{x - \delta\, E[c \,|\, c \leq c_a^*]}{1 - \delta(1 - F(c_a^*))(1 - F(c_b^*))}$$

which, rearranging terms, gives:

$$x \left[\tfrac{1}{1-F(c_b^*)} - \delta + \delta F(c_a^*)(1-\beta) \right] = \beta\delta \left[c_a^* \left(\tfrac{1}{1-F(c_b^*)} - \delta \right) + \delta F(c_a^*)(c_a^* - E[c | c \leq c_a^*]) \right] \quad (5)$$

Second, we investigate cases in which projects are complements. Here again, a natural example would be politicians in charge of the development of their own jurisdictions, in situations where investments generate positive spillovers. For simplicity, we assume that politicians undertake their projects sequentially.[14] The first politician enjoys a private benefit x at the date at which he embarks on his own project and benefits from a positive externality α when the second politician undertakes his project. The politician who invests second enjoys both the private benefit x and the externality

[14]The analysis could be extended to situations in which both politicians can embark on their projects at the same date but computations become much more intricate.

α generated by the (already developed) project of the other jurisdiction at the date at which he embarks on his own project.

Proposition 4 *(Rush under interdependent tasks).*

(i) *When agents pursue competing tasks, they are less likely both to rush and to make high profits.*

(ii) *When agents pursue complementary tasks, they are more likely to rush.*

Proof. Part (i). Equation (5) can be rewritten as $\tilde{B}(c_a^*, c_b^*; x) - \tilde{W}(c_a^*, c_b^*) = 0$ with:

$$\tilde{B}(c, c_b^*; x) \equiv x \left[\tfrac{1}{1-F(c_b^*)} - \delta + \delta\, \phi(c-m)(1-\beta) \right]$$

$$W(c, c_b^*) \equiv \beta\delta \left[c \left(\tfrac{1}{1-F(c_b^*)} - \delta \right) + \delta\,(c-m)\phi(c-m) + \delta\, \varphi(c-m) \right]$$

Therefore:

$$\frac{\partial c_a^*}{\partial c_b^*} \propto \left. \frac{\partial [\tilde{B}(c, c_b^*) - \tilde{W}(c, c_b^*)]}{\partial c_b^*} \right|_{c=c_a^*}$$

So, $\dfrac{\partial c_a^*}{\partial c_b^*} > 0$ if $c_a^* < \hat{c}$ and $\dfrac{\partial c_a^*}{\partial c_b^*} < 0$ if $c_a^* > \hat{c}$. Overall, under competition for projects there are as before at most three symmetric MPEs $c^{**} \in \{c_1^{**}, c_2^{**}, c_3^{**}\}$. Noting that $\tilde{B}(c, c_b^*; x) = B(c; x)$ and $\tilde{W}(c, c_b^*) = W(c)$ when $F(c_b^*) = 0$, then $c^* < c^{**}$ if $c^* < \hat{c}$ and $c^* > c^{**}$ if $c^* > \hat{c}$.

Part (ii). Suppose that politicians invest sequentially and that a undertakes his project first. When a's project has been undertaken, politician b invests if the cost is smaller than $\tilde{c}$ such that:

$$x + \alpha - \beta\delta\, \tilde{c} = \beta\delta\, F(\tilde{c})\, \frac{x + \alpha - \delta E[c \,|\, c \leq \tilde{c}]}{1 - \delta(1 - F(\tilde{c}))}$$

Naturally, $\tilde{c} > c^*$. Self-0 of politician a anticipates that politician b will invest if his cost is smaller than c_b as soon as he undertakes project a. Let $\check{c}$ be the cost below which politician a invests, then $\check{c}$ is an MPE if:

$$x - \beta\delta\, \check{c} + \frac{\beta\delta\alpha F(\tilde{c})}{1 - \delta(1 - F(\tilde{c}))} =$$

$$\beta\delta F(\check{c}) \frac{[x - \delta E[c|c \leq \check{c}]]}{1 - \delta(1 - F(\check{c}))} + \frac{\beta\delta F(\check{c})}{1 - \delta(1 - F(\check{c}))} \frac{\alpha\delta F(\tilde{c})}{1 - \delta(1 - F(\tilde{c}))}$$

Rearranging terms in the previous expression, $\check{c}$ is a symmetric MPE if:

$$B(\check{c};x) + \frac{\beta\delta\alpha(1-\delta)F(\tilde{c})}{1-\delta(1-F(\tilde{c}))} = W(\check{c})$$

As a consequence, $\check{c} > c^*$. Suppose that a has a tendency to rush (i.e. $c^* > \hat{c}$). Moreover, let $\hat{c}_\alpha$ satisfy $x + \frac{\alpha\beta\delta F(\tilde{c})}{1-\delta(1-F(\tilde{c}))} = \beta\delta\hat{c}_\alpha$. Note that if a implements his project when the cost is higher than $\hat{c}_\alpha$, then his expected payoff (taking into account the expected spillover) is negative. Naturally, if α is not too large, then $\hat{c}_\alpha < c^*$ so that $\hat{c}_\alpha < \check{c}$. In other words, in this case the tendency to rush is exacerbated by the presence of spillovers. Last, note that $B(c;x+\alpha) - [B(c;x) + \frac{\beta\delta\alpha(1-\delta)F(\tilde{c})}{1-\delta(1-F(\tilde{c}))} > 0$ for all c. Therefore, $\check{c} < \tilde{c}$: politician a (who enjoys x at the date of investment and α only in the future) rushes less than politician b (who benefits from $x+\alpha$ at the date at which he embarks on his project). □

The effect of project competition on the agent's behavior is twofold. First and not surprisingly, it lowers the maximum expected payoff. Agents are concerned about the possibility of being leapfrogged by their rival, so they are willing to sacrifice some of the benefits of waiting. Formally, if the cutoff when projects are independent is $c^* < \hat{c}$, then under competing projects the new cutoff is $c^{**} > c^*$. Second and more interestingly, competition can mitigate the inefficiency due to time inconsistency, and therefore end up being beneficial. For instance, in a situation where agents are impatient (or distrustful), allowing competition decreases the incentives of individuals to undertake the activity with net losses. Formally, if $c^* > \hat{c}$ when projects are independent, then the cutoff under competing projects is $c^{**} < c^*$. The idea is that individuals are aware of the inefficiency of undertaking the activity, but they use it as a commitment device against a future behavior more inefficient from the current perspective. In this setting, competition decreases the pressure to undertake the project with losses: the rival may undertake it himself, in which case the commitment against future negative payoffs is achieved *at no cost*. In other words, by introducing competition, distrustful agents do not become more patient, but they try to "let the rival rush". By contrast, when projects are complements, the incentives to rush are exacerbated. Indeed, spillovers increase the benefit of each task. Moreover, if the agent is the second one to undertake his task, then the extra benefit is immediate, i.e. overweighed. As a result, complementarity of projects increases the agents' likelihood of getting a negative payoff via an increase in the incentives to invest when the cost is still relatively high. Once again, the conclusion is the same as in Section 2: time inconsistency may twist the standard results about the effects of competition and complementarity of tasks on individual decision making.

4 Applications

4.1 Some implications of and solutions to procrastination

As previously noted, many activities are characterized by the existence of an immediate cost and a delayed benefit. The aim of this section is to provide a series of prescriptions in some of these cases.

Competition for promotions. An important issue in the Theory of Organizations is to understand how managers may provide optimal incentives to their employees. The presence of asymmetric information and moral hazard has been identified as a source of conflict between the two parties (managers and employees) that can be handled with the use of incentive contracts. Relative performance evaluation or, more generally, competition between agents is a simple way to increase performance at a low cost for the manager. Proposition 2 suggests that under time inconsistent preferences, competition (e.g. for a promotion) can also be extremely beneficial to avoid procrastination. The interesting feature is that, in our framework, this proposed measure can affect positively the welfare of the manager without implying any loss to agents. In fact, for the later it can just represent a commitment device against procrastination.

Cooperation in R&D. Cooperation has been extensively analyzed in the R&D literature. The main drawback of allowing research laboratories to work together is the free riding problem when efforts are not observable. Our framework exhibits this same kind of inefficiency but in a more extreme way, and even under complete information. Indeed, Proposition 2 shows that R&D cooperation exacerbates the tendency to procrastinate, since agents are all the more reluctant to exert the current costly effort as the delay to obtain the benefit is high. As a result, the expected level of effort exerted at each period is lower than if agents were delegated separate projects, and it may even imply that a valuable project is *never* completed. To sum up, if a regulator wants two research firms to undertake an R&D project, she has to realize that cooperation may be harmful not only for consumers, but even for the firms themselves.

Job search. An unemployed agent will decide to search for a job depending on the size of future benefits relative to the current search costs. Under time inconsistent preferences, agents will procrastinate in their search activity. As a result, they will remain unemployed (on average) during an inefficiently long period of time. As suggested by our analysis, the uncertainty component of the job searching process may not be essential to explain why similar agents find a job after a different number of periods. According to Proposition 1, even in a deterministic environment agents will decide to look for a job at each period only with a certain probability. In other words, introducing time inconsistency increases the variance of the job search duration.

4.2 Some implications of and solutions to rush

In the remaining of the section, we consider activities characterized by an immediate benefit and a delayed cost. Recall that, in those situations, individuals may invest with a negative payoff. In addition, we have evidenced the presence of multiple equilibria which reflects that the tendency to rush depends on the degree of trust on future incarnations.

Personal temptations. It is widely argued that the tendency to succumb to temptations is an intrinsic characteristic of human beings. From a general perspective, a temptation can be defined as the desire to take a decision which provides an immediate "mixed feeling". A clear illustration is the tendency to buy on impulse, that is to acquire goods anticipating regret once the purchase is realized (see e.g. Rook, 1987). Other activities such as gambling or extramarital relationships exhibit the same kind of behavior. Many explanations relying on bounded rationality arguments have been provided. Basically, these theories assume that individuals are subject to unanticipated urges, so that they temporary overweight the benefits and decide to undertake the activity. In our view, this explanation is not entirely satisfactory. Indeed, if the reason for impulsive behavior is simply a temporary urge, agents should exhibit such behavior independently of the delay between benefits and costs. However, different degrees of impulsiveness are observed depending precisely on this temporal gap (buying on impulse is more frequent for credit card payments). Assuming dynamically inconsistent preferences brings a clear answer. In the absence of credit facilities, agents will never acquire (possibly) useless goods that they can barely pay. By contrast, if they are allowed to postpone payments, a purchase with regret (even at the current date) may occur. In terms of our model, this happens when the net payoff is negative, see Proposition 3.[15]

It seems that the tendency to act impulsively can be mitigated using some "personal commitment devices". First, individuals are able to resist to temptations as long as it is sustainable not only in the short run but also in the long run. This is clearly related to the existence of multiple equilibria, on which incarnations coordinate according to their "self-reputation". Second, individuals often rely on others' inconsistency to avoid their own temptations. Indeed, scarcity of tempting goods is the best allied of weak agents: as soon as another agent has purchased the only brand new car available at the dealer's shop, the temptation (optimally) vanishes.

Public projects. Politicians enjoy short run benefits in terms of prestige and chances of reelection when they undertake public projects. However, they also incur in delayed costs since, for example, this impairs the financing of other future (and sometimes more sensible) projects. According to our results, politicians may deliberately make unreasonable expenses. As long as they anticipate that the next politician in office will undertake a given project with high probability, they may find profitable to rush on it. In our view, this behavior is evidenced in many situations. Just to give some examples, expensive buildings are abandoned few years after their construction, and soccer stadiums constructed for international exhibitions become useless soon after the event. Moreover, the decisions of a given politician is generally related to the strategy of his neighbors, since the economic activity of a given jurisdiction generates spillovers or negative externalities on others. As suggested in Proposition 4, spillovers may have the indirect negative effect of increasing the temptation of politicians to rush on senseless projects.

Staying on the job. Our model can be reinterpreted in terms of the willingness of agents to keep their current job in uncertain environments. Basically, x could represent the (fixed and known) wage in the current activity and c the (random) opportunity cost of not searching for a future, better job. In traditional job search theory, this opportunity cost can never exceed the value of the current job otherwise the agent would strictly prefer to quit. This paper claims that too much conservatism in the decision to remain in the current activity may not be due to high risk aversion but rather to the anticipation of future conservative behavior. Since equilibria with and

[15]See Brocas and Carrillo (1999a) for a detailed discussion of the link between impulse buying and time inconsistency.

without excessive conservatism are both sustainable, time inconsistency provides a straightforward explanation to different degrees of job turnover in similar environments. It is interesting to note that, under time inconsistency, agents may procrastinate in their job search (see section 4.1). At the same time, once they accept an offer, they may exhibit an excessively high willingness to keep their position.

5 Concluding remarks

Accounting for time inconsistent preferences may change our interpretation of individual and collective behavior in economic activities as diverse as cooperative R&D, job search, or consumption/savings decisions. Recognizing the origin of impulsiveness and procrastination can be key to correct the inefficiencies induced both to the agents themselves and to the individuals with whom they interact. In this research, we have identified several ways to mitigate the innate tendencies of agents to delay unpleasant tasks and to rush into attractive but unreasonable ones. For example, imposing a sequential completion of projects forces individuals to overcome their self-control problems. Allowing competition between time inconsistent agents is also an efficient way to speed up the completion of painful tasks and to avoid taking pleasant but definitely not sensible decisions. By contrast, partnerships may exacerbate the agents' willingness both to procrastinate and to rush. However, much work remains to be done if we want to have a good understanding of the interpersonal relations of agents with intrapersonal conflicts of preferences.

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